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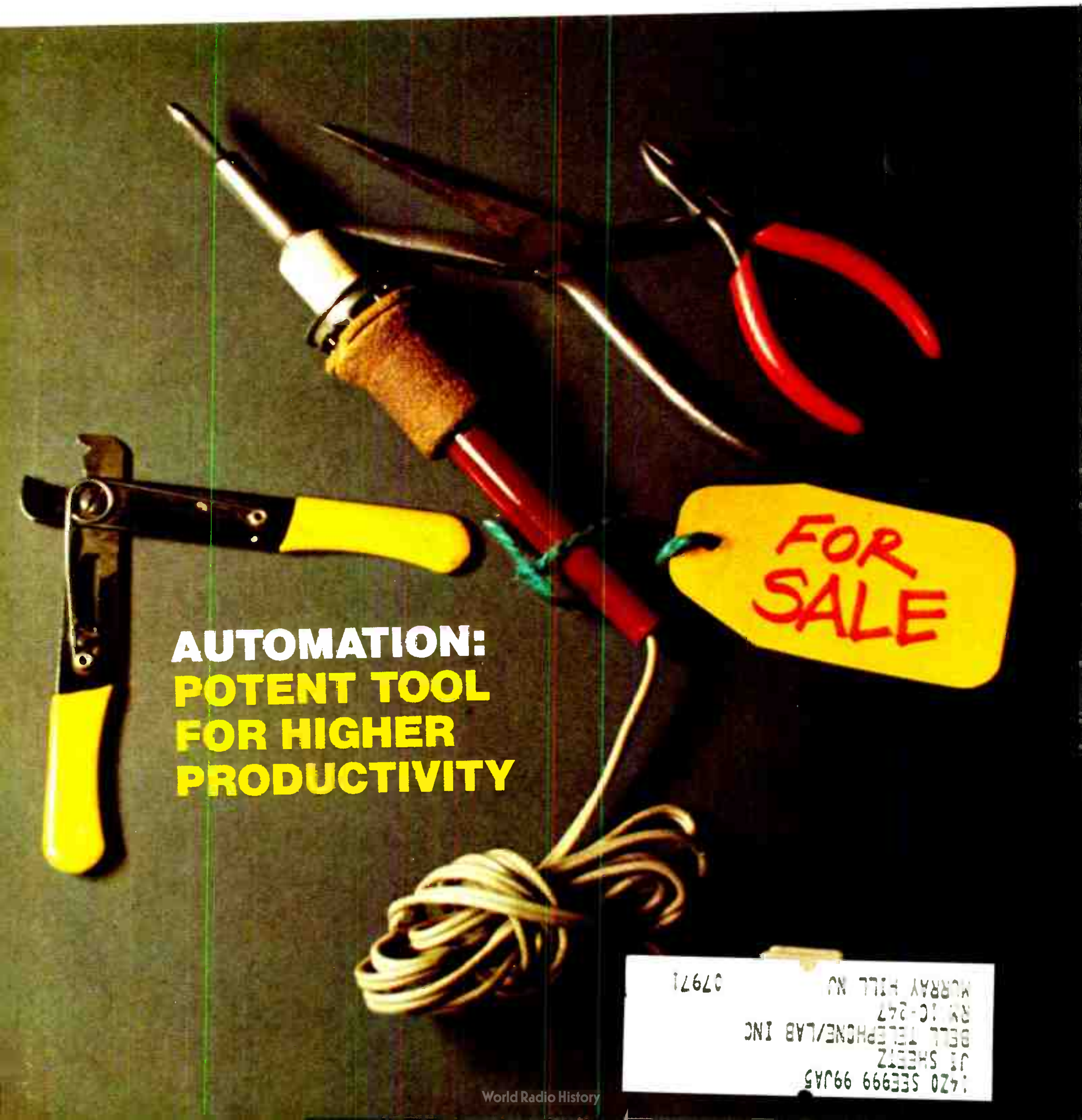
October 25, 1971

Which material is best for LED displays? 74
A guide to timing in memory systems 82
Shortcuts to rapid filter design 90

Electronics®



THE NEW WORD IN DATA COMMUNICATIONS

UÁR/T, a GIANT* device. [*part* #AY-5-1012]

1. the first one-package MOS **Universal Asynchronous Receiver/Transmitter.**

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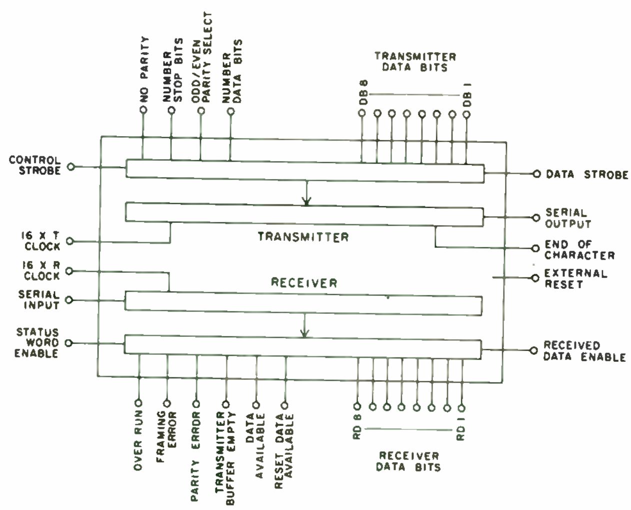
3. the UAR/T is now available in a 40 lead dual in-line package and is priced at **$30.00 each in quantities of 1-99 pieces and $22.50 each in quantities of 100-999 pieces.**

4. newest member of General Instrument's family of MOS LSI data communication subsystems which also includes the AY-5-1008 terminal receiver and the AY-5-1010 terminal transmitter; both, too, are immediately available.

*Registered Trademark for General Instrument Advanced Nitride Technology



UAR/T—BLOCK DIAGRAM

For complete information call 516-733-3138 or write: Marketing Services Manager, General Instrument Corporation, 600 West John Street, Hicksville, N.Y. 11802, or call, in New York: 516-733-3333; in Chicago: 312-774-7800; in Los Angeles: 213-641-7411. In Canada, call or write: General Instrument Canada, Ltd., 61 Industry Street, Toronto 337, Ontario, Canada, Tel: 416-763-4133. In Europe, write: General Instrument Europe S.P.A., Piazza Amendola 9, 20149 Milano, Italy. In the U.K., write General Instrument U.K. Ltd., Stonefield Way, Victoria Rd., South Ruislip, Middlesex, England. In the Far East, write General Instrument of Taiwan Ltd., P.O. Box 22226, Taipei, Taiwan.

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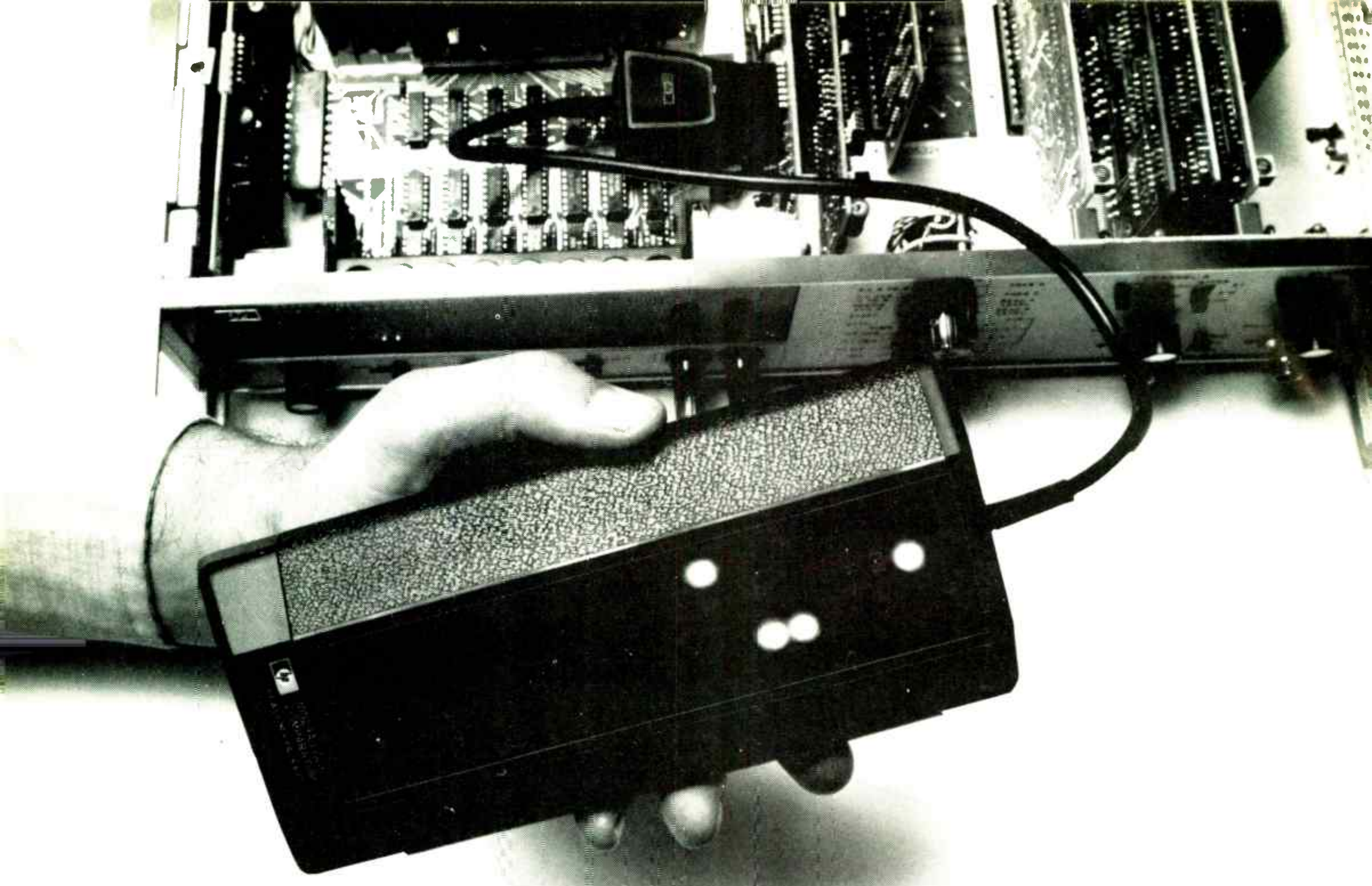

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to hold our other two Troubleshooters — the HP 10525A Logic Probe and the HP 10528 Logic Clip.

The probe lets you trace pulses through integrated circuits simply by touching a pin. The probe's tip flashes a signal for pulses as narrow as 25 ns, and indicates pulse polarity, pulse trains and logic states. It's almost like having an oscilloscope squeezed into a ball-point pen. $95.

The clip is a convenient state indicator. It slips over your DTL or TTL package and bright LEDs display the static state of all 16 (or 14) pins at a glance. It operates like 16 binary voltmeters $125.

You can buy all three as the HP 5010A for $495, saving you time, aggravation and $20.

The IC Troubleshooters march on. Wait until you see what we're working on now! Just call your HP field engineer to get your hands on them right away. Or if you want to know more, write Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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02115

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Electronics
The International Magazine of Electronics Technology

October 25, 1971

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Volume No. 44, Number 22

Publisher's letter

With the special report on automation (see page 62), we've added yet another chapter to our ongoing chronicle of the packaging and production field. Our heavy coverage in this area reflects the growing awareness of the importance of these essentially mechanical techniques in turning a profit.

Yet electronic techniques are coming on strong and are going to make a lot of difference in the profit picture. One of the big barriers to such techniques, though, is the custom nature of many electronic products. Steve Scrupski, our packaging and production editor who put together the cover story, found in his reporting that, as one of his sources pointed out, "the real purpose of the computer in manufacturing is to make the system think it has volume." Thus, he says, "even if many different types of subsystems are being assembled, the computer with appropriate automatic sensors, and computer-controlled handling, can shift machine gears and accommodate the differences. The system hardware goes on as if it were making the same parts."

The promise of "30 and out" may be great for auto workers, but for electronic engineers it's coming to have a more sinister meaning. Gene Dalton and Paul Thompson, professors at Harvard Business School, figure that if present approaches to engineering management go unchanged, 18-year-olds entering school this fall could be over the hill by 30. And no amount of continuing education is going to save them.

We tried to compress their study and conclusions into a story in this issue (see page 109). Dalton, Thompson, and Jim Brinton, our Boston bureau manager—all over 30—discussed the B-school results and found a lot for engineers to worry about: namely, that a manager can turn a talented engineer into a corporate liability in a matter of months or years, and that not only do managers know it but hesitate to change their ways.

"Between the explosive growth of knowledge, and management favoritism shown toward younger engineers, the half life of an EE is getting shorter, faster," says Thompson. "The only thing that might prevent engineering from becoming a youth cult is for the profession to appear so grim that the young won't enter it. And this won't happen."

Dalton and Thompson were eager to reach the readers of *Electronics. Electronics* reaches a great many engineering managers, and it is here that attitudes must change if experienced middle-aged engineers—who Dalton calls "America's most abused natural resource"—are to be salvaged.

"I really got wrapped up in this," says Brinton. "For the past 10 years I've been reading trade press articles praising continuing education as a career panacea. Now we find that this may be far from true, and that the profession could flounder on bad management practice alone. Dalton says, 'it will be a tribute to the engineers if they don't unionize when they find out—really—how they've been treated.' "

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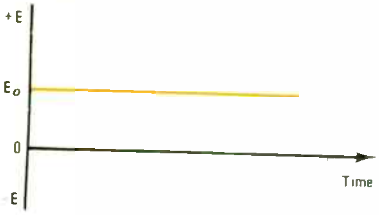
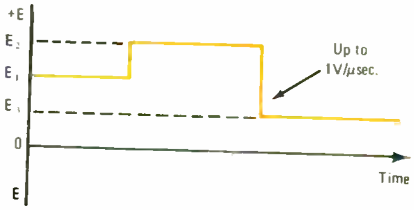


Even programmable ones that can do this:



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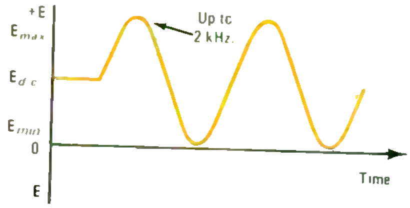
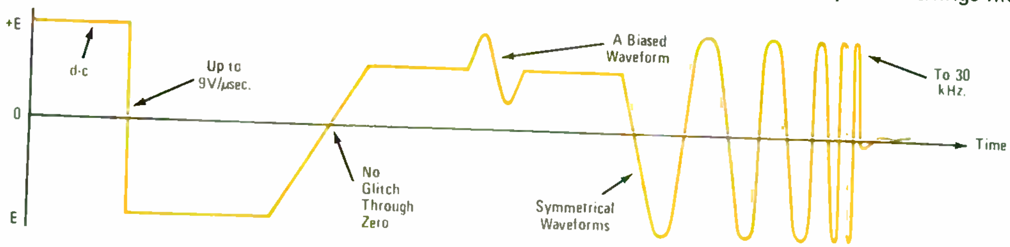


Only a BIPOLAR OPERATIONAL POWER supply (we call 'em BOP) will let you do things like this:



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+36V to −36V @ 5.0 amperes
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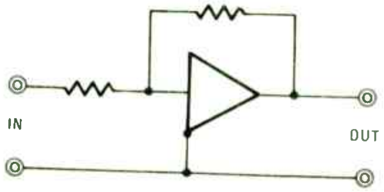
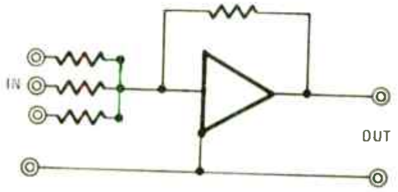
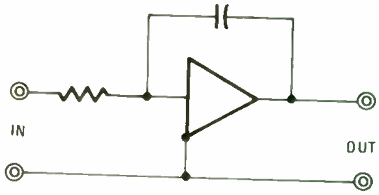
The "OPERATIONAL" part of the BOP means that you use 'em like giant OP-Amps:



SCALE OR AMPLIFY



SUM OR SUBTRACT



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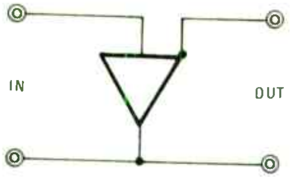
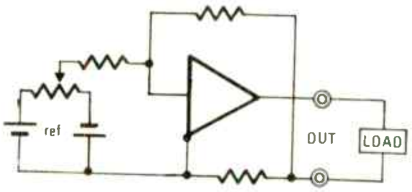
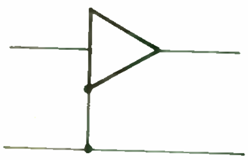


FOLLOW A VOLTAGE



CONTROL A CURRENT BI-DIRECTIONALLY



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Readers comment

'Ghosts'

To the Editor: In your article on the controversy over alleged interference with TV reception caused by the World Trade Center towers in New York, you quote Atlantic Research as saying it "finds interference reduced from the values it calculated five years before . . . And the interference won't bother anyone at all . . ." Nowhere in any report to the Port Authority did we make any such statement. Our reports have consistently presented the results of our studies in terms of ratios of the reflected signal from the World Trade Center to the direct signal from the Empire State Building, leaving to others the final determination as to what constitutes the presence or absence of objectionable interference.

Stuart L. Bailey
Atlantic Research Corp.
Alexandria, Va.

The first

To the Editor: In the Electronics Newsletter of Sept. 13 you state that the Reticon Corp.'s 256 × 1 self-scanned array is the largest built to date, and that it is the only device to contain both the video amplifier and shift counter on the same chip. We announced a 256 × 1 self-scanned array at the Electro-Optics Show in Brighton, England, last March. This device was truly the first 256 × 1 self-scanner. Our first such array was bought by Bell Labs and is being used in experiments in high-resolution graphics. We have also sold arrays to many firms in the U.S., U.K., and Europe.

G.R. Parsons
Integrated Photomatrix Ltd.
Dorchester, Dorset, England

■ *The company's products are distributed in the U.S. by Teknis of Plainville, Mass.*

Microwaves and carpets

To the Editor: The article on "Microwave system measures carpet backing" [Aug. 2, p. 28] reports a pulse spectrum for the time-domain reflectometer of dc to 4 gigahertz. The 5-in. tube spacing would have a dominant mode cutoff of about 1.2 GHz; higher modes would cut off at 2.4, 3.6, and 4.8 GHz, etc. This suggests that the system is more sophisticated than a dc-to-4-GHz pulse feeding a two-wire line. High-frequency Fourier components are naturally low-level. In addition, the sensor feed cables would rapidly attenuate the higher frequencies. Thus it appears that the important measurement frequencies are in the dc-through-uhf bands, not microwave.

Our Aquatec system utilizes a single-frequency microwave transmitter to measure latex carpet backing; a chart recorder plots the coating profile continuously, instead of giving an average reading.

B.B. Childress
Uster Corp.
Charlotte, N.C.

Up the engineer

To the Editor: The opinions expressed in your poll of engineers on unions [Sept. 27, p. 72] are the result of the less-than-honest relationship between employer and employee. The EE is encouraged to work overtime with little or no compensation, to continue studies, and to put in an extra effort at home, in return for which the employer offers a tenuous promise to employ him, a professional title, much rhetoric, a possible raise, and a dollar for his patent. In hard times, or if his specialty is not needed, the EE is discarded.

I feel that a strong, effective professional society—not a union—is the best answer. The society must require its members to maintain high technical skills, promote technology, have a lobby in all important Government centers, and have an effective public relations program. It must provide more than expensive manpower.

When I graduated from college in 1961, I had the naive opinion that I could control my own destiny. I have found, however, that industry is organized against the individual. My personal solution: I am a licensed professional engineer working as a contract engineer. Contract engineering creates an honest atmosphere: I get paid only for work done, no less, no more.

Edwin W. Bennett
Nutley, N.J.

40 years ago

From the pages of Electronics, October 1931

Oriental peach and coddling moths, foes of the peach and apple crops, may be routed with the assistance of the photoelectric eye.

To defeat the moths it was decided to floodlight some experimental orchards and have the light turned on and off by photoelectric relays. When darkness approaches, the photoelectric cells turn on the floodlights; when daylight returns, the cells turn the floodlights off.

Radio's experience with government administration has shown the dangers of admitting Washington commissions or bureaus too far into any business operation. Federal governmental control too often becomes the football of politicians, as those who have been close to Washington well know.

We need laboratory experimentation in economics and industry itself, as has already been freely used and has borne such fruit in science and the products of industry.

Engineers who are closest to the advances recently made in vacuum tubes, and who have contributed most to these advances, frankly admit that more fundamental physics of the electron is needed to be known, before electronic phenomena can be much further harnessed commercially.

The designer produces a new product; it performs dependably in certain ways, but some undetermined factor is soon noted to be present, and the tube's performance becomes "erratic." It is erratic, of course, only because of this X condition, and as soon as that characteristic is isolated, performance stabilizes—until some new variant is detected. The history of radio tubes with their continuously increasing list of definitive characteristics is a striking case in point.

The commercial tube designer for radio or industrial applications, still depends heavily upon the worker in fundamental physical research for clues to unlock the mysteries that present themselves each time an advance is made into new operating terrain.

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more or less

Our **5800** gives you more . . . 0.1 μV DC resolution; 77 readings per second in DC with up to 0.003% accuracy; 8 readings per second in AC from 10 Hz to 100 KHz over 4 full ranges; ohms over 9 ranges with true 4-wire sensing; a Distortion Insensitive AC Converter to measure the RMS value of waveforms; true systems compatability; real time AC and DC ratio; remote override; three reading modes . . . and much more.

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You see, we made the 5800 and 4800 into the best 5 and 4 digit voltmeters available anywhere . . . giving top-of-the-line premium performance and starting at only $1295.00. Why not find out about them for yourself. You have the budget and the decision . . . Dana has the DIGITAL VOLTMETERS.

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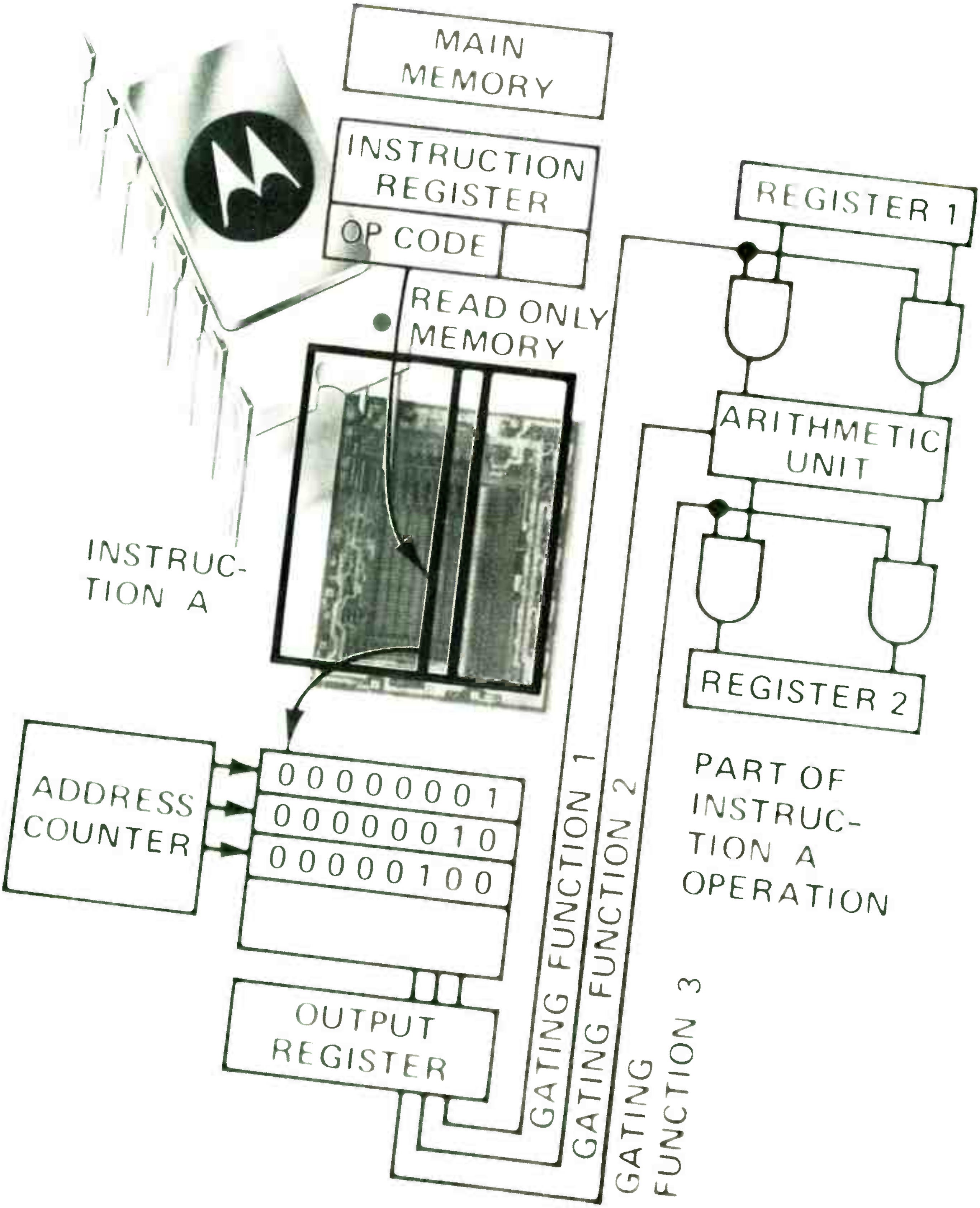

...for *fast* system microprogramming

When your system needs the advantages of custom microprogramming, code conversion, or look-up table functions and you are fighting time plus development cost, Motorola's MCM4004 or MCM4006 1024-Bit ROMs can solve your problem. Just supply your truth table/output option requirement and the final processing steps are completed — the net result, a custom function without the cost and time required for a developmental program.

The basic organization of both memories is 256 four-bit words. By removing appropriate emitter connections on the pre-ohmic mask, each bit can be programmed to meet your specific logic requirement. Both devices offer optional 2.0 kilohm pullup resistors on the four collector outputs. The open collector output option is obtained by removing pre-ohmic connections to the 2.0 kilohm resistors. Utilizing the open collector option at the buffered output bit lines allows many memories to be wire-ORed to form large arrays.

The MCM4006 features a typical address time of 40 ns and chip select time of 20 ns (typ) with standard TTL input loading of 1.6 mA. The MCM4004 offers reduced input loading (0.1 mA typical) and is recommended for large systems. Typical MCM4004 address time is 50 ns and typical chip select time is 25 ns.

Systematic application

Use the MCM4004/4006 wherever there is a need to store information for repetitive use in a system. Typical applications would include look-up tables, character generation, and random logic. The devices are ideal for microprogramming where complex arithmetic subroutines are performed. As illustrated, the ROM generates basic gating functions in a computer. The address counter selects the instructions from the ROM in a fixed sequence to perform the designated subroutine. The resultant advantage is faster processing of information compared to a subroutine contained in the main memory.

Contact your local Motorola representative for ordering information. 100-up price for either ROM is $17.50 and the programming mask set-up charge is a low $600 per program with reduced costs for additional masks. For detailed specifications write Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036.

Evaluate the MCM4004 and 4006 . . .
The option and savings are yours.

Look to Motorola for your memory requirements. Our capabilities in bipolar and MOS provide a comprehensive selection to meet your specific requirement.

MEMORIES TO REMEMBER

DEVICE	FUNCTION	TECHNOLOGY	ORGANIZATION	ACCESS TIME
RAMs				
MC1680/81	4 Bit RAM	ECL - BiPolar	2 x 2	≤ 4 ns
MC1682/83	4 Bit RAM	ECL - BiPolar	2 x 2	≤ 4 ns
MC1684/85	4 Bit CARAM	ECL - BiPolar	2 x 2	≤ 4 ns
MC1036/37	16 Bit RAM	ECL - BiPolar	16 x 1	≤ 20 ns
MC4004/5	16 Bit RAM	TTL - BiPolar	16 x 1	≤ 25 ns
MCM4064	64 Bit RAM	TTL - BiPolar	16 x 4	≤ 60 ns
MCM1170	64 Bit Static RAM	Metal Gate P-MOS	16 x 4	500 ns
MCM14505	64 Bit Static RAM	Metal Gate CMOS	64 x 1	200 ns (typ)
MCM1173/72	1024 Bit Dynamic RAM (6001 Equiv.)	Metal Gate P-MOS	1024 x 1	350 ns
MCM2372	1024 Bit RAM (1103 Equiv.)	Si-Gate P-MOS	1024 x 1	300 ns
ROMs				
MCM4001	128 Bit ROM	TTL - BiPolar	16 x 8	≤ 45 ns
MCM4002	256 Bit ROM	TTL - BiPolar	32 x 8	≤ 50 ns
MCM4004	1024 Bit ROM	TTL - BiPolar	256 x 4	≤ 60 ns
MCM4006	1024 Bit ROM	TTL - BiPolar	256 x 4	≤ 50 ns
MCM5003A/4A	512 Bit PROM	TTL - BiPolar	64 x 8	≤ 75 ns
MCM1130	2240 Bit Static ROM	Metal Gate P-MOS	Programmable	500 ns
MCM1131/32	2240 Bit Char. Gen.	Metal Gate P-MOS	Col. Sel. 64 x 35 (5 x 7)	500 ns
MCM1120	2240 Bit ROM	Metal Gate P-MOS	Programmable	700 ns
MCM1121/22	2240 Bit Char. Gen.	Metal Gate P-MOS	Row Sel. 64 x 35 (5 x 7)	700 ns

MEMORIES TO COME

DEVICE	FUNCTION	TECHNOLOGY	ORGANIZATION	ACCESS TIME
RAMs				
MC10140	64 Bit RAM	ECL - BiPolar	64 x 1	≤ 15 ns
MCM4256/7	256 Bit RAM	TTL - BiPolar	256 x 1/ 128 x 2	≤ 60 ns
MCM1175	1024 Bit Dynamic RAM (6002 Equiv.)	Metal Gate P-MOS	1024 x 1	110 ns (typ)
MCM2377	2048 Bit RAM	Si-Gate P-MOS	2048 x 1	360 ns
ROMs				
MCM4003	512 Bit ROM	TTL - BiPolar	64 x 8	≤ 75 ns
MCM4005	1024 Bit ROM	TTL - BiPolar	1024 x 1	≤ 50 ns
MCM4007	1024 Bit ROM	TTL - BiPolar	512 x 2	≤ 50 ns
MC10139	256 Bit PROM	ECL - BiPolar	32 x 8	≤ 17 ns
MCM5005	1024 Bit PROM	TTL - BiPolar	256 x 4	≤ 60 ns
MCM1110	2048 Bit ROM	Metal Gate P-MOS	256 x 8	600 ns
MCM1140	4096 Bit ROM	Metal Gate P-MOS	512 x 8	700 ns
MCM1150	2560 Bit ROM	Metal Gate P-MOS	256 x 10	600 ns
MCM2340	4096 Bit ROM	Si-Gate P-MOS	512 x 8	500 ns

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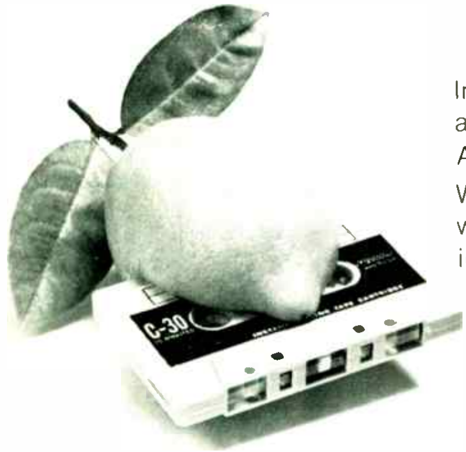
MOTOROLA MEMORIES
...IC Systems for the 70's!

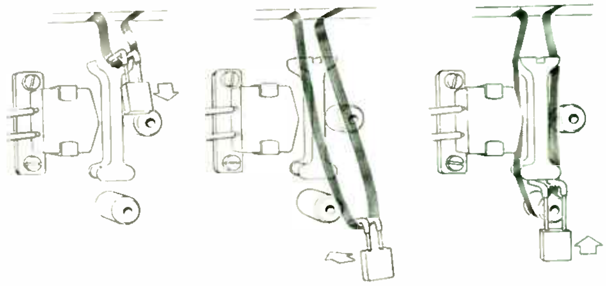
Two Years Ago, Almost



Including us. A digital cassette recorder. Seemed like a great idea at the time. But there was too much garbled info. And lousy reliability. A bumper crop of real lemons.

Well, we licked our wounds along with everyone else. But we also went back to the drawing board because we still thought the basic idea was sound. And we came up with a unit that really works.

A Whole New Concept

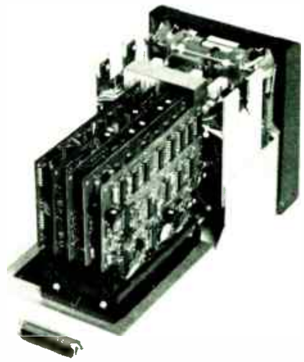


To get super reliability, we reasoned, you have to control that tape. So, we started from scratch. Got rid of the traditional pinch rollers, belts, solenoids, levers and mechanical linkages from the transport. Took out the head guide forks.

Eliminated the need for pressure pads. Those were the main cause of head and tape wear, oxide shed and dropout.

Then, instead of just pushing the head up to the tape as it rolls by, we decided to get the tape out of the cassette. (That way the cassette is just a tape holder.) So we designed two little fingers that pull the tape down past the head, over a precision guide and around a capstan. That maintains optimum head wrap angle—critical for read-after-write operation. And it's all done automatically as you load. (We've got a patent pending, in case you're interested.)

The Insides



Next, we put in three DC motors. One for the capstan and one for each reel. Servos positively control tape tension on both sides of the capstan. And tension sensors confirm proper loading to BOT—no writing on tape leader. There's no drag on the tape. Ever.

So now we have high bi-directional tape speed, fast start/stop times, precise start/stop distances.

Reel motor torque is automatically reduced when EOT or BOT is sensed to prevent pulling tape from cassette reel hubs or other possible tape damage.

All modular electronics. Plug in PC boards. Logic and interface that're TTL compatible.

Everybody Brought One Out

The Outsides

All these components are mounted in a cast aluminum frame. Very, very rugged. So it works for any number of EDP OEM applications. And we supply it for users in a handsome case with straightforward, push-button controls.

Real Reel to Reel Performance

Our basic Model 240 has 2 tracks, selectable data rates from 2 to 20 ips, with start/stop times of 15-30 msec. Same start/stop times for 50 ips search or fast forward/reverse. It operates in incremental and/or continuous modes, and in several combinations of recording codes/data channel selections. Test data indicates: calculated MTBF in excess of 2,000 hours. Thousands of passes without tape damage.

Options

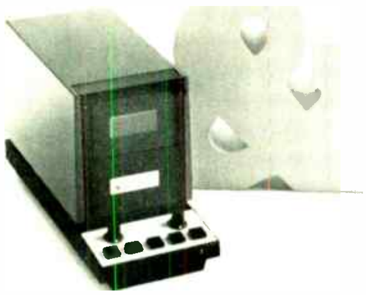
All sorts of options. Like two selectable read/write speeds. Dual gap read-after-write head. Separate read-after-write heads. Power supply. Rack mount kit. Automatic tape cleaner. Etcetera.

Don't Wait. Order Now

Now that we've really licked performance and reliability problems, we figure our recorder's a natural for business machine manufacturers, terminal makers, mini computer builders.

And users. A great replacement for punched paper tape. Even some reel to reel mag tape applications. Especially at the price. About $500 to $600 in bunches.

Bell & Howell & a Digital Cassette Recorder That Works



☐ Send me all the specs.
☐ Send a guy around for a demo.
☐ Here's my P.O. You fill in the blanks.

Name ______________________

Title ______________________

Company ______________________

Address ______________________

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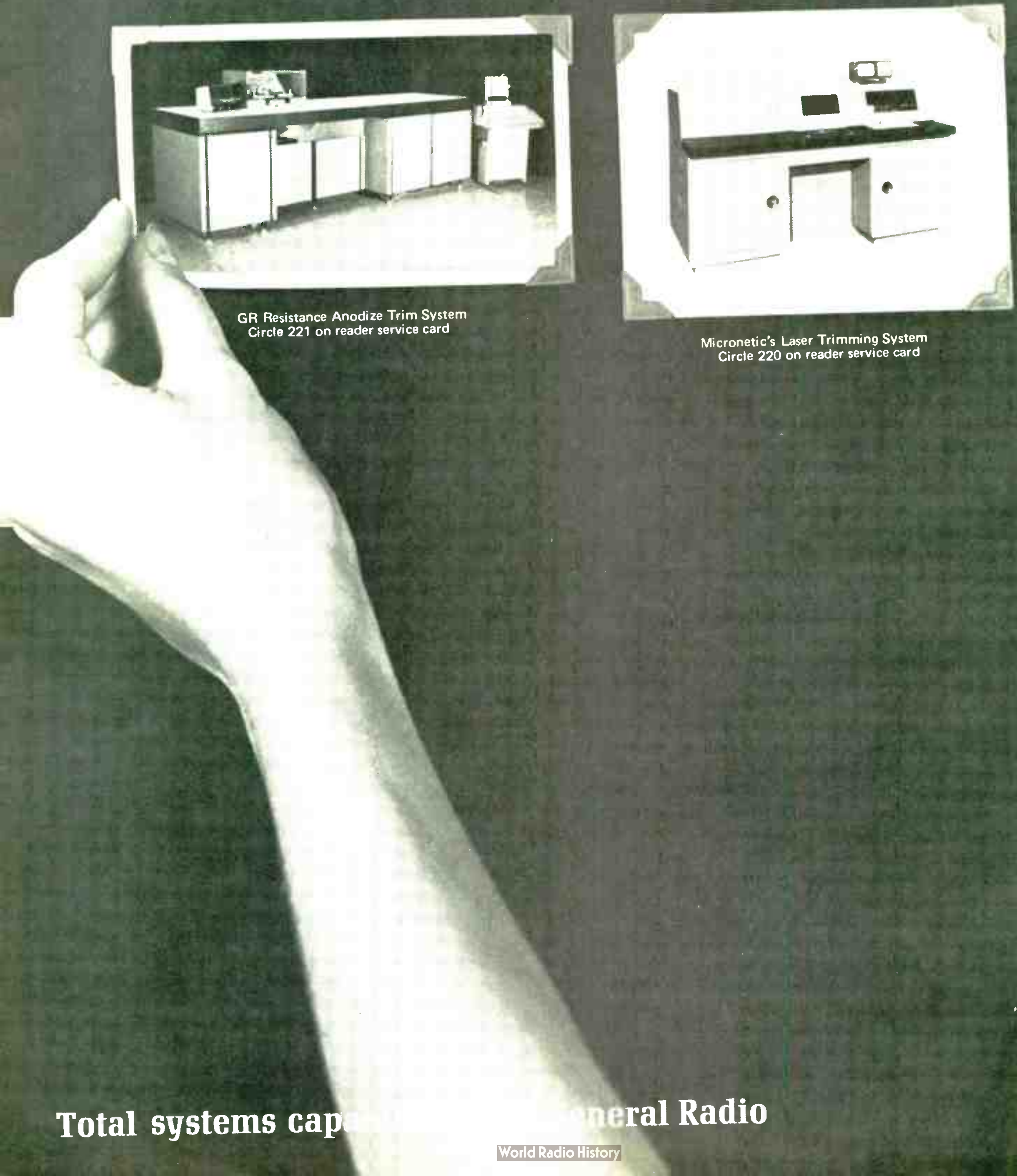
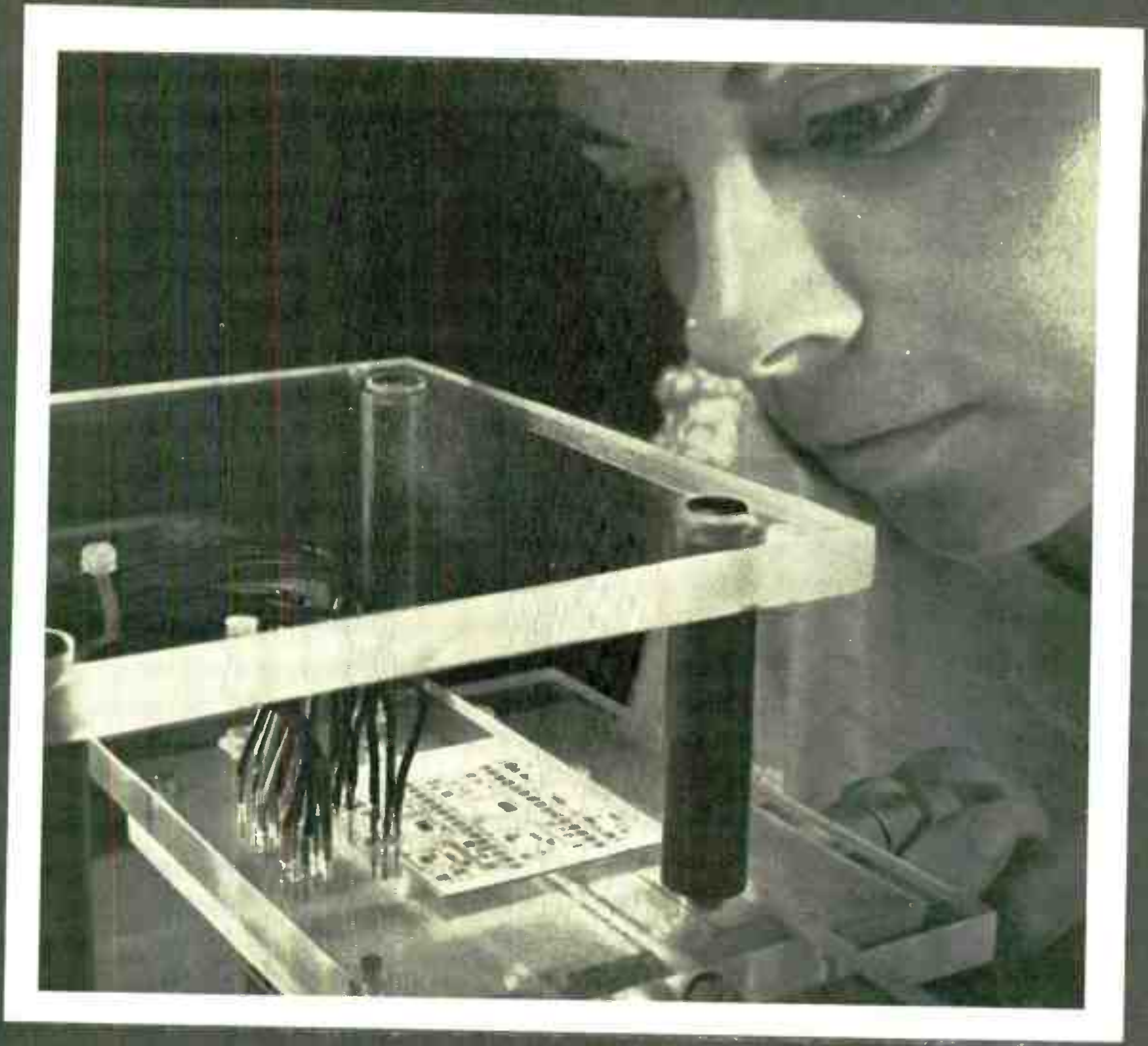
The GR Systems Family



GR Resistance Anodize Trim System
Circle 221 on reader service card

Micronetic's Laser Trimming System
Circle 220 on reader service card

Total systems cap... neral Radio



Now you can anodize 12 tantalum resistors simultaneously to 0.1% in 3 seconds...

. . . And up to 240 resistors on a single substrate. GR makes production trimming to high accuracies possible with its new Resistance Anodize Trim System (RATS).

RATS is a totally new computer-controlled system, designed from the ground up for high-speed anodization of tantalum resistors to accuracies of up to 0.02%. For noise immunity, RATS is designed as a synchronous system to insure that no anodizing or switching occurs while a measurement is being made. It features modular, plug-in measurement and anodizing units so that the number of resistors anodized simultaneously can be expanded for increased throughput.

The system includes a test station with 12 or 24 measurement and anodize-control modules to trim 12 or 24 resistors, a scanner to process an entire substrate of 240 resistors, a minicomputer, a teleprinter, and a status-control panel. Software programs are in user-oriented English language for simplicity. An interactive editor/translator program asks the operator nominal resistor value, anodize current, etc., to which he need only type the answers to prepare a trim program automatically.

The RATS is another of General Radio's growing family of systems for hybrid circuit manufacturing and testing. GR also offers a laser trimming system for thick-film circuits, and a single-channel desk-top anodize trim system, MINIRATS, for laboratories and applications where high throughput rates are not required.

For more information on RATS or a demonstration of the RATS in operation at General Radio's microelectronics facility, contact your nearest GR Office or GR at 300 Baker Ave., Concord, Mass. 01742.

General Radio

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People

McCord: "When I'm pulling logs with the tractor, I'm thinking about the problems at work."

The incentives for attaining success in the electronics industries are many, but A. Ray McCord, 45, Equipment group vice president at Texas Instruments, may have had one of the best.

He was the fifth son of a poor dirt farmer in Keithville, La., near Shreveport, and he decided early that the financial rewards of farming were a bit meager. So after service in the Navy in World War 2, he went to college in Shreveport under the GI bill, and graduated in 1949 with a BS in chemistry. "But I've never really used the chemistry," McCord says; he went from college to a job as a civilian radar instructor with the Air Force, then joined TI as a design engineer in October 1951, and has been with the giant Dallas company ever since.

McCord worked on a series of military projects at TI, in a number of positions, until he became group vice president in 1968. Since then his group has been greatly expanding its efforts into areas in the nonmilitary market that it had not been deeply involved in before, such as process control and computers, including minis and giant scientific machines.

But even though McCord doesn't have to farm for a living now, farming apparently is still in his blood. He lives on a 100-acre farm in Frisco, Texas, about 10 miles north of the TI plant, and often drives to work in his pickup truck. He doesn't grow crops but does raise cows, horses—and five children. An archetypal Irishman except for his North Louisiana drawl, McCord has red hair, long white sideburns, and a no-nonsense manner. Asked the usual question about whether he has a hobby he has an unusual answer. "When you work at TI, it's both your enjoyment and your business," he explains with a smile.

But he does admit to enjoying driving his tractor and working around the farm. However, he says: "I guess that when I'm pulling logs with the tractor, I'm really thinking about some of the problems I have at work."

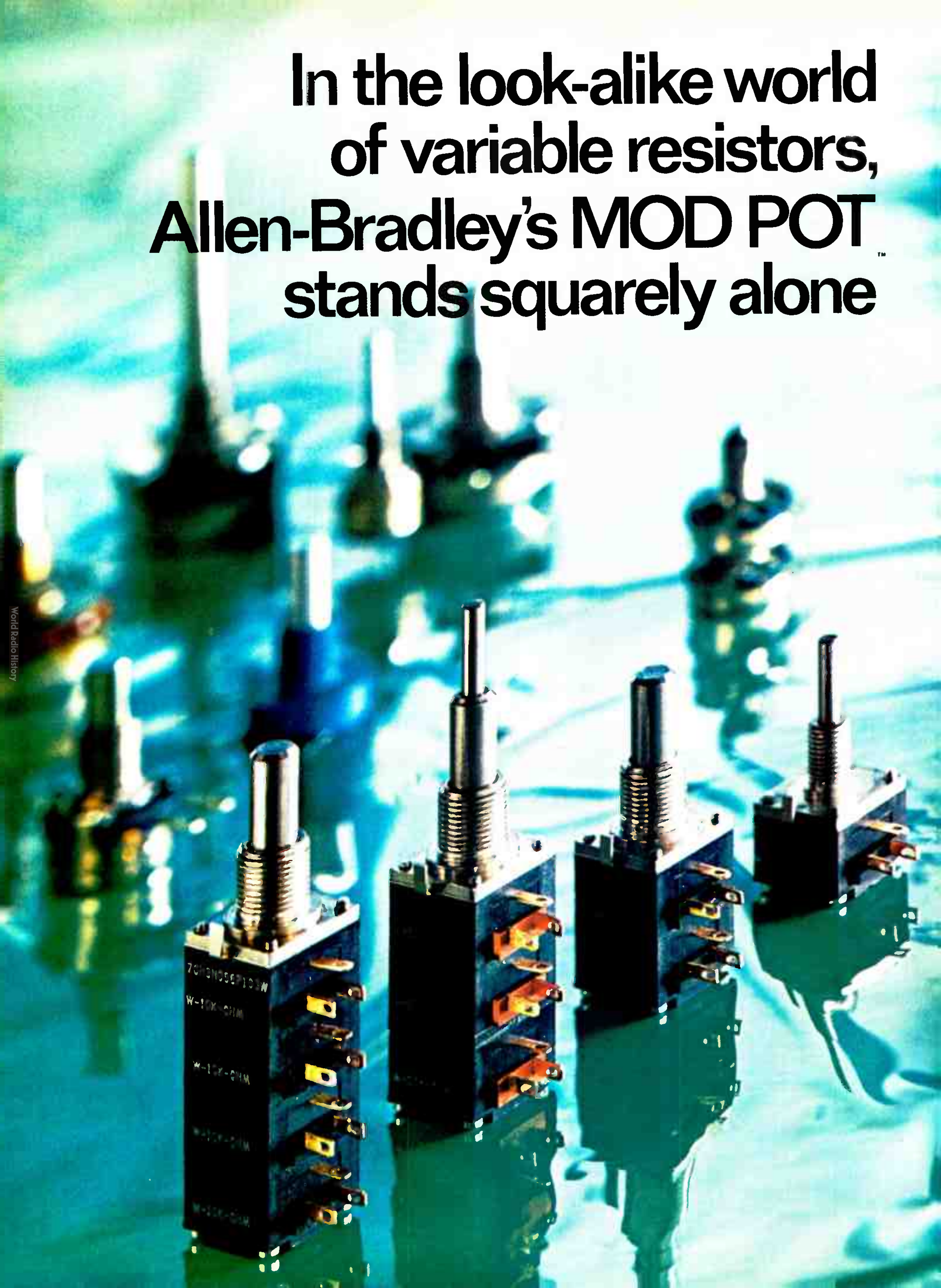
I have spent quite a bit of time in hospitals," says John F. Gall Jr., who was crippled by polio as a teenager. "And this is one reason I became interested in this field." Gall, a 1957 Stanford industrial engineering graduate, is now project director of the Medical Information Systems (MIS) at El Camino Hospital in Mountain View, Calif. This 460-bed, short-term general hospital has recently received the first HEW contract for $373,000 to evaluate a comprehensive medical system. The system is being installed by Technicon

Corp., Tarrytown, N.Y., and according to the 44-year-old Gall, "it will include as much of the medical ordering and information processing as possible."

Information handling, now the single largest hospital cost, accounts for 30% of all operating expenses. Gall, who began working at El Camino six years ago, says, "MIS-1 is the first crack at a real sophisticated medical information system," and if successful, it could revolutionize hospitals. Speaking more specifically, he adds, "if it can take humans out of paper work to leave them free for more important jobs, cut down the human errors, speed up the cycle of patient admittance and discharge, and reduce costs at the same time, hospitals will tumble over themselves to sign up."

Gall foresees a "big, big boom" in hospital information systems, because he believes "hospitals will have to do something to reduce the manual costs of information processing. A hospital just can't afford to pay the high prices of labor today." And, Gall forecasts a bright future for engineers in the hospital information systems field. He points out that "the health care industry is very large and just now catching on to the data processing move. "Hospitals in metropolitan areas and large university complexes," Gall says, "will want to develop their own systems." In an area such as Oakland's so-called "Pill Hill," Gall adds, where there are five or six hospitals within a mile or two sharing services on a non-profit basis, MIS could be most attractive.

Gall, a pioneer of the Bay Area industrial engineering effort in the hospital management field, calls MIS-1 just "a skeleton of what could be done." He envisions launching a community health system in which all private physicians could be linked to MIS-1. Patient scheduling and physiological monitoring are other programs which Gall hopes could be implemented in conjunction with the MIS-1 program. Gall adds "MIS also makes possible drug dosage prepared by automation," a process now being considered by the 10-year-old El Camino hospital.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Allen-Bradley's MOD POT™
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MOD POT: the most versatile 5/8" square potentiometer available today.

Series 70, designed for the 70's. There are a multitude of basic combinations. Potentiometer, switch and vernier drive modules combined to form single, dual, triple or quadruple section controls. With single or concentric shafts. But that's only the beginning.

Resistance modules come in cermet or hot-molded composition. Cermet, 100 ohms to 5 megs. Composition, 50 ohms to 10 megs, available in five standard tapers and also special tapers.

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All standard options are available, including: two different shaft diameters, sixteen lengths with plain, slotted or flatted ends; bushings in two lengths and two diameters with your choice of plain or shaft lock styles. Marked with your part number, or ours.

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Actual Size

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ALLEN-BRADLEY

Circle 19 on reader service card

Meetings

Northeast Electronics Research & Engineering Meeting (NEREM): IEEE, Sheraton Boston Hotel, War Memorial Auditorium, Boston, Mass., Nov. 3-5.

Nuclear Science Symposium: IEEE, Sheraton Palace Hotel, San Francisco, Nov. 3-5.

Fall Joint Computer Conference: IEEE, Convention Center, Las Vegas, Nov. 15-18.

Ultrasonics Symposium: IEEE, Carillon Hotel, Miami Beach, Dec. 6-9.

Vehicular Technology Conference: IEEE, Sheraton-Cadillac Hotel, Detroit, Dec. 7-9.

Reliability Symposium: IEEE, El Cortez Hotel, San Diego, Calif., Jan. 25-27

Power Engineering Society Winter Meeting: IEEE, Statler Hilton Hotel, New York, Jan. 30-Feb. 4.

Aerospace & Electronics Systems Winter Convention (WINCON): IEEE, Biltmore Hotel, Los Angeles, Feb. 8-10.

International Solid State Circuits Conference: IEEE, Sheraton Hotel, Univ. of Penna., Philadelphia, Feb. 16-18.

CALL FOR PAPERS

1972 Electronic Components Conference: IEEE, Statler-Hilton Hotel, Washington, May 15-17, 1972. Nov. 15 is the deadline for submission of abstracts to Harold Sobol, Program Chairman, Electronic Components Conference, RCA Corp., David Sarnoff Research Center, Princeton, N.J., 08540.

1972 G-MTT International Microwave Symposium: IEEE, Arlington Park Towers Hotel, Chicago, May 22-24, 1972. All papers should be submitted to Peter P. Toulios, Cochairman, Tech. Prog. Comm., Illinois Institute of Technology Research Inst., 10 W. 35th St., Chicago, Ill., by Jan. 7.


The New Series 9800 Is
The Best Programmable Calculator System, Now–
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The Model 10 starts at **just $2975.** (If previous experiences have taught you that basic is synonymous with stripped, think about this. The *basic* Model 10 can solve up to 10 simultaneous equations. Need more proof?

Only HP Allows You To "Design" Your Own Problem-Solving System.

With the unique modular-plug-in architecture of the Model 10, you specify — and pay for — only the capability you need. And if your needs change? No problem. You can expand the memory, add peripherals, or change the keyboard of your existing Model 10, at any time, *without costly modifications.*

Only HP Allows You To Customize the Keyboard

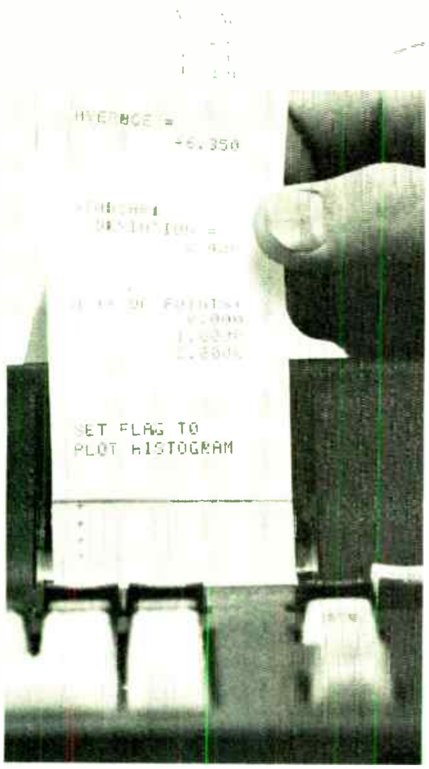
...with interchangeable plug-in blocks. You have a choice of *Statistics* or *Mathematics* functions under single keystroke command. These function blocks include separate (ROM) memories so they *do not* draw on the main calculator memory, leaving it fully available for further problem-solving power. A third keyboard plug-in option, the *User Definable Function* block, allows you to customize individual keys for operations uniquely important to you and your discipline.

HP Offers The Widest Range Of Memory Sizes

In basic configuration, your Model 10 can perform a complete regression analysis or solve a system of 10 simultaneous equations. If you need more power initially, or if growing demand warrants a larger capacity, the memory is easily expanded with simple plug-in modules. You can expand your Model 10 up to enough power for 17 simultaneous equations (clearly the most powerful calculator on the market). Between basic and maximum configurations, you can choose the combinations of program memory *and* data storage registers to match your needs.

Only HP Gives You Simple Programming and Editing.

Symbolic addressing, indirect and register arithmetic, added subroutine capability, special editing keys for software debugging, true "Do-Loop" ability—when you get your hands on the Model 10 you'll quickly see that the mechanics of problem solving need no longer stand between you and your great ideas. You can store often used programs on handy magnetic cards for instant entry into your Model 10. These cards may be linked for automatic call by the calculator so there is no limit to the size or complexity of the problems the Model 10 will solve.

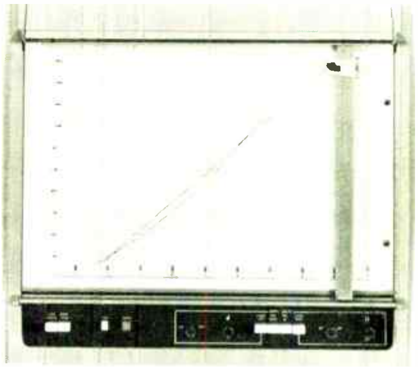


Only HP Gives You Alphanumeric Print-Out

...right on the printer tape. Standard equipment on the Model 10 is the bright, three register LED display. For hard copy you can add (with a modular plug-in) the quiet, low-cost strip printer. For the ultimate in operating simplicity, add the *exclusive Printer Alpha ROM* and you can automatically generate labels, program instructions, and messages—complete with symbols and punctuation—right on the printer tape.

Only HP Offers You a Host of Peripherals

...to build a system suited to your procedures. The integral I/O bus of the Model 10 lets you plug in such work saving Series 9800 peripherals as a Marked Card Reader, Paper Tape Reader, Digitizer, Typewriter, or the exclusive HP X-Y Plotter that plots linear, log-log, semi-log, or polar plots—and writes alphanumerics.



Price. Performance. Simplicity. The Series 9800 is the best desk-top computing system now, and in the foreseeable future. But don't take our word for it; ask our competitors. Or write for more information or a "hands-on" demonstration. Hewlett-Packard, P.O. Box 301, Loveland, Colo. 80537. In Europe: 1217 Meyrin-Geneva, Switzerland.

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This minicomputer memory dropped 2 bits in 7 days... and failed.

Our final performance test is rugged, and sometimes it takes guts to stick to it. But we have found through experience that it is required to be sure that you get a working disc memory that will keep working.

The test is simple: The disc is run continuously for 7 days; each day during the test repetitive write, read, and check operations are performed to verify error free performance. If more than one bit is dropped, the unit goes back for rework—it's pass or fail with no compromises.

Every minicomputer disc memory we ship is factory certified to have successfully passed this final test; the memory you put into your system has been through it.

And we have a memory just right for your system—memories with capacities ranging from 32k to 4200k words for Data General, for DEC, for HP, for Varian, and for most other minicomputers.

To find out more about the disc memories with tested reliability, call your Data Disc representative or contact us at 686 West Maude Avenue, Sunnyvale, California 94086; 408/732-7330.

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Circle 24 on reader service card

Electronics Newsletter

October 25, 1971

Fairchild working in CCD imaging

Interest in charge-coupled devices and bucket-brigade technology for memory and imaging is swelling (see p. 38) as more companies jump into the field. A signal development underlining the trend is the move by Gil Amelio, one of the key CCD developers at Bell Labs, to Fairchild's R&D Center in Palo Alto, Calif.

As an indication that Fairchild is taking more than a cursory look at CCD imaging potential, Amelio caused a stir earlier this month at the International Electron Devices Meeting with an elegantly simple single-phase CCD structure he's developed.

Lockheed ends tests on gas-pump system

Lockheed Electronics Co. has completed a 90-day field trial of an electronic transaction system that controls gasoline pumps from a remote central console. Designed for self-service stations in which the customer pumps his own gas, Lockheed's LTS-30 allows a station operator to unlock the gas-pumping mechanism from the console. Then, as gas is pumped, the system totals the dollar amount of the sale on digital readouts. The LTS-30 controls modules of three pumps, with six- and nine-pump units planned.

Development is handled by Lockheed's Industrial Technology division, which has 10 years experience in the fuel-distribution business with a mechanical register for delivery trucks. At present there are approximately 6,000 self-service stations around the country that could use the system, Lockheed estimates, and this number could increase tenfold by 1975.

Bell System faces EIA intervention in local ratemaking

Threats of intrastate communications regulations and tariffs that would set limits to the use of "foreign" (non-Bell System) attachments may provoke a legal counter from the Electronic Industries Association. The EIA Communications and Industrial division's telephone equipment section is reported to have formed a special committee to monitor state and local filings by carriers and, if necessary, intervene directly with counsel to protect equipment makers' interests.

Western Electric Co., a division member and AT&T's manufacturing arm, was absent from the meeting when the EIA section's plan was adopted, sources report.

TV makers to bow to ad claim demands

Television manufacturers are expected to capitulate to the Federal Trade Commission's demands for "all documentation and other substantiation" for specific advertising claims made by a dozen consumer electronics companies. "This will change the industry's traditional approach to its customer," says an industry spokesman. Rather than divulge proprietary manufacturing information, or go to the expense of collecting comparative data, companies will alter marketing techniques, industry sources predict.

The television industry was pinpointed last year as a target industry when the FTC required Matsushita Electric of Hawaii to print retractions of misleading advertising claims, and later, when it proposed rules attacking the use of "music power" and "peak power" when describing consumer electronics wattage ratings.

Electronics Newsletter

Ebertin to direct Nrmec business system marketing

Nrmec, North American Rockwell's semiconductor arm, is consolidating its search for business system opportunities—such as electronic cash registers and point-of-sale systems—to add to its calculator chip capability. The firm has just named Michel Ebertin to the newly created position of director of business equipment marketing, promoting him from manager of systems development engineering.

Besides focusing the business equipment MOS/LSI effort under one man, Nrmec is also offering a versatile chip set for electronic cash registers, ranging from a single chip for simple machines to six or more, including a tax-calculating chip, for more complex units.

Chalk transmitter tested by Bell

Bell Laboratories is testing a breadboard system that transmits writing on a blackboard over dial-up phone lines and recreates the images using a deflected laser beam. A writing instrument—chalk, pencil, or stylus—is attached to a tiny location indicator that emits ultrasonic pulses. These are sensed by two orthogonal "continuous strip" or bar-shaped microphones, converted to digital data, and transmitted.

At the receiving end, the signals are applied to a pair of galvanometers which, in turn, are used to deflect the beam of an ultrasonic laser. The beam is made to strike a photographic slide coated with photosensitive material. Simultaneously, the information on the slide is projected.

Although the work carried out at Holmdel, N. J., is still experimental, a spokesman says the system is being considered as an adjunct to the 50A portable conference set offered by the Bell system to transmit a lecturer's voice from one location to another.

Quartz crystals made by photolith ready for market

The Statek Corp., a small Orange, Calif., firm that says it's first to make quartz crystals photolithographically, is now turning out the crystals in commercial quantities. The company, which can turn out 5,000 a day, is bidding on commercial opportunities that include irrigation timers and alarm systems, but is already profitable with prototype quantities for a variety of timing applications, including military uses.

The crystals are made much like semiconductors, except that the substrate material is 1-mil-thick quartz instead of silicon. The masking, etching, and separation techniques are used as for semiconductor manufacture, although the etchants and resists are proprietary formulations.

Statek president Juergen Staudte says the crystals, which range in frequency from 10 to 100 kilohertz for standard products, are much smaller and more shock resistant than conventional tube-type crystals.

Addenda

Solitron Devices has bought the rf and MOS lines of United Aircraft's Unisem division. The rf operation will be moved to Solitron's Jupiter, Fla., facility, and the MOS portion will go to the new owner's San Diego, Calif., site. . . . Still up in the air after the shutdown of GE's IC products department is the disposal of the technical expertise. Says a spokesman: "We are open to selling certain segments of our processes and technology and have been conducting discussions with potential buyers." The Minimod packaging scheme is a prime candidate, with TI expected to sign a licensing agreement before GE got out of the IC business [*Electronics*, Sept. 27, p. 17]. . . . Hamilton Standard's Systems Center has a $4.5 million contract from Martin Marietta to develop a strapdown inertial reference unit for the Viking spacecraft lander.

This ADC has priced analog multiplexers right out of business.

ADC-8S is so inexpensive you can convert each channel at the transducer and go digital all the rest of the way. Forget pre-amps, noise problems, expensive cabling, time skewing, and last but not least, the analog multiplexer.

Even if ADC-8S didn't save you money, you'd have a better data acquisition system. But it does. Figure each ADC-8S at $49 (100's) and watch the arithmetic come out our way. Then call or write for an evaluation sample.

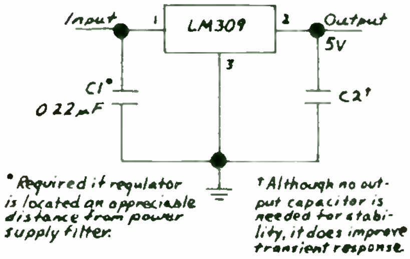
ADC-8S is our third entry in the economy converter class. Check the last two issues for our DAC-10Z (a top performer for only $29) and our DAC-12QZ (at $49, less than half the price of its competition). But please don't forget we have a top-of-the-line and a middle-of-the-line — in fact, more and better modular converters than any other company in the world. Analog Devices, Inc., Norwood, Mass. 02062. (617) 329-4700.

ANALOG DEVICES

Circle 27 on reader service card

When it comes to
regulator or a com
made your choice

LM 309.



Fixed 5V Regulator

The easy-to-use LM 309 is a complete 5V regulator on a single silicon chip. Designed for local regulation on digital logic cards, the 309 neatly eliminates distribution problems caused by single-point regulation.

Significantly, no external components or adjustments are required.

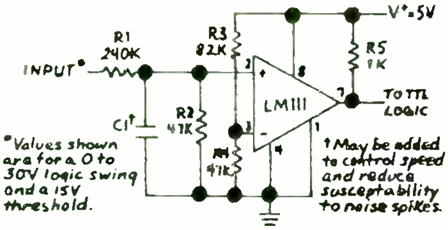
But the real beauty of the LM 309 is the fact that you just plug it in and relax—knowing full well that it's *guaranteed* to limit incoming voltage transients so that the TTL (or DTL) circuits it drives will *always* work. (What comfort to know you've got a regulator that will—in the worst case—actually destroy itself to avoid damaging any of your more expensive digital circuits!)

Both the LM 309 and its military counterpart, the LM 109, are available off-the-shelf in two package configurations: a TO-5 which delivers output currents in excess of 200mA if adequate sinking is provided; and a TO-3, in which the available output current is greater than 1A.

Prices (100-999) are as follows: LM 109H \$20.00, LM 209H \$7.50, LM 309H \$5.50, LM 109K \$25.00, LM 209K \$8.95, LM 309K \$6.50.

selecting a voltage parator, we've incredibly simple:

LM 111.



TTL Interface with High Level Logic

A plug-in replacement for both the LM 710 and LM 106, our new LM 111 voltage comparator has it all over its predecessors.

First of all, the LM 111 is very easy to use.

Then there's the "universal" voltage supply range. The LM 111 can operate from 5V and ground, or any combination of voltages from ground to ±15V.

Another big advantage is the 111's input impedance. It's so high, the resulting input current is a remarkable *one thousand times* lower than the 710's (250 nanoamps versus 25 microamps)!

Since we're dealing in superlatives, here's another: Gain with the LM 111 is 200,000, or *two hundred times better* than previously available.

Designed to drive RTL, DTL, TTL or MOS logic, the versatile LM 111 will also handle lamps or relays up to 50V at 50mA.

Finally, the entire LM 111 series (including the LM 211 and LM 311) is available off-the-shelf in TO-5, flat-pack or dual-in-line package configurations.

Prices (100-999) are very competitive. For example: LM 111H $12.00, LM 211H $7.50, LM 311H $3.25.

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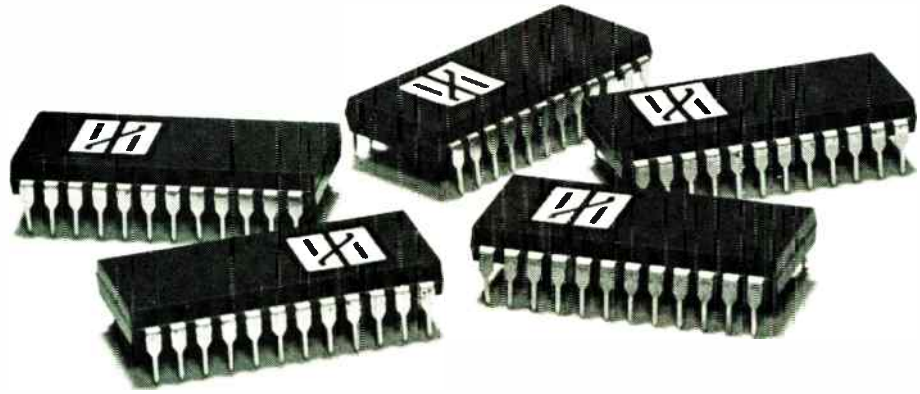
Circle 29 on reader service card



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Laser solves coupling problems of optical communications

Producing a laser beam within a crystal surface simplifies the design of integrated optical systems

There's been a lot of talk about integrated optics systems and how they could revolutionize the communications industry. But there's at least one key component missing—a way to efficiently couple an external light source, usually a laser beam, on to a thin film planar surface. Now, however, a new technique using a solid state laser that may solve this problem has been developed by Frank L. Varsanyi, president of Isoray International Corp., Palo Alto, Calif., and a professor of physics at Stanford University.

In proposed systems, which excite communications people because of their small size and of light's extremely high information capacity, circuitry is made up of thin films shaped into miniature light-guide networks. Components modulate, phase shift, amplify, and detect the signal-carrying light. Several other methods have been tried to obtain coupling, but they all suffer from low efficiency and high complexity. They include diffraction gratings, prisms, and even direct passage of a laser beam into a thin film edge.

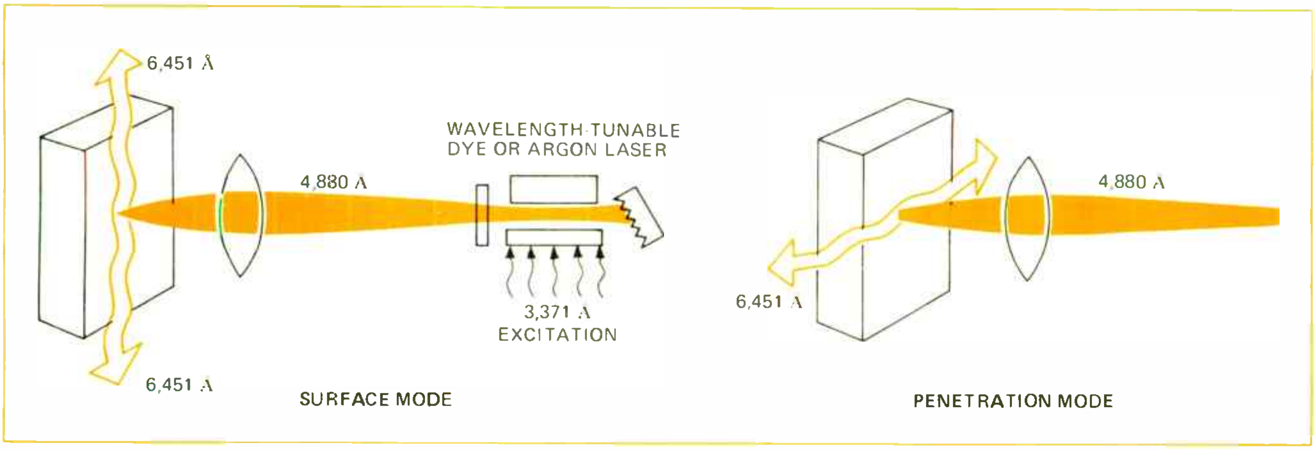
Problem solver. Essentially, since the laser beam is produced directly in a crystal surface, it eliminates coupling problems, Varsanyi says. "Also in favor of the laser is the fact that its extremely small packing densities of well over a million independent laser spots on 1 square inch of crystal surface seem entirely reasonable," he adds. Moreover, the crystal used—praseodymium trichloride—can easily be vacuum-deposited for making thin film "circuits."

Varsanyi says the super-radiant laser action can be generated within the surface of a praseodymium trichloride crystal by directing a laser beam with a wavelength of 4,880 angstroms at the crystal surface. This can be done with a tunable dye laser (pumped by 3,371 Å energy from a nitrogen laser) or with an argon laser used as a direct source of 4,880 Å light. When the cleaved crystal surface is illuminated with the beam, the surface ions are excited to a high energy level which allows the crystal to lase at 6,451 Å. Penetration depth of the radiation is on the order of a micron, and a common 50-millimeter photographic lens can be used to focus the beam on the crystal surface.

If the excitation light is projected on the crystal surface in the form of a slit, a threshold is first reached along the longer dimension, and the laser action occurs along this axis. Varsanyi points out that "the amplification is so large that a strong directional laser beam emerges from an optically pumped length of just a few microns."

If the excitation energy density is increased further, a second threshold is reached. The incoming light saturates layer after layer of active ions until the dimension of this excitation pocket becomes

System in sight. Planar laser developed by Frank L. Varsanyi could be missing link in search for integrated optics systems.



larger in the direction perpendicular to the surface than along it.

Steerable. Also important in integrated optics is the steerability of the generated beam. Because the surface laser action is generated along the longest dimension of the excitation beam on the crystal surface, shifting or rotating the excitation image causes a corresponding change in the output beam direction. Thus, by turning the beam or by using a slit mask that can be rotated, different "circuits" on the crystal surface can be addressed.

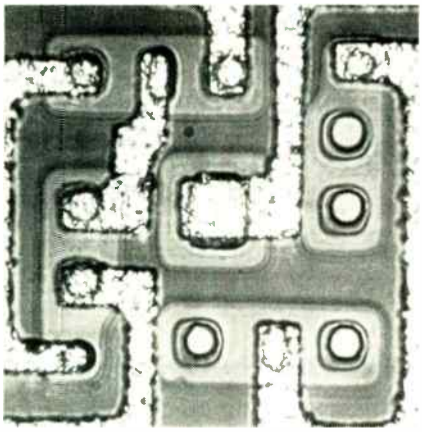
What's more, if a spot is pumped at an energy level that is below the lasing threshold, a memory-type cell is created. For example, if a below-threshold pulse of, say, 5 nanoseconds is aimed at a spot on the crystal, that spot fluoresces and lasts for about 10 microseconds. The arrival of an additional 5-nanosecond pulse of the proper intensity within a specified time would do one of three things. It could replenish this memory spot or, if the new beam were above the threshold, make it emit laser radiation along the surface, or, if the beam were of still greater energy, make the memory spot "read out" by reaching the second threshold of the penetration mode.

"And," adds Varsanyi, "the small active area size makes possible some visually spectacular experiments. If the excitation light is focused on a tiny praseodymium trichloride crystallite hardly visible to the naked eye, the little dust particle lights up with the brilliant red glow of the laser output as soon as the threshold energy density is reached." It is not unlikely, he says, that this "powder laser" dispersed in some liquid or solid carrier material could open up new possibilities in display.

Solid state

Bipolar RAM offers 2K chip

A bipolar circuit technique has been developed that could be the means toward the end sought by semiconductor makers: memories with bipolar speed plus MOS economy and packaging density.



Packs it in. Bipolar circuit developed by IBM in Germany packs 2,000 bits on a standard-size chip made conventionally.

The development, from IBM's research lab at Boeblingen, Germany, could mean bipolar random-access memories with 2,000 bits on a standard-size chip made by conventional processing. If implemented with oxide isolation, the result might be RAMs with as many as 4,000 bits on a chip. Presently, bipolar technology isn't considered a practical RAM technique.

Small cell. The high density is due to a unique cell configuration having a size of only 4 mil^2—more than two-thirds smaller than today's best MOS RAM cells. And since bipolar circuits are static, points out codeveloper Horst Berger, no refresh circuitry is needed as with dynamic MOS memories.

What's more, the new devices, because they are operated statically, dissipate very low power—several hundred times lower than conventional dynamic MOS circuits that must be continually refreshed. Standby power of less than 10 nanowatts per cell has been observed by Berger and his codeveloper, Sigfried Wiedmann. Thus, an entire 4,000-bit array would dissipate only 40 microwatts, well below anything being considered by MOS circuit makers. And even at these lower power levels, speeds are impressive: write time is less than 40 nanoseconds, read time less than 10 nanoseconds.

The small cells are not the result of a processing innovation but rather follow from a clever circuit design. Traditional resistive loads are replaced by two cross-coupled and inversely operated npn transistors of a common n-region. The charges of the flip-flop nodes are maintained by a minority carrier injection directly into this n region.

This results in equal currents to the base and collector of the on transistor, requiring an inverse current gain of only greater than or equal to one in addition to the supply of the leakage current to maintain stability.

Consumer electronics

Ragen confident it can build under-$100 calculator

Now that the wraps are off the mini electronic calculator that Ragen Precision Industries says could retail for under $100, the question is: can Ragen produce them at the 4,000 to 5,000 per month called for by its initial order? The uncertainty results because the shirt-pocket-sized machine boasts two of the newest and least applied electronics technologies: complementary C/MOS semiconductors, used in a calculator for the first time, for the arithmetic, logic, and display drive circuitry, and liquid crystals for the readouts.

"Without a doubt we'll be able to produce them," asserts Ragen's president, I.L. Lopata, adding "Our biggest concern technically is the molded plastic case."

This confidence is shared by Albert H. Medwin, president of the Ragen subsidiary, Ragen Semiconductor Inc. of Whippany, N.J. Medwin directed development of the calculator. The semiconductor company has been making C/MOS chips for more than three years, he points out, and "they have been the largest and most complex" in the industry. "As long as a year ago, we were producing 3,000 to 4,000 chips a month for a data terminal customer."

Displays. There is less corporate experience producing the liquid crystal displays. But Medwin predicts the digital readouts will achieve the 20,000-hour life some industry sources forecast for the devices.

The Ragen calculator—a full four-function machine with eight-digit display and a floating decimal point—tallies up to 16 digits. It will be manufactured entirely in the United States. With batteries, it should weigh about 8 ounces, light enough to be readily shipped back to Ragen's facility in New Jersey for servicing, says Lopata.

So far, Ragen has not assembled a complete calculator but has merely tested the unit's individual components. First deliveries—20,000 units for Alexander's, a New York department store chain—are to begin in January. It has an option to buy 20,000 more calculators.

Altogether, the calculator, measuring 2⅜ x 3 x ½ x ⅞ inches, looks deceptively simple. Its guts consist of two 220-mil square C/MOS chips housed in individual 40-pin dual in-line ceramic packages and an eight-digit liquid crystal display with 7/32 by 5/32-inch digits. These elements are flow soldered to a printed circuit board measuring 2 by 3 inches. This board also supports the keyboard and the calculator's power source—a 12-volt dry cell battery. Ragen says the battery, because of the exceptionally low power drain of the C/MOS circuitry and liquid crystal displays, will last for 2,000 hours of operation. In contrast, competitive calculators often rely on rechargeable batteries, which will last as little as three hours.

Another factor contributing to the unit's low power drain is that Ragen multiplexes the drive lines between the chips and the eight-digit liquid crystal display. Thus, instead of applying power to all digits, at once, it is applied sequentially, with the power to any one digit continually refreshed. To the human eye, the display itself, which relies on reflected light persists and appears continuously on. Power to the eight digits is less than 2 microamps, says Medwin. Another advantage of this technique is that the number of interconnections is reduced from 64 to eight between the C/MOS chips and the displays. And it also simplifies the chip circuitry because a single seven-segment decoder can be time-shared among the display digits.

All of the electronics is contained in the C/MOS chips, which probably accounts for their relatively large size. Generally, the larger the chip the worse the yield. However, Medwin terms the yields "commendable." He points out that Ragen has been producing chips of this size for the last six months, with 300-mil-square chips scheduled to be produced sometime next year.

Displays

Liquid crystal leads reduced

In a multiplexed liquid crystal display, the number of leads required for adding the matrix can be a significant problem. In an eight-digit, seven-segment display, for example, 64 leads would be required, as well as 56 diodes to isolate the various segments—enough to boost cost and reduce reliability.

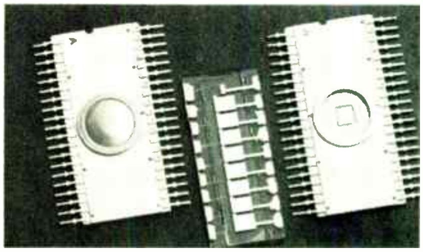
Now two researchers at General Electric Co.'s Corporate Research and development Laboratories in Schenectady, N.Y., have taken advantage of a unique characteristics of nematic liquid crystals to significantly reduce the number of leads and components required for strobing. Their two-frequency addressing scheme reduces the number of leads for an eight-digit display from 64 to 16, and eliminates the need for diodes.

Liquid crystals derive their display qualities from the light-scattering effect they exhibit under electrical excitation. Ordinarily, dc or single-frequency ac is used to induce scattering to convert the crystals from a clear to an opaque state.

Two signals. In the GE addressing scheme, devised by C.R. Stein and R.A. Kashnow, two ac sinusoidal signals of different frequencies are used instead. When the two signals are simultaneously applied to the liquid crystal, the scattering threshold for the material is exceeded and the device opaques.

To demonstrate the principle, Stein and Kashnow adapted the circuitry of a conventional pocket calculator and hooked it up to an eight-digit liquid crystal display. In the model, the high-frequency addressing signal of about 4 kilohertz is applied to a common line going to all the segments, and a 30-hertz signal is switched sequentially to turn on the specific segments required to produce the desired digits. Only 16 external leads connect the panel to the calculator circuitry.

One disadvantage is that a voltage level on the order of 45 volts is required for the sinusoidal drive.



In hand. Wooden mockup of Ragen calculator, which will sell for under $100. Electronics, in two C/MOS chips, drives the calculator's liquid crystal display.

Conventionally driven liquid crystal displays can run at 15 V dc, which is more compatible with MOS drive circuitry. Even so, says Stein, the GE Components division at Owensboro, Ky., is seriously considering adapting the scheme into a product.

Swiss variation. In a variation of the technique, P.J. Wild and J. Nehring of Brown Boveri Research Center in Baden, Switzerland, have developed an addressing scheme that uses a combination of dc and ac to select the cells in a liquid crystal display. In this case, the ac voltage is used to suppress the scattering effect that opaques the liquid crystal.

If a voltage $V_1 + V_2$ (where V_1 is a dc or low-frequency voltage greater than the scattering threshold voltage and V_2 is an ac signal of suitable amplitude and frequency) is applied to a row of a matrix and $-V_1 + V_2$ to a column, scattering only occurs in the fully selected cell, which does not see the suppressing signal.

Communications

Bell data will hitchhike on existing voice systems

To meet the demand for digital service through 1977, AT&T has said it will go largely with existing facilities. To help do this, a new modulation technique has been developed at Bell Laboratories to permit data signals to "hitchhike" on existing microwave radio systems by using the lower end of the currently used baseband frequencies.

The new development, called Data Under Voice (DUV), will be built around existing L600 and U600 terminal equipment. Only that portion of the frequency band below 500 kilohertz will be used to transmit data. These frequencies are generally not utilized now because they are too noisy for voice transmission.

Low errors. Digital error rate is expected to be very low, says a Bell spokesman. Even when the signal fades severely enough to trigger a switch to a protection channel, the company claims, digital signal error rate will be better than one bit in 10^7.

The company is not divulging technical details of the new system. However, this system will be used to connect 90 cities by 1974 for all digital private line service.

Annual data transmission revenue at AT&T, says H.I. Romnes, chairman and president, will increase to $5 billion by 1980, about 10 times present rates. The company had previously forecast that data transmission would contribute only $2 billion to revenue by that date. The higher forecast was explained as the result of a new survey of likely data transmission users.

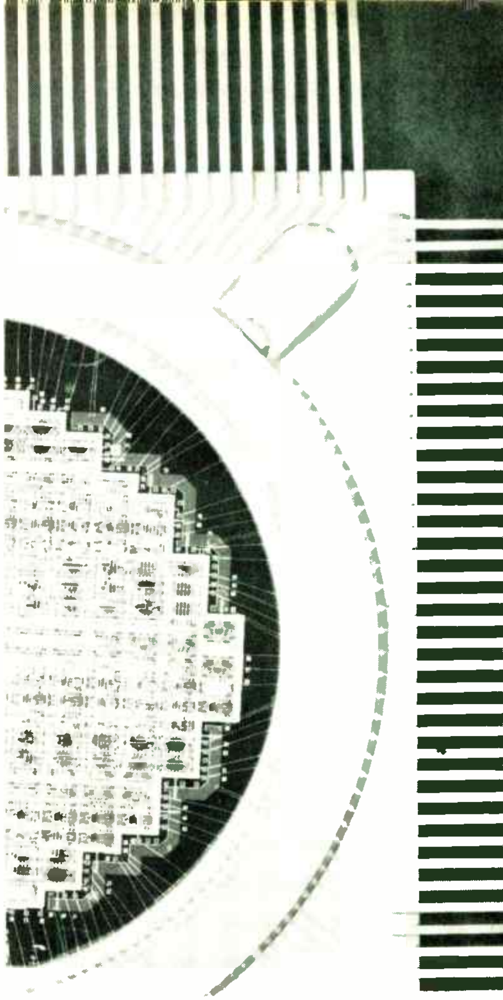
Manufacturing

Pad relocation bows in eight-bit multiplier

The pad relocation interconnection technique, developed at Hughes Aircraft Co. two years ago, has finally moved to the production stage—though on a limited basis. The first product, being made at Hughes' Microelectronic Products division in Newport Beach, Calif., is an eight-bit multiplier, plus a sign. It can form 8 million products per second, multiplying two eight-bit numbers and sign, to form a 16-bit result and a sign each time.

Essentially, pad relocation moves a circuit function from a bad cell on a fully probed wafer to the nearest good cell through a unique interconnect mask [*Electronics*, Oct. 13, 1969, p. 44].

As for the multiplier, it's fabricated on a full 1.5-inch-diameter wafer, and is made up of 52 transistor-transistor-logic full adders and 96 gates to give the equivalent of 616 gates. George Wolfe, manager of the LSI technology department at the Hughes division, says there are three kinds of cells on the wafer: one type contains two D-type flip-flops, another has a full adder plus two four-input NAND gates, and the third is a quad three-input NAND gate cell.

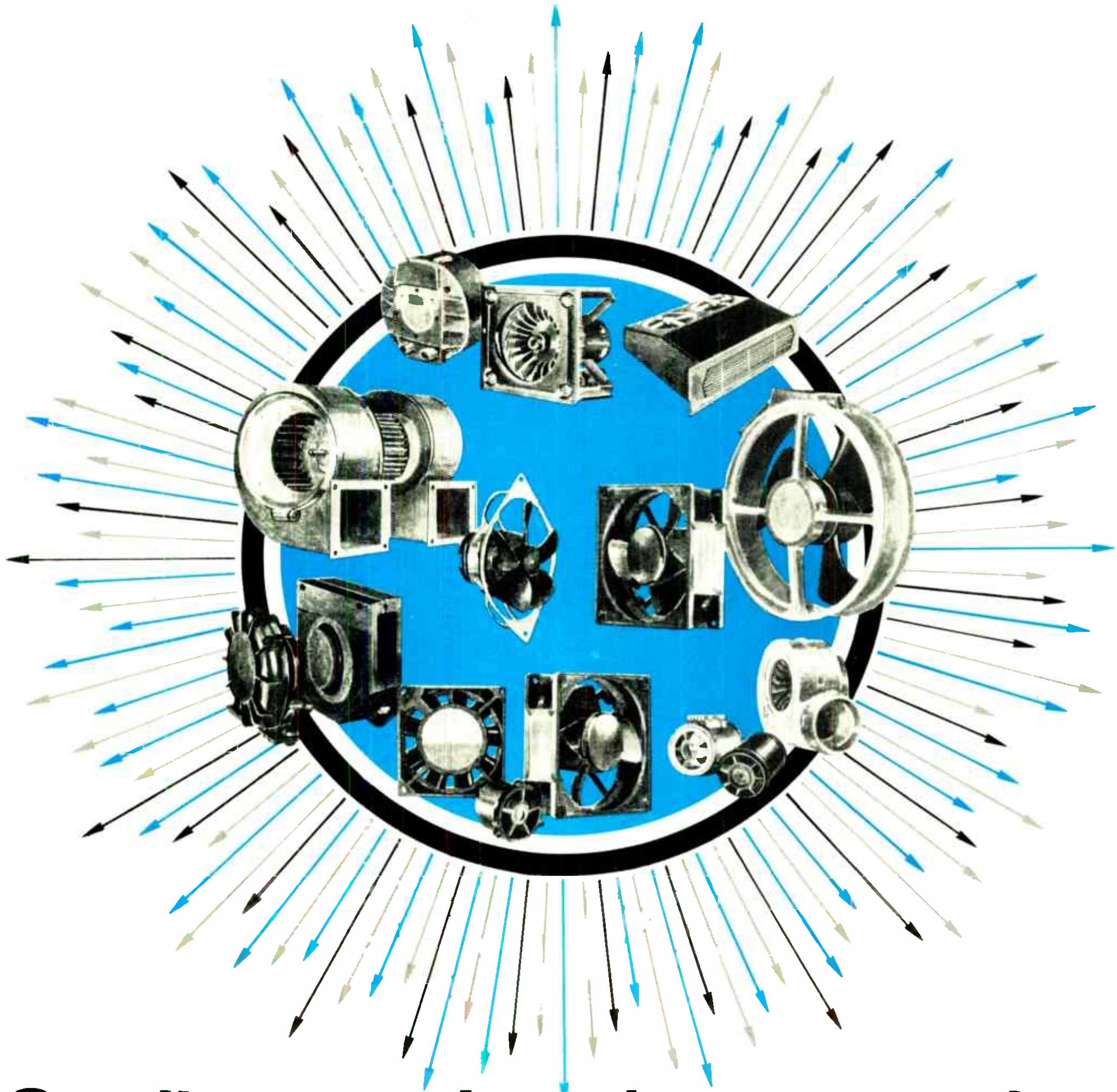


Multiplier. Hughes eight-bit device is first product to use pad relocation technique.

One for 20. The multiplier replaces a 20-chip hybrid in the aerospace data-processing functions at the Hughes Aerospace division in Culver City, Calif. Wolfe says he knows of no comparable eight-bit multiplier, especially at this speed, that's available in monolithic form.

Wolfe believes the multiplier is probably the most complex bipolar LSI device available, and he sees as initial customers military buyers interested for high-speed signal processing and digital filtering applications. The unit is housed in a 156-lead, 2.25-inch-square hermetically sealed ceramic package. Electrical characteristics are typical of the TTL 5400 series. Typical gate propagation delay is 10 nanoseconds, gate fanout is 10, and gate power dissipation is 10 milliwatts.

Since early this year, the Newport Beach division has been delivering the multiplier, designated the H1002MC, to its sister division for use in missile and aerospace computer applications; the first outside delivery was made last July. But



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Circle 35 on reader service card

William Eckess, marketing manager, says his Microelectronic Products division is ready to deliver small quantities to outside customers in two to four weeks. The price is $1,000 for a single unit, but drops to approximately $300 each in quantities of 1,000.

Unmasked. Hughes engineers at Culver City and at Newport Beach say the pad-relocation concept is simpler than traditional discretionary wiring because fewer masks are required.

In the Hughes system, the first-layer glass passivation mask is standard for all wafers with the same yield pattern. The first aluminum metal layer has already been deposited, and 100% dc testing of all cells has been performed, generating a yield map of good cells. The probe yield results are stored in a computer to generate the pad-relocation mask, the only variable mask compared to variable masks for each layer in the traditional discretionary wiring approach to full-wafer large-scale integration.

Lasers

Competition mounts for weapons delivery . . .

The laser, long viewed by the military as a system with great promise but not much else, is coming into its own. The impetus has been provided by the development of reliable, high-power systems and the success claimed by the Air Force for some of its 30 position and velocity (PAVE) systems.

Laser components in the PAVE package in use or under development are used for designation and homing by so-called smart bombs and missiles equipped with seeker optics. With the Navy already test-firing laser-guided ordnance and the Army mounting a $28 million effort this fiscal year under the umbrella of Laser Designator Seeker System (LDSS) [*Electronics*, Sept. 27, p. 33,] the use of lasers throughout the military for such missions as target detection, rangefinding, and weapons guidance is expected to climb sharply in the next five years.

One military estimate puts the market at 4,200 systems in the next five years, although that number is hedged with the observation that "precise numbers are hard to pin down at this stage. A great deal depends on the kinds of quality we get in terms of reliability and power output, but it would be reasonable to assume for the long term that every aircraft that can deliver a weapon will probably have a laser system to help it do the job."

Moreover, says the same Pentagon source, new Army and Navy artillery and missile batteries as well as forward air and ground observers will likely require similar laser systems for rangefinding and guidance.

Neodymium yttrium-aluminum-garnet lasers are highly favored for such applications now, particularly in the Air Force view, although gallium arsenide is a contender for illumination functions. And, not to be left out, in experimental development with the Air Force are flowing copper vapor systems reputed to have quantum efficiences of 70% and the consequent potential for operating under any atmospheric conditions [*Electronics*, Aug. 30, p. 31].

Among the multiple programs that companies are examining, one major effort is expected to come with PAVE Lance. That target-acquisition and weapon guidance system updates the pod-mounted PAVE Knife package that was designed by Philco-Ford for the McDonnell Douglas F-4 and uses a Westinghouse Nd-YAG laser. Should Pave Lance be approved also for the Navy LTV A-7 Corsair light attack plane or the Air Force's new F-15 fighter, then the number of systems to be bought could run to 2,000 or more during a period of five-to-seven-years.

More asked. Other laser procurements proposed include an estimated 50 systems for the Lockheed AC-130 gunships for weapons delivery; between 200 and 300 for Lockheed's P-3C land-based antisubmarine warfare plane; as many as 400 for the Navy's Seasparrow and Tartar ship missiles, and a possible 150-200 for the Air Force F-111 interceptor.

Also proposed were an unspecified number for the Lockheed AH-56A Cheyenne helicopter if it finally moves to production as an Army "tank buster" next fiscal year, as expected, plus a variety of systems for Navy ship navigation, including the proposed high-speed hydrofoils, and rangefinders for Army tanks and ground observers operating as the eyes of the Army's artillery and helicopters.

. . . with IBM entering an 'eye-safe' Raman unit

A first principle of defense contracting is to win the competition; a better one, however, is to preclude competition by having the system performance specification incorporate your design. This appears to be the approach being taken by IBM's Federal Systems division, Gaithersburg, Md., in the competition for a bigger share of the market for laser rangefinders, target designators, and weapons delivery systems.

The IBM approach is keyed to a passive and proprietary dye Q-switch and small, comparatively low-cost Raman laser whose quan-

Looker. IBM's James Vanderslice with the low-cost Raman laser for military use.

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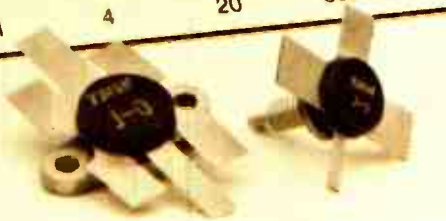
J02001	10	40	200-400
J02401	7	35	400-600
J02601	4	20	600-1000



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tum efficiency of 40% at 5 megawatts output is expected to improve to 60%, according to James T. Vanderslice, manager of electro-optical systems development.

Moreover, Vanderslice says the IBM Raman laser, triggered by a 1.06-micron neodymium YAG unit, emits in the so-called eye-safe region of 1.54 microns.

Informal estimates of the market competition indicate IBM has a way to go to knock down the leader, acknowledged by some military sources as Martin Marietta's Orlando, Fla., operation. Indeed, a listing of others active in the market reads like a who's who of the electronics industries: Hughes Aircraft, North American Rockwell, RCA, Westinghouse, Sperry Rand, Texas Instruments, Union Carbide, and Korad, among others.

Nevertheless, IBM's Vanderslice believes he has a winner in the combination of an eye-safe Raman laser with its high efficiency at 5,300 angstroms and its 2-inch-long Raman cell. Its size and weight, and price of the system are held down, explains Vanderslice, by the dye Q-switch between the Nd-YAG and Raman lasers since it eliminates the need for the complex and often unreliable mechanical mirror systems used for switching.

Over the last two years, IBM has picked up from the Army Electronics Command at Fort Monmouth, N.J., an $86,000 R&D award for nine months of computer modeling of Nd-YAG performance.

Microwave

Novel cavity phase-locks LSA oscillator

Only by phase locking an LSA oscillator can it be made to give the precise control needed in phased-array radars. Now researchers at Cornell University have accomplished this by phase-locking a limited-space-charge-accumulation circuit for the first time.

This ability to phase-lock the LSA diode is a significant step toward placing the device in practical circuits. But this seems to be only the beginning if limited space charge accumulation is being groomed for use in phased arrays.

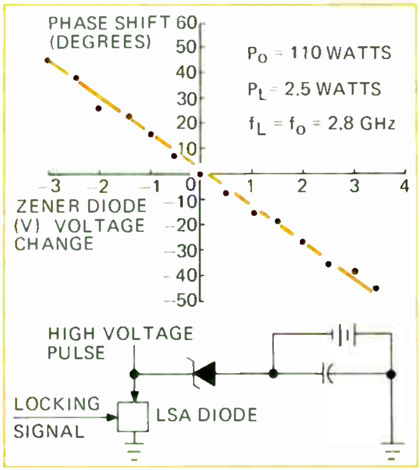
"In most of the previous LSA research," says William L. Wilson, who is directing the research, "little or no attention has been paid to the problems involved in achieving frequency stability in the output of these devices. As it turns out, the problems encountered are not trivial, and special operating characteristics inherent with the LSA mode must be taken into account if good device performance is to be achieved."

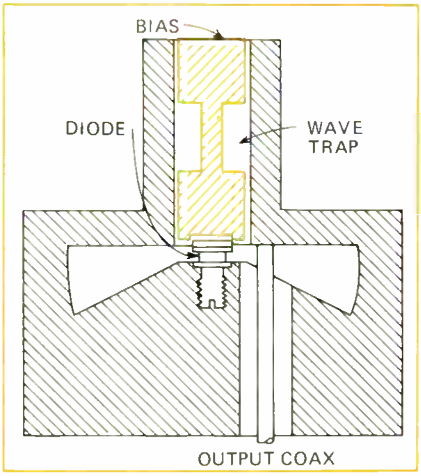
Two cascaded LSA diodes are used to get 110 watts pulsed output that is phase-locked to a backward-wave oscillator. Phase is controlled at the final output stage to within a few degrees over a 100° range. The operating frequency is 2.8 gigahertz. This performance is accomplished by a novel circuit, a multi-axis radial circuit (MARC) developed at Cornell.

Lowest. "Using this circuit," says Wilson, "the diode will always oscillate at the lowest frequency for which it can find a suitable load. For this experiment, the operating frequency is somewhat lower than the cutoff of the cavity as a resonant element."

The half-wavelength distance of the oscillation frequency is always greater than the wall-to-wall distance across the cavity. In this case, the cavity functions simply as a shortened length of radial transmission line. Because the distance from the diode to the wall is less than a quarter wavelength, the cavity forms an inductive load necessary for diode oscillation. The height of the cavity at any point on the radial line is increased linearly with the radius so that the line's characteristic impedance can be kept constant.

The diode is located on the axis at the center of the circuit. The output line forms a second axis, and couples to the diode by sharing magnetic field loops. The phase at the output is controlled by changing the dc bias to a zener diode in the pulse driving circuitry, as shown in the diagram on this page.





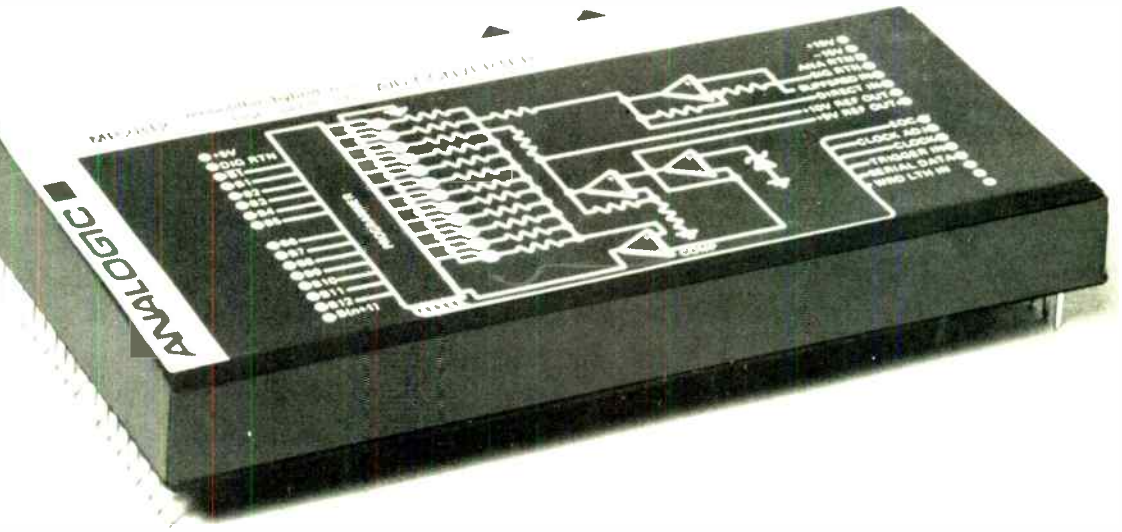
Phase control. LSA diode circuit, left, is controlled within few degrees over 100° range. At right, the height of circular cavity at any point on radial line is increased linearly with the radius so that the characteristic impedance of the line can be kept constant.

Advanced technology

Simpler CCD approach means better images

Until now, General Electric hasn't talked about its charge-coupled imaging array design—the application that many people feel is the most promising, immediate one for CCD. Now, GE has unveiled a novel approach to imaging that could make a CCD vidicon even simpler to

Analogic technical leadership scores again...



8-14 bit hybrid A/D converters that stay put.

An Example of Progress Through Restraint

Leadership in any field takes *cool judgment*. Otherwise, you may lead your followers right over the cliff. As the leader in A/D/A technology, we felt an obligation to *hold back* on the use of custom monolithic components, until we could *verify* their stability and reliability... could justify their *appropriate* use in our products.

After more than a year of study, design, testing, redesign, etc., etc., we have validated, beyond any reasonable doubt, the switching integrity, stability, and voltage-tracking precision of an exclusive six-element temperature-compensated monolithic switch for use in A/D and D/A circuits. And we've developed an exceptionally fast, accurate, and low-cost family of A/D converters around them — the AN2800 Series. These 8/10/12/13/14 bit successive-approximation ADC's cost 30% to 50% less than anything remotely approaching their performance and reliability. The AN2800's are designed to fill an important gap in ADC hardware *— the need for a low-cost, high-speed device with stability (against both time and temperature) that supports the rated accuracy and linearity . . . for years and years.*

You see, earlier low-cost hybrid ADC's all use thin-film or thick-film resistors (which simply do *not* have the required stability for long-term reliability) and they use monolithic switches with inferior temperature compensation. They are cheap, all right, and they are small . . . but they just won't *"stay put."* We've tested every one we could find, and they just don't cut the mustard. The AN2800 Series does. Why? Our very special monolithic switch chips, *and wire-wound resistors for all critical networks.*

So, in 3-12 months, when those cheapie chips are wandering hopelessly out of spec, *Analogic* customers will be in clover . . . all relaxed and happy, because their AN2800 Series ADC's will be right on the money, and good for many years more.

You'll want to call or write for the full set of data on the AN2800 Series . . . but here's a mouth-watering list of features, and a tasty slice of the complete spec on the 12-bit design:

- **An ultra-stable, selected, aged, "pedigreed" zener reference.**
- **Electromagnetically and electrostatically shielded.**
- **Fully hermetically-sealed semiconductors, optional.**
- **Choice of Modupac™ format (2" x 4" x 0.39") or Modupac-on-a-Card format.**
- **Pin-compatibility with older designs (of ANALOGIC or other manufacturers).**
- **Complete, including offset and range adjustments. Optional external remote trims.**
- **Optional internal buffer amplifier, which permits gain setting (±1 or ±10) and choice of single-ended or balanced differential input.**
- **Adjustable clock rate (by external voltage).**
- **Extended-temperature-range options (typical: from −30°C to +71°C).**
- **Optional BCD output codes (standard is straight binary).**
- **Completely isolated analog and digital grounds — i.e., no digital currents in analog ground return.**
- **Serial data line, in addition to normal bit-parallel output.**
- **Typical speeds for full accuracy: 8 bits, 1 μsec/bit; 12 bits, 2 μsec/bit; 14 bits, 6 μsec/bit.**

EXTRACTED FROM MP2812 SPEC:

• Resolution: 12 Bits. • Relative Accuracy at 23°C: ±.015% of full scale range (20V) ±½ LSB quantizing error inclusive of reference accuracy. • Monotonicity Guaranteed. • Temp. Coeff. of Diff. Linearity: ±3ppm/°C, typical. • Long-Term Stability: ±.01% of full scale maximum per 2000 hours, referred to input, exclusive of initial accuracies. • Worst-Case Temperature Coefficient of Offset: ±12ppm/°C of 20V. • Worst-Case Temperature Coefficient of Reference: ±5ppm/°C of 10V. • Worst-Case Temperature Coefficient of Conversion: ±5ppm/°C of 10V. • Noise: Equivalent conversion noise referred to input is .005% of 20V p-p (3σ) inclusive of reference noise. • **$150. in reasonable OEM quantities.**

For premium performance — that *stays* that way — at lower prices than you're paying for *gambler's* chips, call Perry Pollins or Dick Conant at (617) 246-0300, or write Analogic Corporation, Audubon Road, Wakefield, Massachusetts 01880. (Evaluation demo units available.)

ANALOGIC®

. . . The Digitizers

Circle 39 on reader service card

NEW! THE PRAM.™

The first 4-channel programmable op amp. With more application possibilities than we could possibly list on this page.

HA-2400/2404/2405
Take a good look at this new linear building block. It's unique and so versatile we keep discovering more and more applications for it.

Each PRAM contains four preamplifier sections, one of which is selected through the DTL/TTL compatible inputs and connected to the output amplifier. The selected analog input terminals and the output terminal form a high performance operational amplifier for just about any use you can dream up. And we hope you'll dream up some. If you do, send them along to us and we'll see what we can dream up by way of a reward.

Features:

Offset current 5nA

Voltage gain 150K

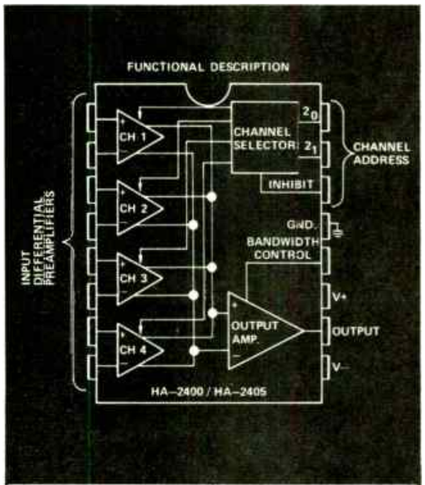
Slew rate
Av = +1 ±15V/μs
Av = +10 ±50V/μs

Gain Bandwidth Product
Av = +1 8MHz
Av = +10 40MHz

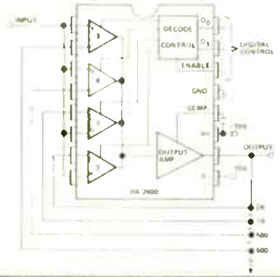
DTL/TTL compatible

	100-999 units
0°C to +75°C	**$10.45**
-25°C to +85°C	**$15.95**
-55°C to +125°C	**$23.65**

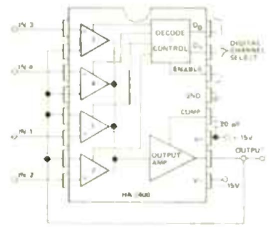
For more details on the PRAM contact your Harris representative or distributor.



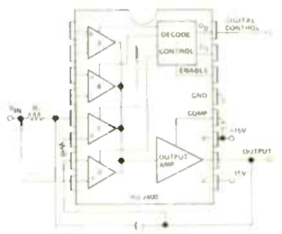
Amplifier, non-inverting programmable gain



Analog multiplexer with buffered input and output



Integrator/ramp generator with initial condition reset



More challenges:
The foregoing diagrams show just three of many applications we've designed using the PRAM. The following lists other possibilities we haven't had time yet to prove out. Why don't you try your hand at designing them or any other ideas you come up with, and send them to:
E. Fernandez
P.O. Box 883
Melbourne, Florida 32901.

- A to D converter, Dual Slope Integrating
- Active Filter, State Variable Type with Programmable Frequency and/or Programmable "Q"
- Amplifier with Programmable D.C. Level Shift
- Chopper Amplifiers
- Crossbar Switches
- Current Source, Programmable
- F.M. Stereo Modulator
- F.S.K. Modem
- Function Generators, Programmable
- Gyrator, Programmable
- Monostable Multivibrator, Programmable
- Multiplier, Pulse Averaging
- Peak Detector with Reset
- Resistance Bridge Amplifier/ Comparator with Programmable Range
- Sense Amp/Line Receiver with Programmable Threshold
- Spectrum Analyzer, Scanning Type

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fabricate, cheaper to build, and more reliable to operate than other CCD imaging approaches. The method was illustrated in a four-by-eight element array built by developers William Engeler, Jerome Tieman, and Robert Baertsch at the Research and Technology Center in Schenectady, N.Y.

Transfer key. What makes it simpler is the way the image is transferred. Previous CCD imagers had separate sections for storage and line readout. The scene was illuminated on the image section, the resulting charge was allowed to collect for a time, and then it was transferred row by row to the storage section. From there the charge was run off serially row by row. This method required twice the CCD elements that were used for imaging; a vidicon would need a double array of 250 by 250, for example.

The GE approach cuts the number of CCD elements in half, because the functions of storage and readout occur simultaneously. Each element of the image section is attached to a runoff bus diffusion. After the scene is imaged and the charge is collected, each element in a row is dumped onto the bus and collected at once, element by element.

The advantage of the GE approach is that now the image can be truly x-y addressed with only one transfer per element. This gives uniform characteristics over the entire array. Other approaches, because of repeated transfers, could lead to image blurring and unequal charge density over the image.

However, one problem that must be taken into account is that when capacitance of the runoff bus is not low in relation to the capacitance of the individual CCD element, small transfer signals could occur.

The GE device transfers when two conditions are met on the surface transfer element: the transfer gate is turned on and potential of the source reservoir is raised enough to allow charge to flow.

Bell work. Meanwhile, Bell Labs' CCD effort also has taken a quantum jump. It has shown an ion implant technique that could simplify the construction of CCD for both memory and imaging. Without implants, charge was kept moving in the desired direction with a three-phase clock system for single-level-metalization devices. Or, if a simpler two-phase clock system was used, more complex double metalization was required.

But if an implant (p-type in a p-substrate device) is made under one transfer electrode in each CCD element, then a single-metalization, two-phase system can be used. The reason, says Bob Krambeck, the Bell researcher who did the work, is that "the implant acts as the barrier to charge reversals, eliminating need for the third electrode." Krambeck points out further that only implants could achieve the doping levels (1.5×10^{12} per cm^2) required.

Aside from allowing single-level, two-phase devices to be built, the implanted CCD also improves transfer efficiencies. An eight-bit implanted shift register has been operated at 17 megahertz with 98% transfer efficiency. Also, element stripe geometry can be relaxed to 5 microns instead of the tough 2-to-3-micron separations needed for old single-metal devices.

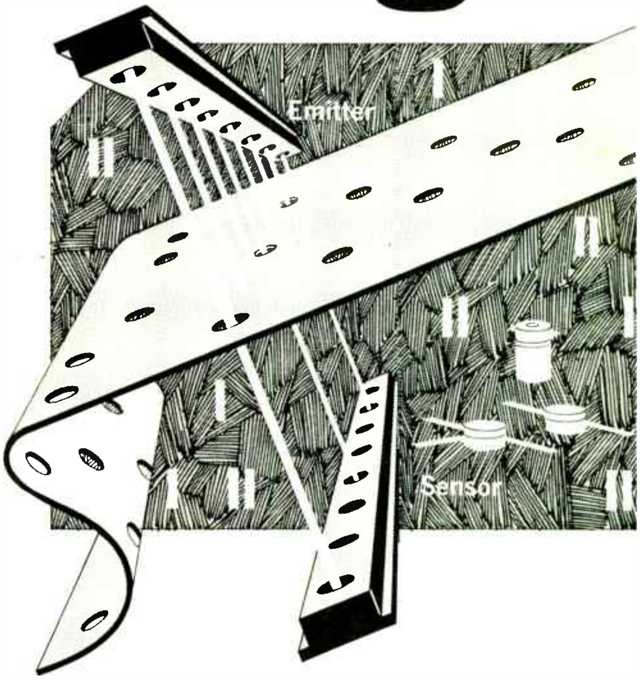
Meetings

Instrument Society finds show business quieter

In most ways the Instrument Society of America's annual conference and exhibit was a replay of other broad industry shows that have been held this year [*Electronics*, Sept. 13, p. 30]. Exhibits were off, attendance was off, but companies that were there mostly reported good quality traffic through their booths.

The ISA show, held in Chicago Oct. 4-7, attracted 250 exhibitors (last year there were 335) and 10,200 attendees (the total last year was 15,893). But in a typical report, Perry Pollins, product manager of Analogic in Wakefield, Mass., noted there was interest from firms confronted with pollution and hazard problems and others looking for more accurate process control.

Read Light Right



Read Light Closely!

Light emitted from concentrated, multiple, high density light sources calls for light sensors of comparable mechanical mounting capability. Motorola plastic Micro-T* and hermetic "pill" detectors can be mounted close as 85 mils in discrete applications using manual soldering and 100 mils with flow soldering. Perfect emitter-detector matching is ensured through use of identical array packaging. For extremely high resolution requirements, Motorola standard monolithic, 39-element diode/transistor arrays are on 0.005" center-to-center spacing. The active area is 0.005" x 0.0045" with 0.0005" space between elements. Use both in OCR, mark sensor and card/tape reading designs.

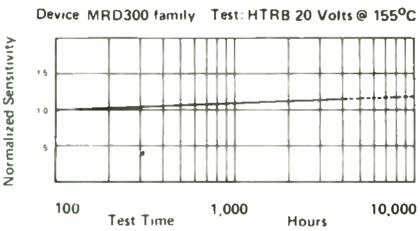
Read Light Quickly!

RELATIVE RESPONSE TIME

Light Sensor	Time
Motorola Pin Photodiode	1 ns
Photomultiplier Tube	4 ns
2N2369 Switching Transistor	6 ns
Motorola Phototransistor	4 μs
Motorola Photodarlington	300 μs
Cadmium Selenide Cell	0.5 ms
Cadmium Sulfide Cell	1 ms
Human Eye	16 ms

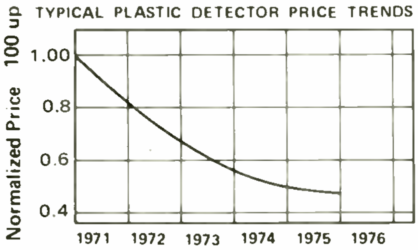
Ultra-fast recognition of red or IR wavelengths in laser detection, light demodulation, shaft/position encoders, switching and logic circuits in the nanosecond range demands ultra-fast devices. MRD500/510 PIN diodes typically respond in 1 ns; conventional, bulk-effect detectors need longer response times. Both units feature high sensitivity and are available with convex or flat glass lenses in standard, TO-18 cases. Exclusive Annular* passivation ensures long-term reliability and stability.

Read Light Reliably!



Critical to any application requiring stable characteristics over very-long-term operating life expectancy is detector sensitivity which must remain constant so system biasing is not thrown off spec. Similar to beta measurement in a conventional transistor, phototransistor sensitivity = output current ÷ light input. Curve shows the sensitivity for a standard hermetic, MRD300 detector family having little or no change in documented or projected sensitivity beyond 4,000 hours of testing. Indications from this and other ongoing tests show Motorola's family of Annular passivated light detectors to have identical reliability as standard metal-can transistors which have shrugged off millions of hours of rugged, mil-type life testing without significant failures.

Read Light Economically!



The trend in silicon photodetector pricing is *down!* And you can control light-generated current flow with 24 different Motorola PIN photodiodes, phototransistors and photo Darlingtons for optimized optical performance in dc to high frequency designs. For example, 100-up prices on the *metal*, MRD3050 series now start at only 80¢ — a level comparable to plastic! Select the right light detector for your design from the broadest light detector line available — Motorola's! Write Box 20912, Phoenix, AZ 85036 for complete detector data.

MOTOROLA OPTO

Let There Be Light

*TRADEMARK MOTOROLA INC.

Electronics review

Not surprisingly, anti-pollution gear—in the form of environmental control equipment—was the star of the show. Displays included virtually the full spectrum of instrumentation that could be applied to monitoring of liquids and air, and improving control of processes and hazards. There was some resentment by exhibitors who maintained that ISA show management could have offered a more attractive program on environmental issues.

And that's what's going to happen next year. The ISA executive board met after the show and scheduled the first annual symposium on environmental quality instrumentation to be held next Oct. 9-12 in New York concurrently with the ISA meeting.

The environmental symposium will be held along with three others on control elements, data handling, and test measurement, which were fixtures at the show this year. The ISA says the new session is not a reaction to criticism but recognition of the need to bring the environmental quality problems into focus.

It's also a move calculated to gain attention of firms facing pollution problems, and will help the ISA compete against more vertical events such as the Water Pollution Show in San Francisco which attracted such firms as Honeywell, General Electric, and Fisher-Porter, none of which was at the ISA show.

Optoelectronics

GaN, spinel substrates widen LED technology

Although light-emitting diodes made of gallium-arsenide-phosphide and gallium phosphide are rapidly attaining a firm foothold in the numeric readout market [see p. 74], plenty of LED technology remains to be exploited. There is a good deal of activity in applying new materials and techniques to improve the versatility, performance, and cost of these devices, according to reports earlier this month at the International Electron Devices

Meeting in Washington.

At RCA Laboratories in Princeton, N.J., a team of researchers led by J.I. Pankove has successfully produced gallium nitride LEDs that emit green and blue light at room temperature with dc excitation.

The devices are made by epitaxially depositing GaN, which is naturally n-type, on a sapphire substrate, followed by a zinc-doped insulating layer of GaN. Quantum efficiency in the experimental devices is about 1% with external power efficiency of 10^{-4}. However, the work with GaN indicates the real possibility that pn junctions might be producible. If so, this would greatly increase the efficiency and reduce drive power.

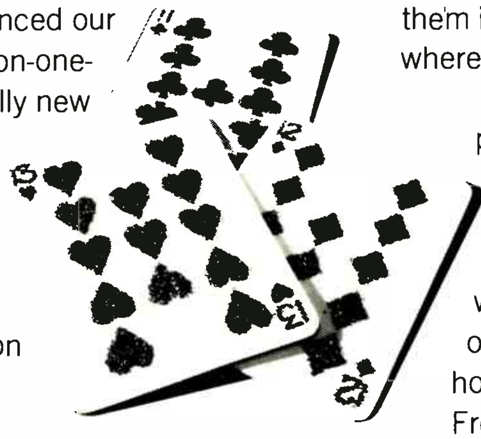
All on one. The prospect of integrating monolithic LED displays with driving and coupling circuitry on the same chip has been brightened by another RCA Laboratories development. I. Ladany and C.C. Wang reported the successful growth of GaAs and GaP films on a spinel substrate by a two-step epitaxial process, followed by formation of mesas by etching or machining into the film down to the junction, yielding individual diodes or arrays.

Because spinel is compatible with silicon-on-sapphire IC process technology, it's possible to fabricate on-chip driving and coupling circuitry along with the light emitters.

Other advantages include the fact that spinel is transparent at the wavelengths of interest making it possible to build arrays of diodes that emit light from one side of the substrate, while all the contacts are made through the other side. Furthermore, spinel is an excellent heat sink for the relatively high current densities that would be needed for such arrays. And, according to Ladany, larger slices of spinel now cost less than GaAsP or GaP.

The devices are fabricated by growing an initial GaAs or GaP film on the spinel by a vapor phase process, then following with a liquid epitaxial deposition. Then the mesas are formed. Quantum efficiencies of 0.1% to 0.2% have been achieved with GaAsP and 0.1% with GaP.

How to beat us at our own game.



Recently we announced our full line of "everything-on-one-card" memories: a totally new concept in random access, coincident current core memory systems. We explained that each memory is completely contained on a single printed circuit card. That each circuit card contains all the required logic, drive and sense circuitry. And that we offer this new concept in three different series—with the widest possible range of size and performance characteristics.

"But," said a lot of people, "since these card memories are so unique, if we do let you structure them into a customized system, where do we find a second source?"

(Well, maybe not a *lot* of people. But it *has* been said. Honest.)

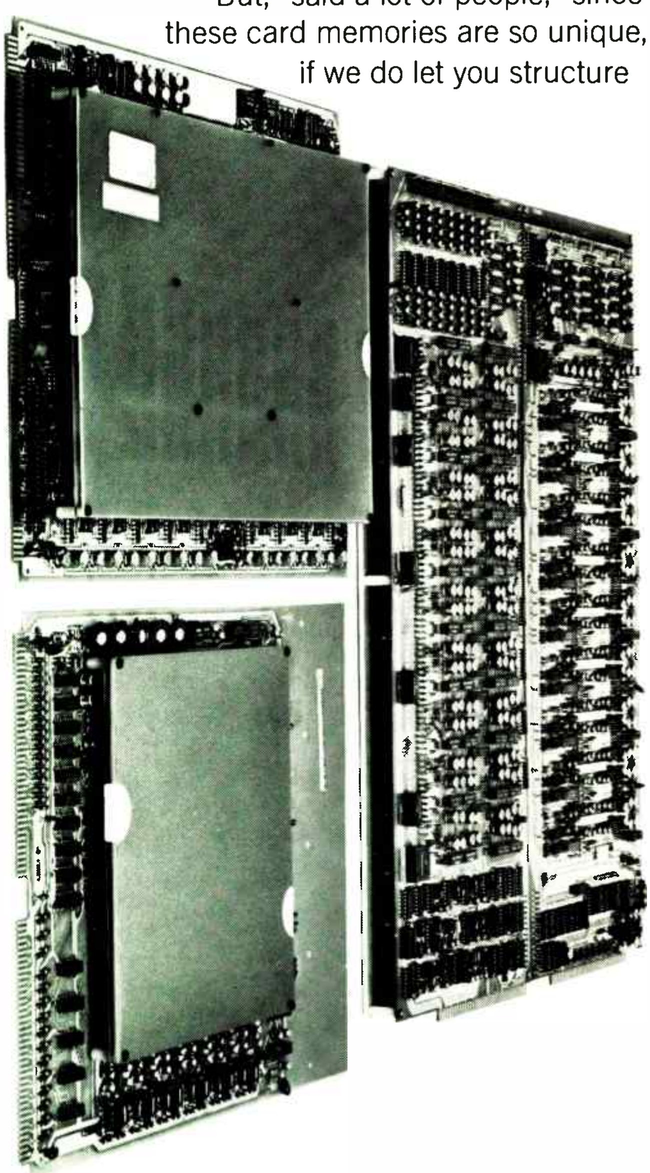
Answer: our unique customer licensing agreement which permits *you* to be your own second source. Here's how it works:

From the three series of Micromemories, we select the right card memory for your system. Each card is in quantity production for immediate off-the-shelf delivery. And each is fully TTL compatible with no analog or critical timing inputs required. So the system design possibilities are almost unlimited. We can stack the individual cards to form any size system that you need.

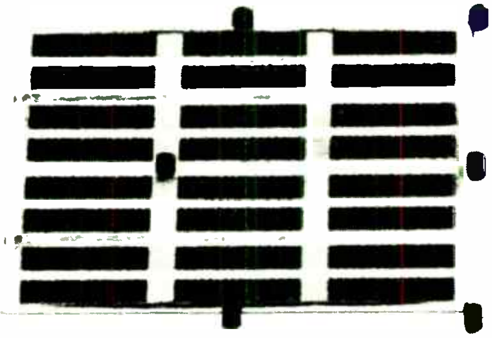
So we design and deliver your customized system based on the Micromemory series. We make the full system design available to you. And there's no charge for our system engineering.

Once you're satisfied with the system, we enter into a licensing agreement with you for the manufacture of our new card memories. And we give you assistance in setting up to do the job. You become your own second source.

So now you have your customized system design.



And you have a license and full know-how on the manufacture of the memory cards. You are now set up to manufacture your own



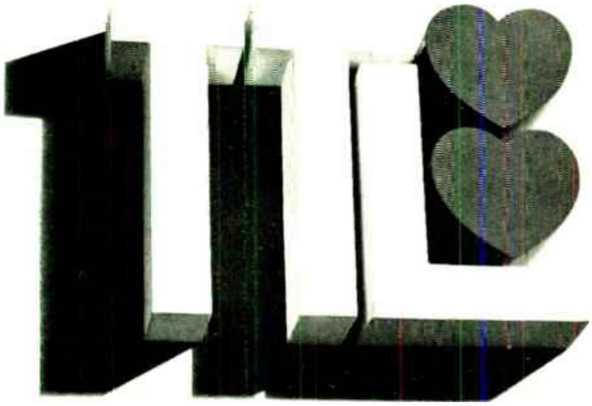
Do it yourself!

system using EM stacks. (We figure the least we can do for anyone courageous enough to go into the memory systems business, is to make sure they start out with the very best.)

♥♦♣	MICROMEMORY 2000	MICROMEMORY 3000	MICROMEMORY 4000
Configuration	4,096x9	8,192x18	32,768x18
Alterable to:	—	16,384x9	65,536x9
Full Cycle Time	1.0 μs	650 ns	1.5 μs
Access Time	400 ns	300 ns	800 ns
Modes	R/R. C/W. R/M/W	R/R. C/W. R/M/W	R/R. C/W. R/M/W
Byte Control	—	X	X
Data Save	X	X	X
Required Voltages	+5V	±15V, +5V	±5V
# of PCBA's	1	1	1
PCB Size	11¾"x15"	11¾"x15.4"	17½"x22"
Allowable PCB Spacing	1"	1"	2"
Expansion in a single chassis to:	16,384x9 8,192x18	65,536x9 32,768x18 16,384x36	Open
Extended address to:	32,768x9	65,536x18	256kx18
In increments of:	4,096x9	16,384x9 8,192x18	32,768x18 65,536x9
Stack	3W, 3D	3W, 3D	2W, 2½D
TTL Compatible	X	X	X

NOTE: Each PCBA contains a complete memory system, i.e., address registers, data registers, timing and control, etc.

OPTIONS: Power supplies and a chassis for 19" rack mounting are available.



Incidentally, if you did miss last month's ad, take a quick look at the table of specs. And take into consideration that the prices are low enough to make you a hero. How low? Give us a chance to talk to you about them.

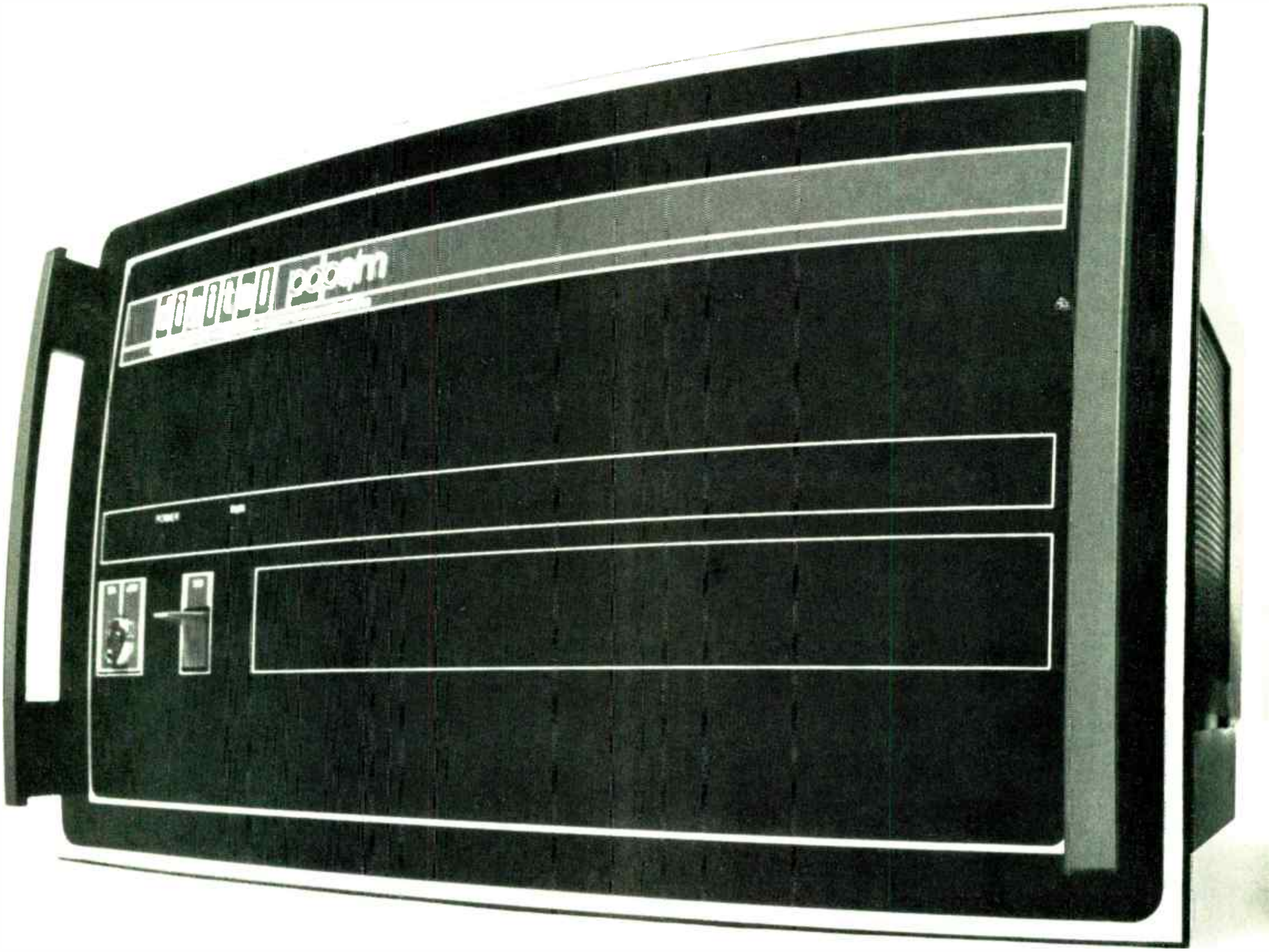
That's all we ask. A chance to let you beat us at our own game.

electronic memories

The Here and Now People

EM A division of Electronic Memories & Magnetics Corporation • 12621 Chadron Avenue, Hawthorne, California 90250 • Telephone (213) 644-9881

Introducing the



On your left, the 12-bit PDP-8/M. On your right, the 16-bit PDP-11/05. Our brand new additions to the world's most popular families of minicomputers.

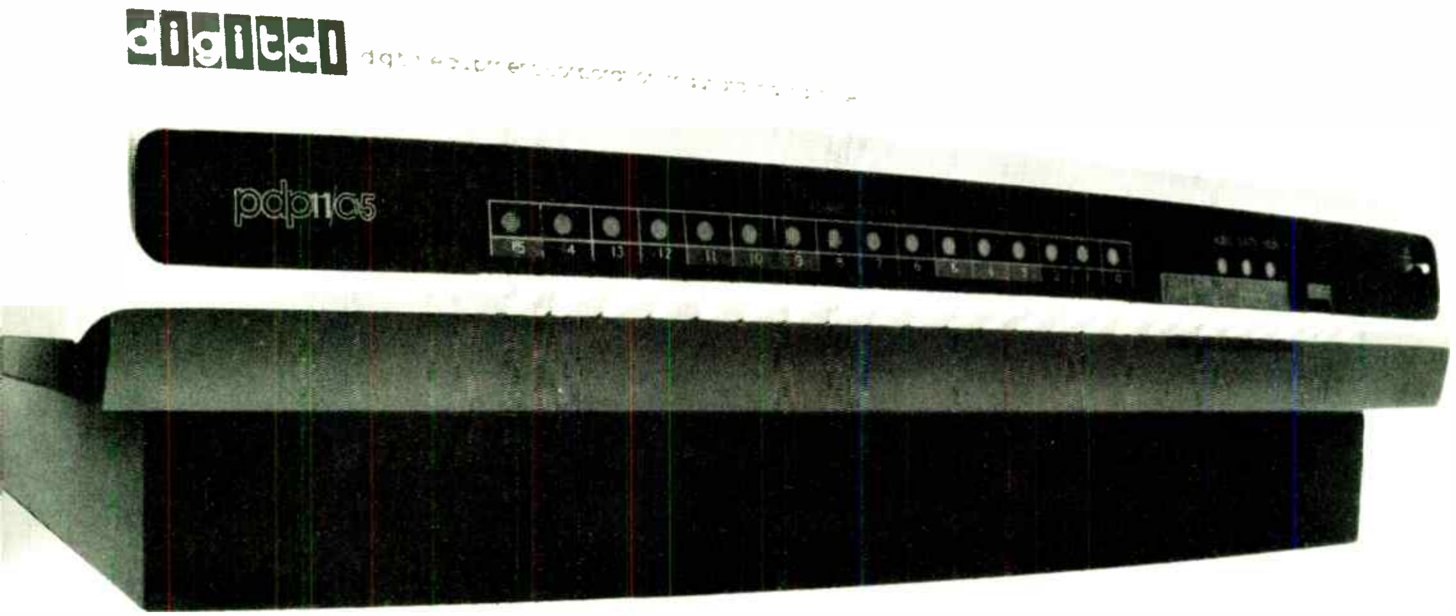
Complete computers — at incredibly low prices. Like $3,069 for the 11/05, and $2,362 for the 8/M in quantities of 100. Even the discount schedule is new. Very attractive.

In addition, they're compatible with the rest of the family members. Their options. Their peripherals.

They have the features of their bigger brothers. And, a full instruction set. OEM-oriented architecture. Both the UNIBUS™ architecture of the 11/05 and the OMNIBUS™ architecture of the 8/M permit easy, flexible configuring and interfacing. Real pluses for the OEM.

They're built with the kind of reliability that comes easy after delivering over 11,000 minicomputers.

OEM Yardsticks



And, they're supported with more field backup than you can get anywhere else. Worldwide.

PDP-11/05. PDP-8/M. Designed for the OEM. Priced for the OEM. Choice for the OEM. From the leader in OEM computer applications.

Now there's a whole new set of standards to measure up to.

Write for more information. Digital Equipment Corporation, Main Street, Maynard, Massachusetts 01754, (617) 897-5111.

digital

Circle 49 on reader service card

Washington Newsletter

October 25, 1971

Electronics share in DOD FY '73 request foreseen as rising

Defense electronics procurement contracts, as well as research and development awards, are forecast as rising between $375 and $500 million in President Nixon's fiscal 1973 budget package that goes to Congress in January. Administration sources say the total DOD package could top out at nearly $80 billion if no major programs are knocked out by the White House, and they predict a low figure of between $76.5 and $77 billion in any event. The forecast is premised on the expectation that the President in an election year will move to counter rising criticism, from the political right and from some Democrats as well, of growing Soviet weapons superiority. Moreover, he is said to want to pump more funds into a still-soft defense economy in an election year. His program is expected to be made more palatable to defense-spending critics by linking it to his planned program for new technological initiatives [*Electronics*, Sept. 27, p. 33].

The in-house estimates of defense budget plans are higher than those of 15 member companies of the Electronic Industries Association, which recently placed 1973 spending at $75.9 billion, including an average 15.2% for electronics. Government sources contend the electronics content is likely to jump to 16% or more as new and heavy emphasis on research and development for intelligence, reconnaissance, space, strategic missiles, and antisubmarine warfare develops.

DOD also considers cutback affecting Naval commands

Besides countering the buildup in Soviet seapower by significantly increasing the Navy's fiscal 1973 budget request of next January, the Defense Department is contemplating reorganizing the service later in the year in order to cut back on military and civilian personnel. One reported target of the cut is the huge Naval Materiel Command (Navmat), which has six subordinate systems commands for air, electronics, ordnance, ships, facilities engineering, and supply, plus 15 supporting laboratory operations (not to be confused with the 14 labs of the Office of Naval Research).

However, DOD officials are quick to scotch rumors that any restructuring will eliminate the six-year-old electronics systems command (Navelex), and distribute its functions among the larger commands for air and ship systems. They also point out that no final reorganization plan is likely to be adopted until Adm. Isaac C. Kidd, Navmat's new chief, has been on board for some months and is able to make his own recommendations. Kidd, commander of the Sixth Fleet and reputedly a strong personality, takes the Navmat helm in December when Adm. J. D. Arnold retires.

New U.S. network of computers weighed by five agencies

Five agencies—the Office of Telecommunications Policy, the Office of Science and Technology, DOD's Advanced Research Projects Agency (ARPA), the National Bureau of Standards, and the National Science Foundation—have had informal discussions on the need to create a national shared computer network modeled on ARPA's system for joint use by Government and the private sector. Their interest indicates a growing need for shared data bases and capabilities.

Should they pursue the idea, they will have to ask some major policy questions: should the network be operated under Federal or private

Washington Newsletter

auspices? If it's privately run, how far should the Government underwrite costs for R&D and operation? How difficult would it be for the Government to set it up and then turn it over to a private carrier? There are also regulatory problems. **The Office of Telecommunications Policy would probably have a major shaping role if the concept gets off the ground.**

Supreme Court to study case for software patents

Still trying to close the door on patenting software, the **Justice Department has asked the Supreme Court to review a lower court's decision that earlier this year directed the Patent Office to patent a Bell Labs** digital program for converting decimal into binary signals.

The Patent Office claims that Bell "husbanded this particular case through the Patent Office and courts to get a test case." Bell disagrees, pointing to patents previously granted on software. Patent Office associate solicitor, Jere W. Sears, however, explains that the **earlier applications did not disclose a digital program but an analog variant** for controlling some ancillary process [*Electronics*, Sept. 1, 1969, p. 37], **whereas "the Bell case is for data processing itself."**

Significantly, it's only the third time the Government has appealed a U. S. Court of Customs and Patent Appeals decision, says Sears. He adds that **there is some doubt whether the Patent Office has adequate facilities to process software patents.**

Honeywell may earn $150 million from WWMCCS win . . .

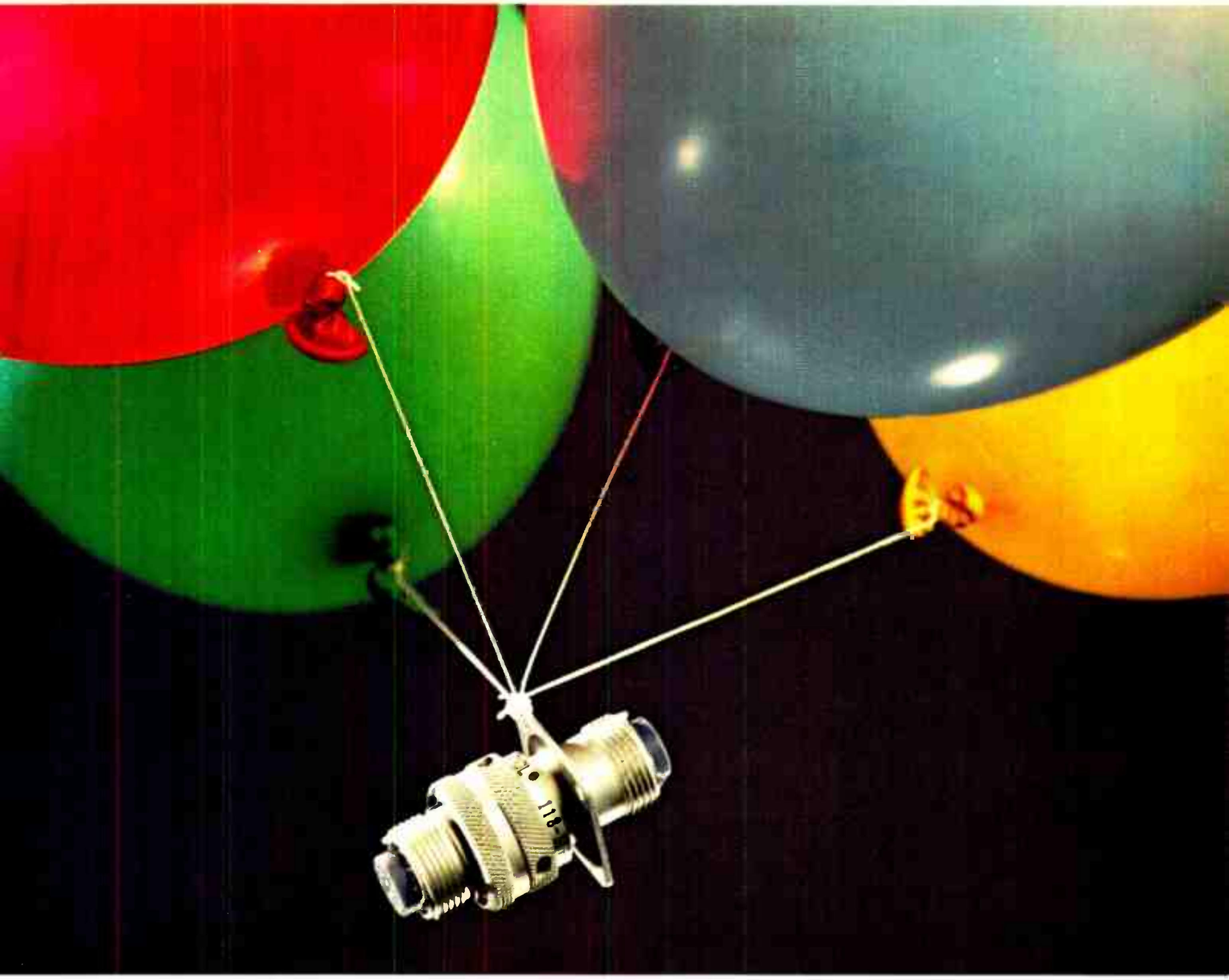
Honeywell Inc.'s prestigious win of the World Wide Military Command and Control System computer contract could produce $150 million or more for "the other computer company," say Defense Department sources. **The General Services Administration's $51.3 million price tag was computed by officials as a 60% to 70% discount from Honeywell's list price,** compared to the reported 50% cut of IBM's losing bid. The GSA average price has a $150 million high end for 35 Model 6000 machines in their largest configuration and a low of $8.5 million for nine of the smallest computers. **However, Honeywell's income under a lease arrangement would probably be higher,** if the military wants it and is able to swing it. **Moreover, individual commands will be acquiring additional peripheral equipment under their own budgets** as the systems are delivered over the next two years. First customer: Strategic Air Command Headquarters.

. . . and IBM reshuffles Federal sales unit

The day after **Honeywell Inc. walked off with the World Wide Military Command and Control System package, loser International Business Machines Corp. confirmed it had "restructured" its Government systems sales operation.** IBM officials say that its former GEM organization—for Government, Education and Medicine—is now entitled Public Sector Operations, though it will retain its existing management and essentially the same number of people.

Though IBM does not link this shuffle with the General Services Administration's WWMCCS buy, **industry sources see the move as one designed to concentrate IBM's efforts on GSA, which is now virtually the sole Federal buyer of business machines,** except for special-purpose, one-of-a-kind equipment. "Beyond stating their requirements, users don't influence computer orders anymore," summarizes one industry man in the capital. "GSA is the customer. Period."

The new Merlin 1® connector.



40% lighter than anybody else's.

Through the magic of Amphenol engineering we now bring you a rear-release, cylindrical, environmental connector that is not only 40% lighter than competition, but ½-inch shorter than most.

A one-piece thermoplastic retention disc, molded of tough Astrel 360* replaces the individual metal retention clips common in heavier connectors. Therefore, a 61-pin Merlin configuration has one retention disc instead of 61 individual metal clips. The result is a lot less useless weight. And, without all those parts, more reliability.

Adds a little magic to cost-cutting, too.

Our new Merlin exceeds all performance requirements of MIL-C-83723, MIL-C-26482 and NAS-1599 and is fully intermateable and intermountable with all three of these types.

Shell sizes are available in the eight most popular configurations with your choice of straight plug and both wall-mounted or jam-nut receptacles.

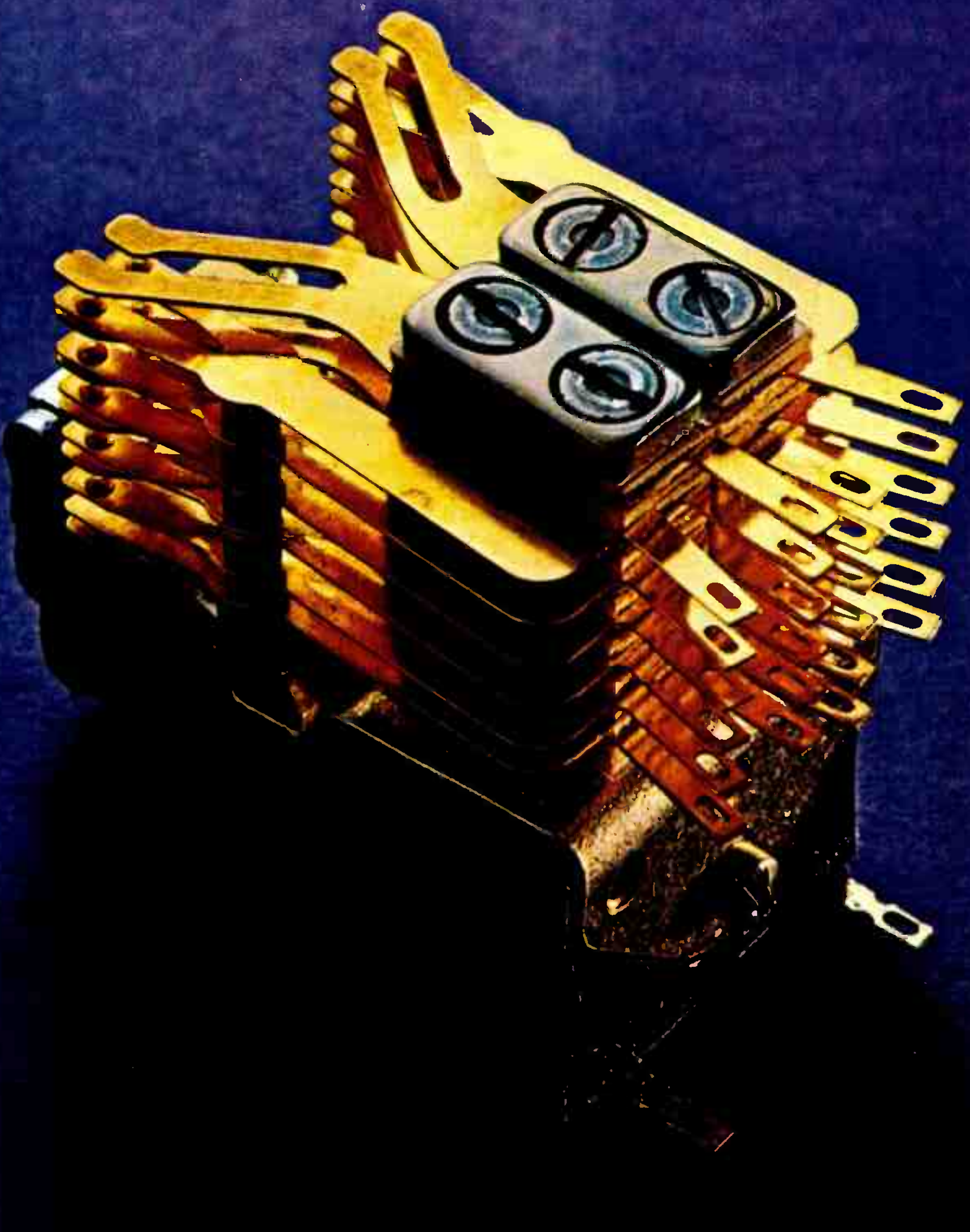
To get the full story on the new Merlin 1 connectors, just write or call Steve Kelleher, Amphenol Connector Division, Bunker Ramo Corporation, 2801 S. 25th Avenue, Broadview, Ill. 60153, (312) 261-2000.

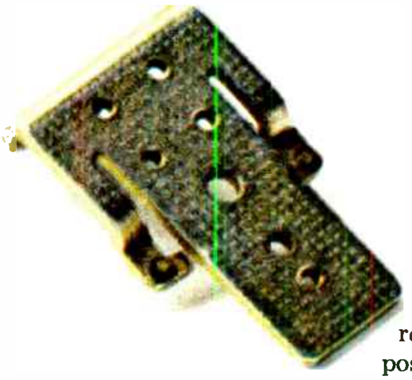
*Registered Trade Mark 3M Company.

BUNKER RAMO AMPHENOL

Circle 53 on reader service card

Reliability is six things we do that nobody else does.





We're fanatics.

We build our relays stronger than we have to. That way, they last lots longer than they ever have to. Our Class E relay (shown on the opposite page) is a good example of our way of thinking.

The industry's strongest heelpiece.

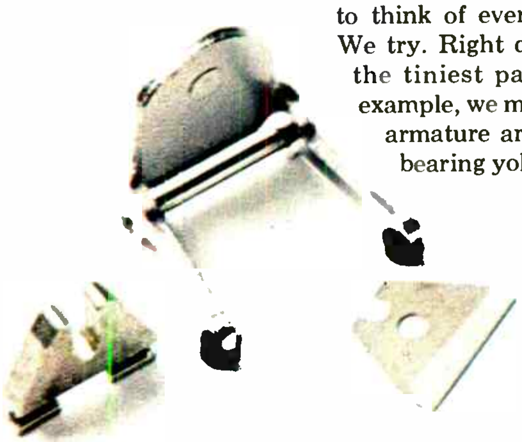
We make the strongest heelpiece in the industry. A gigantic machine bangs them out extra fat and extra flat.

Extra fat to carry a maximum of flux. To handle big loads. Extra flat so that once an AE relay is adjusted, it stays adjusted.

Since our backstop is part of the heelpiece, it's just as thick and flat. But, tough as it is, the slightest wear here would throw the entire contact assembly out of whack. So, to be safe, we weld two tiny, non-magnetic pads where the armature arms meet the backstop. You might say we created the no-stop backstop.

Three parts that'll wear like crazy.

When you build a relay like a small tank, you have to think of everything. We try. Right down to the tiniest part. For example, we make our armature arms and bearing yoke extra thick.



Thicker than years of testing and use say they have to be. Then, to make sure they don't cause wear problems, we insert a hardened shim between the hinge pin and the frame. The pin rides on the shim, instead of wearing into the heelpiece. (You can forget the bearing, it's permanently lubricated.)

Buffers with lots of muscle.

We make our buffers of a special tough phenolic material that lasts. And lasts. And lasts. All without wear or distortion. Another reason why our relays stay in whack.

To make sure our buffers stay in place, we weld the buffer cups to the armature arms. We weld, instead of using rivets, because our lab found that rivets have a habit of falling out.

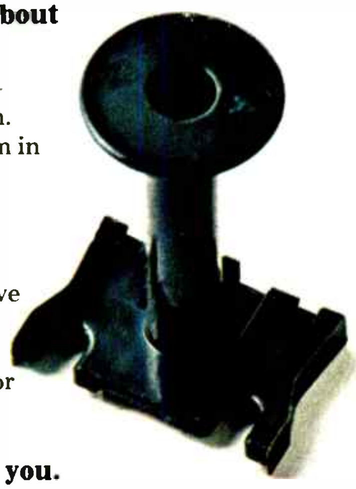
For the very same reason, we weld buffer cups to the contact springs. And also use the same special tough phenolic buffers.

No, we didn't forget the contact springs.

We have some strong feelings as to what makes a contact spring reliable. Our sentiment is that two contacts are better than one. So, we bifurcate all the springs, not just the make and break. This slotting and the addition of another contact to each spring means you get a completed circuit every time.

We make each set of contact points self-cleaning. The bad stuff doesn't have a chance to build up.

Now, what's different about our bobbin?



Our bobbin is one piece—molded of glass-filled nylon. This provides the maximum in insulation resistance.

Because our bobbin is nylon, we don't have to impregnate with varnish. Moisture and humidity have no effect on the stubborn nylon material. No effect means no malfunctions for you to worry about.

What all this means to you.

What this all adds up to is reliability. The kind of toughness no one else can give you. It means an AE relay works when it's supposed to, longer than it has to. Isn't this the kind of reliability you really need? GTE Automatic Electric, Industrial Sales Division, Northlake, Illinois 60164.

GTE AUTOMATIC ELECTRIC

OUR ANGLE: High Speed Accurate and Automatic Angle Position Indicators

MODEL 545/100

If you're converting synchro/resolver data to digital format, you need both speed *and* accuracy to keep pace with today's data explosion. Only one converter meets both these requirements without compromise. And for under $4K. . . . North Atlantic's Model 545/100.

The solid-state Model 545/100 converts both resolver and synchro data with 0.01° accuracy and resolution. And continuously digitizes input angle data at 20,000° per second in the face of real-life noise, harmonics and quadrature levels. BCD output is available at the rear connector. Conversion can be stopped by a data freeze command. If multiplexed signals are your bag, acquisition time is less than 30 ms.

Options? Other models offer many options, including 0.001° resolution with 10 arc-second accuracy; data frequencies from 60Hz to 2.4kHz, binary output, small size.

No matter what your conversion problem, if you require ultra-fast, ultra-accurate tracking, contact your North Atlantic sales engineering representative today. He'll show you a better angle.

WHAT'S YOUR ANGLE?

N A ®

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industries, inc.

200 TERMINAL DRIVE, PLAINVIEW, NEW YORK 11803
cable: noatlantic / twx: 510-221-1879 / phone: (516) 681-8600

For built-in reliability, design with "Scotchflex" Flat Cable/Connector Systems.

''SCOTCHFLEX'' IS A REGISTERED TRADEMARK OF 3M CO.

"Scotchflex" Flat Cable and Connectors can offer you trouble-free packaging for your next generation equipment.

There's built-in reliability for your circuit inter-connects. Our flat, flexible PVC Cable has up to 50 precisely spaced conductors. The gold plated U-contacts are set into a plastic body to provide positive alignment. They strip through the insulation, capture the conductor, and provide a gas-tight pressure connection.

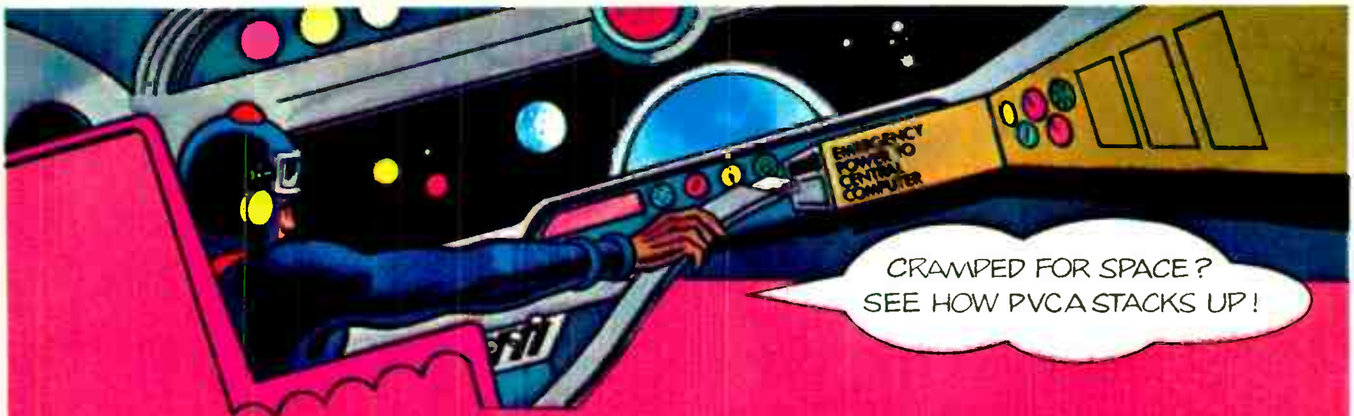
Assembly cost reductions are built-in, too. "Scotchflex" Connectors make up to 50 simultaneous connections without stripping or soldering. No special training or costly assembly equipment is needed.

Off-the-shelf stock offers you flat cable in a choice of lengths and number of conductors from 14 to 50. Connector models interface with standard DIP sockets, wrap posts on .100 x .100 in. grid, or printed circuit boards. Headers are available to provide a de-pluggable inter-connection between cable jumpers and printed circuit boards (as shown). Custom assemblies are also available on request.

For full information on the "Scotchflex" systems approach to circuitry, write to Dept. EAH-1, 3M Center, St. Paul, Minn. 55101.

3M COMPANY

Circle 57 on reader service card



Brand-Rex introduces PVCA cable; a new concept in flat power distribution systems.

If you're trying to cram more power distribution cable into an enclosure than there's room for, Brand-Rex can help. We've got a packaging idea that's as modern as tomorrow. New PVCA™ cable. A flat, vinyl insulated aluminum strip that can be stacked, run in trays and ducts, bent at any angle for branching or to follow any contour.

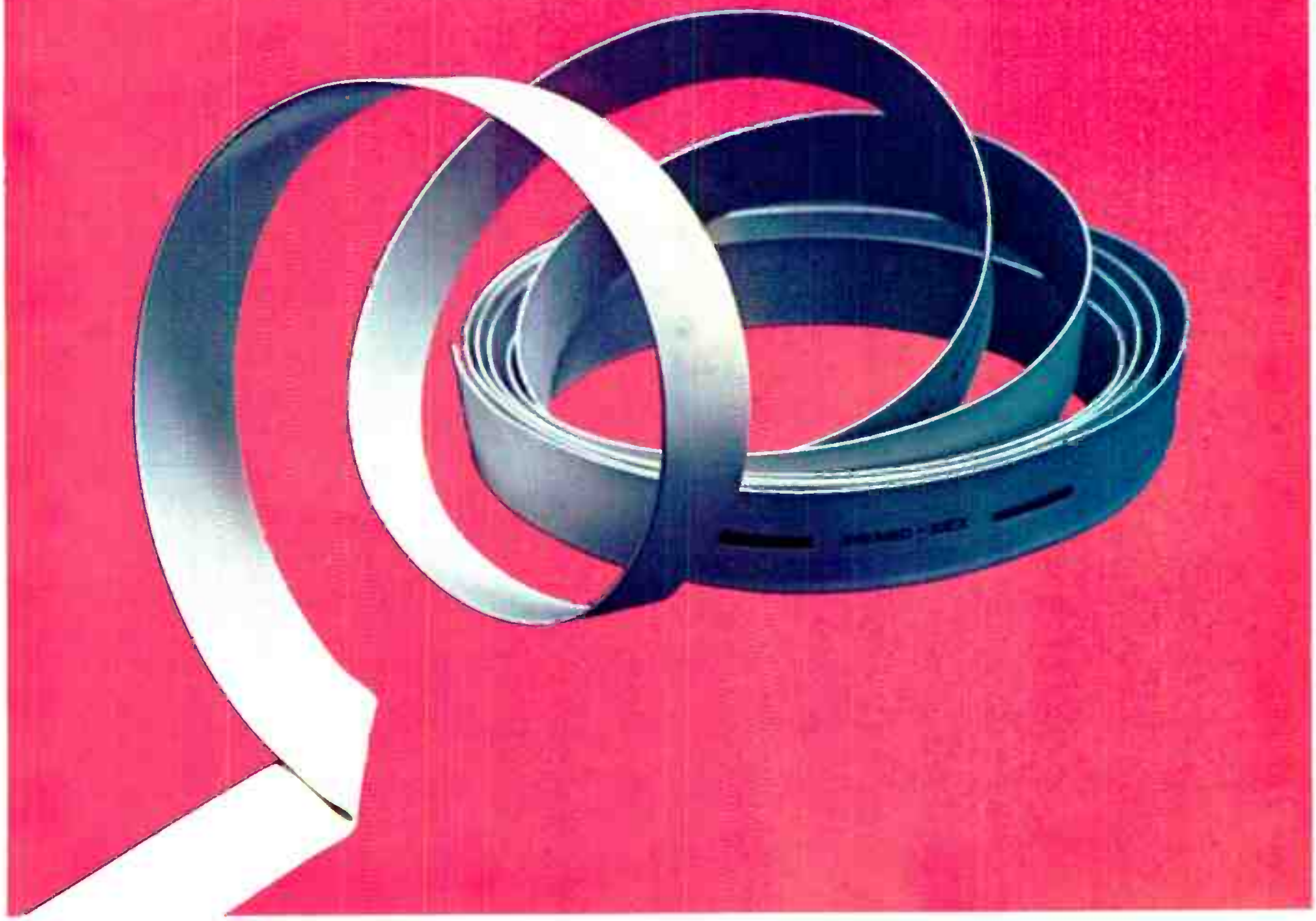
PVCA™ cable is U.L. recognized for 105°C, 100 volt operation. It passes the U.L. vertical flame test and is resistant to oil and grease.

No termination problems either. Standard terminals, including center tap are readily available for fast, economical, airtight, moisture-resistant connections and splices.

Cost? Less than the conventional cable it replaces.

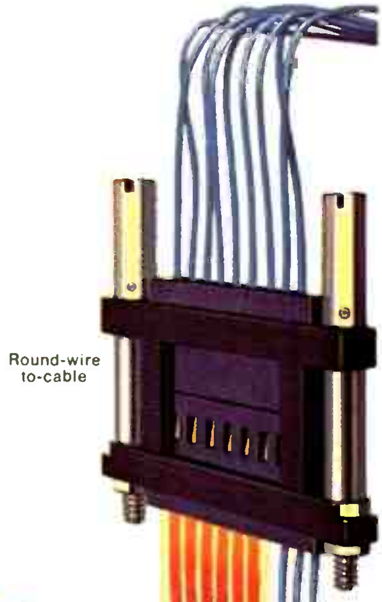
See for yourself how the new PVCA™ cable stacks up. For the free Fact File write to Buck Rogers, Brand-Rex Co., Willimantic, Conn 06226. Or call (203) 423-7771.

BRAND-REX...WAY AHEAD IN WIRE AND CABLE



Circle 59 on reader service card

Here's enough to put you onto flat flexible cable.



Now you can have all the benefits of flat cable—weight, density and flexibility—to use it, everywhere. Our full line of connectors, specifically designed to take advantage of what flat flexible cable offers, will take you wherever you want to go—cable-to-cable. cable-to-wire, cable-to-post and cable-to-printed-circuit board. Now with the addition of our newest one-piece connector, we can also offer cable-to-printed-circuit board with a card-edge connector.

Once you decide on how to go, AMPECONOMATION, our unique automated termination technique, makes getting there fast, reliable and easy. No need to prepare the cable. Just cut to length and the machine terminates up to 3400 connections per hour . . . automatically. Four areas of contact, made with our exclusive insulation displacement crimp technique, assures the utmost in reliability.

We can supply connectors and application machine for flat cable assembly production in your plant, or provide finished assemblies to your specifications, ready for your equipment. For complete information write:

AMP Incorporated, Industrial Division, Harrisburg, Pa. 17105.

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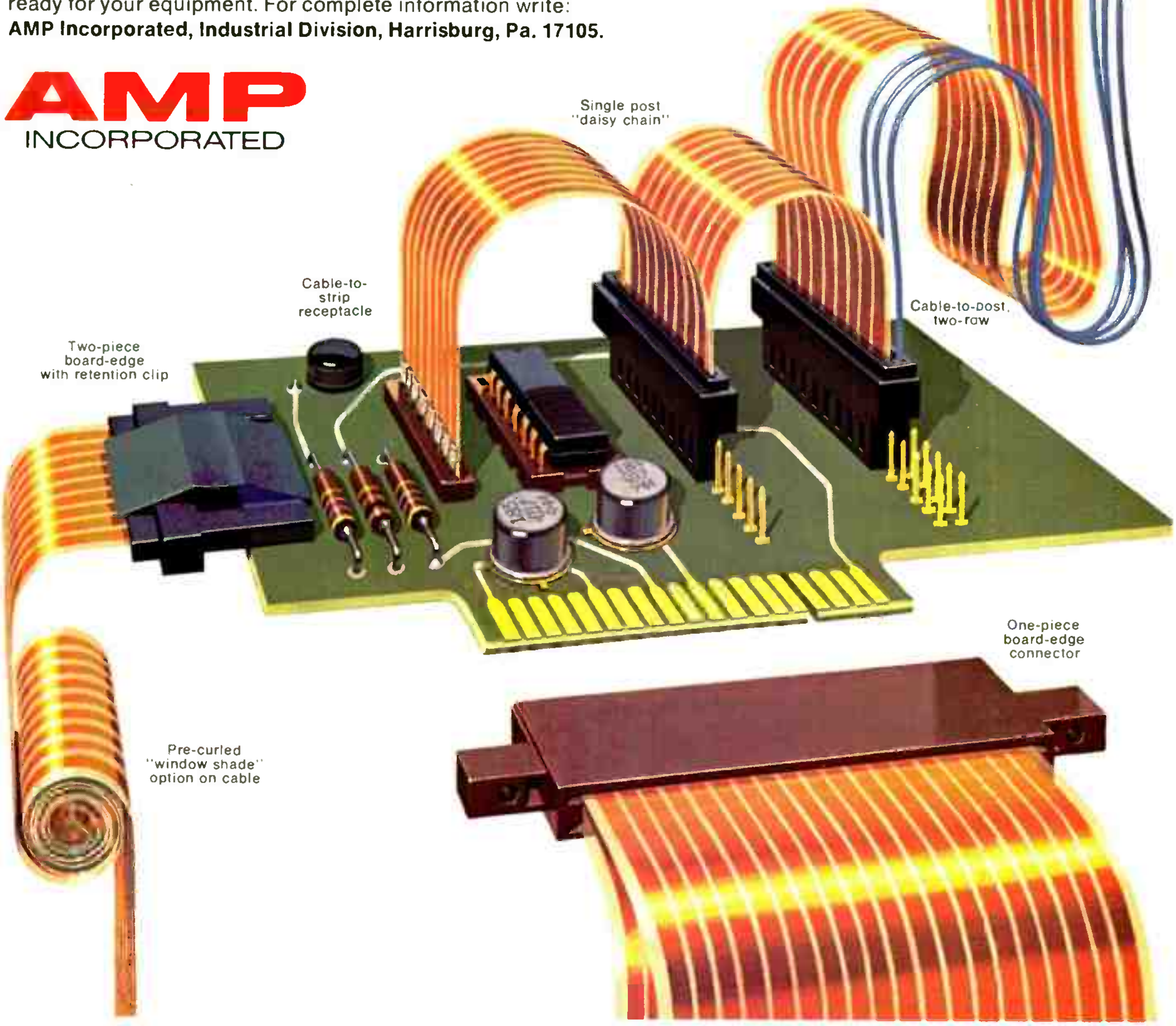


Technical articles

Special report: automation means survival and profit in electronics: p. 62

Higher costs and lower productivity add up to a squeeze for survival at electronics producers. To keep their heads above water, the companies will have to take a good, hard look at implementation of automated design, production, testing, and management control systems, says author Stephen E. Scrupski—and the computer will be the lifesaver.

The cover: The hand tool is going the way of the dodo and the dinosaur as electronics companies implement computer-based automation systems to maximize productivity.

GaP or GaAsP? Let the choice fit your application: p. 74

Both gallium phosphide and gallium-arsenide-phosphide are available as materials for light-emitting diodes, but there's no clear-cut superiority for either, says author George E. Smith. GaP gives more colors and has higher quantum efficiency than GaAsP, but it's more expensive; and GaAsP is brighter to the eye at equivalent currents and is better for strobed displays. Your choice depends on just what you want in your display or indicator application.

Bringing order out of semiconductor memory delay chaos: p. 82

Almost every manufacturer of semiconductor memories specifies his product's switching speed differently, asserts author John Springer. And with the memories becoming an integral part of the processor instead of remaining a kind of subsystem, the lack of standards can be very confusing for designers. It can be cleared up, however, with a coherent explanation of memory switching characteristics related to the most common specs on data sheets; the data then can be used to construct a timing diagram for a system.

Here's the quick way around filter designs: p. 90

Designers need no introduction to the merits of Chebyshev and Butterworth filters, nor are they strangers to the drudgery associated with working them out the long way. However, says author Einar C. Johnson, designers can take a shortcut to accurate filter configurations by using a set of simplified equations that keeps the dogwork on a short leash.

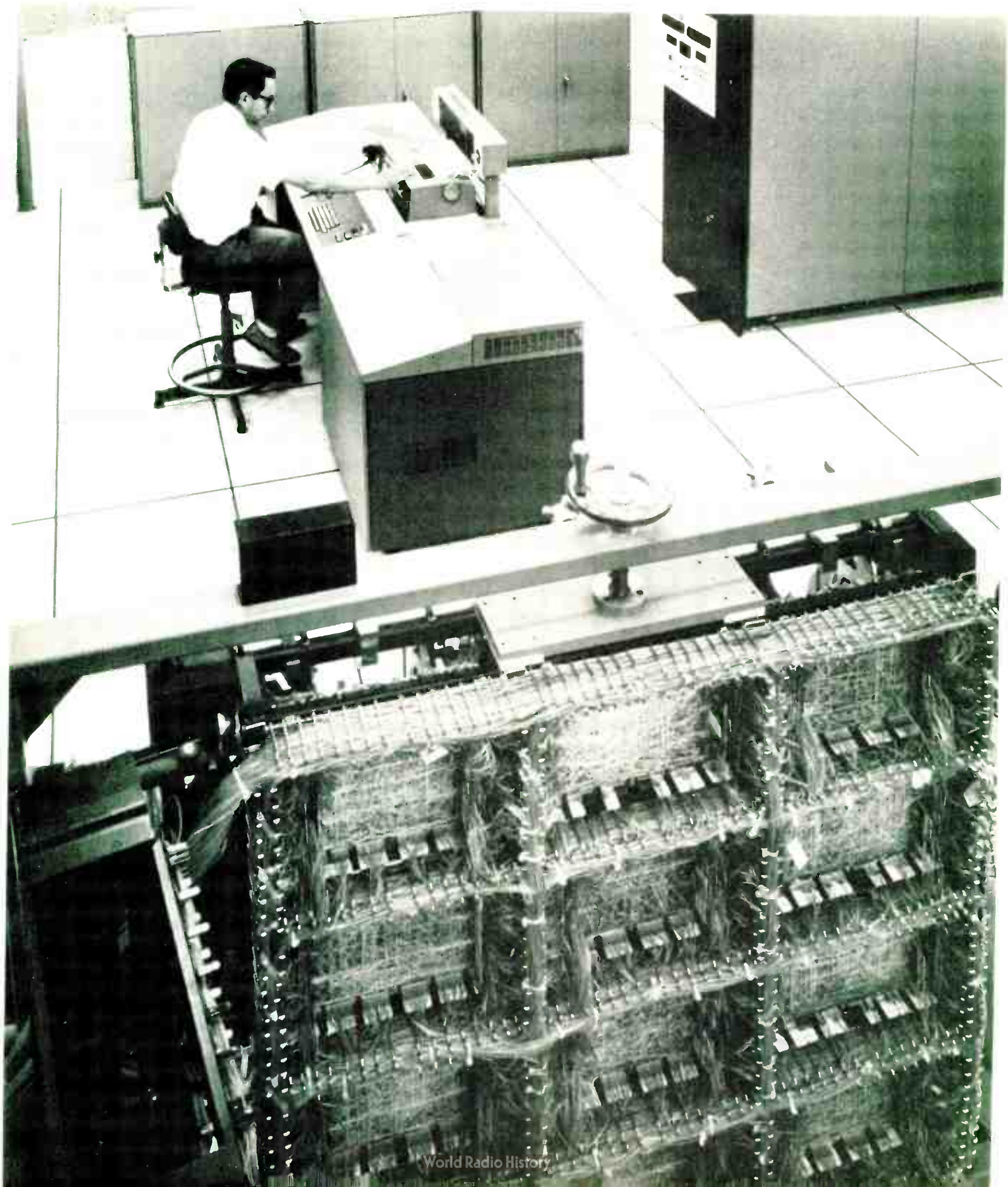
And in the next issue . . .

Special report on the new developments in optoelectronics technology . . . strobing techniques for light-emitting diode displays . . . testing dynamic integrated circuits . . . using MOS in silo and stack memories.

Special report: automation for survival and profit

With cost and wage increases far outpacing productivity gains, electronics companies will have to implement computer-based design, production, testing, and management control systems to keep their heads above water

by Stephen E. Scrupski, *Packaging & Production Editor*



☐ Caught in a crossfire of declining profits, decreasing Government support, increasing foreign competition, and spiraling labor costs, producers of electronic equipment are finding themselves involved in a battle for survival. The companies with the best chance of winning out will be those that automate their design, production, testing and management control procedures.

Yet the ironic fact is that automation still has had relatively little impact in the electronics community itself. For one thing, it takes time to set up automated procedures. In the fast-changing electronics business, products can be obsolete by the time they hit the shipping dock. And many products have custom features that don't lend themselves to standardization. What's more, there's been little activity in curbing the proliferation of parts used in even simple designs. Then, too, automation equipment for electronics production hasn't been around long enough to have significantly affected a large segment of the electronics industries.

Nonetheless, given the critical outlook for business conditions, electronics companies that expect to stay in business will have to automate. The gravity of the situation was put in perspective last July by Secretary of Commerce Maurice H. Stans. In testimony before the House subcommittee on science, research, and development, Stans attributed many of America's balance-of-trade problems to the country's decreasing productivity growth. Between 1965 and 1969, he noted, the average productivity growth rate for the U.S. was 1.7%, while Japan racked up a 10.6% average rate and an aggregate of European countries (Italy, Germany, France, Belgium, Netherlands, and the United Kingdom) scored a 4.5% average rate. At the same time that U.S. productivity has been sloping off, wages have been increasing rapidly, averaging about a 4.4% increase a year for the same 1965 to 1969 period, according to the Bureau of Labor Statistics.

Closer to electronic equipment producers, one major electronics manufacturer with only stateside production facilities showed a total increase of output per man-hour between 1967 and 1970 of 13%, while compensation per man-hour increased by about 22%. This productivity growth rate, about 4%, outstrips the national industrial average, but still hasn't kept up with the increases in labor costs.

Profit potential

Some relief will certainly come from the President's recommendations on tax credits for investment in capital equipment and from the surcharge on imported goods, even though Congress may not fully implement the President's suggestions. Some electronics producers may be tempted to hold off capital equipment investments on the grounds that the import surcharge will by itself reduce the competitiveness of foreign manufacturers. However, over the long haul, the benefits gained from investing in automated equipment will far outweigh the short-term gains made in competitiveness.

"Obviously, automation will result in more profits," says Harvey P. Newquist, vice president of manufacturing at minicomputer maker Data General Corp., Southboro, Mass. But then he cites the stumbling block: "Usually, in the electronics industries, automation has to be justified over a shorter time since electronic products historically have shorter product lives. We introduce a new computer every year and we look for automation that will pay off rapidly."

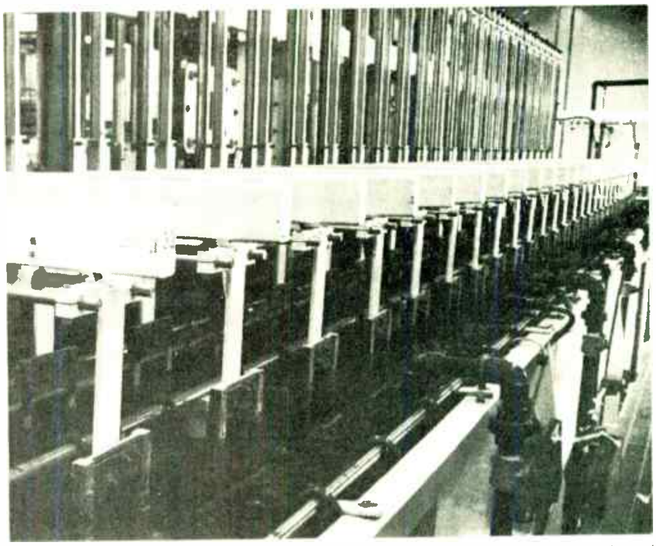
Another reason why production runs can be uneconomically short is that salesmen can be too ready to commit the plant to special variations of standard products. Here, though, companies are taking a harder stand. "We don't make it easy for a customer to order a custom design," says David Pratt, manufacturing manager at Dana Laboratories, Irvine, Calif. "We price them high, we take more time doing them, and we usually modify an instrument to fit the special task."

Needed: standardization

Another problem is getting engineers to design with standard parts that can easily be handled by automated equipment. Because profit-and-loss responsibility is decentralized among various groups or departments, each group manager uses his autonomy to generate any design he feels will make a profit. But each manager might be working in a vacuum, with no attempt to use the parts being employed by the others. It can even be a problem in a large company like General Electric, where Gardner Hartwell, senior engineer in GE's manufacturing engineering consulting service, says the firm, with its 120 departments, is similar to smaller companies where individual product managers are given profit-and-loss responsibility.

Some companies are attacking the standardization problem by using a computer to store descriptions of standard parts. At Data General, for example, an engineer can query the computer on the current production parts (actually the same list as used by the inventory group) and use this information in choosing parts for a new design. But if he decides to use an unlisted part, management demands that he justify it.

1. Machine checks machine. An IBM 1130 computer checks trilead cables interconnecting circuit boards in the IBM 370/145 computer. Errors in connection points are identified and printed in order.



2. Copper plater. Printed circuit boards are automatically plated with a system developed by Sel Rex, Nutley, N.J., for Friden division, Singer Co. Equipment cut cost of board plating by 75%.

SPECIAL REPORT

Automation in design

Computers also can be used to store information directly related to system design. Many companies use logic simulation programs based on a stored catalog of commercially available digital circuits; the designer simply describes his logic system to the computer and it, in turn, supplies a logic diagram based on available circuits. Once such a design is completed, the same data base can be used for many other purposes: pc board layout, numerical control tapes for equipment fabrication, and other documentation.

One company offering such services is Algorex Data Systems, Hicksville, N.Y. Shelly Newman, president of the firm, says the cost of designing electronic equipment typically runs between 5% and 25% of the total. Right now, says Newman, Algorex seeks military systems design jobs, where the 25% figure is typical (the low-end 5% figure covers the mass-produced equipment such as television receivers, Newman says).

Algorex' system (called AIDE, for automated integrated design and engineer) takes raw logic diagrams or logic equations and provides drawings, pc board artwork, numerical control tapes for pc board drilling, wire-wrapping, and troubleshooting documentation. With the system design stored in the computer memory, Newman says, there's no chance for human errors. In some cases the system can save enough just in testing and troubleshooting to pay for itself, he notes. "The greatest impact is made on the first-time user when he builds the system and it actually works the first time," Newman says.

Samuel Gordon, marketing manager at Autologic Inc., San Francisco, another design automation firm, puts the error-prone-people problem another way: "Get the data into the computer as early in the flow as possible before people have a chance to pollute it." Even digitizing a printed circuit board layout that was created manually can introduce errors. A problem-solving human should be able to interact with the computer only to the extent that the system cannot complete the task, he says; as soon as the design is satisfactory, the data base should be used for numerical control tapes.

One user of the Autologic system is telephone-equipment manufacturer North Electric, Galion, Ohio, a division of United Utilities. The system has been operating since May, and according to W.T. Wood, executive director of engineering, "We're quite pleased with it. We had the expected startup problems, but now we've completed about 120 board designs with it."

Wood gives the following comparison to demonstrate the value of the system. For a typical board, measuring 10 by 14 inches with 80 ICs, manual layout might take 160 hours, the taped master about 60 hours, and the documentation another 60 hours, resulting in a total cost of about $1,220 for the 280 hours. With the automated system, however, the total job takes 60 hours and costs about $350, including leasing.

"The big advantages are the completeness and accuracy of the data—no chance for human errors—and the quick turnaround it affords us," says Wood. "Since all operations are serial, manual layout would take about seven weeks, whereas the automated system produces a layout in two weeks," and, he adds, "even this amount

CHARACTERISTICS OF COMPONENT INSERTION MACHINES

	Component insertion machine	Manufacturer	Price ($)	Mfr rate (comp/hr)	User rate (comp/hr)	Working area (inches)	Tooling costs ($)			Parts preparation		
							Work holder	Template	Tape	Ready as received	Lead cutting and bending needed	Sequencing needed
AXIAL LEAD	N/C Indicator	Ragen	9,200 to 17,000	700	300 to 750	10 x 10			20 to 40		X	
AXIAL LEAD	Pantograph	Universal USM	8,500 to 18,000	2,500 to 3,000	2,000	13 x 13 to 16 x 16	400 to 1,000	100 to 500		X		X
AXIAL LEAD	N/C Insertion	Universal USM	27,000 to 29,000	3,500	1,800 to 2,600	13 x 13 to 15 x 15	400 to 1,000		100			X
AXIAL LEAD	Computer	Universal USM	43,000 to 51,000	5,000 to 6,000	4,000 to 5,000	12 x 12 12 x 18 18 x 18	400 to 1,000		100			X
DIP	N/C Indicator	Ragen	8,000	700	240 to 500	10 x 10			20 to 40	X		
DIP	Pantograph	Universal USM	24,000 to 33,000	800 to 1,800	1,000	12 x 12 to 12 x 14	400 to 1,000	100 to 500	100	X		
DIP	N/C Insertion	Universal USM	43,000 to 47,000	1,000 to 2,000	1,200 to 1,500	12 x 12 to 15 x 15	400 to 1,000		100	X		
DIP	Computer	Universal USM	43,000 to 51,000	3,500		12 x 12 12 x 18 18 x 18	400 to 1,000		100	X		

Manufacturers: Ragen Precision Industries, 9 Porete Ave., North Arlington, N.J. 07032, 201-997-1000
Universal Instruments Corp., East Frederick St., Binghamton, N.Y. 13902, 607-772-1710
USM Corp., Balch St., Beverly, Mass. 01915, 617-927-4200

of time could be reduced, if necessary."

However, experience with automatic pc board layouts hasn't always been good, according to many other users. For example, Larry A. Maguire, data communications group manager for data acquisition systems in Hewlett-Packard's Automatic Measurements division, Palo Alto, Calif., says that HP tried it three times and, "out of the three tries it worked once." The problem, he says, is that often when the program can't lay out 100% of the board, it just hasn't left enough options for a human to step in and complete the job. He says he's also had problems with programs that work to tighter tolerances than the pc board manufacturing process can handle. "But," he adds, "automatic pc card layout is desirable and we will try it again."

A design automation system is expected to be in operation at General Radio Co. by the year-end. "All this automation of circuit board production is expected to cut dollars tied up in board inventory by about 25%," says Richard F. DeBoalt, manager of manufacturing engineering at the West Concord, Mass., firm. "We'll have better inventory control, which is necessary because there are about 200,000 boards used yearly in the basic assemblies of our products and at least some of them are always in a state of flux as designs change."

Such redesigns can be costly, DeBoalt says, "by causing overpurchase of boards, thus forcing us to throw some away, and by adding lag time between engineering and product."

Europe: up, up, and away

European electronics industries also are feeling the pinch of rising labor costs and Japanese competition. Common Market officials admit Japanese firms have put the labor-intensive electronics community in a difficult economic position. European electronics companies therefore are automating, although at different paces in the various countries. West Germany, for example, is making the quickest progress—since they face high labor costs and a shortage of skilled German labor, electronics firms are installing labor-saving equipment and also are importing labor from other European countries.

In France, electronics workers have nearly doubled their salaries since 1965 and now get a base cash wage of 6.20 francs ($1.12) an hour. In addition, employers contribute about 60% more to help finance a wide array of fringe benefits, including four weeks paid vacation, an extra three weeks pay at the end of the year, rent allowances, free door-to-door transportation in some regions, and the usual unemployment and retirement plans. In January 1971, a new policy went into effect giving workers a guaranteed monthly wage regardless of hours worked or the number of days in the month.

West German workers also have received large wage hikes. Wages in the electrotechnical industries rose an average of 7.6% in 1969, keeping pace with the productivity increase of 7.1%. However, in 1970, wages spiraled upwards 16.1% while productivity increased by only 4.9%. Present contracts expire this month and the powerful metalworkers' union has indicated it will press for a big hike (15% has been rumored), while, at the same time, productivity in 1971 is not expected to be above last year's 4.9%.

In addition to last year's wage increases, companies also were hit heavily by a new health benefit scheme that requires them to pay six weeks wages to sick employees, a tab previously picked up by the country's federal health agencies.

And in the Netherlands, fringe benefits make up about 40% of labor's pay package; it's about the same for Italy, where wages have risen about 20% in the last two years.

On the production line

In many cases, there are substantial added benefits to be realized if the design automation program is made to overlap with an automated production system. One example is the IBM circuit package manufacturing plant in Endicott, N.Y., where a central computer facility (360/65 and 360/50) monitors and controls manufacturing and testing operations throughout the plant. The computers supply numerical control and diagnostic data to each production and test site and also compile reports for production management control.

At the plant, pc boards are made starting from the basic materials. During lamination, the temperature profile in the stack is monitored by the computer. And in subsequent etching and cleaning steps, the boards travel in holders on a conveyor line and are dipped in

3. Follow the arrow. One user of Ragen's PCP-75 reports up to 75% increase in production over hand assembly; another user says the machine does the work of two to three hand assemblers. Unit operates from a numerical control tape, which positions an arrow-shaped light from the overhead source to show component location. The component bins rotate under instruction from tape.

the proper tanks under computer control. Holes then are drilled and boards are assembled via computer; the boards are then tested, and the computer prints out the results.

At Recognition Equipment Inc., Dallas, Texas, a design automation program is closely tied in with the wire-wrapping machines. From a logic simulation and trace program developed in-house, REI provides documentation for use in manufacturing and servicing instead of the traditional logic diagrams, and then feeds data to the wire-wrapping machines for production. The same program also furnishes data for automatic testing of the completed system.

North Electric also uses wire-wrapped boards. Right now, engineering director Wood says, he's using the Autologic system to generate the tape that could control an artwork generator, but more often he uses the tape to run a wire-wrapping machine—it gives more flexibility and faster turnaround time. But he says there is no doubt that the layout can be converted to a pc board.

This hasn't always been the case with other companies involved in wire-wrapping techniques. Generating a tape to control the wire-wrapping machine is no guarantee that the same interconnection pattern can be built in pc form, he points out. But Wood's system attacks the pc board layout problem first and then, if requested, turns out a wire-wrapping tape.

Automatic component-insertion equipment also has been slow in proliferating. Companies like Universal Instruments Corp., Binghamton, N.Y. and USM Corp., Beverly, Mass., have been selling automated component-insertion gear for several years, but only recently, with the introduction of the easily insertable dual in-line package, has the business started to take off. USM product manager Walter S. Haug estimates that only 20% of the companies that can economically benefit from automatic insertion actually are using it. A survey conducted by *Electronics* of component insertion methods in general use bears this out. For example, one respondent said that his company makes 125,000 circuit modules a year, and 85% of them are completely assembled by hand. Another producer says that all his 60,000-odd boards are assembled by hand.

Nonetheless, efforts also are being made among socket manufacturers to supply units that allow easy entry of the dual in-line package for use on automatic insertion machines. Augat Inc., Attleboro, Mass. recently announced a tapered-entry socket terminal that guides the DIP lead right into the socket. AMP Inc., Harrisburg, Pa., also has such a terminal. For these sockets, the insertion machine is made without the normal cut-and-clinch mechanism that's commonly used when components are inserted in plated-through holes on pc boards.

The AMP terminals are staked in the board with machines supplied by the company. Such machines can be built with a modular design, according to Milton Ross, automation specialist at AMP. Ross is trying to develop an insertion head for his company's many terminals; the customer then could start with a single-head, manual machine to begin his production. For higher volume, the same heads could be used on a pantograph machine, moving up to a numerically controlled version. Or several heads could be assembled on a bridge-type machine, where the work passes under the row of heads suspended from a bridge over the assembly line.

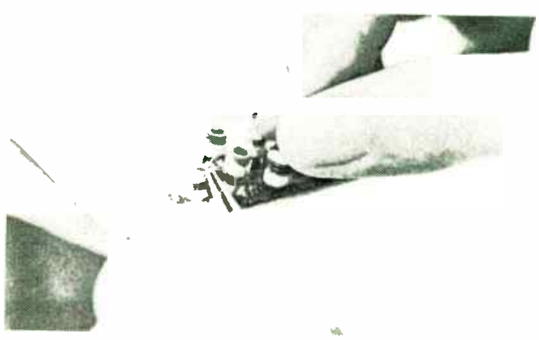
Many production equipment suppliers are faced with almost impossible design tasks when the customer comes to them too late. That's why Ross says the customer should select his machinery vendors before he designs the product. Zenith Radio Corp., Chicago, for example, designed new boards for color TVs with the cooperation of AMP engineers to make them adaptable to AMP machines.

Happy hands

Not all the advances on the production floor are being made in the name of automation. With a large number of manual assembly operations remaining, keeping production workers motivated can be a real problem, says Martin Cooper, vice president for operations, Motorola Inc., Communications division, Schaumburg, Ill. Therefore, on one new product, Motorola has given each production worker complete responsibility for the whole job; assembly, test and final packing for shipment. The product, the new Pageboy 2 fm radio paging receiver, even carries a personally signed note from the worker asking the customer to contact her if any problems arise. "The result, says Cooper, "is a turned-on group of individuals who enjoy their work and have pride in their product."

Each receiver has about 80 components, some of them hybrid circuit assemblies completed earlier. But due to dense packing, the final assembly of the 80 components must be performed manually. "What we do is identify the operations that can be done by hand and then give a single person responsibility for all those operations," says Cooper.

"We've even extended the concept to the stockroom," he adds. "In most plants, the stockrooms are so large that the guy who picks out the parts has little involvement in the job. But for the Pageboy project, we segregated all the parts needed for the unit and set up a small stockroom right in the production area, with just one man running it. He does everything—issues parts, bugs purchasing when he's running low, keeps the records, etc. We've eliminated the computer in this case in favor of individual motivation."



Zenith, known for its emphasis on hand-wired sets, has made the move to pc boards to allow modular construction and easy servicing. All pc boards are the same size and shape, and, with only a few exceptions, have the same conductor pattern. Each board has 225 holes arranged in 15 parallel rows, and conductor strips are laid out to interconnect from three to seven holes in each path. Each circuit thus is given its character by placing components at different points on the boards, making contact with different conductor patterns.

The Zenith boards also feature contacts for manual insertion that securely grip the leads and thus avoid the need to cut and clinch the leads on the assembly line, holding the components in place during subsequent handling prior to the soldering operation. Such gripping-type inserts also are produced by Berg Electronics, New Cumberland, Pa. under the name "Griplets." However, they are not generally used for automatically inserted components, since these insertion machines already have cut-and-clinch mechanisms built in.

The four types of component insertion machines are compared in Table 1, which is based on a similar table included in a recent report on manufacturing costs of modules for missile systems (report OR11,220, U.S. Army Missile Command, Redstone Arsenal, Ala.). The first is numerically controlled positioning with manual insertion, such as used in Ragen Precision Products' PCP-75. The second is pantograph positioning with mechanical insertion. In this approach the operator positions a pointer on a template and presses a button to activate the insertion head, which is linked to the pointer through a pantograph arrangement and thus follows its movement. The third is an all-numerically controlled method, in which the pc board is placed on an X-Y table moving under direction of a tape under a fixed-position insertion head. Finally, there's the computer-controlled machine—the computer takes over the function of the tape.

Looking at the total picture, the overall savings that can be realized with automated equipment are shown in a cost analysis in the report on missile systems. For a module with 40 axial-lead components and eight transistors, the analysis shows that if 160,000 such modules are required, then up to 15 cents per module, or $24,000 total, can be saved with computer-aided assembly. USM's Haug points out, for example, that his firm has an axial-component insertion pantograph machine selling for $8,500 which he says can be justified for as few as 500,000 components insertions a year. Another benefit, says Haug, is that his machine is run by a PDP-8E computer, which also can do other programs when it's not controlling insertion.

An unusual approach to automatic insertion of capacitors is being used at Digital Equipment Corp. DEC buys capacitors from Sprague Electric Co., North Adams, Mass., in a strip form that can be used with a

4. Through its paces. General Electric's GE-Mac 7000 industrial controllers are tested with a computer-controlled station at the company's West Lynn, Mass. plant. ICs and automated production make the unit cost competitive with earlier simple pneumatic controllers.

special insertion machine from Universal Instruments. The same strip is also used in Sprague's final processing, testing, etc., so that Sprague ships the capacitors to DEC in the strip form directly off the production line rather than cutting them apart and shipping in bulk, as it does for other customers.

Transistors must be specially handled with automatic component-insertion machines, since the transistor leads come out the bottom of the package. Both USM and Universal offer transistor insertion machines, in which the radial lead format is converted to axial leads by bending two leads to one side and the third lead to the other side and then taping them. The machine then grips the leads and performs the insertion.

Simple speedup of production is not the only benefit to be gained from machine assemblies—the machine often does a better job than a human. For example, David Prigmore, director of manufacturing for computer systems operations at the Honeywell Information Systems plant in Billerica, Mass., points out, "A machine-inserted IC has a better and cleaner crimp and makes a better contact" than a manually inserted IC.

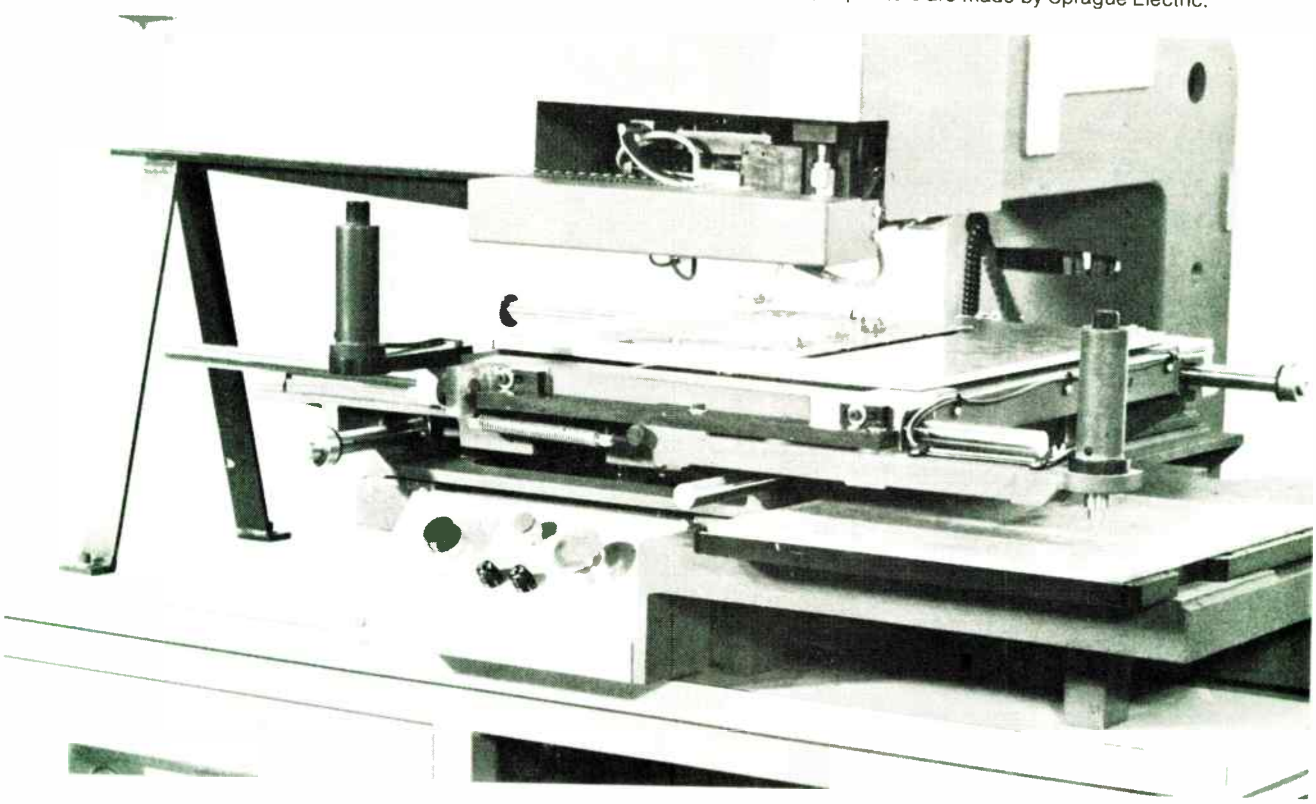
However, with a machine handling the components, tolerances on dimensions must be much more stringent. "Automatic feeders are the best parts sorters in the world," jibes T.E. Blazak, manager of sales engineering for General Electric Co.'s automation equipment operation in Schenectady, N.Y. Workers, he points out, can make allowances for small variations in components, but a machine is a lot more demanding.

However, LSI devices in 40-lead packages will probably continue to be inserted by hand for a long time to come. Few production managers will trust an automatic insertion head to provide gentle handling for the devices' fragile wire bonds and lead frames. In fact, large-scale integration has been creating a quiet revolution of its own in electronic assembly operations; the day of simple "screwdriver" assembly appears to be fast approaching. With LSI, most of the equipment circuitry is built on a single chip, so assembly simply involves plugging a few LSI packages into a board and attaching a couple of discrete components. For example, the entire Sharp Corp. ELSI-8 calculator, which uses four LSI chips, requires only about an hour to assemble and may even take less time in the future.

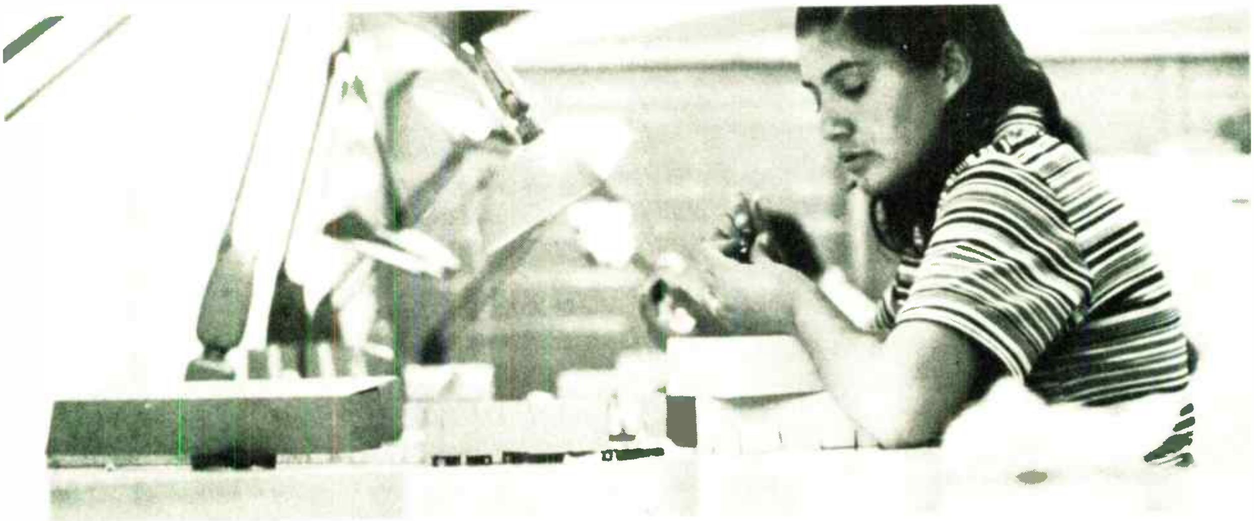
When the unit's display tubes are replaced with a single-envelope display such as a liquid crystal, assembly time could be cut to 20 minutes, asserts Charles Kovac, vice president for marketing at North American Rockwell Microelectronics Co., Anaheim, Calif.; suppliers of the chips. What LSI can do for plant capacity is shown in Kovac's estimation that if one of NRMEC's domestic business-machine-chip customers would commit to LSI rather than the electromechanical technology he's now using, the customer could increase plant output 100 times.

However, the cost of the LSI devices themselves still is preventing users from going that route, according to at least one prospective user, Dana Laboratories' Pratt. Pratt says he's been looking at LSI but the circuits must justify themselves on materials costs, not labor costs. "When they get as attractive in price as ICs, we'll probably use them," he says.

5. Disk jockey. Disk capacitors are automatically inserted onto printed circuit boards from strip format used in their production. This Universal Instruments insertion machine is used by Digital Equipment Corp., Maynard, Mass; capacitors are made by Sprague Electric.



Hands across the border



Electronics companies seeking inexpensive hand labor need not go to the Far East, says John E. Kent, senior consultant at Arthur D. Little Inc., Cambridge, Mass. Kent, in a recent study, notes that since 1966, the Mexican government has encouraged a program for industrial development along its northern border. The program is based on a "twin-plant concept" in which U.S. companies establish plants just across the border in each country, with the American plant handling the technical and mechanized operations and the Mexican plant handling the labor-intensive aspects.

Minimum wages rates along the border, including all fringe benefits, range from 50 cents to 70 cents an hour. Compared with labor costs in the Far East, Mexican labor is higher priced, as shown by the table listing minimum wages, but the added benefits of proximity to the U.S. plant could outweigh the difference in wages. As an example of Mexican labor costs, in Nogales, about 60 miles south of Tucson, Arizona, the starting rate is 34 cents an hour, and with 50% more fringe benefits, the cost is 51 cents for each working hour. Thus a company operating in Nogales would pay each operator about $2.00 less an hour or about $4,000 less a year than in the U.S. In a typical labor-intensive product such as a wiring harness, where half the manufacturing cost of $100 is labor, the wage savings would amount to about $40 per unit.

In the example shown below, the hourly cost comparison is given for U.S. operations vs twin-plant operations. The U.S. cost for one hour of labor is $14.06, while the twin-plant cost is $3.56, including duty on the value added to the product in Mexico. Although transportation is not included in the total, such costs would be minimal, with the plants nearby on opposite sides of the border.

Kent says that the industrial parks being established along the border generally meet the standards of the better U.S. facilities. Management personnel of the parks are well-versed in both U.S. and Mexican manufacturing operations and practices, and can help lessen the "cultural shock" of a U.S. company attempting to manufacture in a foreign country with its different language and culture.

One of the better industrial parks (designed by ADL) is located across the border from Nogales, Arizona, says Kent. Construction of the park began in the summer of 1970; now four buildings are complete and several more are under construction totaling more than 200,000 square feet. All buildings are leased by major U.S. companies.

MINIMUM WAGES — SELECTED COUNTRIES

(including fringes, per hour worked)

United States	$2.50
Japan	.90
Taiwan	.16
Korea	.31
Hong Kong	.40
Singapore	.35
Mexico — Border	.51
Mexico — Interior	.37

ROUGH COST CALCULATIONS

Present U.S. cost

Labor	$ 4.50	(1 hour, with fringes)
Material	.56	
Overhead	9.00	(Twice labor cost)
Mfg. cost	$14.06	

Twin-plant cost

	U. S.	Mexico	
Labor	$ .45	$ .51	(10% of present U.S. rate; 1 hour Mexican rate)
Material	.56	—	
Overhead	.90	1.02	
Duty	—	.12*	(See below)
Totals	$1.91	$1.65	
Total mfg. cost	$3.56		Plus transportation

*Duty calculation:

Value of U.S. components — labor, materials, and overhead plus 10% profit	$2.10
Labor (Mexico)	.51
Overhead (Mexico) — 100% of labor cost	.51
Profit (Mexico) — 10%	.31
New "value" of product	$3.43
Less: value of U.S. goods	– 1.75
Under Tariff 807, assume:	
Dutiable value	$1.68
Duty — 7%	$ .12

SPECIAL REPORT

Computers for testing

Another big time-and-money saver is automated testing. Digital circuits, for example, are becoming more complex and only a computer has the patience to run through all procedures to determine if an error is made. Instruments are becoming more accurate, more sensitive, and are operating over wider frequency ranges, while the number and extent of tests are increasing. In the consumer field, for example, the increased emphasis on throughput and even Government legislation (on cathode ray tube radiation, for example), is causing more tests to be performed.

One factor that's making it easier to test automatically is that most instruments now are digitally programable. With a computer in control, the operator need not know much about the instrument; he simply checks a sequence and looks for the proper readings.

At one of the industry's largest instrument producers, Tektronix Inc., Beaverton, Ore., industrial engineering manager Peter H. Mackie says testing represents his highest labor costs. Thus, automated equipment is applied at all stages of assembly—continuity checks of blank boards, function tests of partially completed boards and subassemblies, and final testing.

The chief labor-saving innovation at Dana Labs was introduction of automatic calibration and test equipment about eight months ago. Manufacturing manager Pratt agrees that checkout is overshadowing assembly as a labor cost; the equipment, made by Zehntel Inc., allows Dana to be "several times more efficient. With it, the operator can troubleshoot as well as calibrate, freeing a technician for other tasks," he says.

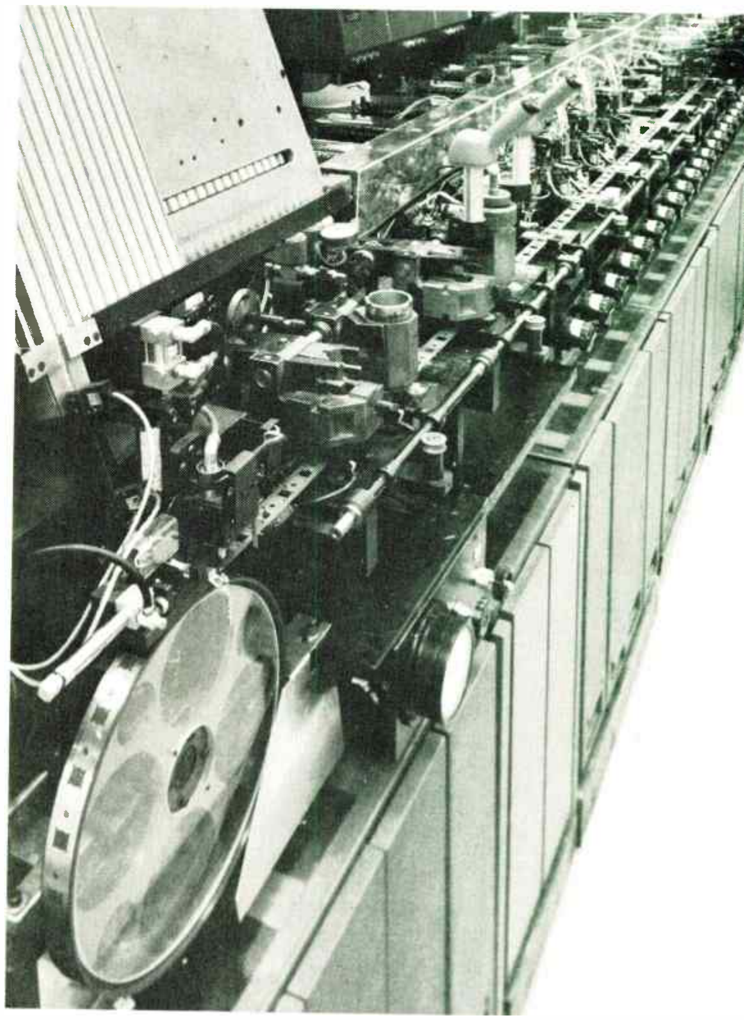
"In addition to the dollar savings," says General Radio's DeBoalt, "automated testing eliminates the possibility of incomplete testing owing to human oversight or fatigue, and often performs combinations of tests simply too lengthy or complex to be performed manually." William J. Pote, General Radio's manager of test engineering, notes, "As the complexity of the products GR makes rises, the number of tests needed for proper calibration rises exponentially, and since many of the needed tests are repetitive, they are good candidates for computerization."

The thick-film people

The most automated production lines within the electronics community do not deal with conventional components on printed circuit boards, but rather with thick-film hybrid circuits. Three companies—IBM Corp., East Fishkill, N.Y., Delco Electronics, Kokomo, Ind., and the RCA TV manufacturing operations in Bloomington, Ind.—have installed automated lines for such circuits. The hybrid approach lends itself to automation better than the conventional printed circuit boards and soldered connections for several reasons: small substrates (from about ½-inch square up to about 1 by 2 inches) are used; conductive and resistive inks can be automatically applied and fired on a moving belt, and devices also can be applied and connected into the circuit automatically.

At Delco, which is producing circuits for automobile voltage regulators and radios, the big advantage of the hybrid approach, says Dwight Callaway, assistant superintendent for manufacturing development, is that the thick-film resistors can be adjusted after the circuit is put together, nnd thus can be trimmed on a functional basis, rather than simply to tolerance. For example, an audio amplifier's gain might be determined by the value of a particular resistor. In discrete form, the circuit would have to be carefully designed, taking account of all component tolerances. However, in thick film form, an actual input can be applied to the circuit and the resistor trimmed until the gain reaches the desired value, without having to consider the actual value of the resulting resistance.

RCA is turning to hybrid circuits to hold the line on production costs in the U.S. and thus keep the U.S. operation competitive with circuits made in the Far East, according to Barton Kreuzer, RCA executive vice president, consumer electronics. Hybrid circuits are being built for the RCA all-solid state XL-100 color TV sets, and will probably be extended soon to other models. According to Robert A. Schieber, division vice president for operations in the Consumer Electronics division, the eventual target is for 80% of all circuitry to be built on ceramic substrates.



In GR's case, the move to automatic testing resulted in a new product. When GR was gearing up to produce the 1192 counter several years ago, the company built the first model of what was to become the 1790 logic circuit analyzer.

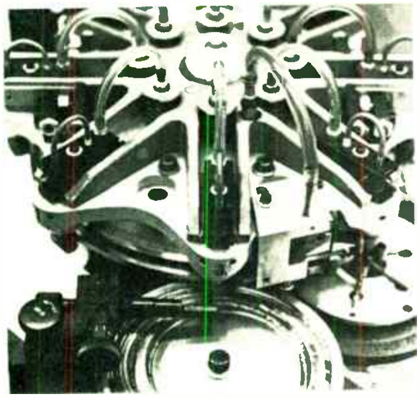
The move toward market began when "we found that we were saving $73,000 a year by using the tester. And using the tester to recycle failed subassemblies saves another $15,000 yearly over the costs of manual testing and fault location," says DeBoalt. Then test engineering and quality control collaborated, seeking to save even more money by collecting data on the frequency of failure of certain components used in particular ways, and then increasing the stringency of incoming tests. They thus weeded out weaker units before they were built into the boards. This is estimated to have resulted in an added saving of another $12,000.

Management systems

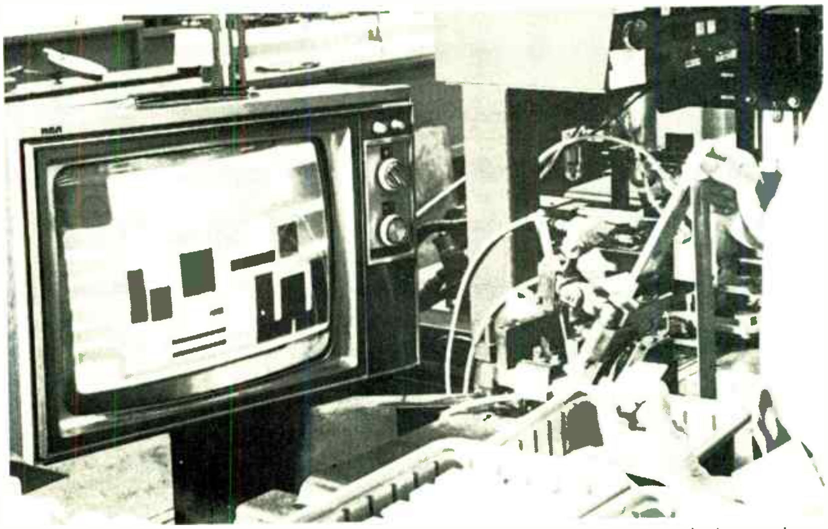
Such use of the computer for help in parts selection highlights its potential as a management aid. "Every act from parts selection to sales is interconnected, sometimes quite subtly," DeBoalt points out, and the key to profits is inventory turnover. Since a large part of GR's assets is always invested in inventory, the more frequently GR can turn over this inventory, the higher the total profits.

To help monitor the inventory, "GR has a management information system that allows us to look about four months ahead into our production schedules and to recognize parts and subassembly requirements that could be troublesome," notes DeBoalt. "Parts shortages, for example, can cost us sales, make our marketing forecasting less accurate, and result in over-shoots of finished inventory and thus produce higher overhead." But the system, he notes, allows GR to keep in the pipeline only those parts or raw materials needed for manufacturing and cut inventory time as short as possible. "I reckon the time saved by instituting this management automation system to be about 90% of that spent previously," he asserts.

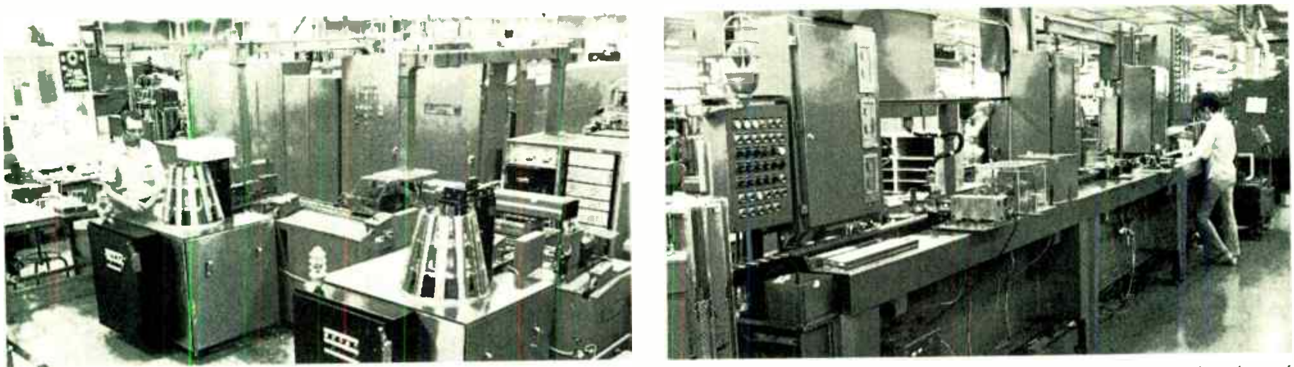
Another company setting up a comprehensive computer-based management system for manufacturing is Texas Instruments Equipment Group, which makes computers, test systems, peripherals, and military equipment, in Houston, Austin, Dallas, and Sherman, Texas. Dale E. Cunningham, manager of operating



Chips are down. Handling mechanism (above) places integrated circuits on hybrid substrates (left), at IBM Corp. Chips are picked from small vibrating bowl and then placed on substrates before being delivered to furnace for soldering of connections.



TV watcher. Hybrid modules made at RCA color TV plant in Bloomington Ind., are viewed on closed-circuit TV after laser trimming. Laser trims three resistors per second.



This year's model. Hybrid circuits for automobile voltage regulators and radios are handled from stacks (left) prior to laser trimming of resistors. Transistors, diodes, and capacitors are assembled and soldered automatically (right) as substrates move on conveyor belt.

services, says the operation is complex because the group makes different products in many locations, with no large production runs in individual products.

Cunningham says that TI's main goals are very wide-ranging: replacing the engineering drawings and associated paperwork for proposals, and controlling purchasing and inventory, scheduling, design, fabrication, verification, and warehousing of products. To accomplish this involves a radical swing away from the conventional dependence of a manufacturing operation on the drawing, says Cunningham. And because of the different facility sites, the plan is to have a computer at a central location that will be able to communicate with nu-

Single-chip systems cut assembly costs

By L.J. Sevin, Mostek Inc., Carrollton, Texas

The single-chip systems era is fast approaching: it's now possible to integrate systems of up to 1,500 equivalent-gate complexity on a single chip, and within the next year, the capability will increase to the 3,000-gate level. More complex calculators, central processors for computers, and small, special-purpose computers for control applications all will soon appear in single-chip form.

How do we gauge the impact of these developments on system assembly costs? The cost of a system, not to mention the reliability, has always directly depended on the number of interconnections. With conventional integrated cricuits, many of the interconnections are batch-fabricated, but system complexity has grown by so much that assembly cost advantages haven't necessarily been evident. However, large-scale ICs present an opportunity to drastically reduce interconnection costs.

The data in the table provides such an example for a small digital system with the equivalent of 1,000 gates. The system cost is estimated for five different implementations of the circuitry: discrete components, TTL gates, TT/MSI and ICs, six MOS/LSI chips, and finally, a single MOS chip. To derive the data, it was first assumed that a digital system with 1,000 gates requires 4,500 discrete components at 5 cents each. The discrete components then could be replaced with 300 digital ICs (either DTL or TTL) at 20 cents each. If TTL or DTL/LSI were used, the total package count could be reduced to 100 at an average price of 40 cents; with MOS ICs, only six chips would be needed at $6.00 each. The single chip is assumed to have a unit price of $20.00.

For all cases except the last two, it is assumed that printed circuit board labor, material, and amortized tooling costs average about 1 cent per pc board hole. However, because of the lower board density with six-chip and single-chip systems, a cost of three cents per hole was used.

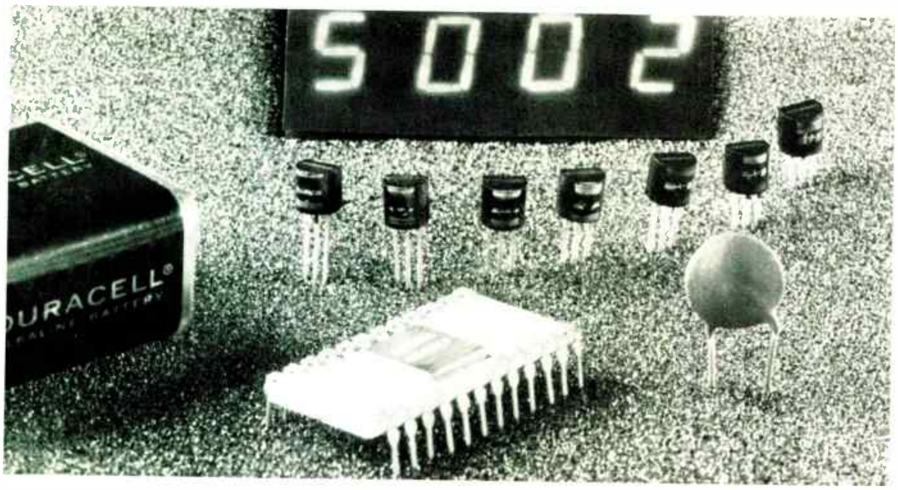
1,000-gate subsystem — cost comparisons based on 1972 competitive pricing levels

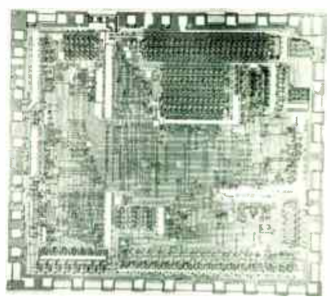
Element type	No. of connections	Assembly cost	Component cost	Assembly plus component cost	Special device tooling costs*
Discrete	11,000	$110.00	$22.50	$132.50	$ –0–
ICs (TTL)	4,000	40.00	66.60	106.60	–0–
MSI and ICs	2,500	25.00	40.00	65.00	–0–
6-chip MOS	180	5.00	36.00	41.00	120,000
1-chip MOS	40 or less	1.20	20.00	21.20	60,000

*May or may not be borne entirely by customer.

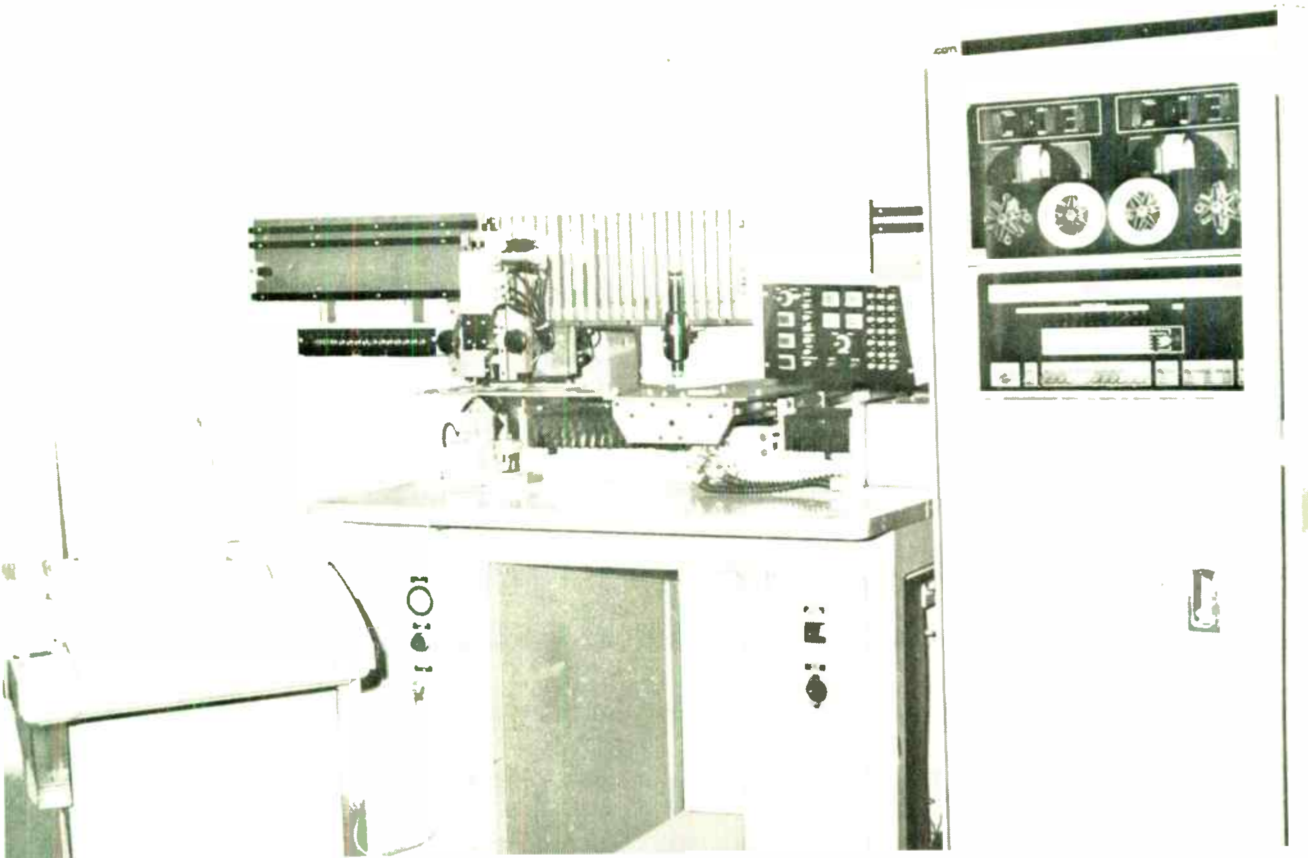
Total system cost assembly plus components thus is reduced sharply with the single-chip approach. However, chip tooling costs are not included; these must be amortized over the number of systems being built. If, for example, 10,000 systems are to be built, the $60,000 would break down to $6.00 a system, for a total cost of about $27, still far less than any of the other approaches. And in some cases, the customer may not have to bear the full cost of developing the chip, since most MOS suppliers would share in the costs as such developments increase their capability to serve future needs. Users also can expect tooling-cost reductions as computer-aided design methods are refined.

Another important aspect of the single-chip approach is reliability. It's an established fact that far from degrading when component density is increased, IC reliability improves far more due to fewer interconnections and reduced component count. As a bonus, spare parts inventory costs are reduced, as are power and space requirements.





In the chips. Calculator chip (above) is 180 mils square. MK5002F counter/display chip (left), almost a complete digital voltmeter, replaces 12 TTL units.



6. DIPs in. Computer-controlled machine inserts 14- and 16-lead DIPs from any of 20 stick carriers. The USM Corp. unit selects the DIP, positions the board, straightens package leads, inserts, and cuts and clinches leads, at up to 4,000 components an hour.

merically controlled machinery at any of the company's other locations.

However, the system, says TI, will use minicomputers extensively: with minicomputer prices dropping sharply toward those of terminals, it's possible to have local intelligence and memory at each machine site. Otherwise, the central computer would have to be very massive to control nonintelligent terminals. "Don't take a production line and add a computer, take a computer and build a production line around it," says a TI spokesman. "The computer must be deeply buried in the system." He says he's shooting for a minimum increase in productivity of 50%.

One company that's aiming for a management control system is Recognition Equipment Inc. REI makes a data entry terminal that reads hand-written numbers. Says Dwight V. Goldstrom, staff industrial engineer, "It's hard to keep track of the many changes engineers keep coming up with. You need on-line capability for entering changes; punched cards aren't really convenient or practical." But with an REI Input 3 system, "the person making the change is his own keypuncher, since he simply needs to write in a few numbers," he says.

According to Data General's Newquist, purchase, receipt, stocking, and issuing of parts represent at least 50% of the time to make a computer and the cost to produce it. "This is true of any computer manufacturer who doesn't make his own ICs," he says, adding, "It's difficult to put figures on this, but I feel that there is a reduction in time of about 50%" with a computerized management control system, "and we probably save an equal amount of money. We did this in 1969, our first year of production.

"Because of short product life and technological change, you have to be careful you don't upset inventory control by producing too much. I think many electronics companies forgot this and in 1970 were caught with an inventory of obsolete products," he says. "DG had an inventory turnover seven times—twice as good as the industry average. When we automated, we didn't want to upset or disrupt inventory."

However, one of the industrywide problems in monitoring parts levels with a computer is the wide variety of component designation schemes prevalent among suppliers, according to Clark Coffee, an automation consultant in San Francisco. Coffee is a prime mover in a new group, called the Data Exchange Standards Society, which will attempt to establish standard formats for numerical control programs as well as standard types of parts numbers for component identification.

For example, Coffee says many other industries are adopting a nine-digit code, in which the first four digits identify the component manufacturer and the last five the specific item.

Additional reporting for this article came from *Electronics*' staffers James Brinton and Gail Farrell, Boston, Paul Franson, Dallas, Lawrence Curran, Los Angeles, Stephen Wm. Fields, San Francisco, Charles Cohen, Tokyo, and Michael Payne, London, and McGraw-Hill World Newsmen Robert Ingersoll, Bonn, Andrew Heath, Milan, Michael Johnson, Paris, and Michael Kolbenschlag, Brussels.

The display job calls the shots in contest between GaP and GaAsP

Gallium phosphide light-emitting diodes show more colors and have higher quantum efficiency than gallium-arsenide-phosphide LEDs, but GaAsP is brighter to the eye and works best in high-current strobed displays

by George E. Smith, *Litronix Inc., Cupertino, Calif.*

☐ Debating the virtues of gallium-arsenide-phosphide and gallium phosphide in light-emitting diodes is much like arguing the merits of summer vs winter—it's all relative. There's no LED for all seasons, and the designer's choice depends mainly on which type of diode is most suited to his application.

LED performance factors are such a melange of electronic, optoelectronic, and optical parameters that a good case can be made for the superiority of either diode by stressing one function or another. The only way a designer can tell which is better in a display or indicator is to stack both types against each other.

Gallium phosphide diode aficionados cite the higher quantum efficiency of GaP as an indication that the material eventually will make the brighter, more economical display. GaP puts out many more photons for a given electrical input power than GaAsP, but much of the radiation is invisible to the eye. GaAsP diodes are 2.5 to 3.5 times brighter to the eye when radiating the same amount of power as GaP diodes.

Fortunately for GaP, it emits so much more radiation than GaAsP for the same electrical input power that its overall luminous efficiency is about equal to that of GaAsP when both types are operated at recommended currents. (GaP at low current, GaAsP at high current). As it stands now, GaP is well suited for use in low-current indicators, but GaAsP works best in displays.

The lead that GaAsP now enjoys in the major application for LEDs—seven-segment numeric displays—is due primarily to its lower cost. In fact, for the price of a single GaP diode chip, a large bar of GaAsP can be bought. Several diodes can be diffused in the bar, raising the segment's luminance. And small monolithic displays can be made. GaP, on the other hand, requires a grown-junction process; the diodes are produced by dicing the wafer (Fig. 1). GaAsP can be operated in a strobed or multiplexed pulsed mode at high peak currents to conserve power, and it's also preferable for high-temperature applications.

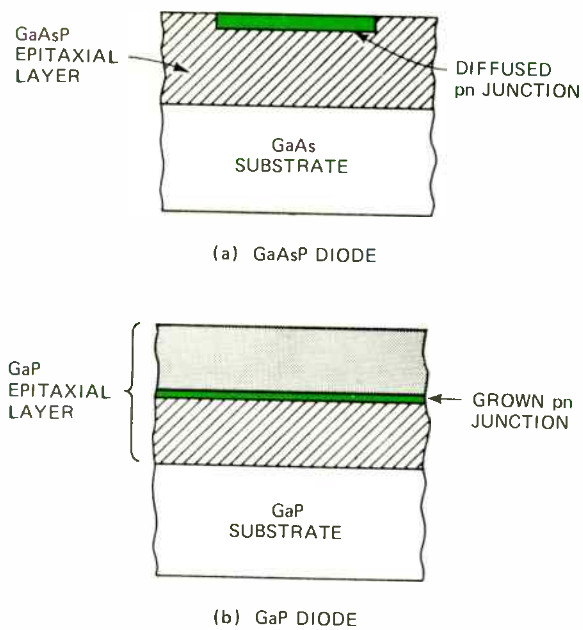
On the other hand, GaP is just about the only source of three-color displays. Although GaAsP can give both red end amber, only GaP can produce green as well—and the eye is most sensitive to green. Therefore, a GaP display might show green for safe equipment operation, yellow for caution, and red for danger.

GaP chips emit light in all directions, while GaAsP diodes provide a well-defined forward lobe. And with the added brightness achieved in pulsed operation, dot-matrix GaAsP arrays are ideal for alphanumeric character display and film recording. Some recorders using such arrays record 30,000 characters a second.

A good place to start sorting the optical parameters is at the human eye. The International Electrotechnical Committee's (CIE) standard photopic curve in Fig. 2 is known as the "standard eyeball," showing how the eye's response varies with wavelength.

Luminous efficiency in lumens per watt, or luminosity, depends on the retina's response to the wavelength (color) and the rate at which radiant energy falls on the retina. Standard LED colors and their luminosity are shown in Fig. 2. This is a much more valid measure for displays than radiant energy (light power output) as measured by an optical instrument.

GaAsP diodes generally emit radiation in a narrow



1. Two techniques. Radically different fabrication methods account for some of the differences between gallium-arsenide-phosphide and gallium phosphide light-emitting diodes. GaAsP diodes are diffused, while GaP diodes are grown-junction devices.

spectrum between 650 and 670 nanometers, as shown in Fig. 3. The corresponding visible light peaks at a slightly shorter wavelength and has an average luminosity of 45 lumens/watt for 660 nm radiation, rising to 75 lumens/watt for diodes peaking at 650 nm.

The eye's response causes the peak wavelength of the light output to shift down as indicated by curve 1 on the graph. Curve 2 is the actual radiated power output as measured by an instrument. Most of this output is visible to the eye.

A GaAsP diode's emission wavelength may be altered by varying the proportions of arsenic and phosphorus in the crystal. At higher phosphorus concentrations, the wavelength is shorter and the luminosity higher, but power efficiency (radiated power out divided by electrical power in) falls.

Proper proportions

Optimum concentration is near $GaAs_{0.6}P_{0.4}$, or 40% phosphorus. The emission peaks at 660 nm (red), where about 45 lumens/W is obtained. As indicated on the CIE curve, $GaAs_{0.5}P_{0.5}$ produces an amber light with high luminosity, but at a sacrifice in power efficiency.

Red GaP diodes emit at 690 to 790 nm; average luminosity is only about 20 lumens/W. Most of the radiated output power, however, is not sensed as visible light by the eye—only the "foot" at the left-hand side of GaP's total radiation spectrum curve (Fig. 3) is useful in displays. The GaP diode's color appears more orange than GaAsP's because of the large shift between the radiated output and luminous output flux in the GaP diode.

GaP can be doped to emit green, usually peaking near 550 nm with luminosity of 680 lumens/W but, power efficiency is poor.

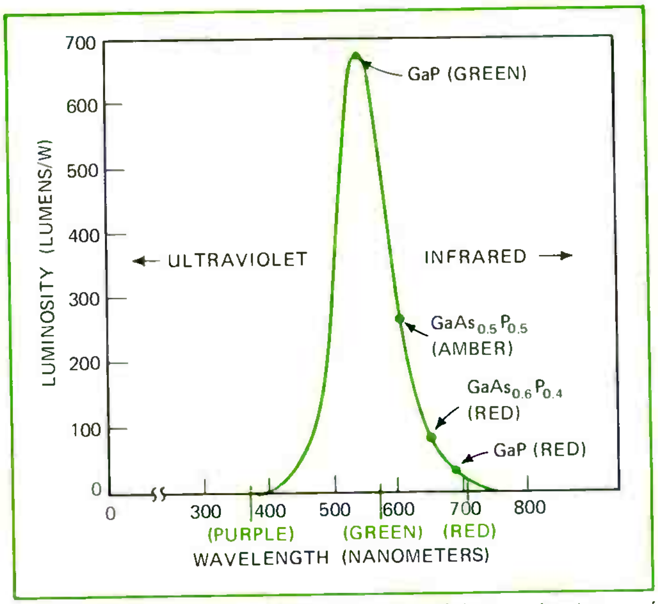
Efficiency is an important consideration because the lower the power needed for a display, the cooler the operation for the closely spaced diodes—light output drops drastically if the diodes heat up. Also, the supply power may have to be budgeted carefully.

Typical power efficiencies reported by LED manufacturers show:

- Red GaP—1% at 20 lumens/W gives 0.20 lumens/W average luminosity.
- Red $GaAs_{0.6}P_{0.4}$—0.3% at 50 lumens/W for 0.15 lumens/W average luminosity.
- Green GaP—0.006% at 675 lumens/W with 0.04 lumens/W average luminosity.
- Amber $GaAs_{0.5}P_{0.5}$—0.044% at 340 lumens/W and 0.015 lumens/W average luminosity.

Many production GaAsP devices have 0.4% power efficiency (the oft-quoted figure of 0.15% for red GaAsP is outdated), while GaP manufacturers report over 1.0%. Although GaP seems to have a 2.5:1 advantage in power efficiency, GaAsP does as well when luminous efficiency (lumens out/electrical watts in) is calculated over its luminosity range.

Brightness includes several other factors unrelated to quantum efficiency (which is the ratio of photons out to electrons in). GaAsP has a lower quantum efficiency in terms of photons escaping from the crystal. Its external quantum efficiency is about 0.5%, while production GaP diodes reportedly are around 2%. Bell Laboratories even reports 7% in experimental GaP devices.



2. Standard eyeball. Average luminosity of four major types of LEDs is shown by their wavelength location on the CIE standard photopic luminosity curve. The eye's response to light energy, in lumens per watt of radiant energy, peaks at green, and falls off rapidly at the edges of the visible-light spectrum. Gallium phosphide is less luminous than gallium-arsenide-phosphide when emitting red light.

Brightness is an eyeball response, not an exact measurement. More photons do not translate into more visibility if the radiation is in the invisible region. That's one reason why the GaAsP diodes appear to be up to 3.5 times as bright at equal radiated output power.

Another reason is the shape of the diode emission pattern. Brightness of each type is both helped and hindered by crystal transparency. GaP is transparent, so most of the light generated at the pn junction gets out of the chip, accounting for its high power efficiency. GaAsP absorbs a great deal of the light—about 98%—before it can escape, but the light is focused better and is more luminous.

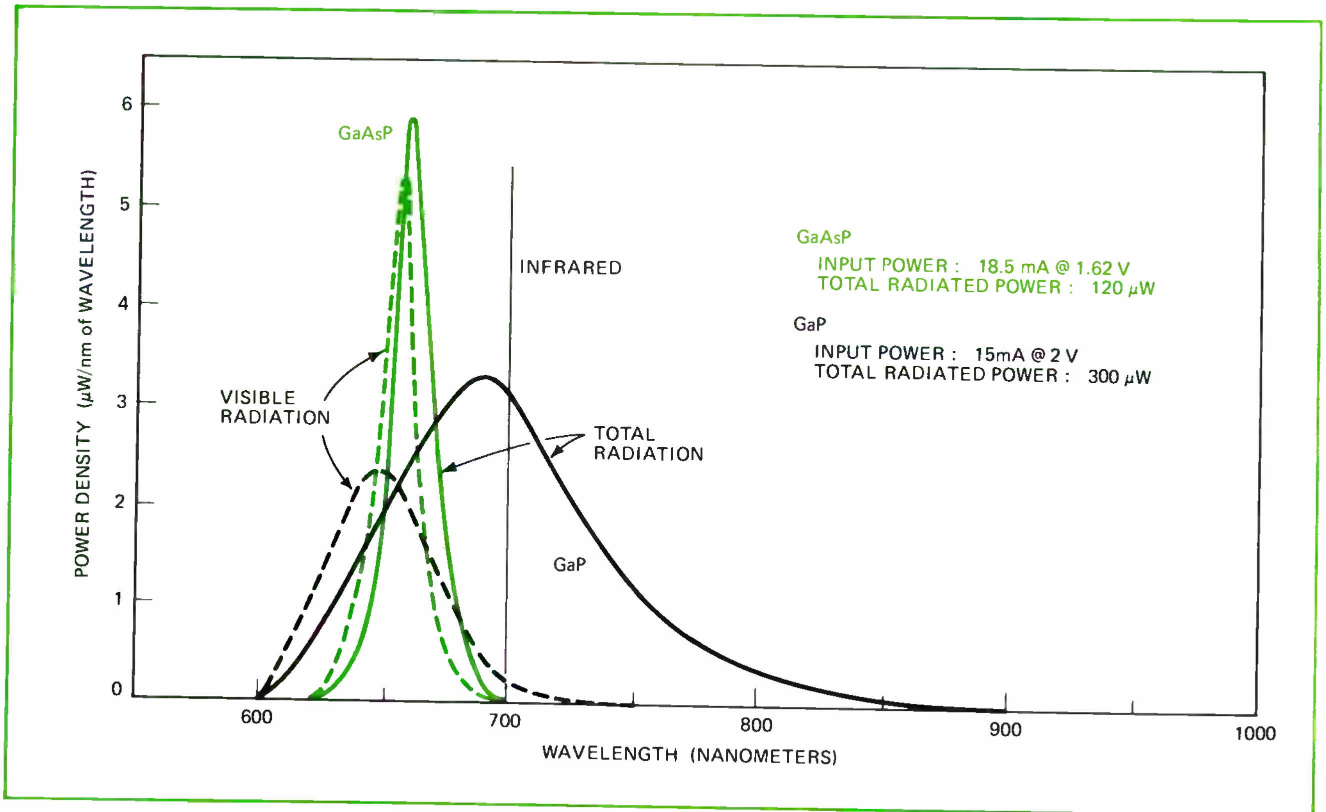
Light output

Both crystals have high refraction indices. (The index $N_2 = 1$ in Fig. 4 is that of air and $N_1 = 3.5$ is that of the crystals.) Because of this high index any ray from the pn junction has slim chance (about 2%) of not being totally reflected. Any light diverging at an angle greater than 17° from the diode axis is reflected back into the crystal (I_c is the critical angle). About 30% is reflected by the surface in addition to the total reflection at angles over I_c. The reflection coefficient for light normal to the surface is:

$$[(N_1-N_2)/(N_1+N_2)]^2$$

Since GaAsP absorbs the reflected light, not more than 1.5% of the electroluminescence is actually visible. However, such light as does emerge is ideal for viewing, with most of the radiation in the forward direction. In this emission pattern (Lambertian) the luminance is constant over a wide viewing angle and an eyeball can move about and still see a clear image.

By contrast, the whole GaP chip lights up. Reflected light bounces around in the crystal and emerges randomly at the chip faces. Because the emission pattern is



3. Visible shift. Emission spectra of typical red GaAsP and GaP diodes show why GaAsP appears as bright despite its lower quantum efficiency. GaAsP emits a narrow band of wavelengths and the shift between luminous flux visible radiation and the total radiated output is small. The GaP spectrum is broad, much of the energy is invisible, and the power density at any given wavelength is lower.

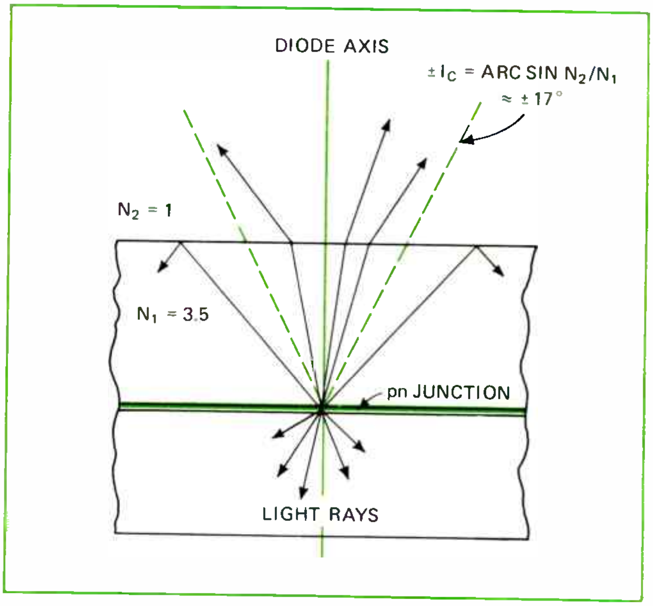
nondirectional, or isotropic, the spacing between chips must be adequate to preclude optical crosstalk lest the viewer be unable to tell which were radiating and which were illuminated by their neighbors.

Hence, GaP diodes could not be used in a dot matrix or other high-density array unless baffles were placed between them. If an opaque material filled the spaces between chips, the extra power output through the chip sides would be lost. Generally, reflectors and lenses are used to make the outputs of GaP diodes directional. They cause multiple images, which the eye can blend, but a microfilm recorder or film annotator can't.

For economy, the segments of seven-segment GaP displays usually are made by embedding a diode chip in a faceted plastic light pipe. The facets caused a line of images to appear, making the segment look like a line, not a square. Off-axis visibility is poor with clear plastic. However, if the plastic diffuses the light, most of it is concentrated at the center of the line. Clear plastic with a rough surface improves off-axis visibility and gives a good line, but must be handled carefully since moisture or finger oils will tend to make the surface clear again.

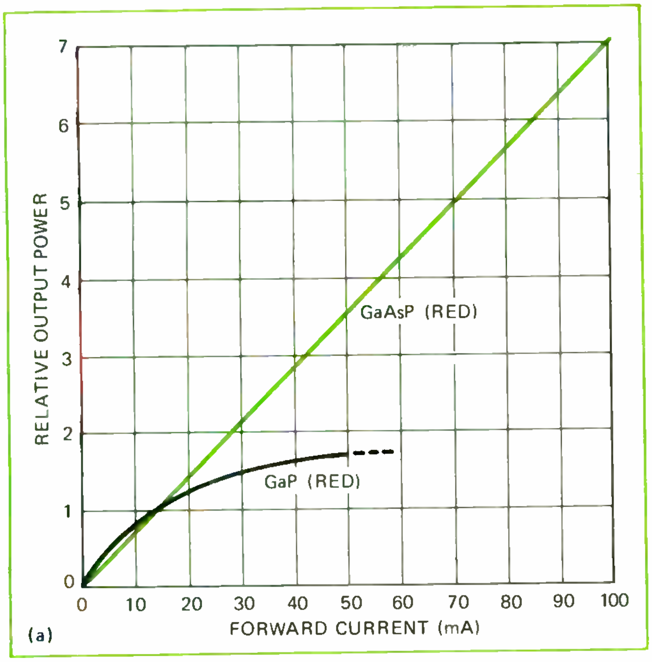
Because the energy is spread out, this technique reduces luminance. The display cannot be used in an aircraft cockpit or other location with bright ambient lighting. The approach for GaAsP diode chips also was to place the units in light pipes. Now the line is formed and brightness multiplied by diffusing several diodes in a row in a large, bar-shaped segment. Some GaAsP devices are as big as display tubes.

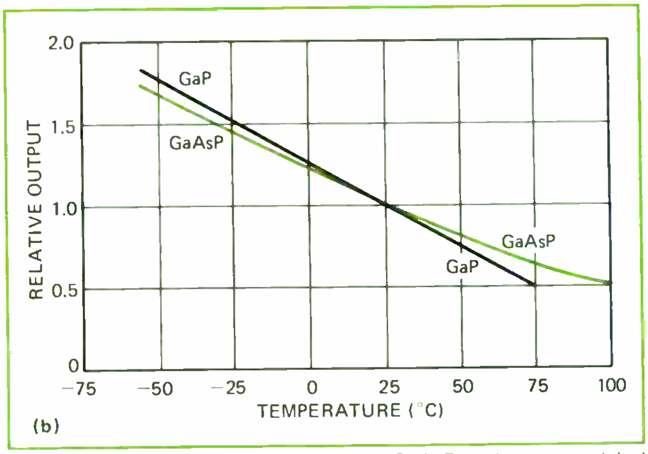
As for costs, multidiode GaP segments are expensive.



4. Getting out. Light generated at the pn junction has a tough time getting out directly because of reflections from the crystal surface caused by high refractive index.

GaP costs several times as much as GaAsP. GaP wafers are sliced from ingots pulled by the Czochralski method from a GaP melt encapsulated in boron oxide at a pressure around 700 psig. The wafers are only about ½-in. in diameter and not commercially available—the LED manufacturer has to grow his own. Red GaP diodes are made by growing an epitaxial layer in two steps, introducing the impurities to form a pn junc-





5. Lineup. GaP is more efficient than GaAsP at low current but won't operate as well as GaAsP at high current or high temperature.

tion in the epitaxial layer (see Fig. 1). Then the wafer is cut into diode chips. GaP segments may not be uniformly bright. The grown-junction process results in large variations in diode forward voltages for a given current, compared with diffused diodes.

On the other hand, GaAsP wafers up to 1.5 in.^{2} are commercially available. Wafers of 4 to 5 in.^{2} are being made and may soon be commercially available. Substrate GaAsP is vapor-grown epitaxially on a GaAs substrate. After the diodes are diffused into the epitaxial layer, the wafer is cut into segment bars, dot-matrix arrays, or indicator diodes after the top electrodes are metalized.

A GaAsP diode's light output remains directly proportional to the diode forward current (Fig. 5) as long as the current density is not so high to cause the junction to overheat. Strobed displays are operated with very high peak currents at low duty cycles. The eye integrates these very bright pulses into a continuously bright display. In film recording, pulse times as short as 10 microseconds are used.

GaAsP's efficiency increases with current. Below 1 milliampere, nonradiative recombination phenomena reduce quantum and power efficiencies. Conversely, GaP is most efficient at low currents. High current densities cause nonradiative recombination processes to dominate, making GaP unsuitable for high-speed pulsing. Nor can high currents be used to get high brightness levels. To do so, the chip area must be increased, raising the number of photons generated—and the cost.

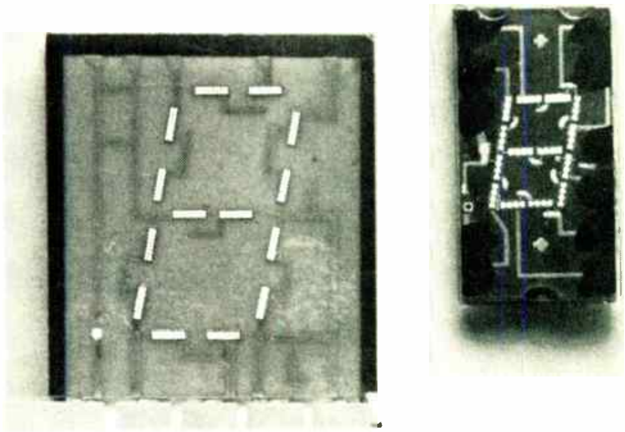
Right now, the application best suited to GaP's properties is indicators using low current. The material is suitable for multicolor displays: green and red are available now and green seven-segment devices are being made, although they are not yet cost-competitive.

GaP can be made to emit green and red in various proportions, giving colors through yellow and orange. If green and red chips are placed close together on a three-pin header, the color can be tuned from green to red by varying the current to the chips. In this case, crosstalk between the two chips helps the optical mixing (as seen by the eye—a spectrometer would see only green and red, not yellow or orange).

GaP prices will certainly drop and allow multichip diode arrays to be made that might compete with similar GaAsP displays. But since GaAsP will also be getting cheaper, the GaP displays are not likely to gain a cost edge. GaAsP will probably remain the more economical technology for numeric and alphanumeric displays, and for bright red and orange lights.

Both materials should exhibit further improvements in light outputs and efficiencies. GaAsP has come up two orders of magnitude in light output in the past five years, without much being done so far to decrease its light absorption. GaP, already transparent, can be expected to show higher quantum efficiency.

If the problems of growing GaP on top of GaAsP can be solved, the combination should give devices with impressive light output. The GaAsP diode on the bottom could be operated at high current for intense brightness and the GaP overlay shaped into dome lenses. The light from the GaAsP would enter the dome with little reflection at the interface. Since most rays would be normal to the curved face of the dome lens, a high percentage would emerge without being reflected back. □



6. Light. Large display is the 0.6-in.-high Litronix Data-Lit 6; the other is typical of the 0.25-in.-high display made last year. Two segments light at a time, making the device a seven-segment numeric display. Multiple dots are used in GaAsP bar-type segments.

Designer's casebook

Positive and negative gates trim logic package count

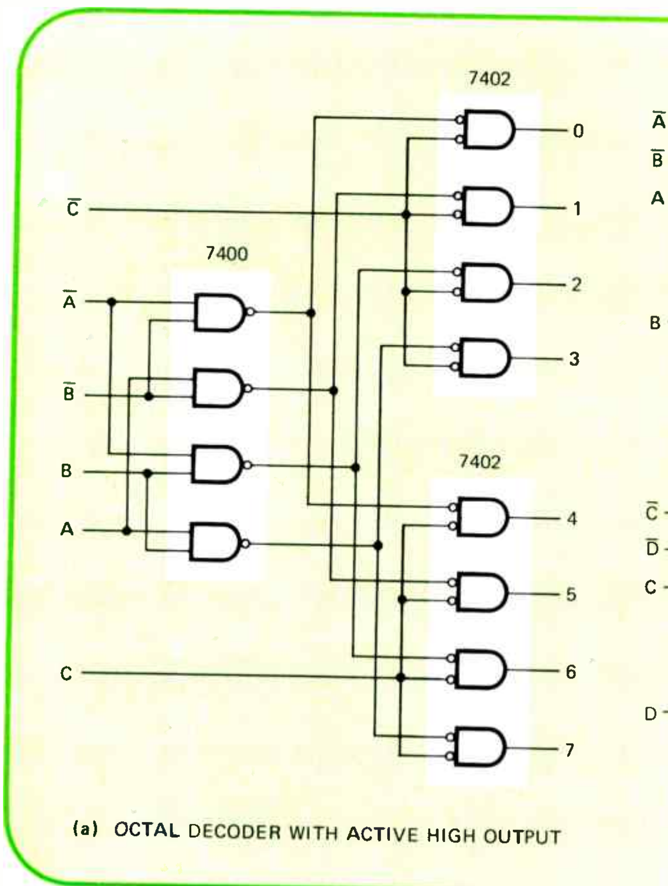
by Louis E. Frenzel Jr.
National Radio Institute, Washington, D.C.

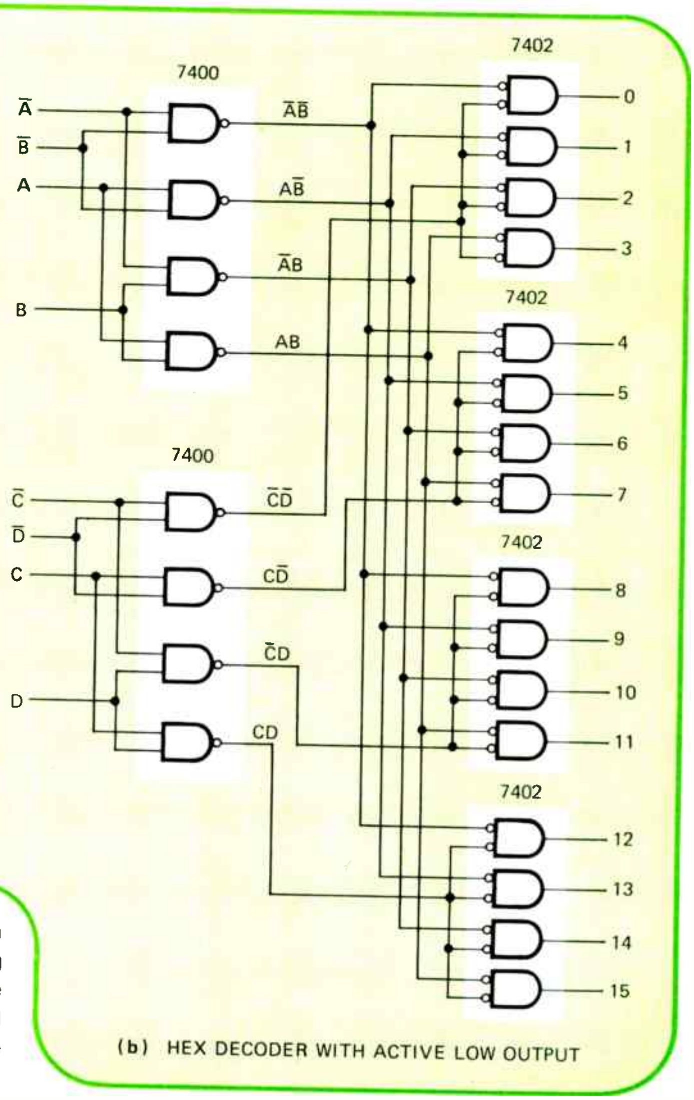
The number of logic packages needed to implement a decoding function can be significantly reduced, and costs can be held down, by mixing and matching individual gates to build your own decoder. The scheme is effected by mixing positive and negative gates from the same logic family. Package count is reduced because the mixed logic uses a tree or cascade decoding arrangement.

Normally, five type-7410 positive NAND gates (each 7410 package contains three triple-input NAND gates) are required to realize a binary-to-octal decoder with an active low output. A decoder with an active low output produces a binary 0 at the selected output, while all other outputs are at binary 1. Additional inverter packages are required to achieve an active high output.

The circuit of (a) uses only three IC packages to realize the same decoding function, but with an active high output. Four dual-input positive NAND gates decode least-significant bits A and B; two quad dual-input negative NANDs provide the final decoding for the C bit.

This positive-negative mixing technique can also be applied to a hex decoder. Ordinarily, eight type-7420 positive NAND gates (each 7420 package consists of two four-input NAND gates) are needed for a one-of-16 hex decoder that has an active low output. However if positive NAND gates are mixed with negative NANDs, only six ICs are needed (b).





Mixed gates. Binary-to-octal (a) and binary-to-hex (b) decoders can be built with only three and six logic packages, respectively. Mixing both positive and negative logic from the same logic family does the trick. The circuit uses positive NAND gates for the input lines and negative NAND gates for the output lines. Either decoder can be built with an active low output or an active high output.

High-impedance driver boosts detector's dynamic range

by Robert J. Matheson
U.S. Department of Commerce, Office of Telecommunications, Boulder, Colo.

Most detectors have a limited dynamic range of around 40 decibels because the diodes they employ do not conduct effectively when diode voltage falls below 0.1 to 0.5 volt. By driving the diodes with a high-impedance current source, the dynamic range for a full-wave detector can be increased to 120 dB.

Although diodes do not detect efficiently below their threshold voltage, they can conduct a very small current. The high-impedance driver, then, performs like an ideal current source, always forcing the proper current through the diodes regardless of diode voltage. Hot-carrier diodes are used in the detector shown since their threshold voltage is lower than that of ordinary diodes (0.1 to 0.2 V, rather than 0.5 V).

Commonly, detector dynamic range is increased by driving the diodes from a high-voltage step-up transformer. However, this technique is limited by diode reverse breakdown voltage and produces only about a 60-dB range. Operational amplifiers are often added to the circuit to broaden detector dynamic range, but they restrict operation to relatively low frequencies.

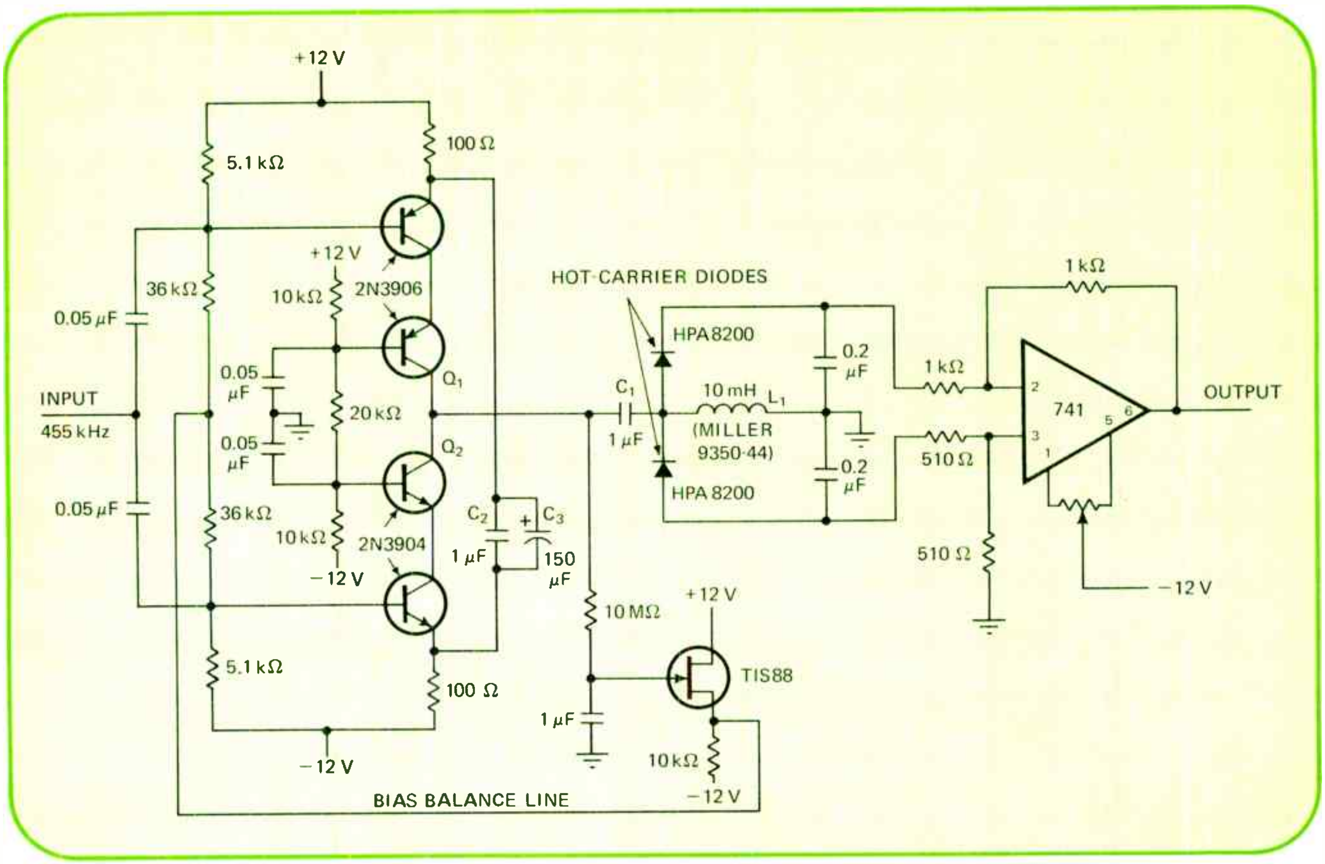
In the wide-range detector, two transistors, biased in a complementary common-base configuration, are the basic driving components. Transistors Q_1 and Q_2 provide an output impedance of about 2 megohms at a capacitance of 10 picofarads. Inductor L_1, which has an equivalent parallel resistance between 500 kilohms and 1 megohm, tunes out this capacitance. (The inductor should be kept out of a direct current path since any dc flow may significantly reduce its parallel resistance.)

Because the driver stage operates at an extremely high impedance level, even a minute direct current imbalance (due to component tolerances) introduces a large voltage change that could force either Q_1 or Q_2 into saturation. An FET source-follower prevents this by balancing the bias currents in each half of the driver. The hot-carrier diodes are isolated from any net dc imbalance at the driving point by capacitor C_1.

Both positive and negative half-cycles of the input signal are detected by the diodes, resulting in full-wave detection. The detected signal has a ripple frequency of 910 kilohertz, which is smoothed by a low-pass filter and a differential amplifier buffer. Capacitors C_2 and C_3 improve detector large-signal performance, particularly for short-duration pulses.

For a 455-kHz input, detector output is linear from 10 millivolts to 10 V. From 10 microvolts to 10 mV, the output deviates slightly from linearity, with a maximum deviation of 0.1 dB for an input change of 1 dB.

Full-wave detector. Complementary four-transistor array forms high-impedance driver that forces desired current through hot-carrier diodes. FET source-follower balances driver bias current to prevent unwanted transistor saturation. Diodes detect positive and negative portions of input signal, which is then filtered and buffered. Detector operates over 120-decibel dynamic range for 455-kilohertz input.



Analog-digital circuit turns scope into curve tracer

by Robert D. Guyton
Mississippi State University, State College, Miss.

Any standard oscilloscope having a vertical differential amplifier input can easily be made to function as a transistor curve tracer. With an inexpensive analog-digital circuit, the common-emitter characteristics of npn transistors can be displayed, and with two slight modifications pnp transistors also can be accommodated.

The circuit generates two waveforms: a staircase step function (V_B) to drive the transistor's base, and a triangular wave (V_C) for the collector. A pair of RTL $\bar{J}$-$\bar{K}$ flip-flops and two operational amplifiers are the major circuit components.

Flip-flops FF_1 and FF_2 form a binary counter output is summed by op amp A_1. The output of A_1, a four-step staircase voltage, supplies the base drive. Additional voltage steps can be added by increasing the number of flip-flops and summing resistors.

The output square wave of FF_1, when integrated by op amp A_2, provides the triangular collector voltage. The amplitude of this voltage is controlled by an input clock frequency; the higher the frequency, the smaller the amplitude. Diode D_1 clamps the waveform to a positive swing so that the test transistor is protected against a wrong voltage polarity.

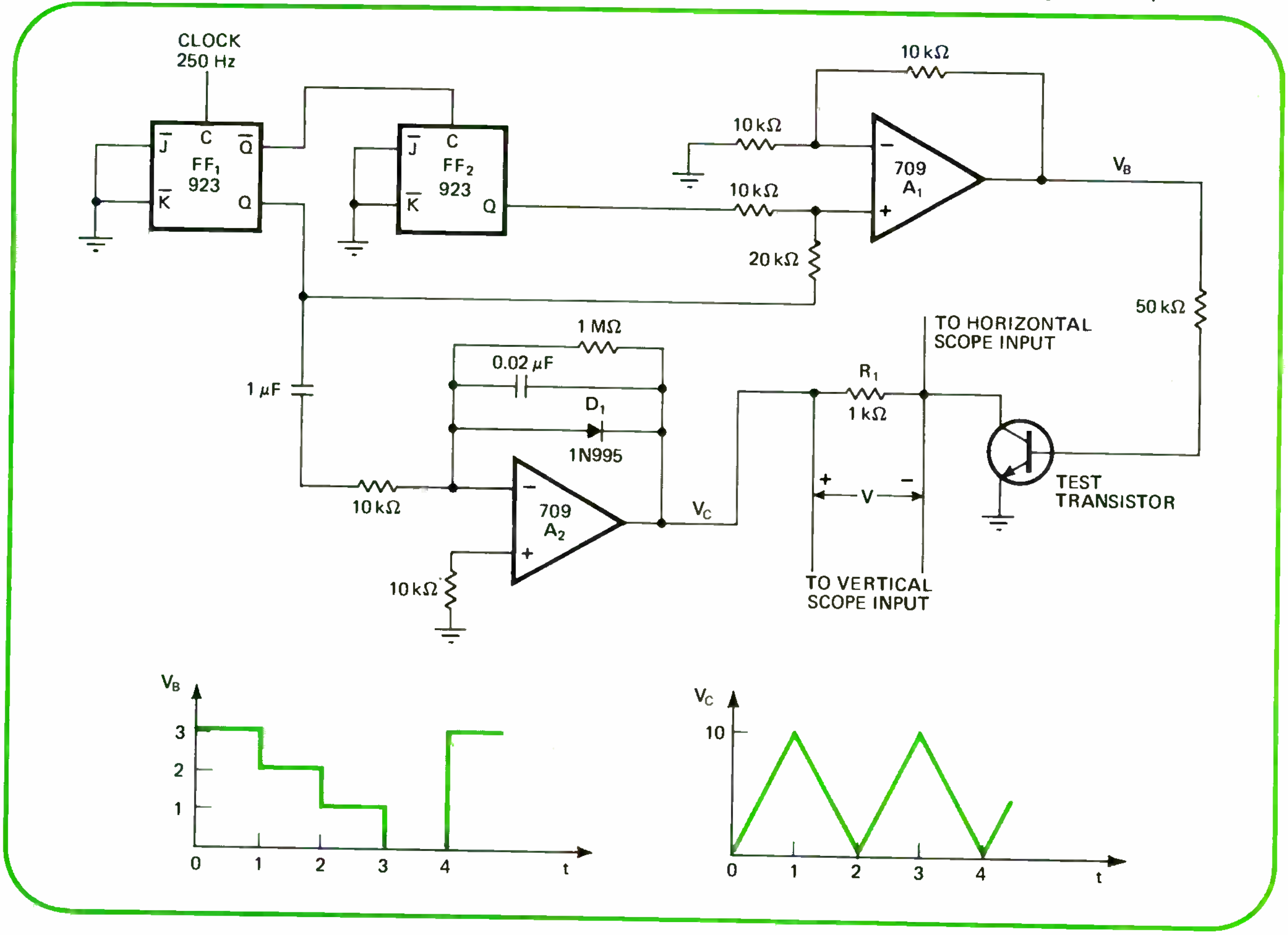
Collector current is determined by measuring the voltage across the collector supply resistor, R_1. For example, if R_1 = 1 kilohm and the scope's vertical attenuator is set to 1 volt per centimeter, the vertical current scale is calibrated at 1 milliampere per centimeter, and the horizontal voltage scale to 1 volt per centimeter.

Circuit current and voltage ranges are limited by amplifiers A_1 and A_2. Tacking a power transistor on the output of each op amp is a simple way to extend the circuit's operating range.

To display the characteristics of a pnp transistor, the output of FF_2 must be summed at the negative input of A_1 to invert the staircase voltage, and diode D_1 must be reversed to clamp the triangular wave to negative voltages. Or, adding a multiposition switch to accomplish these changes would permit checking either transistor type with just the flick of a switch.

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.

Curve tracer. Inexpensive circuit allows common-emitter characteristics of npn transistor to be displayed with ordinary scope. Output of binary counter (FF_1 and FF_2) is summed by A_1 to generate staircase base drive (V_B) for test transistor. Triangular collector drive (V_C) results when square-wave output from FF_1 is integrated by A_2. Transistor voltage-current curve is displayed by using voltage across R_1.



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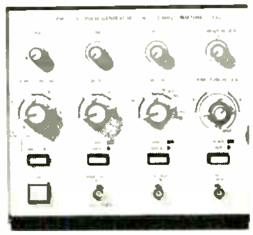

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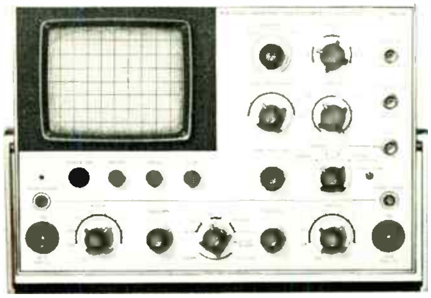

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Making sense out of delay specs in semiconductor memories

There are almost as many ways of defining delays in memories as there are arrays; here is a coherent view that can be used as the basis for a system timing diagram

by John Springer *Fairchild Semiconductor, Mountain View, Calif.* *

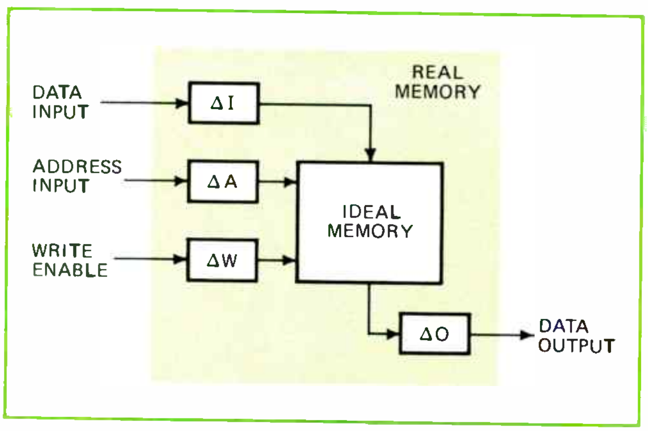
☐ The manufacturers of semiconductor memories are highly inconsistent in the way they specify the switching speeds of their products. Sometimes the delays are defined in terms of how the device works, and at other times in terms of how it reacts to external signals.

This wouldn't matter so much if memory system design were still in the hands of specialists. But now that semiconductor memories are becoming an integral part of the processor instead of a quasi-peripheral subsystem, logic designers are taking over, and they often find the lack of standards for memory timing notation quite confusing.

To clear up the confusion, this article develops a coherent explanation of a memory's switching characteristics, relates this to the most commonly specified quantities on data sheets, and shows how to use this data to construct a timing diagram for a system.

The simplest way of analyzing a semiconductor memory in terms of its delays starts from the assumption that it's an ideal device with three kinds of input and one kind of output (Fig. 1). The device may be a single storage cell, or an array of such cells. Being ideal, it has no intrinsic delays, but its external connections all have individual delays—ΔI on the data input, ΔW on the write-enable signal, ΔA on the address input, and ΔO on the data output. And if the device is a large array, the external lines may be multiple, carrying whole bytes or words instead of single bits, for example.

* Now with Advanced Micro Devices, Inc., Sunnyvale, Calif.



1. Ideal. A simple approximation of the delays in a memory system lumps them all into the inputs and outputs, and substitutes an ideal device with no intrinsic delays for the physically real device.

Each input and output in the diagram is binary—that is, it has only two stable conditions, a more negative level and a more positive one. For a given device, each delay shown has two values, one for the propagation of a negative-to-positive transition through the delay element, and one for the propagation of a positive-to-negative transition. Moreover, it's combinations of these input and output delays that create the real device delay times. Access time, for instance, is the sum of the delays on the address input, ΔA, and on the data output, ΔO (since the delay through an ideal device is zero). Since ΔA and ΔO each have maximum and minimum values, their sum also has a maximum and a minimum value. Likewise, data may appear on the input lines, and at some later time a write-enable signal appears, making the device's data setup time $\Delta I - \Delta W$.

Limited differences

In general, a memory system contains many devices for which the delays are different yet whose maximum and minimum limits must each be known. Moreover, when a system is intended for high-volume production, the range for the devices to be used in all systems must be known, to avoid the need to tune each system individually. A given pair of paths may turn out to have the maximum delay, and, for the system to operate reliably, this defines the system's minimum timing. Yet the designer must also remain aware of the fact that access time, say, may be shorter than the maximum, and that the output of the memory device is unknown between $(\Delta A + \Delta O)_{min}$ and $(\Delta A + \Delta O)_{max}$.

At this point, interrelations between the individual delays in the simple model must be taken into account. In the absolute sense, this would involve specifying the delay in every pair of paths—a rather large number of parameters. More practically, the output delay is usually important only during a read operation, so only a few measurements need be specified on it. But the input timing is completely under control of the system, and must be specified for every input path with respect to every other input path. Once he knows how these inputs behave in relation to one another, the designer can guarantee a reliable system.

All these delays are internal device parameters, not system parameters. But because of the widespread failure to distinguish between the two kinds of measurements, some manufacturers list a guaranteed minimum access time and others a guaranteed maximum—the maximum for the device is the minimum for the system. For clarity, this article designates all device delays with a small t and all system delays with a capital T.

There are eight important memory device delays, all composed of some combination of the four delays in the simple model: access time, read recovery time, write time, data setup time, data release time, address timing, write recovery time, and chip-select delay.

Access time may be specified as t_{pd+} and t_{pd-}, or simply as t_{access}. It is the length of time from the appearance of a valid address on the address input to the appearance of valid data on the data output—and also, if specified, the time from the disappearance of the address to the disappearance of the active level. Where both are specified, system access time can sometimes be improved by taking advantages of the difference between them at the gate driven by the data output line. Where only one is specified, it may be the larger of the two, but more often it is just t_{pd-}, the active output state being the more negative one. Since the output stage of a memory usually has open-collector circuits, access involves pulling the output line from its normal positive level to the negative level if the stored data demands it.

Both maximum and minimum access times are important. The maximum access time specifies how long the system must wait for valid data after it supplies an address, and the minimum time specifies how long the data remains good after the address has been removed.

The read recovery time, t_{rr} is the time required for the output of the memory to return to its normal (usually the positive) level, after the address has been removed. This delay, which is mostly caused by the sense amplifiers inside the device, must be taken into account when two successive read operations from different addresses within a single device cause the output data line to be first low, then high: the high level cannot be attained until after t_{rr} has elapsed. Read recovery time is basically the t_{pd+} for an open collector output. It is usually of no consequence, because it will be covered up by the access time of a second read cycle.

In the kind of system where data is taken from a series of sequential locations at a high rate, however, t_{rr} is important. It's also important when the data input and output lines share a common pin in the memory package—as they do, for example, in Fairchild's 93400 memory. After a read operation that produces a low level, the common pin will remain low for the read recovery time, and this may interfere with a subsequent write operation—external logic cannot bring the common input-output line high while the internal open collector is holding it low.

The write time t_w is the length of time that an active level must be present on the write-enable line to guarantee successful writing in the memory. (A better name for it would be "write pulse width," but this would confuse it with a similar system parameter.) The system must provide the write-enable signal for the full length of $t_{w_{max}}$ to guarantee writing in the slowest memory devices; and if the write enable signal is generated by a decoder circuit, any glitches on the decoder output must be less than $t_{w_{min}}$ to guarantee not writing in even the fastest devices.

Because the write-enable signal begins and ends the writing operation, it is a convenient reference for the other input delays, serving in fact as a sort of clock or basic timing pulse.

The data setup time and the data release time for both high and low output levels make up four parameters associated with a memory's data input and symbolized as t_{dsh}, t_{dsl}, t_{drh}, and t_{drl}.

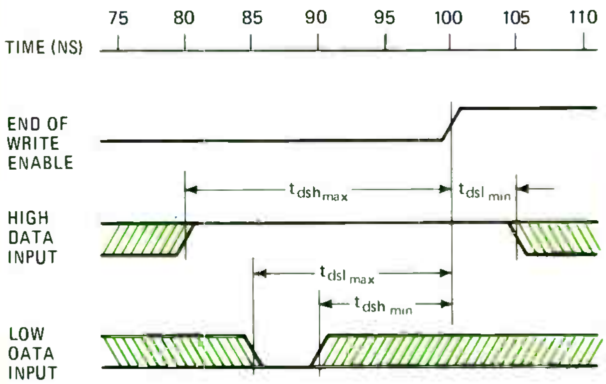
Consider the two external delays, ΔI and ΔW, shown in Fig. 1. Since the write time is the critical parameter, let the time scale begin at the point where the write-enable line becomes active—in most cases, where it undergoes a high-to-low transition. The level on the data line is not important at this time, because most memories accept input data up to the low-to-high transition of the write-enable line, just like an edge-triggered flip-flop. But when this low-to-high transition occurs, the data input to the ideal cell must represent the data to be stored. Thus the correct levels must be present at the input of the memory ΔI earlier. This deadline is ΔI – ΔW before the end of the write-enable signal at the real memory input.

Only the low-to-high transition of the write signal is important, but both transitions of the data are significant. These are the setup times for high and low data, or

$t_{dsh} = \Delta I_+ - \Delta W_+$, and

$t_{dsl} = \Delta I_- - \Delta W_+$

Suppose that these are 20 ns and 10 ns respectively. If



	Parameter	Definition	min	typ	max	units
A	t_{dsh} t_{dsl}	High data setup time Low data setup time	10 −5		20 15	ns ns
B	t_s	Data setup time	−5		20	ns
C	t_s t_r	Data setup time Data release time			20 −5	ns ns
D	t_s t_h	Data setup time Data hold time			20 5	ns ns
E	T_s T_h	Data setup time Data hold time	20 5			ns ns

2. Difficulties. Delays illustrated in simple timing chart are often incorrectly and confusingly specified in many different ways, as the table shows. Meaning of shading is explained in Fig. 4.

data represented by a high level is to be stored, then it must be on the data input lines at least 20 ns before the write-enable signal rises—at the real memory, not at the ideal device. This high data must also remain on the data lines long enough to get stored in the memory. Now a low level takes 10 ns to get through the delay, and, if it appears less than 10 ns before the rise of the write-enable signal, won't get to the ideal device before the preceding high level has been stored and the write-enable signal is gone.

Therefore, the high level must be applied at least 20 ns, and be removed at most 10 ns, before the rise of the write-enable signal. The 10-ns figure is commonly called the data release time for the high level, or t_{drh}, but it is obviously also the data setup time for the low level, or t_{dsl}. Hence $t_{drh} = t_{dsl}$, not only in magnitude, but in every other respect, too.

Range versus timing

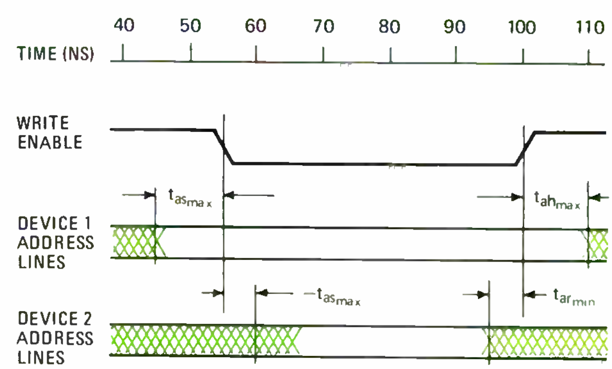
In a system containing more than one device, however, the ranges of setup and release time affect the timing of data availability on the inputs. For example, to store data represented by a high level, the level must be applied not later than the longest t_{dsh} before the rise of write-enable, and maintained at that level until after the beginning of the shortest t_{drh}, or equivalently the shortest t_{dsl}. Conversely, to store the low level, it must be present before the maximum t_{dsl} and remain until after the minimum t_{dsh}.

It is worth noting that if the delay through the data path is very short, then $\Delta I - \Delta W$ may be negative, and appear as a negative value for one or both of the minimum data setup times. It means that under certain circumstances data that changes after the removal of the external write-enable signal will be stored at its new value because in fact the write-enable signal was still moving slowly through the delay when the new data arrived. Data sheets specify this as either a negative release time or a positive hold time.

By now, it should be clear that the four setup and release times are really only two different quantities, which can have maximum, minimum, and sometimes negative values. Yet many device people insist on specifying all these quantities separately. Confusion abounds, particularly when the distinction between maximums and minimums, or between positive and negative numbers, isn't clearly specified.

Some of the difficulties that can result are illustrated in Fig. 2 and the associated table, which shows five different ways timing specifications can be—and often are—published. The figure is a timing chart for the memory device with a write-enable pulse that ends (goes high) 100 ns after the reference time. The chart also shows the required inputs for high and low data: data can change in the shaded areas, but must be stable in the unshaded areas to guarantee writing as specified.

The first specification (A) follows the method recommended in this article. To write high data, the low-to-high transition must occur no later than 80 ns after the reference time, which is the maximum t_{dsh} before write-enable rises, and the level must stay high until 105 ns after reference, a time later than the rise of write-enable because the minimum t_{dsl} is negative. A later rise or



	Parameter	Definition	min	typ	max	units
DEVICE 1	t_{as}	Address setup time			10	ns
	t_{ah}	Address hold time			7	ns
DEVICE 2	t_{as}	Address setup time			−10	ns
	t_{ar}	Address release time	5			ns

3. Setup and release. Although basically similar parameters, these delays are measured relative to two different reference points—the leading and trailing edges of the write-enable pulse.

earlier fall makes the correct storage doubtful. But to write low data, the high-to-low transition can occur as late as 85 ns after reference, allowing the maximum t_{dsl}, and can be reversed as early as just after 90 ns, for the minimum t_{dsh}.

Specification B ignores the difference between setup times for high and low signal levels. Specification C chooses to list high data release time instead of low data setup time; besides the confusion in terminology, the time is listed in the wrong column—a common error. Specification D uses still another term, data hold time, which simultaneously changes the sign of the quantity and changes the minimum to a maximum, so that now the column is correct. Specification E is written from the system instead of the device point of view—the most common source of confusion.

Address timing

To revert to the next of the eight device delays being considered, address timing, like data timing, involves four different quantities: setup time, t_{as}; release time, t_{ar}; hold time, t_{ah}; and another quantity that is often called simply address time, or t_a. But unlike data timing, both edges of the write-enable signal are important relative to the address signal. In most devices an address is always present on the address inputs, and this must remain unchanged during the write process.

There is likely to be less difference between the times at which nominally simultaneous high and low address bits arrive at the ideal memory than there is with data bits, because address bits usually pass through less combinational logic en route from their source. This means the worst-case fast and slow bits are usually fairly close together, and differences between high and low address bits need not be specified. However, two parameters must be carefully considered; these are the maximum setup time relative to the leading edge of the write-en-

Timing diagram symbol	Meaning	
	Forcing functions	Other functions
	Must be steady HIGH or LOW	Will be steady HIGH or LOW
	HIGH to LOW changes permitted	Will be changing from HIGH to LOW sometime during designated interval
	LOW to HIGH changes permitted	Will be changing from LOW to HIGH sometime during designated interval
	Don't care	State unknown; changing

4. Uncertainties. Sometimes the exact time of a transition may vary or can be unimportant. On a timing chart different hatchings are used to represent each kind of uncertainty.

able signal, and the minimum setup time relative to the signal's trailing edge.

The first parameter is the longer of $\Delta A_+ - \Delta W_-$ and $\Delta A_- - \Delta W_-$. It specifies how much time the device with the slowest address path requires to get the address into the ideal memory ahead of the write-enable pulse. Its symbol is $t_{as\,max}$.

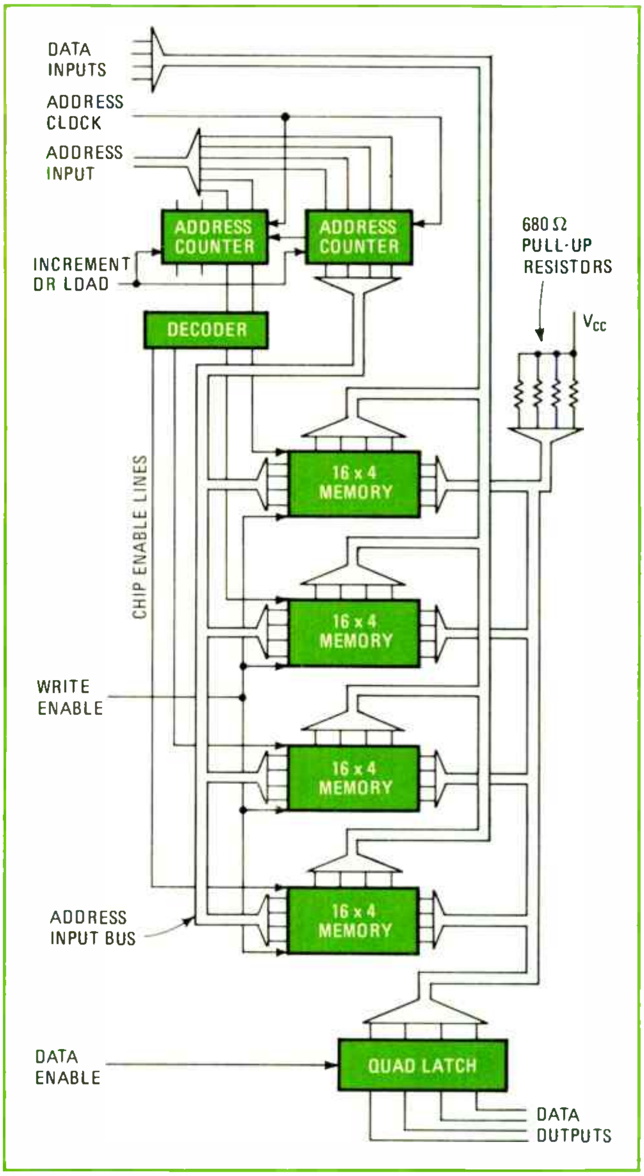
The second parameter is the shorter of $\Delta A_+ - \Delta W_+$ and $\Delta A_- - \Delta W_+$. It specifies how long the fastest device takes to get an address into the ideal cell. No change in an address can be permitted until less than this time remains before the end of the write-enable signal. Although it is actually the minimum address setup time, it is measured relative to the rising edge of write-enable, whereas the maximum setup time is measured relative to the falling edge and deserves a different name. Since the minimum setup time is likely to be either zero or negative, it is commonly designated address hold time, or t_{ah}; where it is positive, address release time, or t_{ar} is used.

Figure 3 demonstrates this graphically for two hypothetical memories. Device 1 is typical of most semiconductor memories, but occasionally one is encountered with the characteristics of device 2. In both, a substantial difference between ΔW_+ and ΔW_- is assumed, emphasizing that the address setup and release times are not two limits of the same parameter. As the diagram and the accompanying table indicate, a release time is a minimum, but a hold time, because it has the opposite sign, is a maximum.

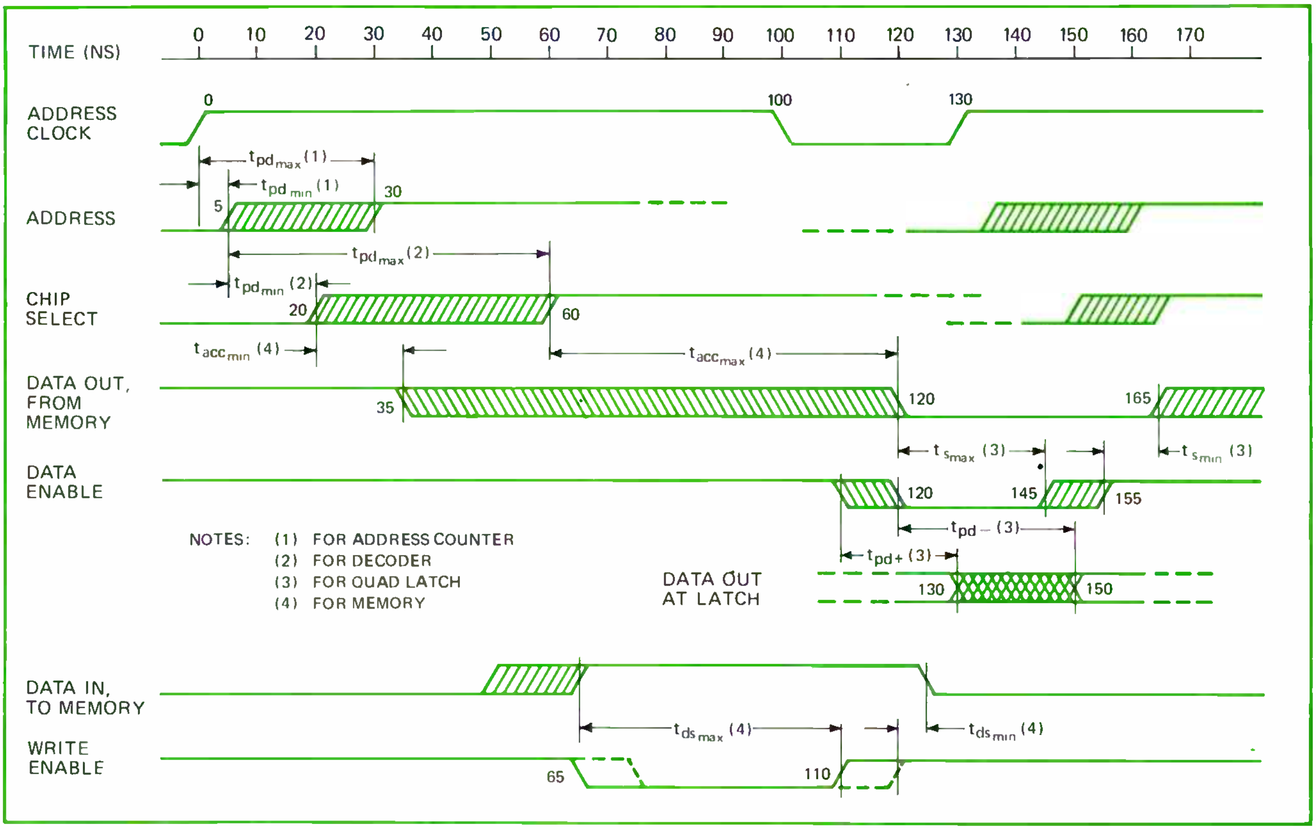
Although addresses for most memories are in conventional binary form, occasionally one has some other scheme. Then the minimum address pulse width becomes important, because sometimes a nonexistent address may be presented between valid address pulses to the array. Since writing can be guaranteed only if a valid address is present long enough for the slowest memory to respond, the address time, t_a, is analogous to, and lasts about as long as, the write pulse width, t_w.

But the really important criterion for writing is that, at the ideal memory, both the address and the write pulse coincide for long enough to allow the slowest device to respond—during a maximum time, again, from the device point of view, and a minimum time from the system point of view. Either of the two pulses can start the operation when the other is present, and the trailing edge of either can end it. Generalizations are difficult but in most systems, the address brackets the write pulse, so that the write operation depends on the duration of the latter.

The second-last of the memory delays under discussion is the write recovery time, t_{wr}, which restricts the use of the data output lines following a write operation. It is quite like the read recovery time—the sense amplifiers respond to the data being written just as they do during a read operation, and when the written data



5. Scratchpad. Typical simple design shows how all the different delays can be balanced against one another. Two timing charts, for two approaches to memory operation, appear in Figs. 6 and 7.



6. Simple and fast. This first pass at determining the timing of a simple scratchpad memory yields fast operation, but the different cycle times for read and write could cause difficulties for the processor system using the scratchpad.

drives the output to its more negative level, the amplifiers require a short time to go positive.

An example of this behavior is found in Fairchild's MμL 93403, 4-bit-by-16-word memory, whose output follows the input during a write operation, but is inverted during a read operation. Thus, writing low-level data into the memory causes the output to be low while the write-enable pulse is present; but, when the write-enable ends and the address remains unchanged, the newly written data appears as a high level at the output. Because the sense amplifier inverts the data, each stored low level appears as a high level—but not until after the write recovery time has passed.

Finally, most memories have chip-select inputs that let address and data lines be shared by several chips. One chip can be enabled for a read or write operation.

In some memories the chip-select is simply part of the address. It is decoded in the same way and is subject to the same delays. But in newer designs, where the chip-select is independent of, and is considerably faster than, the address, it has its own delay time specified: the delay from the leading edge of the chip-select signal to the time the output becomes active is the enable time, t_e, while that from trailing edge to inactive output is disable time, t_d. For a write operation, the enable time has minimum and maximum values relative to the trailing edge of the write pulse, just as the data input does, although in general the chip-enable signal should be active at least as long as the write-enable signal.

So far, the discussion of memory delays has assumed that the signals are self-timed by their own rise and fall. But some memories, notably large MOS arrays, require two or more clock pulses, and are subject to fairly rigid timing. Their timings are analogous to those already discussed but referenced to the clock pulses rather than to each other. Otherwise, their timing can be designed in the same way as the self-timed memories.

In designing the timing of a memory system within the framework of these eight device delays, it's best to start by showing all the signals relative to a single time axis in a timing diagram. Only one pulse train can be precisely known at all times, and that pulse train must be taken as the reference. All other signals will show some uncertainty relative to this reference. Fig. 4 shows the best way to draw such timing-diagram signals.

As a specific example, take the job of designing a scratchpad memory containing 64 words of four bits each and using four MμL 93403 memories. These memories have open-collector outputs, so respective data lines can be connected in a wired-OR configuration sharing common external pull-up resistors. The 64 words require a six-bit address, four of which go directly to the address inputs on the four memories, with corresponding inputs common to all four chips. The other two bits are decoded into one of four chip-select signals.

The address itself can be held in two parallel loadable counters, which can either increment the address of the previous cycle by 1, or accept a new address from an external source, depending on the state of a controlling input line, at the time of an external clock pulse.

The data output lines drive the parallel inputs on a quad latch, which accepts the data when its data-enable input is low. Its outputs present the data taken from the memory to the system's processing logic.

The complete design is shown in Fig. 5. Examples of the integrated circuits used, all from the Fairchild line, are two 9316 address counters, a 9321 decoder, and a 9314 quad latch, plus of course the four 93403 memory arrays.

The system must supply a clock pulse to the address register, an enable pulse to the quad latch, and a write-enable pulse. These must be properly timed to do their jobs and to permit the necessary propagation delays to take place. The parameters that affect the timing of these pulses are listed in the table, in the format A discussed earlier in this article (see Fig. 2).

Start with the clock

Since the address register clock is the event that starts any memory cycle in this design, it is a convenient reference timing signal. Assuming that it makes its low-to-high transition at reference time T = O, the address register outputs may begin to change after the minimum propagation delay of 5 ns, but will be settled only after the maximum time, 30 ns, as shown in Fig. 6. The design uses two four-bit counters as the address register, one providing the address bits directly to the four memory chips, and the other driving a decoder to produce one of four chip-select signals. This decoder output, a negative-going signal, may appear as early as 15 ns after the register output begins to appear, or as long as 30 ns after it is settled—that is, anywhere between T = 20 and T = 60.

The memory's data may begin to appear on the output lines as early as the minimum access time after the earliest possible address appearance. But reliable data isn't available until the maximum delay following the latest chip-select signal—that is, at T = 120. Until then, the memory output remains uncertain for all of 90 ns. But once the data output is established, the quad latch enable signal may become active. Waiting out this 120-ns interval also lets the data from the previous cycle stay in the latch for the longest possible time—a possible benefit for the external system.

The latch enable signal must be kept active (low) for at least $t_{e\,max}$, or 25 ns; it must have begun by T-120 at the latest, just as the data becomes reliable; and allowing for 10 ns uncertainty at its trailing edge, it must have ended by T = 155. But because the latch's minimum setup time is 7 ns, the data from the memory must remain good until nearly T = 165.

At the end of the 165 ns interval, new data can appear—and that fact determines the minimum duration of a read cycle. Data first began appearing at the output of the chip 35 ns after the rise of the address register clock. A new clock pulse can also therefore be applied to the address register 35 ns before new data can be permitted to appear at the memory output, or at T = 130. Thus the minimum read cycle time is 130 ns.

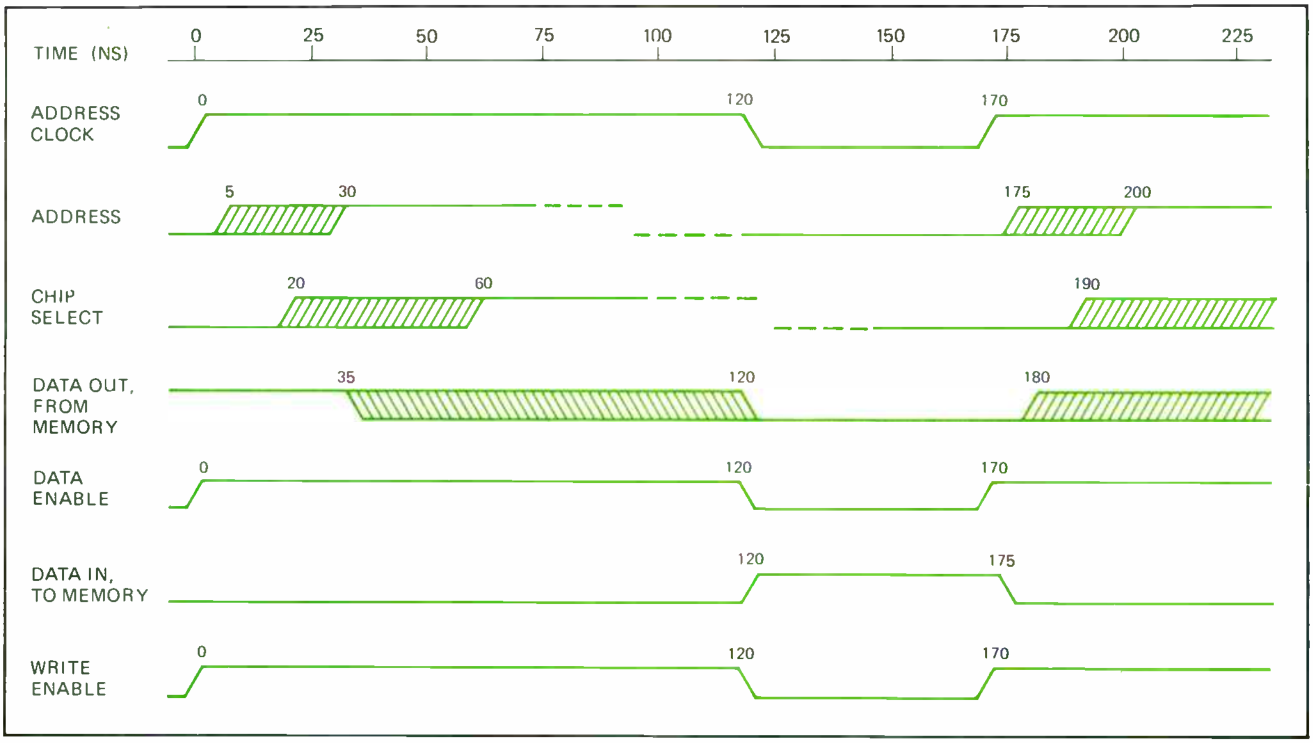
Of course, the memory must be capable of writing in new data as well as reading out previously stored data. Starting from the fact, established during the read-cycle computations, that the address becomes valid at T = 60, at the latest, and knowing from the specifications that the address and chip-select set-up time is a maximum of 5 ns, the write-enable pulse can be timed to begin at T = 65.

The specifications give a minimum width of the write-enable signal of 45 ns. This width can be assumed to be constant, but starting time may shift; if the uncertainty is 10 ns, the latest time that the write-enable signal can end is T = 120.

But the earliest that it can end is T = 110, and the maximum data setup time is 45 ns, so the input data must be available, at the latest, by T = 65. Furthermore, the minimum data setup time is -5 ns, so the data must remain available 5 ns past the end of the write-enable pulse, or until T = 125. Because the address re-

DELAYS IN SCRATCHPAD MEMORY DESIGN

Function	Parameter	Definition	min	typ	max	units
Binary counter	t_{pd}	Delay from − -to- + transition to appearance of output data	5		30	ns
Decoder	t_{pd+}	Delay low-to-high transition	15		35	ns
	t_{pd-}	Delay high-to-low transition	13		30	ns
Random-access memory	t_{acc}	Delay address in to data out	30		60	ns
	t_{as}	Address setup time			5	ns
	t_{ah}	Address hold time			0	ns
	t_w	Write pulse width			45	ns
	t_{ds}	Data setup time	−5		45	ns
	t_{wr}	Write recovery time			65	ns
	t_{rr}	Read recovery time			60	ns
Quad latch	t_s	Data setup time	−7		25	ns
	t_{pd+}	High data in to output			18	ns
	t_{pd-}	Low data in to output			32	ns
	t_e	Data enable pulse width			25	ns
	t_{pd}	Delay, enable in to data out			28	ns



7. Stretched and combined. The altered timing pattern for a scratchpad memory isn't as fast as the first design, but the read and write cycles are equal in length, and three major external pulses can have a common source, simplifying the job of generating them.

lease time is zero, the address supplied to the memory could change at T = 125, implying that a new address register clock pulse can be applied at T = 120. Thus the minimum write cycle is 120 ns, when two write cycles are to occur in succession. But because of write recovery time, the earliest the output can be used after the write operation is 120 + 65 = 185 (not shown on the timing diagram in Fig. 6).

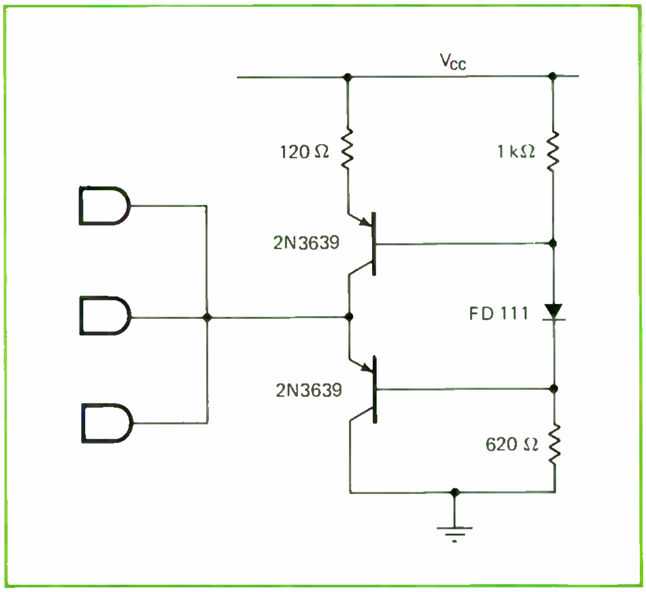
Variations

In an actual design, the timing could be implemented in several different ways. If speed were the prime consideration, the timings shown in Fig. 6 could be followed exactly, although the different read and write cycle lengths would be a bit of a disadvantage. A more common approach is to stretch parts of the cycle beyond their minimum lengths so that read and write timings are identical.

One way to do this is to combine the data-enable pulse, which transfers memory data into the quad latch, with the write-enable pulse. Every cycle would then contain this common timing signal, but its function would depend on whether the cycle were for reading or writing. For instance, in a read cycle the data-enable cannot begin until T = 120, forcing the write-enable signal to be moved back from T = 70 to T = 120, and so extending the write cycle.

Then, although the data-enable signal need last no longer than 25 ns, the write-enable has to be 45-ns long, so that both signals when combined end at T = 170. Because the address may also change at this time, the new address register clock can come at T = 160—resulting in a longer cycle for both read and write than when minimum durations were assumed for all signals.

An interesting result of this combination of functions is that the address clock, data-enable, and write-enable may all make the low-to-high transition simultaneously, at T = 165—the beginning of a new address pulse and the end of the active period for the enable signals. Since there is no specification for the trailing edge of the address pulse, all three pulses can be made identical. Skew between the three pulses can then be minimized by generating them from a single inverted pulse gated into three NAND gates in one package. This produces the final timing diagram shown in Fig. 7. □



8. Current source. This circuit can replace a network of common collector resistors where several open-collector memory outputs are connected together. It supplies a constant current as the output level changes, thus driving the output to its new level faster.

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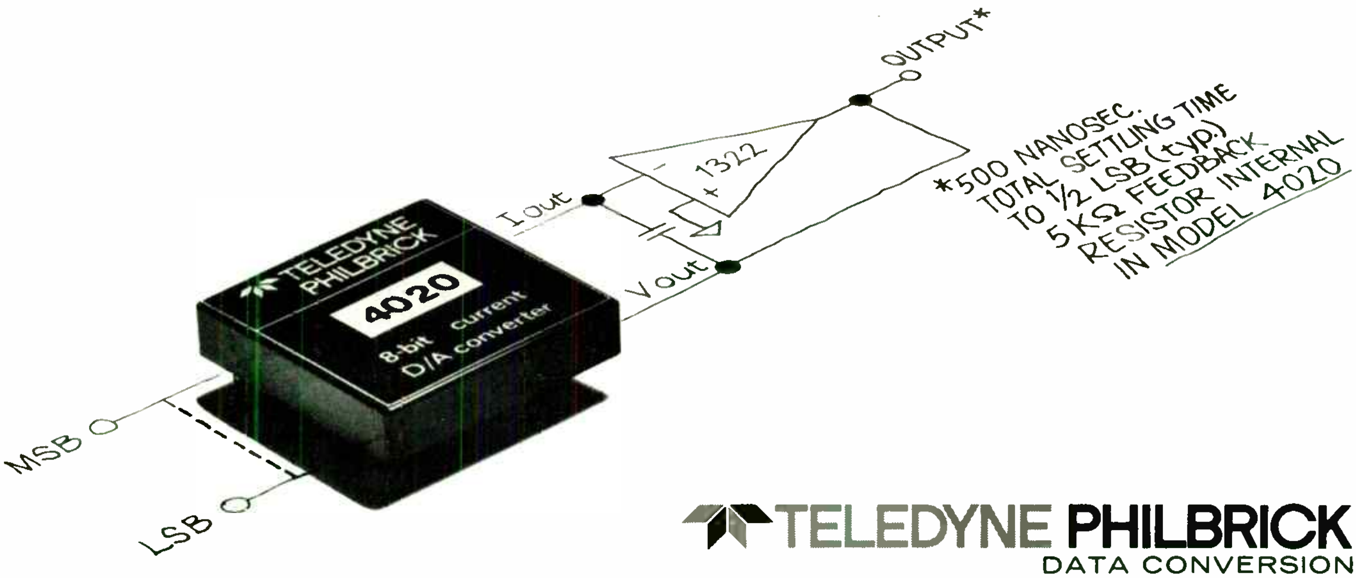

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Take a shortcut to filter design

Approximations with simplified equations take the drudgery out of designing Chebyshev and Butterworth filters, speeding the way to accurate designs of standard functions

by Einar C. Johnson, *Naval Air Development Center, Warminster, Pa.*

☐ Chebyshev and Butterworth filters are valuable design tools in a long and impressive list of applications. Though their value has been proven over and over again, analyzing and assessing the filters in specific jobs is often a painfully tedious design chore. However, a few easy-to-remember shortcuts permit very quick and accurate assessment of filter specifications and measured data. These design aids can be used for both types, and for high-pass, low-pass, bandpass, and band-reject functions.

Of the two filter types, the Butterworth (maximally flat) filter offers the better transient response. But greater selectivity can be realized with a Chebyshev (equal ripple) filter. Ripple inside the Chebyshev passband increases with this filter's selectivity; the greater the ripple, the steeper the attenuation skirts. When ripple is zero, the Chebyshev characteristic is identical to that of the Butterworth.

It's more convenient to examine the Butterworth characteristic first—it's the simpler of the two, and some of the definitions and results developed for the Butterworth filter can be applied to the Chebyshev.

If B_L denotes filter bandwidth at an attenuation of L decibels, B_3 the bandwidth at the filter's 3-dB point, and x is the ratio of these two bandwidths, then:

$$x = B_L/B_3$$

for low-pass and symmetrical bandpass filters, or:

$$x = B_3/B_L$$

for high-pass and symmetrical band-reject filters.

The Butterworth characteristic then can be:

$$L = 10 \log(1 + x^{2n}) \quad (1)$$

where L (the attenuation or loss in decibels) represents the ratio of peak output voltage in the passband to the output voltage at point x; and n is the number of reactances in a low- or high-pass filter, or the number of resonators in a bandpass or band-reject filter. When x^{2n} is much greater than 1, Eq. 1 becomes:

$$L = 20\,n \log(x)$$

or, expressing x in decibels [x in dB = 10 log(x)]:

$$L = 2nx \quad (2)$$

Center frequency (f_o) of bandpass and band-reject filters can be considered as the geometric mean between two frequencies where the attenuation is L dB;

$$f_o = (f_1 f_2)^{1/2}$$

where f_1 is the lower of the two frequencies, and f_2 the higher. Since percentage bandwidths are usually small:

$$2(f_o - f_1) \cong 2(f_2 - f_o) \cong B$$

where B is the filter bandwidth, which can be defined by:

$$B = f_2 - f_1$$

For low-pass and symmetrical bandpass filters, Eq. 1 can be solved for $x = B_L/_3$:

$$B_L/B_3 = (10^{L/10} - 1)^{1/2n}$$

When x^{2n} is much greater than 1:

$$B_L/B_3 = 10^{L/20n} \quad (3)$$

A useful figure of merit for most filters is the ratio of the bandwidths at two widely separated attenuation levels; the 60- and 3-dB points usually are selected. Using Eq. 3 and letting L = 60 yields:

$$B_{60}/B_3 = 10^{3/n} = (1{,}000)^{1/n} \quad (4)$$

This equation is accurate to six significant places when n = 2; it's even more exact when n increases.

From Eq. 3, it can be seen that:

$$B_{2L}/B_3 = 10^{L/10n} = (B_L/B_3)^2, \text{ or}$$

$$B_L/B_3 = (B_{2L}/B_3)^{1/2} \quad (5)$$

Therefore, the bandwidth at the L-dB attenuation level is the geometric mean of the bandwidths at the 2L-dB level and the 3-dB level.

Applying Eq. 5 repeatedly to Eq. 4 gives:

$$B_{30}/B_3 = (B_{60}/B_3)^{1/2} = (1{,}000)^{1/2n} \quad (6)$$

$$B_{15}/B_3 = (B_{30}/B_3)^{1/2} = (1{,}000)^{1/4n} \quad (7)$$

$$B_{7.5}/B_3 = (B_{15}/B_3)^{1/2} = (1{,}000)^{1/8n} \quad (8)$$

Accuracy of Eqs. 6, 7, and 8 decreases as L and n decrease. Equation 8, where L = 7.5 dB, represents the lowest attenuation for which reasonably accurate results can be obtained in this way. (The equation is accurate to about 5% when n = 2). Accuracy again improves with larger n.

Thus, Eqs. 4, 6, 7, and 8 can be used to quickly obtain several points for a Butterworth plot if n is known. Beyond the 60-dB level, the Butterworth characteristic has a slope of 6n dB per octave or 20n dB per decade. For convenience, the table lists the roots of 1,000 for several

INTEGER ROOTS OF 1,000

n	$(1{,}000)^{1/n}$	n	$(1{,}000)^{1/n}$	n	$(1{,}000)^{1/n}$
2	31.6228	7	2.6827	14	1.6379
3	10.0000	8	2.3714	20	1.4125
4	5.6234	9	2.1544	24	1.3335
5	3.9811	10	1.9953	40	1.1885
6	3.1623	12	1.7783	80	1.0902

(For low- and high-pass filters, n represents the number of reactances; for bandpass and band-reject filters, it is the number of resonators.)

integer values of n from 2 to 80.

Another useful simplification for graphical analysis can be obtained by using Eq. 3 to compute B_L/B_3 for 20-dB increments of L:

$B_{20}/B_3 = 10^{1/n}$
$B_{40}/B_3 = 10^{2/n}$
$B_{60}/B_3 = 10^{3/n}$
$B_{80}/B_3 = 10^{4/n}$
$B_{100}/B_3 = 10^{5/n}$

showing that the exponent changes by a factor of 1 for each 20-dB step in L.

In addition, a universal Butterworth curve (Fig. 1), valid for any value of n, can be drawn by plotting L/n vs log(x). Attenuation for a given B_L/B_3 (or B_3/B_L) is found by multiplying the ordinate by the desired value of n. At the passband's edge, the plot becomes dependent on n, as indicated by the shaded area.

To illustrate how to use some of these results, suppose a low-pass filter has six reactance arms (n = 6) and a cutoff frequency (3-dB attenuation) of 20 kilohertz. To find the frequency at which attenuation will reach 60 dB, use Eq. 4:

$B_{60}/B_3 = 1{,}000^{1/6} = 3.16$

Solving for the bandwidth at 60-dB attenuation:

$B_{60} = 3.16\ B_3$

Since $B_{60} = f_{60}$ and $B_3 = f_3$ for a low-pass filter:

$f_{60} = 3.16\ f_3 = 3.16(20) = 63.2$ kHz

Next, suppose a Butterworth bandpass filter is required that will attenuate all signals by 80 dB if they occur 0.6 megahertz or further from its center frequency. The 3-dB bandwidth should be 0.2 MHz. To find how many resonators are required, note that since $B_L = 2(f_o - f_1) = 2(f_2 - f_o)$, then:

$B_{80} = 2(0.6) = 1.2$ MHz

Applying the definition of $x_L = B_L/B_3$ for a symmetrical bandpass filter:

$x_{80} = B_{80}/B_3 = 1.2/0.2 = 6$

Expressing x in decibels:

x_{80} in dB $= 10 \log(x_{80}) = 10 \log(6) = 7.78$ dB

Assuming that x^{2n} is much greater than 1 and solving for n in Eq. 2 yields:

$n = L/2x_{80} = 80/2(7.78) = 5.15$

Since only an integer number of resonators can be specified, choose:

n = 6 resonators

To derive a graphical analysis of a Butterworth characteristic, suppose five points are needed for a Butterworth plot when n = 3. Using Eqs. 4, 6, 7, and 8, and selecting the appropriate roots of 1,000 from the table:

$B_{60}/B_3 = (1{,}000)^{1/3} = 10.0000$
$B_{30}/B_3 = (1{,}000)^{1/6} = 3.1623$
$B_{15}/B_3 = (1{,}000)^{1/12} = 1.7783$
$B_{7.5}/B_3 = (1{,}000)^{1/24} = 1.3335$

The fifth point is supplied by the 3-dB bandwidth:

$B_3/B_3 = 1$

The resulting plot is shown in Fig. 2. A sixth point can be obtained for the graph by noting that the piecewise slope of the Butterworth curve approaches 6n dB per octave at high attenuation levels. The slope, then, can be approximated as 18 dB per octave. Doubling the bandwidth ratio of B_{30}/B_3 gives a point at:

$L = 30 + 18 = 48$ dB

so that:

$B_{48}/B_3\ \Gamma\ x_{48} = 2(x_{30}) = 2(3.1623) = 6.3246$

It's not possible to achieve such simplification for the Chebyshev filter because of its more complex nature. However, a few aids can be developed to ease the analysis problem.

Again, a look at the filter's attenuation characteristic is a good starting point. Using the definitions already assigned to L and B_L, the Chebyshev characteristic can be expressed as:

$$L = 10 \log \{1 + S \cosh^2 [n \cosh^{-1}(B_L/B_V)]\} \qquad (9)$$

where B_V is the bandwidth when attenuation equals the ripple in the passband, and:

$S = (V_P/V_V)^2 - 1$

where V_P is the peak output voltage in the passband and V_V the output voltage when attenuation and ripple are equal. Variable S can also be written in terms of the ripple:

$S = 10^{R/10} - 1$

where R is the peak-to-peak ripple in the passband, expressed in decibels. Maximum ripple is limited to 3 dB in Eq. 9.

Solving for B_L/B_V in Eq. 9 yields:

$$\frac{B_L}{B_V} = \cosh\left[\frac{1}{n}\cosh^{-1}\left(\frac{10^{L/10} - 1}{S}\right)^{1/2}\right] \qquad (10)$$

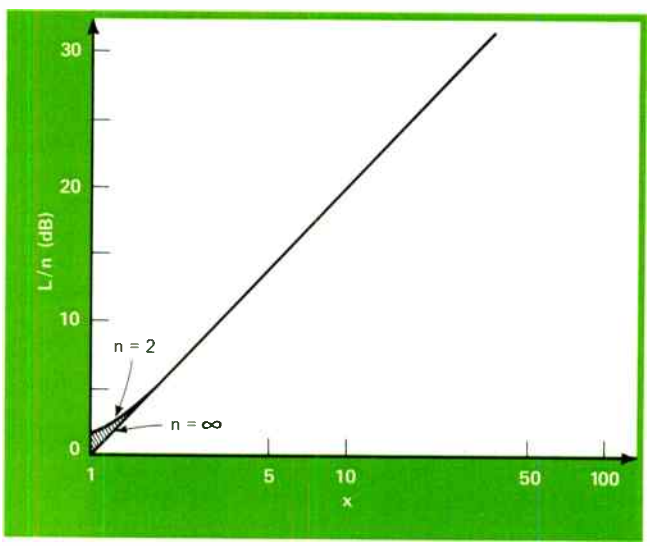
When L = 3 dB;

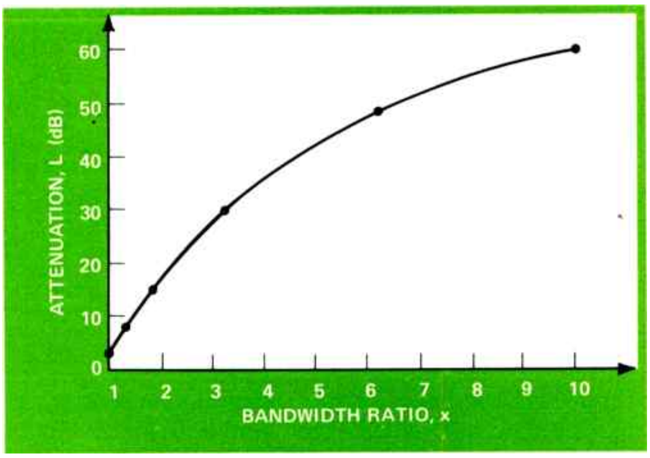
$$\frac{B_3}{B_V} = \cosh\left[\frac{1}{n}\cosh^{-1}\left(\frac{1}{S}\right)^{1/2}\right] \qquad (11)$$

Dividing Eq. 10 by Eq. 11 and solving for L gives:

$$L = 10 \log \left\{1 + S \cosh^2\left[n \cosh^{-1}\left(x \cosh\left[\frac{1}{n}\cosh^{-1}\left(\frac{1}{S}\right)^{1/2}\right]\right)\right]\right\} \qquad (12)$$

1. Universal curve. Attenuation (L) of any Butterworth filter can be found once number (n) of reactances or resonators is known. Curve becomes nonlinear only in region below 5 decibels (shaded area). Variable x is the ratio of filter bandwidth at a given attenuation (B_L) to the bandwidth at the 3-dB point (B_3); $x = B_L/B_3$ for low-pass and bandpass filters; $x = B_3/B_L$ for high-pass and band-reject filters.





2. Butterworth plot. Several points for graph of attenuation (L) versus bandwidth ratio (x) for Butterworth filter (when n = 3) can be obtained with a few simple calculations. At high attenuation levels, slope of any Butterworth characteristic may be approximated as 6n decibels per octave or 20n decibels per decade. Moreover, the 3-dB bandwidth always yields a point at $x = B_3/B_3 = 1$ and L = 3 dB.

With these equations, it's easy to find the difference in attenuation, ΔL, between the Chebyshev and Butterworth responses to be expected for large values of x. By using a difference equation, attenuation limits can be established to represent zero ripple in the design band (for the Butterworth response) and 3 dB of ripple (the maximum allowable Chebyshev ripple for the equations developed).

Subtracting Eq. 1 from Eq. 12 yields:

$$\Delta L = 10\,K \ln S + 20\,K \ln \cosh \left\{ n \cosh^{-1}\left[x \cosh\left(\frac{1}{n}\cosh^{-1}\left(\frac{1}{S}\right)^{1/2}\right)\right]\right\} - 20\,Kn \ln(x) \qquad (13)$$

where K = log(e), approximately 0.4343.

For large values of x, Eq. 13 becomes:

$$\Delta L = 10\,K \ln S + (n-1)\,20\,K \ln 2 + 20\,Kn \ln \cosh\left[\frac{1}{n}\cosh^{-1}\left(\frac{1}{S}\right)^{1/2}\right] \qquad (14)$$

By letting R = 3 dB and S = 1 (for maximum ripple) Eq. 14 can be simplified even further, so that:

$\Delta L = 20\,K(n-1)\ln(2)$

Substituting K = 0.4343 and ln(2) = 0.6931 yields:

$\Delta L = 6(n-1)$

This equation makes possible a convenient graphical technique. Once the Butterworth response outside the passband is known, a line can be drawn parallel to the response, spaced 6(n − 1) dB above it. The two curves form a boundary for all values of ripple between 0 and 3 dB for the Chebyshev response, so that attenuation can be estimated. The curves must bend together near the edge of the passband, and both, of course, will pass through L = 3 dB at x = 1.

Solving Eq. 14 for common ripple values provides a set of attenuation differences that can be used to extend this graphical technique.

When R = 1 dB;

$\Delta L = -5.87 + 6(n-1) + 8.69n \ln[\cosh(1.297/n]$

When R = 0.1 dB;

$\Delta L = -16.33 + 6(n-1) + 8.69n \ln[\cosh(2.567/n)]$

When R = 0.01 dB;

$\Delta L = -26.37 + 6(n-1) + 8.69n \ln[\cosh(3.729/n)]$

As in the Butterworth filter in Fig. 1, a type of universal curve can be plotted for the Chebyshev filter. However, a separate graph is needed for each ripple value. And each graph for a specific ripple must show several curves, since Chebyshev attenuation rate depends on the value of variable n.

A Chebyshev filter with a ripple of 1 dB gives considerably steeper skirts than a Butterworth response. Furthermore, it can serve as a reference from which other Chebyshev responses can be evaluated effectively.

Figure 3 is a computer plot of L/n vs log(x) for both Butterworth and Chebyshev responses, when R = 1 dB and n varies from 2 to 10. (Again, x is B_L/B_3 for low-pass and bandpass filters, $B_3/_L$ for high-pass and band-reject filters. To obtain filter attenuation in decibels, the ordinate is multiplied by the appropriate n.)

The worth of this computer plot can be demonstrated by a short design problem. Suppose a bandpass Chebyshev filter with a 1-dB ripple has a center frequency of 10.7 MHz and a 3-dB bandwidth of 0.5 MHz. It is composed of six resonant circuits (n = 6). To find filter attenuation when a signal occurs ±1.25 MHz from the center frequency, first calculate the bandwidth:

$B_L = 2(f_o - f_1) = 2(f_2 - f_o) = 2(1.25) = 2.5$ MHz

Now the bandwidth ratio can be computed:

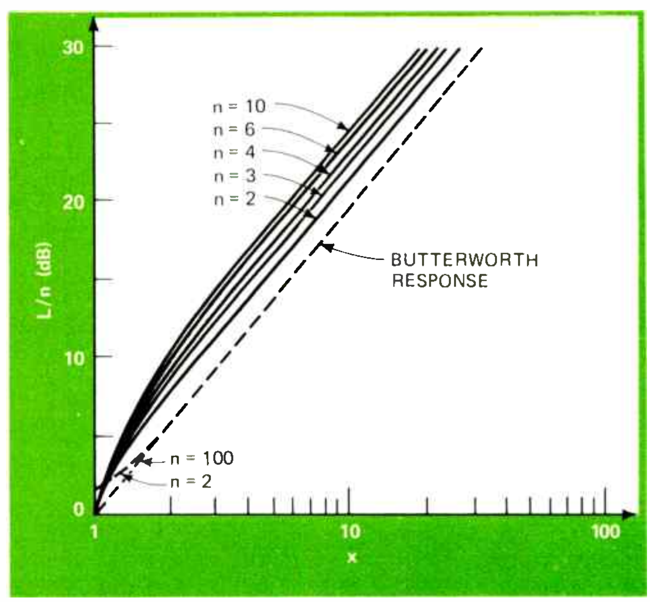
$x = B_L/B_3 = 2.5/0.5 = 5$

From Fig. 3, it can be seen that x = 5 intersects the curve for n = 6 at:

L/n = 18 dB

Solving for attenuation, L, yields:

L = 18 n = 18(6) = 108 dB □



3. Chebyshev curves. Chebyshev attenuation characteristic depends on amount of ripple in passband. A set of curves can be plotted for given ripple content and various values of n. Steeper Chebyshev skirts (solid lines), shown for 1-dB ripple, increase in selectivity as n goes from 2 to 10. When ripple is O dB, attenuation characteristic becomes that of Butterworth filter (dashed lines).

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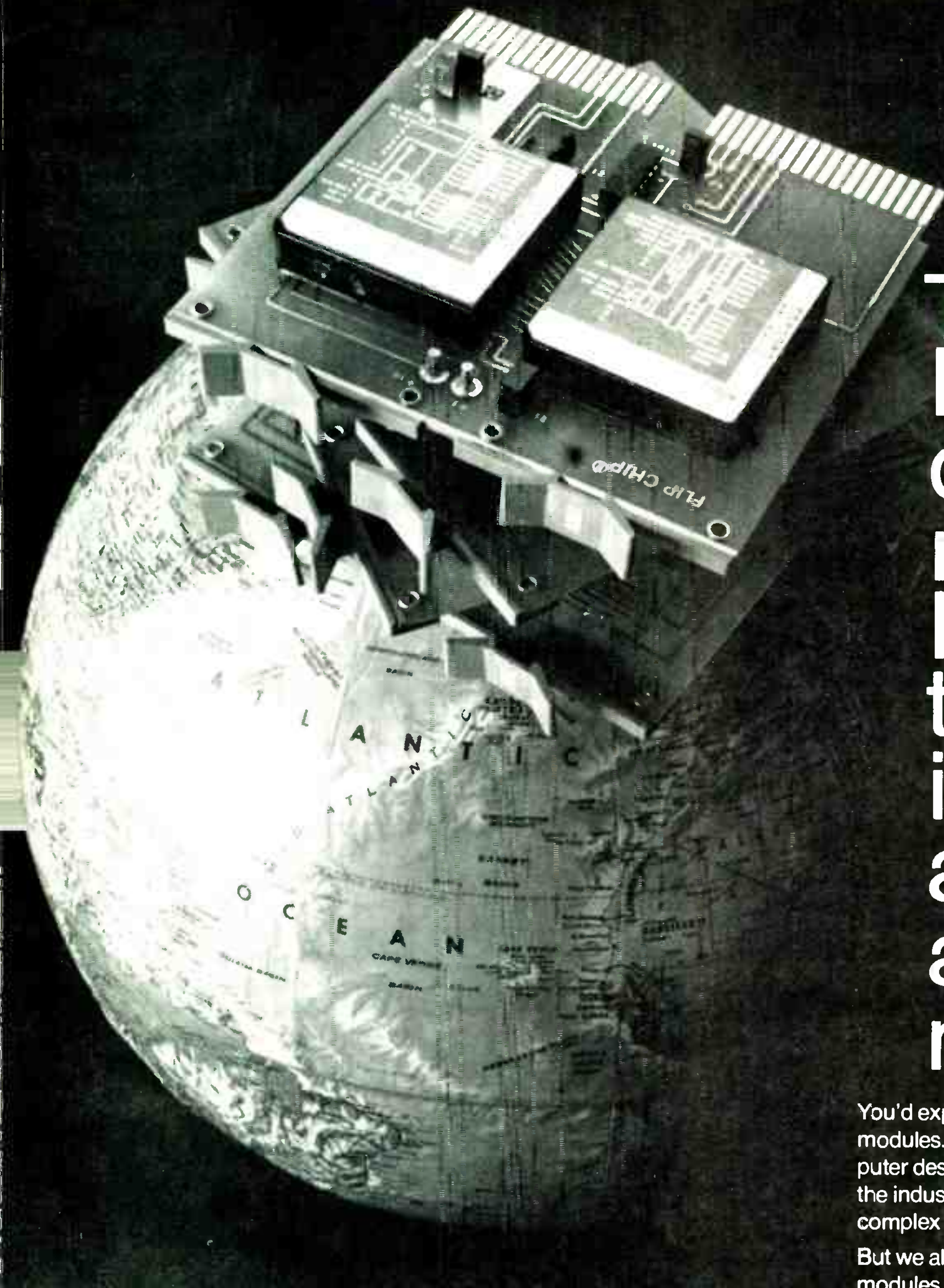

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IC houses gripe about new Mil Spec

100% testing feature of Mil-M-38510 could sextuple prices, say some makers, but Government indicates willingness to play ball

by Stephen Wm. Fields, San Francisco bureau manager

Some of the largest semiconductor houses selling integrated circuits to the Government are saying that the new standardization requirements—supplements, or "slash sheets"—to Mil-M-38510 are creating chaos in the industry. It's largely the result of the specification for 100% (rather than sample) testing of all ICs under extremely rigorous conditions, a procedure that could possibly double or even sextuple IC prices.

After a meeting between the semiconductor suppliers, Government, and contractors at which specs were presented, Joseph L. Flood, director of reliability and quality assurance at Motorola's Semiconductor Product division said, "It looks like they've picked the best aspects of everyone's part."

The basic intent of Mil-M-38510 was to provide the industry with an IC counterpart of the JAN-TX specification for transistors. But according to Gene Hnatek, military integrated circuits manager at National Semiconductor, Santa Clara, Calif., "38510 is another well-laid plan gone astray. It's being implemented this year in a way that will at least double the price of ICs bought for military electronics programs."

But Joseph Brauer, chief of the solid state applications section in the reliability branch, Rome Air Development Center, stresses that the installed price of semiconductor devices is the figure of merit, not the received part price. Brauer, the principal architect of Mil-M-38510, says equipment manufacturers will be willing to spend more for more fully tested parts to avoid the reworking and testing of circuit boards in equipment, which often doubles the cost of the gear.

Brauer adds that there have been procurements in quantity at "very reasonable prices" to specifications tighter than those called out in the slash sheets though these costs were higher than catalog prices.

Flood says that the only customers making any push for parts that meet Mil-M-38510 are those building hardware for the F-15 aircraft, especially Hughes Aircraft Co. Flood says an F-15 parts working group, made up of potential customers, is writing the slash sheets that cover the electrical specs for these parts, "and the specs are very tight." There are 10 slash sheets out so far. One covers a linear op amp—a 741 type—and the rest are for digital bipolar parts, mostly gates, buffers, and flip-flops. The linear specs are exceptionally tight, Flood says, so tight that they might necessitate a redesign of the op amp.

Hnatek says that the 741 specs (dealing with input impedance over a temperature range and offset temperature coefficients) "were arbitrarily tightened up about 10%." He adds that the preliminary draft of the 741 slash sheet "failed to tighten the gain-bandwidth product spec but this loophole was removed at a later negotiation session, otherwise, a processing change that degrades gain-bandwidth product could be used to optimize the other specs."

No waivers

The same prevails for the digital circuits. Jack Carsten, manager of TTL marketing at TI in Houston, says that while TI is behind the program and is actively pursuing business, the parts will be expensive since no waivers are permitted and devices can't be tailored to give a customer what he needs at reason-

Some are stoic

While some IC firms moan about slash sheet supplements to Mil-M-38510, others are stoic. A spokesman for General Instrument Corp.'s Semiconductor Products Group, Hicksville, N. Y. says, "If the buyer says 'Thou shalt,' then we 'shalt' do it or we lose the business." However, GI admits it hasn't seen the new slash sheets yet, although the company has been delivering circuits under Mil-M-38510 since it was issued in November, 1969.

RCA's Solid State Operations Department, Somerville, N.J., doesn't seem perturbed about the new specs, either. The company has had the new slash sheets for about a month and "doesn't see any problems now." However, it's still evaluating the specs, says Bernard Vonderschmitt, vice president of IC operations. He doesn't think any fundamentally new equipment will be needed, although longer test time will be required because there are more parameters to measure.

These specs are supposed to be agreed upon at meetings held by the Defense Electronics Supply Center and Wright Patterson Air Force Base with representatives of the companies and government prime subcontractors present. Each company has one vote at these meetings, but at the meetings held so far, the Government side (including contractors that were said to have been briefed beforehand as to which way to vote) has always outnumbered the supplier's side.

able cost. There will be a large increase in capital equipment, he feels, as well as people to implement the program if or when it becomes mandatory. Carsten says that ultimately, parts will be from six to 10 times more expensive. Another cost-boosting rule in the new spec is that no foreign assembly is permitted. Flood points out that "the IC industry isn't living very well now with overseas assembly, and the prohibition of it will have an added impact on prices."

Why specs are tight

On the other side, Brauer at RADC says specs are tight "because we don't want to buy the garbage off the line. If you compare the spec value to the typical values listed for the parts, they're not too tight. If a vendor says they are, he isn't telling the truth about his typicals." Using the 741 as an example, Brauer says RADC isn't going to please everyone. "One guy might get hurt on slew rate; another on offset voltage," he notes, depending on which parameters the vendor chooses to concentrate on. "But we've tested devices off the shelf, so there are people who've been able to hack it," says Brauer.

And while Brauer himself characterizes the vendor reaction as ranging from irate to cautious, he points out that some specs already have been amended as a result of information exchanged between RADC and the vendors, and, he adds, RADC is willing to listen to legitimate complaints. He stresses that the slash sheets as issued are "limited coordination" specs, they're only Air Force items so far, and primarily intended to get good devices into the F-15 aircraft. "We'll tinker with the machinery until we publish the triservice military specification," he notes. "We're modifying the slash sheets and we'll continue to do so. We published three drafts of 38510 before the first coordination meeting that was set up to come up with the final draft."

One of the problems with all of this, Flood points out, is that while "RADC has the technical capability to make evaluations on such things as device characterization, the Defense Electronics Supply Command in Dayton, which is administering the 38510 program, doesn't." This leads to problems, he says, because most of the data is coming from Brauer and such companies as Hughes and McDonnell Douglas.

"They want to run this the way we work with Autonetics on the Minuteman program, and I can't see DESC being able to do this," Flood asserts. He says that the vendor must submit a production flow chart to the Government, which may demand to see all the vendor's production specifications, and then order parts. One of Flood's chief complaints is that he doesn't think DESC is qualified to evaluate parts. Even if DESC could administer the task, Flood believes, no variations from the submitted production flow plan would be allowed. "We wouldn't even be allowed to change a rinse cycle," he says. "We may not be able to improve yields, lower costs, and improve device performance," he adds.

OEMs, too

It's obvious that the military will push 38510, and some people wonder if OEMs will follow in line. Richard McCoy, director of reliability programs at Signetics Corp., Sunnyvale Calif., says that "even though OEMs will have to justify why they would go against 38510, I suspect that some will try to use their own specs if they feel that the parts will be less expensive." Motorola's Flood backs this up: "There has been speculation that the major customers, primarily the F-15 hardware manufacturers, won't want to procure to 38510 specs," he says. "They'd rather use their own specs than pay the higher prices for 38510 parts."

In the end, however, it all comes down to price. Flood sums it up best by saying that while tightening of electrical specifications and the requirements for complete production documentation "may discourage some suppliers, and certainly will delay deliveries and increase prices, we feel that we have to qualify as a permanent 38510 parts supplier. The question is whether we can make money and whether the customer is willing to pay the price." □

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Government electronics

Transportation agency maps electronic roads

Plans to optimize existing roads through communications, control, and surveillance mean huge market

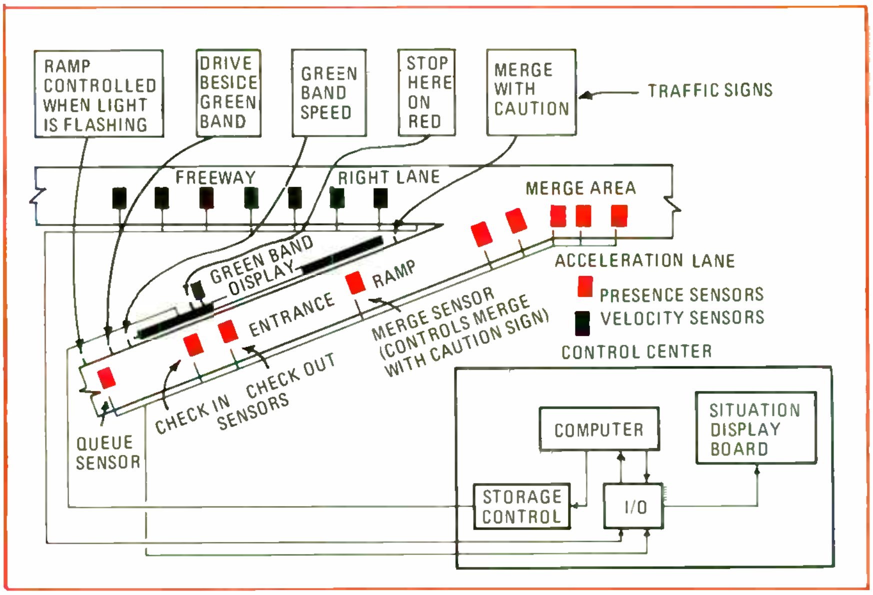
by Larry Armstrong, Washington bureau

The political climate for highway construction, once perennially sunny and warm, is growing distinctly chilly as land acquisition and other costs approach $100 million a mile in dense urban areas and ecological objections to paving over the nation mount. The approach taking shape at the Department of Transportation is to optimize existing roads through electronic communication, surveillance, and control systems.

Even in rural areas, the cost of converting two-lane roads to four lanes runs to $750,000 a mile, says William W. Wolman, DOT's chief of the Highway Traffic Systems Division. A nationwide conversion to electronic road signs alone would mean a Government market in the billions of dollars, says Wolman.

"There's only one way we can begin to optimize existing roads," says G.W. "Buck" Cleven, associate administrator for research and development in the department's Federal Highway Administration, "and that is through exploiting electronics." The first solid indication that electronics is on the government's new road map showed up in the department's recommendations for transportation in the Northeast Corridor, released last month [*Electronics*, Sept. 27, p. 25]. That report spells out $80 million for highway electronics between Washington, D.C. and Boston by 1985—for an intercity information network, and for ramp metering and freeway surveillance around congested urban areas.

Follow the moving green band. In Raytheon's traffic control system, a computer paces vehicles from the ramp to the freeway.



The Northeast Corridor recommendations may provide the catalyst for sparking a nationwide market. As Wolman puts it, "That report may be the vehicle toward developing all of the things we're just dabbling in now."

The report recommends that $27.2 million worth of ramp metering and freeway surveillance gear be installed on 531 miles of existing roads in the Northeast Corridor. The expressways included run around Washington, Baltimore, Philadelphia, Boston, and New York, and at selected locations around Providence, Hartford, Waterbury, Trenton, and southeastern Connecticut. Ramp metering in its simplest form is computer-controlled stop-and-go lights that prohibit vehicles from entering congested freeways. Equipment has already been installed around Houston, Chicago, Los Angeles, and other cities. In Houston, for example, traffic throughput has increased 25% and rear-end collisions fell by 20% to 30%, says Wolman.

The Northeast Corridor report projects that if the planned network of roads was supplemented with an intercity highway information system, the estimated yearly time lost to intercity travelers in 1985 due to highway congestion could be almost halved. With surveillance and control systems on Northeast Corridor freeways, DOT estimates that, for a cost of $27.2 million, almost 3 billion vehicle-miles of capacity would be added to the network, and some 60,000 accidents per year could be avoided.

Budget quadruples, but . . .

The Department of Transportation expects to quadruple its highway R&D budget to $28 million next year. But there are no direct fiscal rewards from DOT research contracts, points out an industry source: "The principal pitfall in the process of doing business with DOT is that they don't believe in paying a profit," he says. A department official reluctantly concurs: "Companies had better think twice unless they want to put up their own research money to get in." But companies are ready to do just that.

Raytheon's Civic Technology Group, Sudbury, Mass., is developing a "moving merge" control on an entrance ramp to Route 128 in Woburn, Mass. In addition to providing the usual ramp-metering functions, moving merge uses a Raytheon 703 computer and a series of buried inductive loop sensors to detect gaps in expressway traffic. It paces vehicles down the ramp to fill those gaps via a series of ramp-mounted lights. DOT says moving merge can greatly increase the volume of merging traffic as well as the headway of merging vehicles.

If the data could be incorporated into other meaningful control strategies, implementation of freeway surveillance systems could have far greater benefits, such as reversible lane control, bridge and tunnel regulation, detection of environmental and emergency situations, and police traffic supervision. In an embryonic highway control net, Raytheon has instrumented 42 miles of the Los Angeles freeway loop. That city's ambitious plans parallel the Northeast Corridor recommendations, which include such items as helicopter TV surveillance, variable message displays, motorist aid systems, ramp control, and freeway signs that direct vehicles to alternate lanes or alternate routes.

The Highway Administration is basically trying to provide the motorist with information. The Traffic Systems Division in the Office of Research has already developed experimental electronic road signs and low-power roadside transmitters, as well as the ill-fated Electronic Route Guidance System killed by Congress before a prototype network was built [*Electronics*, Aug. 18, 1969, p.138].

"We're leaning toward message displays on the side of the road, such as matrix displays—grids of lights—and remotely driven scroll displays," says Lyle G. Saxton, head of the division's systems development and technology group. Saxton notes that much of DOT's background and human factors studies of motorist information systems fell out of ERGS contract work. The final configuration for the Northeast Corridor will probably include message displays augmented with audio communications via small roadside transmitters, he says.

Audio communication with the motorist will probably require frequencies not in the broadcast band, Saxton explains. The Traffic Systems Division is concentrating on two highway audio communications systems—coaxial and microwave. Contracts have been let for evaluation of a buried antenna system developed by Sylvania Sociosystems Labs, Mountain View, Calif., and for a microwave repeater setup devised by Cutler-Hammer's AIL Division, Deer Park, N.Y.

Seen and heard

Sylvania's final report, to be submitted to DOT next month, will evaluate buried coaxial systems over a half-mile link of highway, and point-to-point communications from a roadside transmitter to a particular vehicle. AIL's F1-F1 system consists of receiving and transmitting antennas on poles along a segment of the Sagtikos State Parkway, Long Island, N.Y. Driving over a sensor imbedded in the road would trip the in-car adaptor, turn on the vehicle's a-m radio and establish communications with the roadside transmitter.

Both the AIL and Sylvania systems would require in-vehicle hardware, and the Highway Division is working with NASA's Office of Technology Utilization to minimize the cost of such circuitry. Under evaluation is the use of lower-grade transistors, inductorless and capacitorless circuits, and the package may be "put together offshore," says a DOT engineer.

Communications back to a highway control center (probably located at a state police station) would be via coded pulse, pushbutton systems in the car. "We want to communicate, but we don't want to let the motorist talk to us," Cleven notes. "Most Americans are gadget-conscious, so there'd be a big market for a $5 to $25 adaptor that would utilize existing circuits in the car radio," he says. On interstate highways, he suggests that the adaptor could be issued at toll gates and picked up at the other end of the highway.

"Implementation is now a system design problem," says Saxton. □

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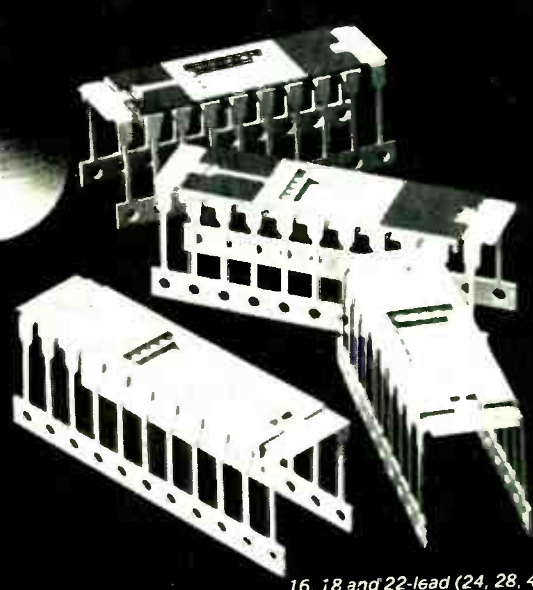

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Circle 103 on reader service card

Consumer electronics

Cartridge TV rush loses momentum

Myriad of consumer versions touted for '71 are being postponed as lack of standards, technology problems, and FCC proposal stall progress

by Marilyn Offenheiser, New York staff

The gospel according to most cartridge television manufacturers as recently as a year ago was that inexpensive systems for consumers would hit the stores during 1971, presaging a potential billion-dollar market [*Electronics*, Sept. 28, 1970, p. 89]. But during the interim, the litany chanted by enthusiastic salesmen went sour as a series of problems—including a potentially adverse ruling from the Federal Communications Commission, the economic slump, and troubles with standardization, technology, and software—ganged up to postpone introduction of cartridge TV systems.

The FCC dropped a bomb last summer by proposing regulations governing broadcast-frequency rf radiation in video players that can cause electromagnetic interference in nearby TV sets and other receivers. Shielding can help; another solution is to cut the power level of the video signal, but if it goes too low, picture quality is destroyed.

Until the FCC reaches a final decision, only two systems are exempt: the CBS-Motorola Electronic Video Recording and one model of Cartridge TV's Cartrivision. EVR was modified by lowering signal level; the Cartrivision cassette is built into the TV as a single unit (other players attach via the antenna terminals).

The FCC notwithstanding, most cartridge TV manufacturers still maintain that technology is not a problem. But the need is to get the technology into a low-cost package that consumers will buy. Teldec, Telefunken-Decca's cartridge-TV-on-a-disk only recently was modified for color video, but the problem of short disk life is still not completely resolved. RCA's holographic system originally had no sound and poor color reproduction, and is still being worked on. Ampex is now redesigning its Instavideo VTR, a commercial magnetic tape unit, to comply with FCC radiation standards, and independently re-evaluating the system's technology.

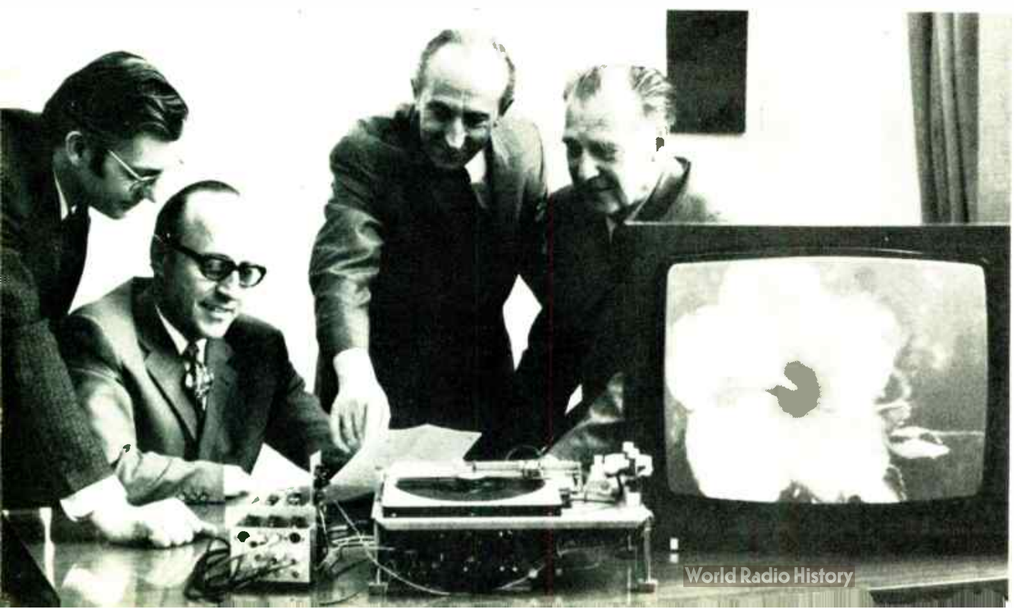
The grim national economic situation has hurt, too. Most cartridge TV makers blame lack of money as the prime cause for delays; in fact, it prompted Cartridge TV to go public and sell $20 million worth of stock last spring. Other companies, such as CBS-Motorola, Sony, and Ampex, are hoping that commercial sales to institutions and companies will yield enough technical fallout and production knowhow to reduce costs on consumer versions; then, with increasing sales volume and competition, they expect prices will drop.

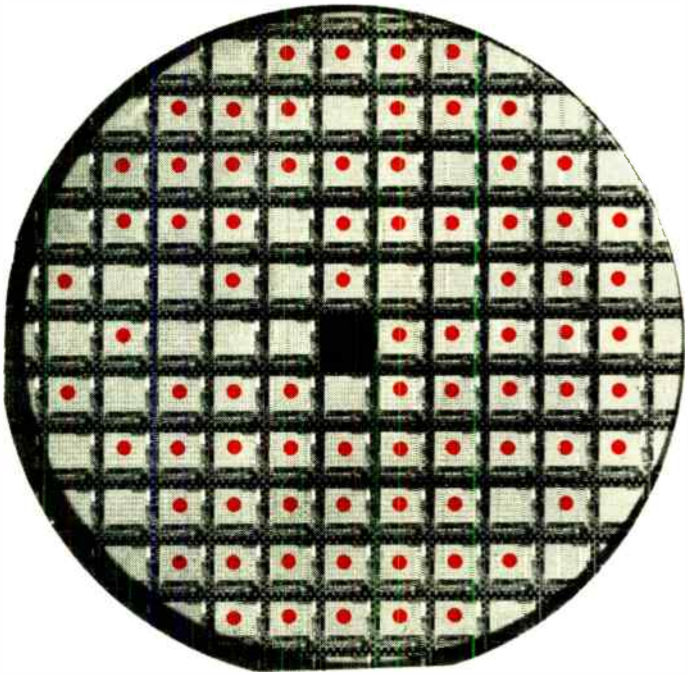
But diversified technology has left the cartridge TV industry bereft of standards. Gerald Citron, cassette production manager at North American Philips, New York, sums it up this way: "Everyone would like standardization as long as the other guy does it; there's take and no give, and for many, the point of no return has been reached." Forgetting about standardization between EVR hologram, and tape systems, so far, only two attempts at standardizing magnetic tape systems have been made. One, under the aegis of the Electronic Industries Association of Japan, is called the Type 1 Standard. It specifies a ½-in.-wide tape and a speed of 7.5 in. per second. Those participating include Panasonic in Osaka, Teac and Japan Victor in Tokyo, and U.S.-based Ampex.

In Europe, N.V. Philips Gloeilampenfabrieken, the Netherlands, has made standardization agreements with almost every TV manufacturer on the continent—England's Thorn Electrical Ltd.; Germany's AEG-Telefunken, Blaupunkt, Grundig, Saba, Nordemende, and Loewe Opta; Switzerland's Lenco and Studer; and Italy's Zanzussi—to make cassettes interchangeable on machines made by these companies.

Another headache is program-

Checkup. Developers of the Teldec system test the new color player. Playing time is 5 minutes; change time between disks is 1 second.





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ing—not only what to produce, but how to produce it inexpensively. This can be partially solved by rentals, but, as one industry leader says, "How many times can you see 'Gone With the Wind'?"

Of the systems with playback-only capability, EVR has been commercially available through licensees including Motorola, Toshiba, Hitachi, and others. Robert Brockway, president of EVR, says his firm has kept to the initial schedule. A spokesman for CBS says within a year a consumer model should be out, tagged at $300 to $400.

But Lloyd Singer, vice president and director of education and training products at Motorola Systems Inc., Chicago, Ill., says though Motorola will eventually make a consumer EVR, there are no plans yet.

Teldec introduced a color version last August and licensing discussions are under way. "What remains to be done now," says Gerhard Dickopp, head of AEG-Telefunken's equipment development section, "is to get the disk playback unit ready for the production line."

To overcome the limitation of short playback time per disk, a record changer unit was developed, with the disks placed in a magazine. A five-minute disk will be used and up to 12 disks can be placed in the cartridge. Dead time between disks is less than one second.

Also, because the very narrow-grooved disk, whose information density is a 500,000 bits/mm², rotates at 1,500 rpm, the smaller its diameter, the simpler the design of the playback system.

The system once reported to be in deep technical trouble is RCA's SelectaVision, which uses a laser to record holographic images on mylar tape [*Electronics*, Oct. 13, '69, p. 43]. Now Robert Bitting, staff vice president at RCA's New York headquarters, says SelectaVision's sound and color problems are solved. But neither the public nor the press has seen the redesigned hologram system. RCA is cautious—if the holographic system fails, there will be a magnetic tape unit to fall back on.

Among the systems that record and play back, New York-based Cartridge TV's Cartrivision is the only consumer model ready to be marketed in the U.S. Its licensees include Admiral (which has already made distribution arrangments with Montgomery Ward, W.T. Grant, Emerson, and Dumont), Packard Bell, and Warwick (Sears). Sears is slated to begin selling Cartrivision by the middle of next year.

With Cartrivision's financing problems ostensibly solved through its stock sales, the company's picture seems rosy indeed. The TV-player console, and the custom adaptor player due for mid-'72 sales, were not affected by the FCC proposal because it plugs directly into a specific brand of TV, but it did affect the universal adaptor model because it uses a cable connection.

The Ampex Corp., Mountain View, Calif., says the introduction of its Instavideo's commercial version, originally scheduled for late '71, has been postponed until the spring of '72 because it didn't meet FCC specs and preproduction engineering problems must be worked out.

Sony, with U.S. headquarters in New York, is cautiously waiting until 1975 or 1977 to market a consumer version; the company is sticking with its original January delivery date for commercial players. As for the FCC, the company believes the agency will drop its proposed ruling before January.

In Europe, Philips' N-1500 system is scheduled for delivery at the end of this year, but no programing is available, only blank tape. In the U.S., where modification is necessary for different TV standards, the system will be handled by North American Philips' Norelco division and called the Norelco VCR. Its commercial version will be ready in the second half of 1972, but a consumer model is not in the works. □

WHO'S GOT WHAT

Manufacturer	System name	Planned introduction date	First market	Type of system	Price	Cartridge playing time	Material cost per hr
CBS Inc.	EVR	commercial available consumer undecided	commercial	silver halide film	$300–$400 (cons.) $895 (comm.)	Color – 25 min b&w – 50 min	color – $37.50 b&w – $23.10
RCA Corp.	SelectaVision (holographic)	late '72–early '73	consumer	mylar tape	$400	30 min+	color – $4 to $6
RCA	SelectaVision	probably mid '72	commercial	magnetic tape	undecided	30 & 60 min	over $30
AEG Telefunken-UK Decca (Teldec)	Video Disc	early '73	consumer	7- or 12-in. foil PVC disc	manual $200 automatic $400	5, 12, & 15 min	$3.30
Ampex Corp.	Instavideo	spring '72	commercial	magnetic tape	b&w/no record $800 b&w/record $900 color/no record $900 color/record $1,000	30 & 60 min 7.5 ips 3.75 ips	$26 @ 7.5 ips $13 @ 3.75 ips
Cartridge TV	Cartrivision	mid '72	consumer	magnetic tape	player deck $500 in a TV $1,000 camera $200 (b&w)	b&w 120 min color 60 min	b&w $12.50 color $17
Sony	Videocassette	Jan. '72	commercial	magnetic tape	$800 ($200 for record adaptor)	30 & 60 min	$30
N.V. Philips	N-1500 (Europe) Norelco VCR (U.S.)	Jan. '72 mid to late '72	commercial commercial	magnetic tape	$700 (b&w camera $500)	60 min	$35

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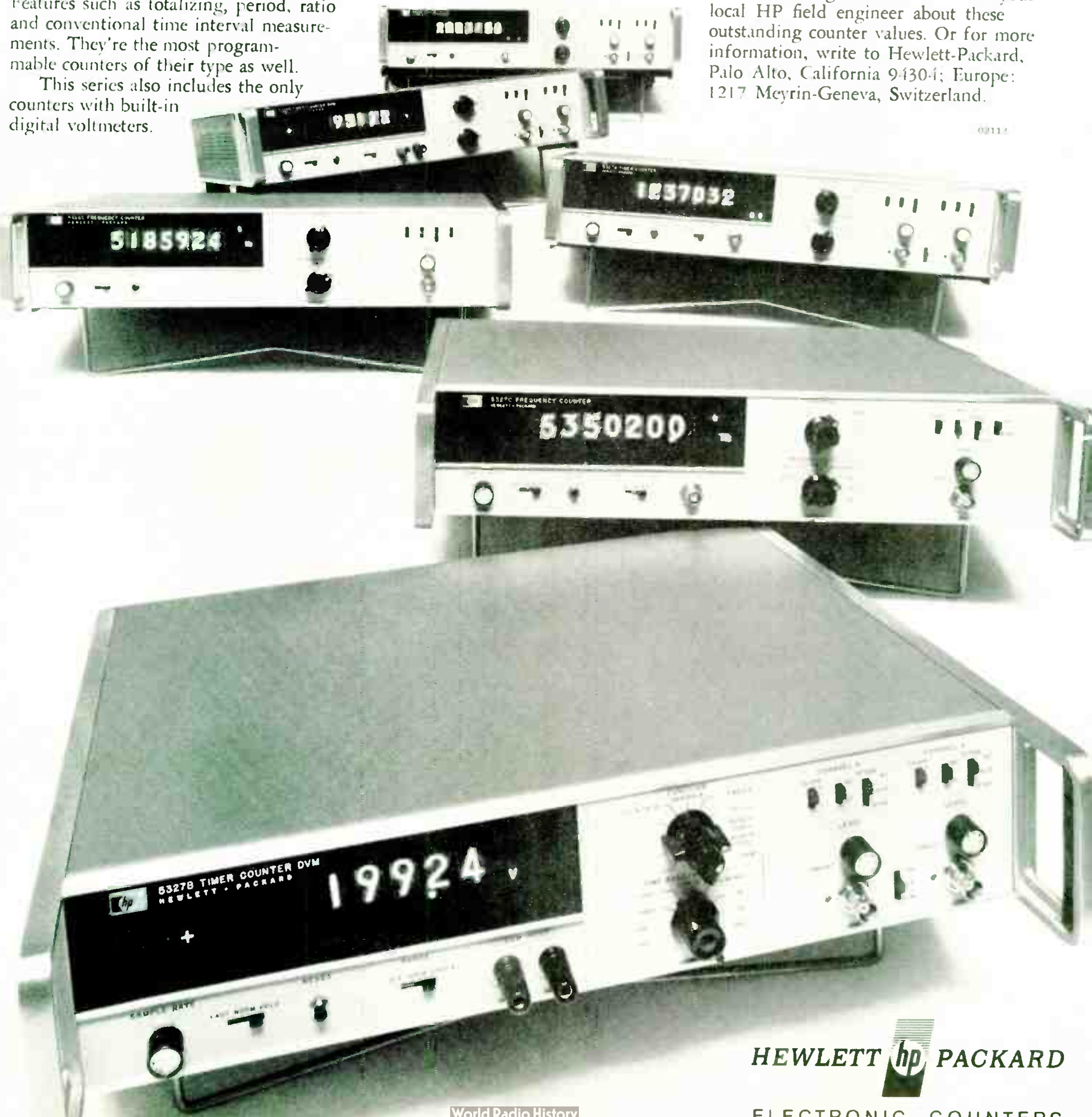

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ELECTRONIC COUNTERS

Circle 108 on reader service card

Manpower

How managers misuse engineers

The decline of engineering creativity with age is swifter today than ever before, thanks to managerial mistakes, say two Harvard researchers

by James Brinton, Boston bureau manager

The cards are stacked against older engineers. Other things being equal, a younger man will tend to get bigger raises, more interesting jobs, more encouragement, and a higher performance ranking than his older counterparts.

And this trend toward obsolescence is accelerating, say professors Gene W. Dalton and Paul H. Thompson of the Harvard Business School in their report on a four-year study of the careers and ideas of more than 2,500 design engineers and managers, most of them in electronics.

Today the average engineer performs best at about age 33. Only 10 years ago, the performance curve was flatter, and an engineer could look forward to about 20 years of high productivity, starting in his early thirties and with the vintage years between 40 and 45. But has there actually been a drop in the staying power of today's engineers? Or is the picture a reflection of the system under which engineers are managed?

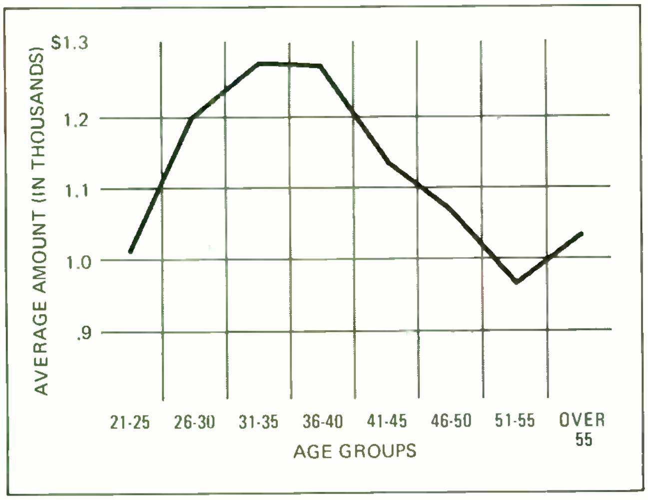
Who's to blame?

Of course, some of the shift toward an earlier career peak is due to the knowledge explosion—it's simply more difficult to stay abreast. But more of it is due to current management practices. For example, because an older engineer tends to be paid more than a younger one, he is less attractive to a manager building a project team. In turn, this tends to isolate the older engineer from new technology that might rub off in work with new men, and like a lawn without fertilizer, he ceases to develop. After 33, men are often shunted into old technology jobs that offer little challenge and great boredom.

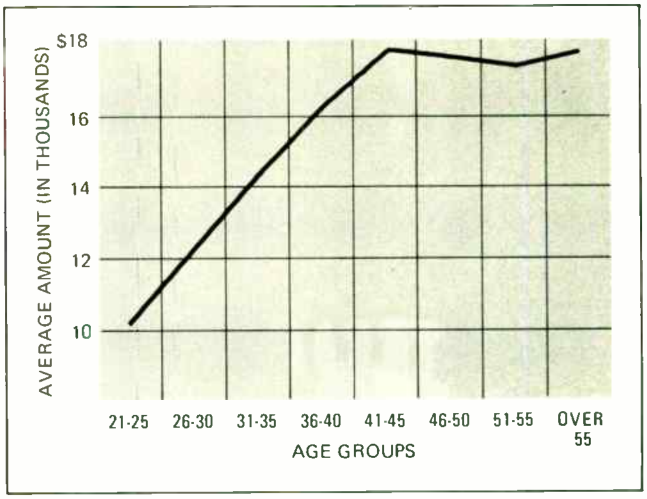
But Dalton and Thompson reserve perhaps their strongest criticism for the performance evaluation system used generally by aerospace managers. "I can already foresee an engineering shortage—perhaps by the mid-1970s," says Dalton, "and if we don't change aerospace management practices, we'll find ourselves facing engineering unions, ultra-high pay scales, and the other pitfalls of buying our way back into technology. These men have been harshly treated in the past two years, and the management practice of the 1960s was rough even on those who kept their jobs. If we do not start soon, we'll find the price of buying back into world competition very high indeed."

When the time comes to review a man's value, or output, managers grade him on the curve—assign him a percentile ranking with the other engineers in his group—and this can have a disastrous effect even on talented men. Even those gradings that are designed to help an engineer find his weaknesses early and correct for them are likely to aggravate a problem more often than they solve it. In one firm, the Harvard

Age and wage. Performance levels off before salary.



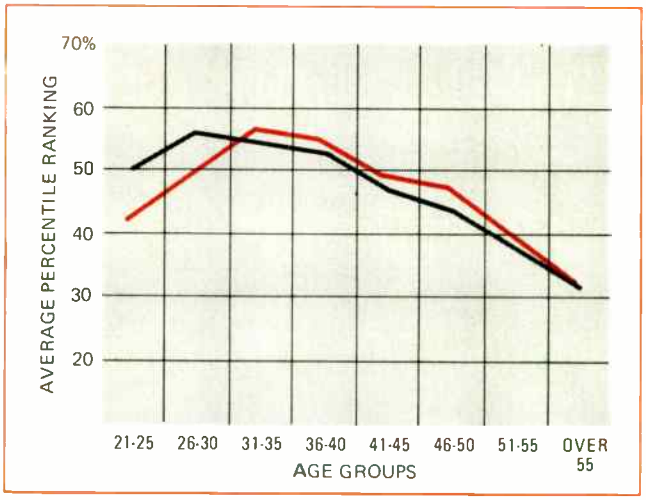
Increases. Annual raises follow performance curve.



men found that engineers over 40 who needed and were taking company-sponsored courses were the same ones whose performance rankings declined in successive years. Management felt that, if the courses were necessary, it was probably too late to salvage the men and ranked them accordingly.

The two Harvard researchers feel that someone should alert managers to the weak spots in their evaluation systems. "Grading 'on the curve' can become self-fulfilling prophecy," says Dalton. "Down-graded men appear to stay down." He explains that the bell-shaped curve of performance, which engineers are willy-nilly "forced to fit," is not just descriptive, but normative. In the hands of unenlightened managers, it can force engineers into low percentile grades simply because they are needed to fill out a Gaussian distribution, not because their performance is so much worse than others.

Short rise time. Managers gauge EE's for performance (red) and job complexity (black).



Hitting men when they're down

Thus an engineer may not be as sad a case as a low rank indicates. Nevertheless, good engineers, forced to fit in at the low end of the performance curve, find it virtually impossible to move out of that category. "The usual result of a low rank is a spurt of energy on the job, and a self-imposed program of re-education into which the man puts a lot of time, money, and emotional energy," the researchers say. But because of prior marks, and the advance of age, the man's rank is likely to rise little if at all.

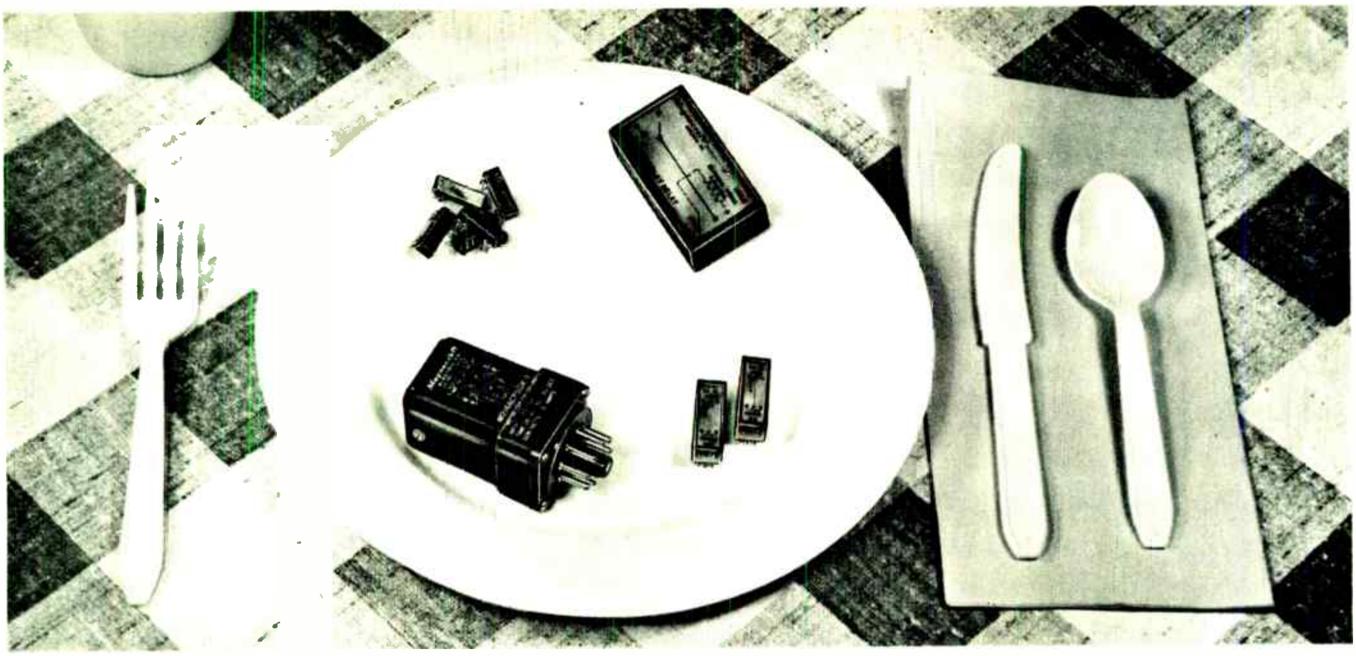
Transferring within a firm doesn't help, since a man's rankings follow him from section to section. Transfer to other companies is a course adopted only by the young, mobile engineers with a maximum of new knowledge—older men usually become angry and fearful, and cling tightly to their present jobs, Dalton and Thompson report.

Meanwhile, the biggest raises go to the younger men to keep them from moving to other firms, and ever younger men are being allowed to enter management for the same reason. This fact also affects an engineer's ranking. Thompson and Dalton found a link between the age of a manager and that of the engineer he ranked: the younger the manager, the higher the ranks for younger engineers. They wonder if this could be a partial cause of the past 10 years' steady downward trend in "peak performance age" from the mid-40s to the mid-30s.

Can an engineer, like Helen Trent, find happiness after 35? Dalton and Thompson are ready with suggestions that might help, but they also note that engineering managers tend to be so conservative that even after the flaws in the way they evaluate, rank, and assign the men under them are pointed out to them, they find it hard to change.

Sabbaticals are best

Continuing education is an obvious need. But as it's carried out today, it does little good. Instead of the night school grind, Dalton and Thompson suggest in-plant paid education programs—but not very strongly. To really grasp emerging technology,



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Circle 111 on reader service card

they feel that engineers should be allowed sabbaticals of, say, three to six months. Mastery of difficult topics would come more readily, and it could be less costly to retrain than recruit men with the necessary skills when a firm's product line changes. But most important, a sabbatical is a sign that a company values a man.

"Older engineers have less and less to look forward to with the younger men getting the big raises and sophisticated tasks. This would reverse that trend, and be a boost to the older man's self-confidence and productivity," they say, and back up their prediction by noting that engineers who go back for their master's degrees after a few years of experience peak out as much as 10 to 12 years later than the average.

Teaming older men with younger engineers would help, too. The new man would benefit from the experience of the older engineer, while the older engineer could learn new technology on the job. Dalton and Thompson point out that younger men get the high technology tasks just because it's more convenient for management to assign them there. But the inevitable result is an enforced obsolescence of older men. Moreover, the two researchers note that engineering is a creative job, and the nature of a man's creativity changes as he ages, perhaps one of the most important changes being the need for professional dialog between the older and younger generation of engineers.

To take advantage of this, the elder engineer might have to change career style, coming to think of himself as a coach or teacher. This would be a wrench for both management and the engineer/teacher himself: both would have to abandon the traditional competition of youth and age and adopt a new developmental and supportive role.

But despite the difficulty something must be done, feels Dalton. "Today's aerospace engineers are perhaps the most abused national resource around," he says, "and in order for the United States to remain competitive with our trading partners, we must employ these men and employ them properly." □

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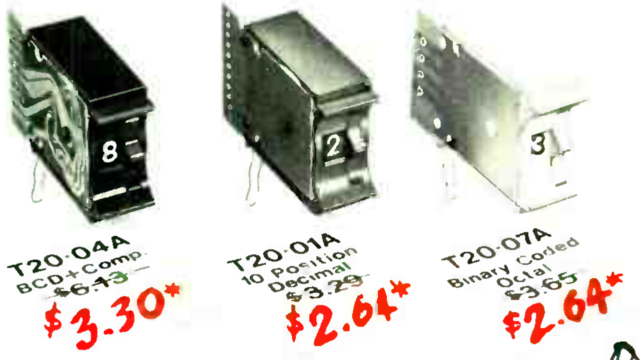

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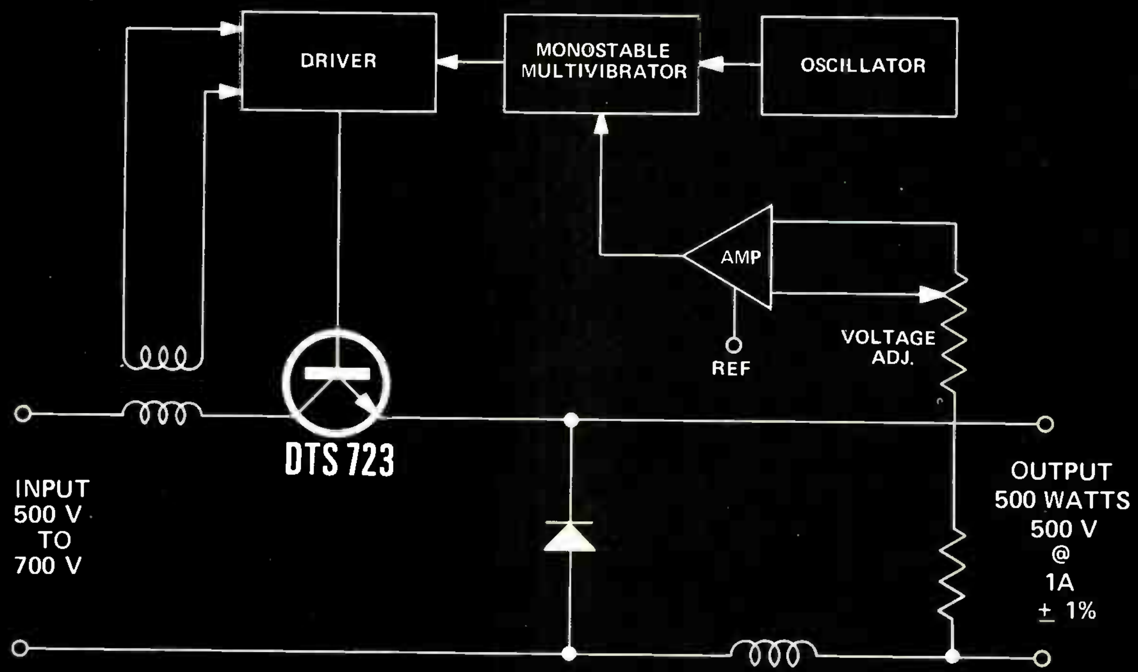
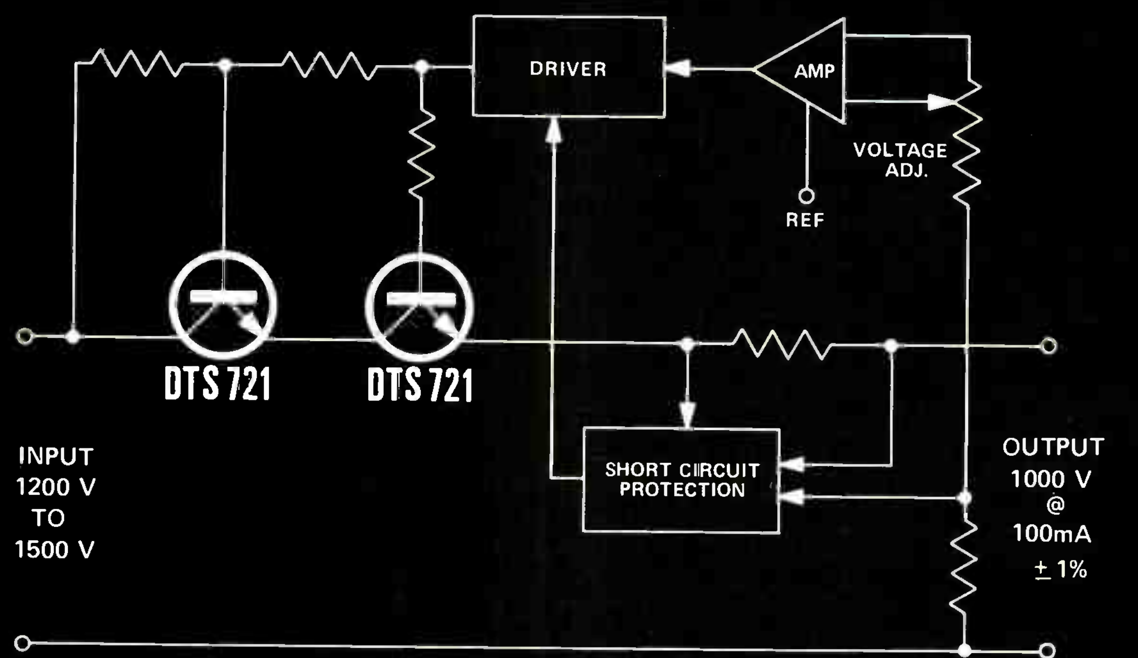


DC Regulator



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DTS-721	1000V	1000V	800	3A	20/60 @ 150 mA	50W
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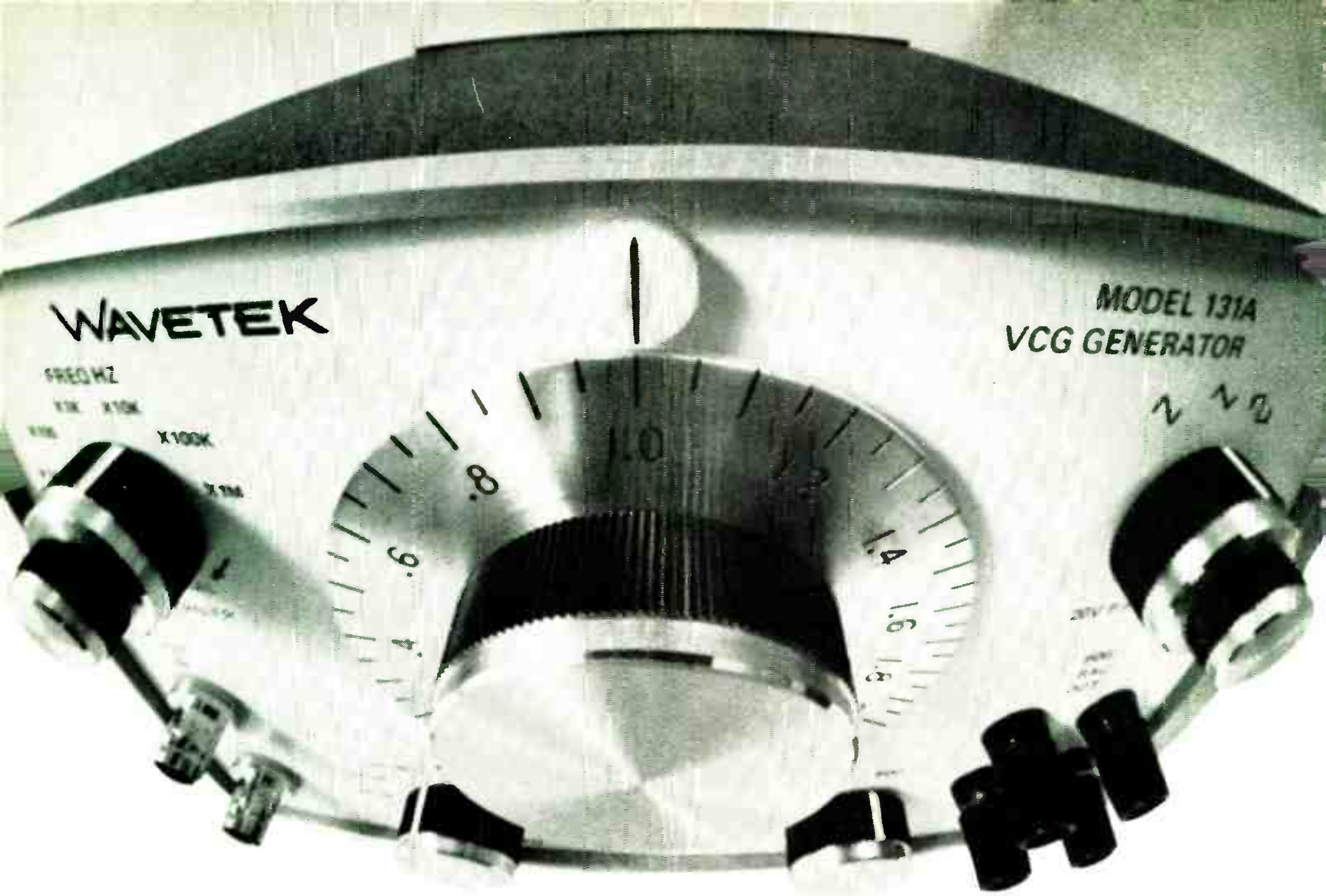

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(Wavetek conquers the communications gap.)

Until the 131A, voltage controlled generators weren't quite ready for the communications testing business. They were either too expensive or not compatible. But the 131A VCG costs just $395, about the same as an oscillator. It has a 600 ohm balanced output (plus a 50 ohm output) and an output step attenuator for precision low-level testing (to 60 dB down). And it cranks out sines, squares and triangles over a dynamic range of 0.2Hz to 2 MHz – with a 1000:1 sweep. Communications people, your VCG has come!

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Circle 116 on reader service card

LSI design system run by minicomputer

by Lawrence Curran, Los Angeles bureau manager

Interactive graphics portion uses storage-type tube; built for in-house CAD and circuit board layout

There are two changes that have evolved recently in computer-aided design systems for LSI, says Robert C. Boe, director of marketing for Systems, Science and Software, La Jolla, Calif.. The first is the move from large, third-generation computers to minicomputers, the second is the switch from cathode ray tubes that require continuous refreshing to storage tubes in the interactive graphics portions of the systems.

The firm incorporates these advances in a CAD system it calls MASK, which sells for $70,000—far below the price of most available computer-assisted LSI design systems. Systems, Science and Software uses a Data General Nova 1200 computer in its system, and a Tektronix storage-type CRT in the Computek input terminal. A 250,000-word disk memory and a nine-track magnetic tape unit that can handle on-line digitizers and plotters round out the system. The ingredient that his company adds, Boe says, is several years' experience in interactive graphics. "We spent much of our effort on this system to develop a compiler that can be used on a minicomputer for interactive graphics, using a higher-level language," Boe points out. Thus, although the standard system includes the Nova 1200, Boe says it's essentially independent of the computer used.

Nor is the system limited to designing LSI devices. Boe says it can also handle printed circuit board layouts and tooling design for the machine tool industry. He believes its relatively low price for a system that includes interactive graphics will bring it within the reach of systems houses that have long sought their own CAD capability, but don't want to spend millions.

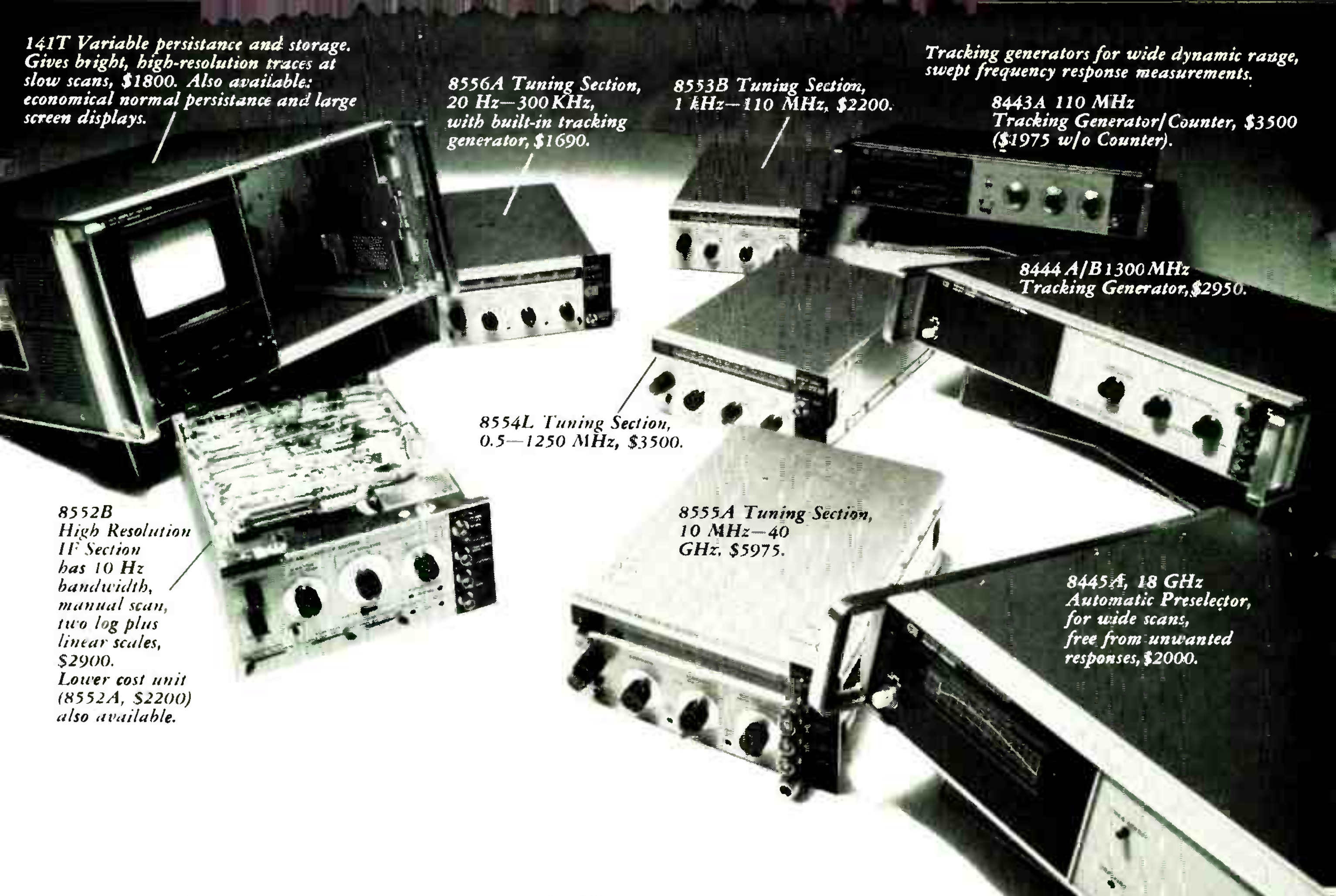
Easy to change. Boe thinks his firm's system offers some advantages over its competition in the $70,000 class. The first he calls screen-oriented functional control, much like that possible with a light pen, including the ability to modify a layout using function buttons, the keyboard, or a joy stick. Another advantage Boe claims is versatility in the "construction" mode: a special interconnect geometry, outline "string", or contiguous rectangles can be used to form metal lines or other extended features in the system, compared to a rectangle-only capability in competitive systems.

The California company's system also can continually add layout features to a design without refreshing the storage tube. And additional input terminals can be added at relatively low cost to allow more than one designer to use it simultaneously. The MASK system can accommodate 32 levels of LSI construction, ranging from initial diffusion layers on up through final metalization, and it provides six visual display features, ranging from lines through dots to circles within rectangles. MASK also offers a dynamically variable design grid.

Billy Link, senior engineer in the Burroughs CAD center, which uses the MASK system, says versatility and expandability are among principal features. Burroughs can add a rubylith cutting table, additional CRT input terminals or a pattern generator to the system, for example. Link adds that his experience with the system indicates it can save 50% of the time required for manual layouts.

Systems, Science and Software, P.O. Box 1620, La Jolla, Calif., 92037 [338]

Design team. Interactive terminal and minicomputer may help spread in-house CAD.



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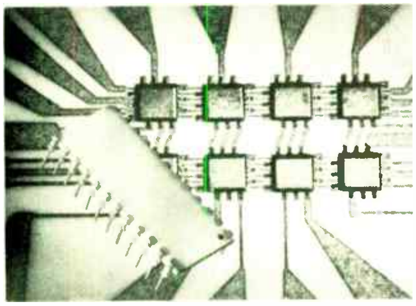
SIGNAL ANALYZERS

Components

Phone switch is hybrid

Multichip crosspoint unit combines beam leads and dielectric isolation

Routing telephone calls in a communications system requires selective switching, usually a job for reed relays. But Motorola's Semiconductor Products division has developed what engineers there believe is



a unique replacement: the SCBH5044 crosspoint switch, a multichip device that marries beam leads and dielectric isolation in a 24-pin package. The switch is a fallout from Motorola's experience with beam leads, nitride passivation, and dielectric isolation in the Safeguard antimissile program.

The unit is not limited to voice communications, however: it can handle digital switching functions as well. Each of the eight chips in the crosspoint matrix consists of four pnp transistors, four silicon controlled rectifiers, four diodes, and four diffused resistors.

Anthony Bryan, the program manager, says the hybrid unit is essentially a two-wire switch—each crosspoint takes the place of two reed relays, making the switching system smaller and more reliable than electromechanical units. Bryan indicates that pricing will be competitive with that of reed relays.

The beam leads and the silicon nitride passivation that is intrinsic to the device are desirable for long life in a telephone system. Because each chip is sealed, only a rubber conformal coating is used on the package. Dielectric isolation is employed because multiple crosspoints are put on the same chip, so that the SCRs must be isolated to prevent crosstalk. Dielectric isolation also lowers intercomponent capacitance and improves transistor efficiency, Motorola engineers maintain.

Bryan explains further that use of beam leads essentially gives Motorola a second layer of metal, but eliminates the need for crossovers or crossunders, which cause resistor variation and will also increase chip size.

Sample quantities are available from stock.

Motorola Semiconductors, Box 20912, Phoenix, Ariz. 85036 [341]

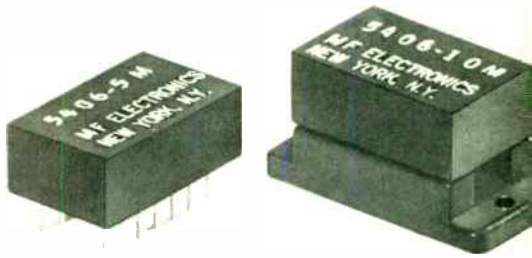
Single-chip rf transistor puts out 50 W at 12 dB gain

Because of single-chip construction and a high gain of 12 dB, the model XB50-28 rf transistor reduces the number of the devices needed in a system. These units can withstand an infinite VSWR at rated output

power and supply voltage because integral ballasting resistors are used to equalize junction temperature over the surface of the transistor chip. The XB50-28 is housed in a microstrip package, and operates at 400 MHz frequency, 28 V, with 50 W power out and an input Q of less than 2. Price is $90 in 1 to 99 quantities. Communications Transistor Corp., 301 Industrial Way, San Carlos, Calif. [344]

Low-profile oscillator allows tight board spacing

Plug-in crystal oscillator model 5406 takes up no more space than an integrated circuit. A low profile of 0.3 inch allows tight board spacing of 0.5 inch. Frequency is any desired value from 4 MHz to 30 MHz, and



the oscillators are in dual in-line packages that may be inserted directly into a standard socket or soldered into a pc board. Typical price is $35 in quantities of 1 to 4. Delivery is from stock.

MF Electronics Corp., 118 East 25th St., New York, N.Y. 10010 [343]

Resistors offer accuracy, and stability of 0.0015%

Hermetically sealed resistors in top-hat design offer an absolute accuracy and stability from 0.0015% and ratio accuracy and stability from 0.0005%. The THA series is available in two sizes: the model 36 measures ⅜ by ½ in. high and the model 38 is ⅜ by ¾ in. high. A standard accuracy of 0.005% is offered for resistor values from 1,000 ohms to 1 megohm. Price is from $1.50 to $7 de-

pending on quantity, resistance, and accuracy. Julie Research Laboratories Inc., 211 West 61st St., New York, N.Y. 10023 [349]

Miniature tantalums use pellet with epoxy coating

Miniature and subminiature tantalum capacitors are designed for use in bypass, blocking, filtering, and decoupling applications in computer peripherals, calculators, automotive electronics, and test devices. Called the DIT series, the units use a tantalum pellet with an epoxy coating. Straight or crimped radial-lead construction permits insertion

into printed circuit boards. They are designed for continuous operation between −55 C and +85 C, and are available with capacitance values from 0.1 μF to 100 μF. Price is 10 cents in production quantities. Capacitor Div., International Electronics Corp., Melville, N.Y. 11746 [345]

Preset encoder combines pulser with counter

Since a large percentage of shaft position pulsers are used with counters, Disc Instruments has combined the two into one unit, a preset encoder that reduces cost and space requirements in process systems. This detecting and controlling element was developed by integrating a 3- to 6-digit preset counter into the company's photoelectric shaft-position encoder. The unit can provide accurate pulse counts up to 5,000 per revolution. The price is under $500. Disc Intruments Inc., 2701 S. Halladay St., Santa Ana, Calif. [346]

Raytheon puts your resistor trimming on the beam.

On the laser beam, that is. Our new SS-328 laser system cuts thick and thin film trimming problems down to size. It's quicker, more efficient and clean. And of course, it performs with pinpoint precision unmatched by other methods.

The SS-328 makes light of handling, probing, and operating, too. Selection of resistor to be trimmed is safely monitored through closed circuit television and conveniently controlled by joy stick. Extremely-narrow straight or L trims are achievable through control knob selection.

The trim itself is performed by a CW, Q-switched, neodymium doped YAG laser. It's safe, can be fully automated and, best of all, takes but a fraction of a second leaving the substrate unscarred. Give yourself the cutting edge. Find out more about Raytheon's new SS-328 laser resistor trimming system.

To arrange for evaluation trimming and obtain a free brochure on the SS-328 Laser System, contact Raytheon Company, Laser Advanced Development Center, 130 Second Ave., Waltham, Mass. 02154. Tel. 617-899-8080. After Nov. 1 our telephone number will be 890-8080.

Circle 122 on reader service card

Microwave

Attenuator is broadband

Crossed-bar element design allows coaxial unit to operate from dc to 18 GHz

In most coaxial attenuators of tee-network design, a small, cylindrical resistor in series with the center conductor is surrounded by a disk-shaped shunt resistor. The latter extends between the central resistor

and the outer coax conductor. This construction introduces a capacitive reactance component that is difficult to control over wide frequency ranges.

A novel design developed under a military contract is being used by Engelmann Microwave Inc. to achieve broadband performance—from dc to 18 gigahertz. It uses crossed-bar resistive elements to get the conventional tee-network configuration.

"The crossed-bar construction of our new unit is the key in controlling unwanted capacitance," says Carl Schraufnagl, sales manager at Engelmann. He adds that this technique also allows a tighter tolerance control across the band.

Using this crossed-bar design, Englemann is introducing the A700 series coaxial attenuators specified for the full dc-to-18-GHz range. Standard attenuation values initially introduced include 1-, 2-, 3-, 4-, 5-, 6-, 10-, and 20-dB levels. A 3-dB tolerance is guaranteed for the 1-, 2-, and 3-dB units, and a VSWR of 1.35 is maintained throughout the band. The first units introduced operate at power levels of 2 watts, but future series are planned that will dissipate much greater power.

Because of its ±0.5-decibel attenuation tolerance over the entire dc-to-18-GHz band, the new attenuator can be used as an impedance-matching network between two circuits. For this application, values as low as 1 dB become useful. With the conventional disk-shaped shunt resistor, an attenuation level of 1 or 2 dB was very often meaningless because amplitude tolerances often hovered about this level.

Price is $45. Attenuators are available with either SMA or type N connectors. Delivery from stock will begin in early December.

Englemann Microwave Inc., Skyline Dr., Montville, N.J. 07045 [401]

Amplifiers in TO-12 cans are useful to 1 GHz

A family of general-purpose amplifiers developed by Avantek Inc. is expected to make things a bit easier for circuit designers in communications, particularly in uhf and microwave bands. The amplifiers, called the GPD series, offer flat response from 5 to 400 megahertz and require only four connections: input, output, +15 volts, and ground. A complete unit, which is a thin film hybrid circuit, is packaged in a TO-12 can and has useful gain from 2 MHz to 1 GHz.

One of these devices can be plugged into a circuit board with the same ease as an amplifier can be drawn on a schematic diagram, says Wayne E. Evans, director of marketing at Avantek. "And it's easier to use than a transistor because input and output matching, and biasing problems are taken care of." Evans adds that the cost of designing and testing an amplifier in-house is eliminated and that the price of the GPD, $25 in quantities of 1,000, compares favorably with the parts cost of designing one from scratch.

Product engineer Paul Walenciak says that the GPDs "offer flat response across seven octaves, can be cascaded in systems requiring more gain. One device offers from 0 to 13 decibels of gain, and noise figures range from 6 to 9 dB." The model 401 has a 13-dB gain with a 6-dB noise figure and requires 15 V at 10 milliamperes; the 402 provides 13 dB of gain with a 7.5-dB noise figure and requires 15 V at 24 mA; and the 403 provides 9 dB of gain with a 9-dB noise figure and requires 24 V at 65 mA. Input and output impedance is 50 ohms.

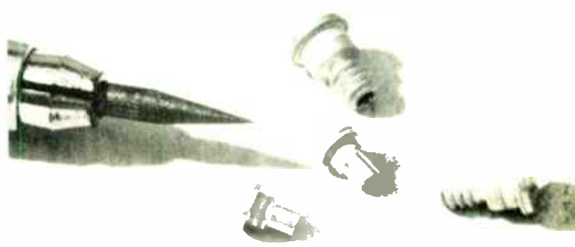
Applications include land mobile communications gear, navigation equipment, paging and personnel locators, direction-finding systems, and some electronic countermeasures jobs. "And since the same basic wideband amplifier can be used in many systems," says Walenciak, "users have to stock only one or two parts." To build a narrow-band system requires only the addition of a filtered network at the amplifier's input, and an isolator can be built by adding resistors.

Delivery of samples is from stock.

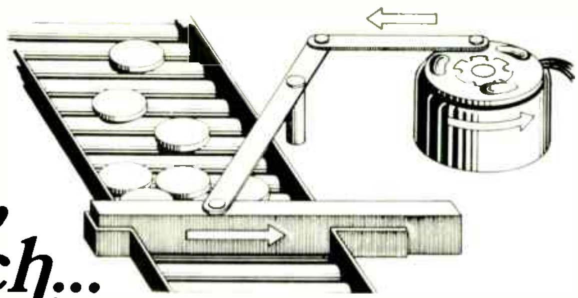
Avantek Inc., 2981 Copper Road, Santa Clara, Calif. 95051 [402]

Silicon Impatt diode puts out 1.5 W in C band

Cw power levels above 1 watt are achieved with silicon Impatt diodes designed for microwave repeater links, telemetry systems, and Doppler navigation radars. The silicon diodes are intended for use as the active element in oscillators and amplifiers, C through K_u band.



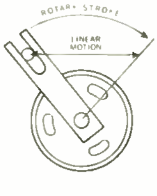
snap, lock, index, punch...

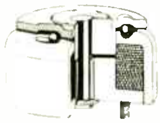


To move a load in an arc or a straight line
. . . consider a Ledex rotary solenoid

A Ledex rotary solenoid gives you a down-hill solution to an up-hill problem.

The force of an electromagnet is inversely proportional to the square of the distance between the pole faces. Most solenoids live with this problem, which means less force in the beginning, where you need it, and wasted energy at the end, where you don't need it.





The Ledex rotary solenoid starts off working where the force is really at, about .030" between the pole faces. Then the armature rides a helical ramp, to distribute the force over the stroke you need. It gives you efficient, direct rotary action and uniform linear movement.

The Ledex rotary solenoid delivers a lot of power for its size. That's because it works in the tiny area where magnetic attraction is highest. It's efficient because it spreads this high concentration of energy over a longer useful stroke.

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MICROELECTRONICS Power drivers, pulsers, time interval controls, level adapters/shifters, voltage regulators—standard and custom circuits to blend microelectronic miniaturization and power with the higher current and voltage levels needed to drive electromechanical products.

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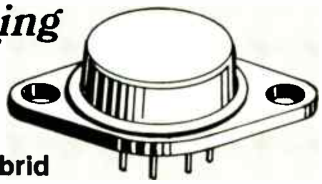
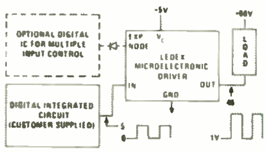


. . . like this hybrid thick film driver

If you're working with a control signal that can only deliver 10 milliamps and you really need 5 to 7 amps, consider the Ledex LMD-5 power driver.



With the LMD-5 you can switch up to 325 watts. It has an expander node terminal, so you can add multiple inputs. An internal diode protects the circuit from damage when driving inductive loads.

Available from the shelf in 1-9 quantities at $32.07 each. Only $14.30 each in 1,000 lots.

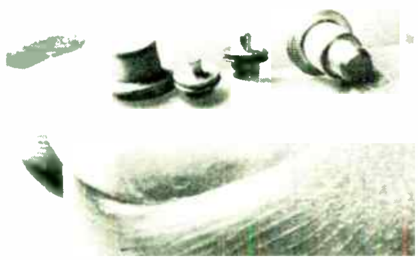
Type 5082-0424 for operation from 5.3 to 8 GHz delivers a minimum of 1.5 W; type 5082-0425, 8-10 GHz, 1.25 W; and type 5082-0426, 10-13.5 GHz, 1 W. Price for 1-9 quantities is $150. It is expected that production quantities will be priced below $60 each. Hewlett-Packard Co., 1601 California Ave., Palo Alto, Calif. 94304 [407]

Broadband horn antenna for uhf systems is compact

A broadband horn antenna that operates over the range of 0.5 to 4.0 GHz measures 19 3/5 in. in length and has an aperture of 10 by 14½ in. The model AN-10E for use in the ultrahigh frequency band is suited for tracking, surveillance, and general laboratory applications both as a principal radiator and as a feed for parabolic reflectors. The antenna features linear, horizontal or vertical polarization, gain of 8.0 to 14.5 dB over isotropic, and VSWR of 3.0:1 maximum relative to 50 ohms. GTE Sylvania, Electronic Systems Group-Western Div., P.O. Box 188, Mountain View, Calif. 94040 [403]

GaAs tuning diodes aimed at Impatt and Gunn sources

Intended for use in wide-tuning-range vhf and uhf oscillators, broad-tuning-range filters, high-stability oscillators, and for tuning of microwave transistor oscillators, gallium



arsenide tuning varactor diodes are particularly suited for Impatt and Gunn sources. The units feature liquid-phase, epitaxially grown, abrupt pn junctions for high tuning ratios. High electron mobility produces low series resistance, resulting in high Q and low loss at microwave frequencies. Varian, Solid State Div., Salem Rd., Beverly, Mass. 01915 [405]

Power supply for Gunn devices includes modulator

A power supply designed to meet the needs of Gunn device oscillators is provided with an integral modulator for frequency stabilization or other modulation requirements. Output of the model 760 is adjust-

able from 6 to 12 v dc at up to 1.5 A, and adjustable current limiting and an overvoltage circuit protect the Gunn device and supply from accidental damage. Modulator bandwidth is dc to 200 kHz, and input 0–10 v at 50 ohms. Price is $275. Micro-Now Instrument Co., 6104 N. Pulaski Rd., Chicago, Ill. 60646 [406]

C-band signal source is tunable over 500 MHz

A solid state C-band signal source is stable over its entire operating temperature range of −40°C to +85°C. Mechanically tunable over a 500-MHz range, from 5.4 to 5.9 GHz, the model S341V1 makes use of a bulk-effect differential negative resistance in specially prepared GaAs material. Price of the unit, called a transferred electron oscillator, is $500 in quantities of one to 10, and $250 in lots of 100. RCA Microwave Solid State Applications Engineering, Harrison, N.J. 07029 [409]

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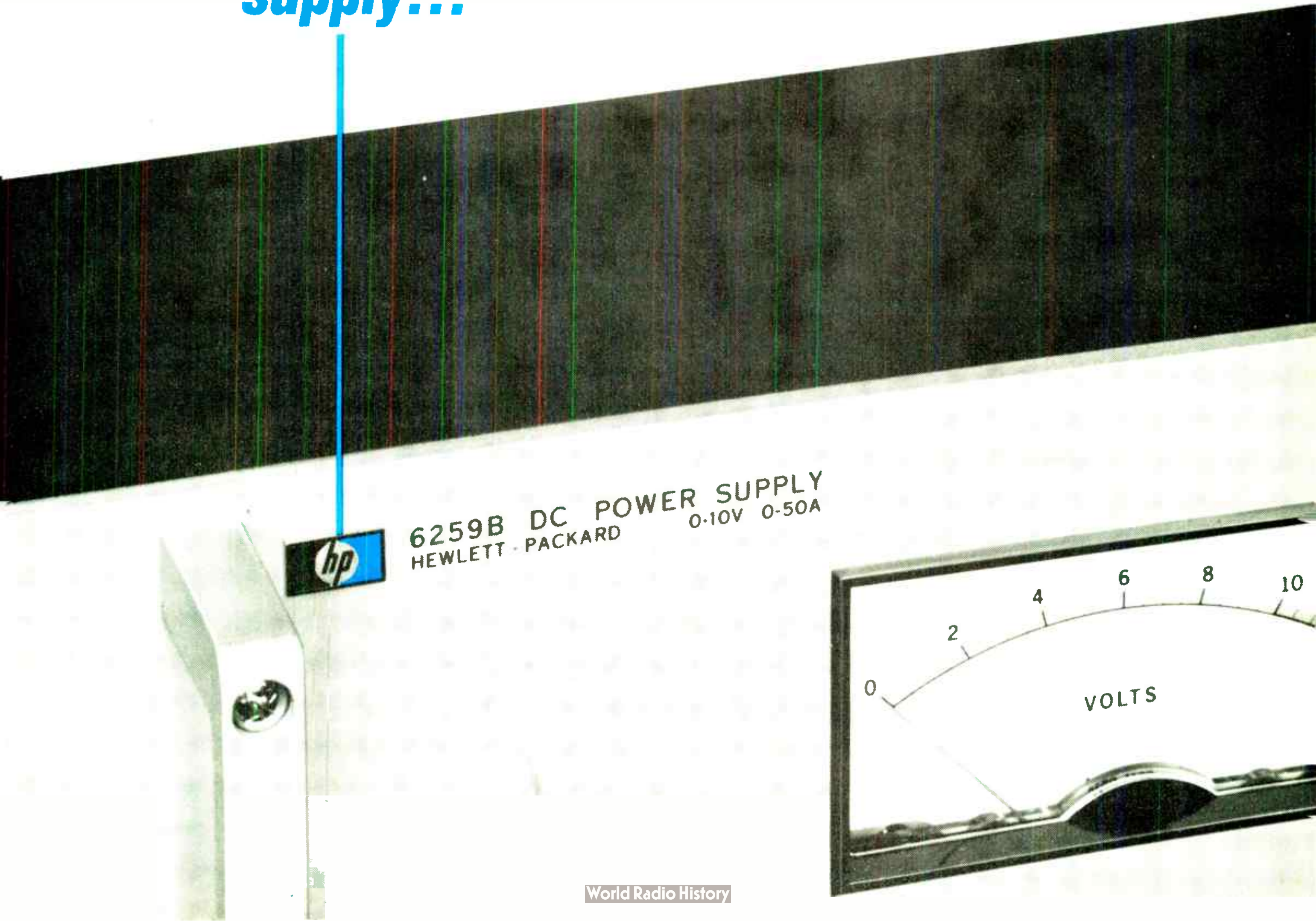

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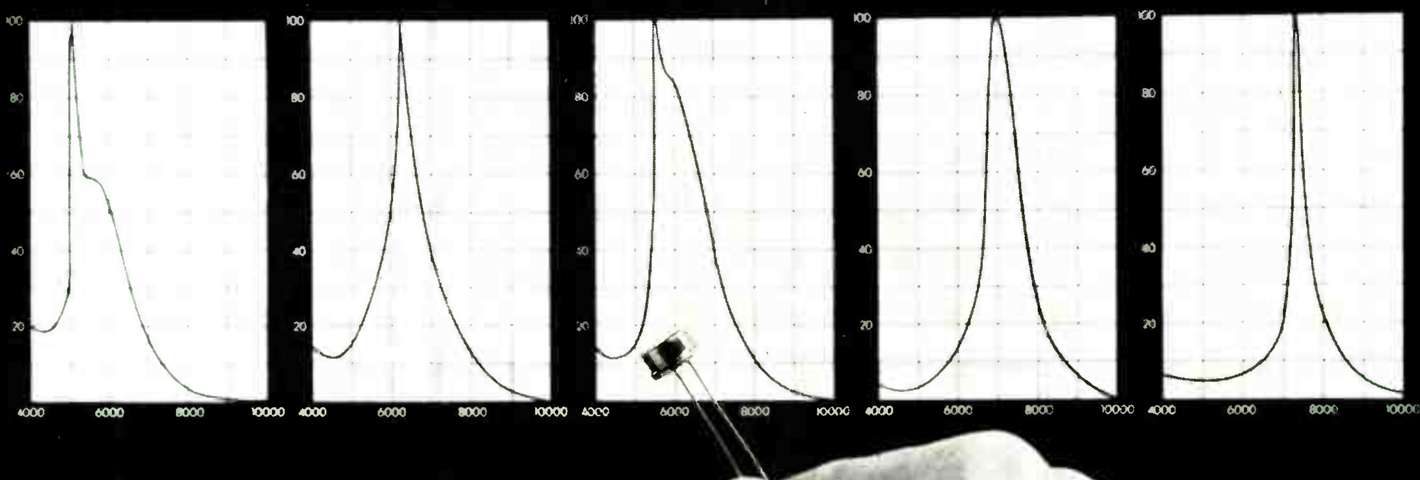

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New products

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Sputtering unit controls itself

Automatic system keeps power level constant for thin film deposition

Because of the need for a thin film deposition process that would handle a wide range of materials, sputtering—a technique that is more than 100 years old—was revived in the 1960s. And now a fully automatic system, called Servo-match, has been developed by Randex Inc. of Palo Alto, Calif.

In most systems, the operator has to work the controls to get the plasma started, then keep a careful watch to make sure the net forward power remains constant and that the impedance of the generator matches that of the plasma so that reflected power is near zero. In Servo-match, the plasma starts itself when an electrical discharge into the argon releases electrons, and power-stabilizing circuitry maintains a constant net power despite input variations. Impedance mismatch is sensed, and a servomechanism adjusts pressure and voltage to maintain the proper level.

The Servo-match system can be used to deposit two materials sequentially, such as titanium and gold in multilayer IC interconnection patterns. Sputtering is also used in the passivation of integrated circuits, particularly those processes involving materials that do not evaporate easily. "Tungsten is an esoteric material that is impossible to evaporate," says Karl Urbanek, president of Randex, "so IC makers grabbed the method and ran with it." Other applications are in beam lead technology and the fabrication of Schottky diodes. An area now being opened up to sputtering is the optical industry, particularly lasers, where at times as many as 19 layers of different materials of highly precise thicknesses must be deposited on mirrors and filters.

Servo-match is available in both single and multicathode systems. Modes of operation are: deposition, rf bias, and etching. Target diameters range from 6 to 24 inches, and rf power supplies from 1 to 10 kilowatts. The sputtering module, power supply, and three target cathodes—without vacuum system—will cost about $25,000.

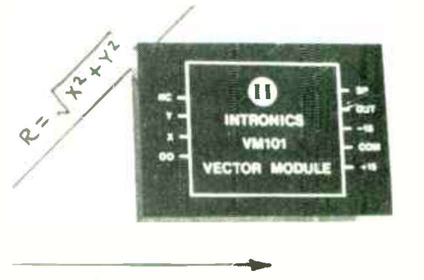
Randex Inc., 815 San Antonio Rd., Palo Alto, Calif. 94303 [381]

Plug-in amplifier operates from 500 kHz to 100 MHz

A wide-dynamic-range amplifier with 20 dB gain at 10 MHz and low intermodulation distortion in a plug-in package has a noise figure of typically 4.5 dB at 30 MHz and 5 dB at 60 MHz. Operation is over the range of 500 kHz to 100 MHz. The model MWDH-20G-12 provides a frequency response which is flat to ±0.5 dB. Price is $225. Anzac Electronics Div., Adams-Russell Inc., 39 Green St., Waltham, Mass. 02154 [384]

Vector module bandwidth is independent of signal level

Vector operator module model VM101 computes $(X^2 + Y^2)^{1/2}$ to 1% accuracy with 1-MHz bandwidth, an operation usually requiring three analog multipliers connected together and the output bandwidth would vary with the signal level. However, in the VM101, bandwidth is independent of the signal level. Applications are vector summation,



rectangular-to-polar conversion, CRT intensity or focus correction, rectification, and fast signal averaging. Price is $95. Intronics Inc., 57 Chapel St., Newton, Mass. [387]

Discriminator eliminates extraneous zero crossings

A monolithic discriminator, called the model 6283 MDB, provides symmetrical characteristics—even beyond peaks—and eliminates extraneous zero crossings that produce false lock-on in afc applications. The monolithic multiresonator of

the unit gives good stability over the temperature range of 0 to 50;C. The filter has a center frequency of 10.2 MHz ±250 Hz, and a peak separation of 10 kHz nominal. Damon Electronics Division, 115 Fourth Ave., Needham Heights, Mass. 02194 [388]

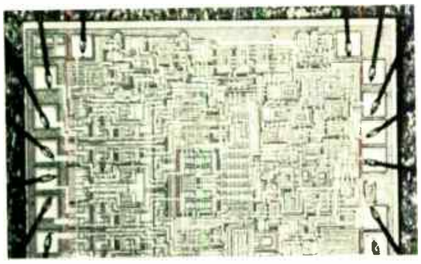
Laser deflector is capable of 400-spot resolution

Solid state acousto-optic laser beam deflector features uniform light output over the entire scan angle, and is capable of 400-spot resolution at high scanning rates independent of light wavelength. Both linear scan and random access are possible. The

wavelength range is from 400 to 1,200 nanometers. The device, called the D-70R, is also usable as an intensity modulator. Zenith Radio Research Corp., 4040 Campbell Ave., Menlo Park, Calif. 94025 [389]

Op amp offers wide range of linear applications

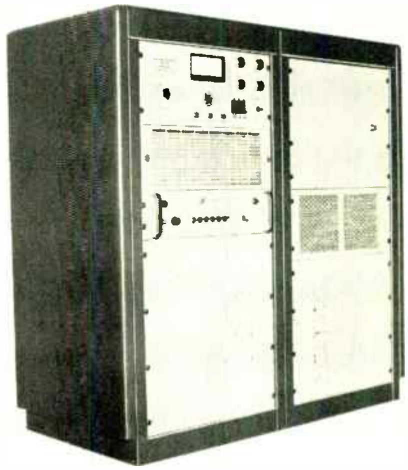
A four-channel operational amplifier consists of digitally selectable input stages sharing a common output stage. The model HA-2400, called Pram, is designed for a wide range of linear applications such as



phase selecting, programable attenuator, and multiplying d-a converter. Connecting similar or different feedback networks from the single output to each of the four inputs allows the selection and conditioning of several input signals or the selection between different op amp functions which are to be performed on a single input signal. Price in quantities of from 100 to 999 range from $10.45 to $23.65 depending on temperature range. Harris Semiconductor, Melbourne, Fla. 32901 [383]

Amplifier is flat from 10 kHz to 220 MHz

One kW of continuous power over the 15-octave frequency range of 10 kHz to 220 MHz without tuning or bandswitching is possible with the model M406L broadband amplifier. The system has a 60 dB power gain, and can be driven to its full output by standard sweepers, synthesizers, and signal generators. Gain variations across the passband are less



than + 1.5 dB. Rise and fall time is 7 ns, and operation is linear. Price is $22,000. Instruments for Industry Inc., 151 Toledo St., Farmingdale, N.Y. [390]

For swept RF measurements of both magnitude and phase, Try this test lab.

HP's 8407A Network Analyzer makes quick RF measurements, 100 kHz to 110 MHz with ease, accuracy and thoroughness. Inadequacies of alternate techniques have been eliminated and swept measurements over a wide dynamic range are now possible.

We're talking about full characterization — both magnitude and phase — of filters, amplifiers, attenuators, transistors, antennas, and any other RF components, devices or networks you can name. And you can check them at any stage of design, development or production.

The system consists of:

- 8601A Generator/Sweeper, a precision swept source, 0.1 to 110 MHz, with flat output, a highly linear sweep and low residual FM.
- 8407A Network Analyzer mainframe with 8412A Phase-Magnitude Display unit for CRT presentation of test results.
- Accessory coax devices and probes to monitor the unknown's responses to the swept test signal.

For coaxial work: 11652A Reflection-Transmission Kit with all the accessories you'll need: precision power splitter, high directivity flat coupler, termination and matched cables. Just hook up — make high accuracy swept measurements of complex transmissions and reflection coefficients simply and quickly. For circuit work: 11654A Passive Probe Kit with high impedance voltage probes and dividers plus current probes. You can measure circuit and device performance without disturbing their behavior. And using voltage and current probes simultaneously, you can make swept impedance measurements with 10,000:1 dynamic range.

Dynamic measurement range is greater than 100 dB, and you can see 80 dB in one viewing of the 8412's CRT. And you can see phase response at the same time with 360° phase range. The system also provides 0.05 dB magnitude and 0.2° phase resolution.

The 8407A is a narrow-band detector that tracks the sweeping test signal. Tracking provides these unique benefits:
1. Wide dynamic range and high sensitivity — make high-gain/high-loss measurements on sensitive networks and devices.
2. Accurate measurements — free from errors encountered in broadband detection methods resulting from harmonics and other spurious signals.

The 8407A RF mainframe costs $2950; 8412A Display, $1575; 11652A Reflection-Transmission kit (for coax), $325; 11654A Passive Probe kit, $400; 8601A Generator/Sweeper (general purpose precision swept source, useful for many applications), $2250.

You can get the full story by phoning your local HP engineer and asking for a demonstration. He'll also be glad to give you Application Note 121-1, a comprehensive description of what this system can do for you; plus Application Note 121-2 which describes how to make wide dynamic range impedance measurements on a swept-frequency basis. Or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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NETWORK ANALYZERS

Semiconductors

Register built for high speed

8-bit storage unit allows simultaneous read-write in minicomputer, control jobs

As logic families get faster, storage needs to get faster too. To fill this need for high-speed storage, Fairchild Semiconductor has developed an 8-bit multiple-register that allows simultaneous read-write operations.

The register, designated the 9338, can be used in conjunction with an MSI arithmetic logic unit to perform the key functions of the central processing unit in a minicomputer. For applications that require only simple add and subtract functions, the register could be used with devices like the Fairchild 9340, which includes an on-chip carry-lookahead feature, or the Fairchild 9341, which is more flexible but requires an external carry-lookahead unit.

The new register is expected to find additional applications in process control systems, intelligent terminals and test instruments.

The 9338 allows data to be written into any one of eight storage locations while at the same time data is being read out from any two of the eight locations. The timing problems usually associated with simultaneous writing and reading at the same location are eliminated by master-slave operation.

In fact, the data transfer timing resembles that of a standard master-slave flip-flop. While the clock line is low, the slaves are held steady, but information on the data input is permitted to enter the selected master. The next low-to-high clock transition locks the masters, making them insensitive to the data input and write address inputs, and also connects each of two slaves to the two selected masters, causing the contents to be read on the output lines. These features make the 9338 useful as address register banks for arithmetic logic units, as a first-in, first-out memory, as accumulators, data registers or as a scratchpad memory.

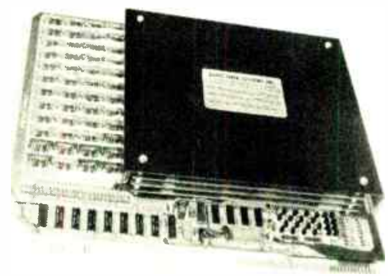
Typical read time (clock to output) of the 9338 is 21 nanoseconds (maximum 35 ns), and typical through delay (data input to output) is 35 ns (maximum 50 ns). Typical power dissipation is 265 milliwatts. The register allows easy expansion for larger word sizes.

The 9338 is available from stock. The 100-999 price in a 16-pin ceramic DIP in industrial temperature grade is $5.90.

Fairchild Semiconductor Div., Mountain View, Calif. 94040 [411]

Low-cost ROM provides 450-nanosecond cycle time

A cycle time of 450 nanoseconds and maximum access time of 180 ns, using 150 microwatts per bit, is offered by the Romtec 450-B read-



only memory. Up to 98,304 bits can be packed on one 13-by-11-by-1.7-in. printed circuit board. Typical configuration is 2,048 words by 48 bits. The unit is available in sizes up to 196,000 bits, and features include random access, DTL and TTL interface compatibility, self-cooling construction. Price is as low as 1 cent per bit. Aztec Data Systems, P.O. Box CR, Irvine, Calif. 92664 [413]

MOS ROM can be erased, reprogramed in the field

A 2,048-bit MOS ROM, designated the E-ROM, permits errors to be corrected and programs to be updated quickly in the field. Two types are available: the 1701, a dynamic/static memory with 650-ns dynamic access time; and the 1702, a static-only memory with 1-μs access. Either may be replaced by the 1301, a mask-programed, pin-compatible ROM. E-ROMS are programed electrically, and can be erased by shining a light from an ultraviolet source through a transparent quartz lid on the package. Price ranges from $160 to $200 depending on model and quantity. Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051 [415]

Capacitive ROM is on single printed circuit card

A capacitive ROM system with nondestructive readout has an access time of 50 ns or slower, as required. The series 1001, on a single printed circuit board, features a capacity ranging from 2k to 36k (or more) bits per board. The size of the board (4-by-6 in. to 12-by-15 in.) and mechanical interface can be made compatible with system requirements. Integrated Memories Inc., 260 Fordham Rd., Wilmington, Mass. 01887 [416]

Planar transistor offers high breakdown voltage

Silicon power transistors, of 100% planar construction, offer 700 V_{CEO}, and are packaged in a Jedec TO-3 case. Other features in the SDT 500 series include gold-plated molybde-

num pedestal mounting, low leakage levels at elevated temperatures (10 μA at 150°C, $400V_{CEX}$), and a temperature cycle of from -55 C to +180 C. Applications are in power supplies, CRT deflection circuits, converters, inverters, relay drivers, and series regulators. Solitron Devices Inc. 1177 Blue Heron Blvd., Riviera Beach, Fla. 33404 [418]

Transformer-isolated chopper operates from dc to 1.5 MHz

A solid state, transformer-isolated microchopper designated the NS8000A comes in a TO-5 package and can be used for low-level and high-speed modulation, demodulation, commutation, and switching. Its operating range is from dc to 1.5 MHz. The unit will withstand extreme environments and offers low values of offset voltage, leakage current, and saturated dynamic impedance. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343 [417]

Photodiode has rise and fall time of 15 ns

A photoamperic silicon photodiode, designed to operate in a reverse-bias mode, has rise and fall times of 15 nanoseconds each at a reverse voltage of 100 volts. Characteristic responsivity is 0.55 ampere per watt at a 0.9-micron wavelength, and the capacitance is rated at 4.5 picofarads. Designated the TIXL80, the diode uses a guard-ring structure to provide low noise characteristics. Price is $23.50 each in 100-lots. Texas Instruments Inc., P.O. Box 5012, MS/308, Dallas, Tex. 75222 [419]

Monolithic clock drivers for MOS devices are fast

Monolithic drivers designated the MH0026 series are said to clock large dynamic MOS memories faster than

hybrid IC drivers or discrete-component driver assemblies. Designed for low-threshold RAM and shift register applications, pulse rate is typically 5 MHz with rise and fall time of less than 20 ns when the driver is pushing a 1,200-pF load. Loads near 2,000 pF can be driven to 2 MHz with rise and fall time of less than

25 ns. With light loading, the rate climbs to 10 MHz and the rise and fall time is 10 ns. The maximum voltage swing is 20 V, and inputs are compatible with TTL and DTL levels. Typical turn-on and turn-off time is 7.5 ns. Peak output current is 1.5 A. National Semiconductor Corp. 2900 Semiconductor Dr., Santa Clara, Calif. 95051 [414]

Single chip holds counter, latch, and decoder/driver

An MSI/TTL integrated circuit in a 16-pin DIP is designed to replace three separate MSI functions. The model SN74142 consists of a decade counter, a four-bit latch, and a 1-of-10 decoder/decimal display tube driver on a single monolithic chip. The IC represents a 67% reduction in package count, and it will accept count input frequencies of up to 25 MHz typically, convert and store as four BCD bits, then decode and provide an output designed to drive Nixie tubes. The TTL device is compatible with DTL and Schottky circuits. Price in 100-lots for the ceramic package is $5.50, and $3.65 for the plastic version. Texas Instruments Inc., P.O. Box 5012, M/S 308 Dallas, Tex. 75222 [420]

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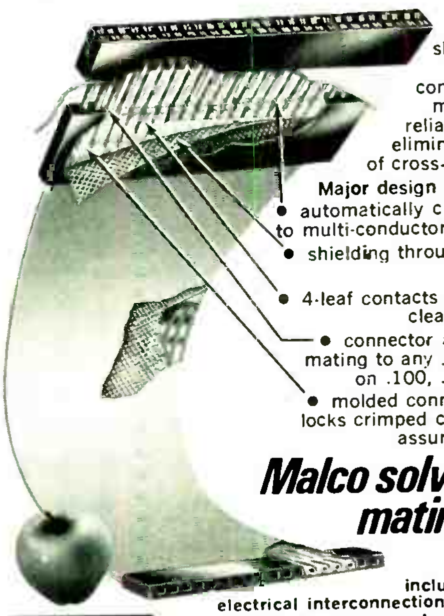

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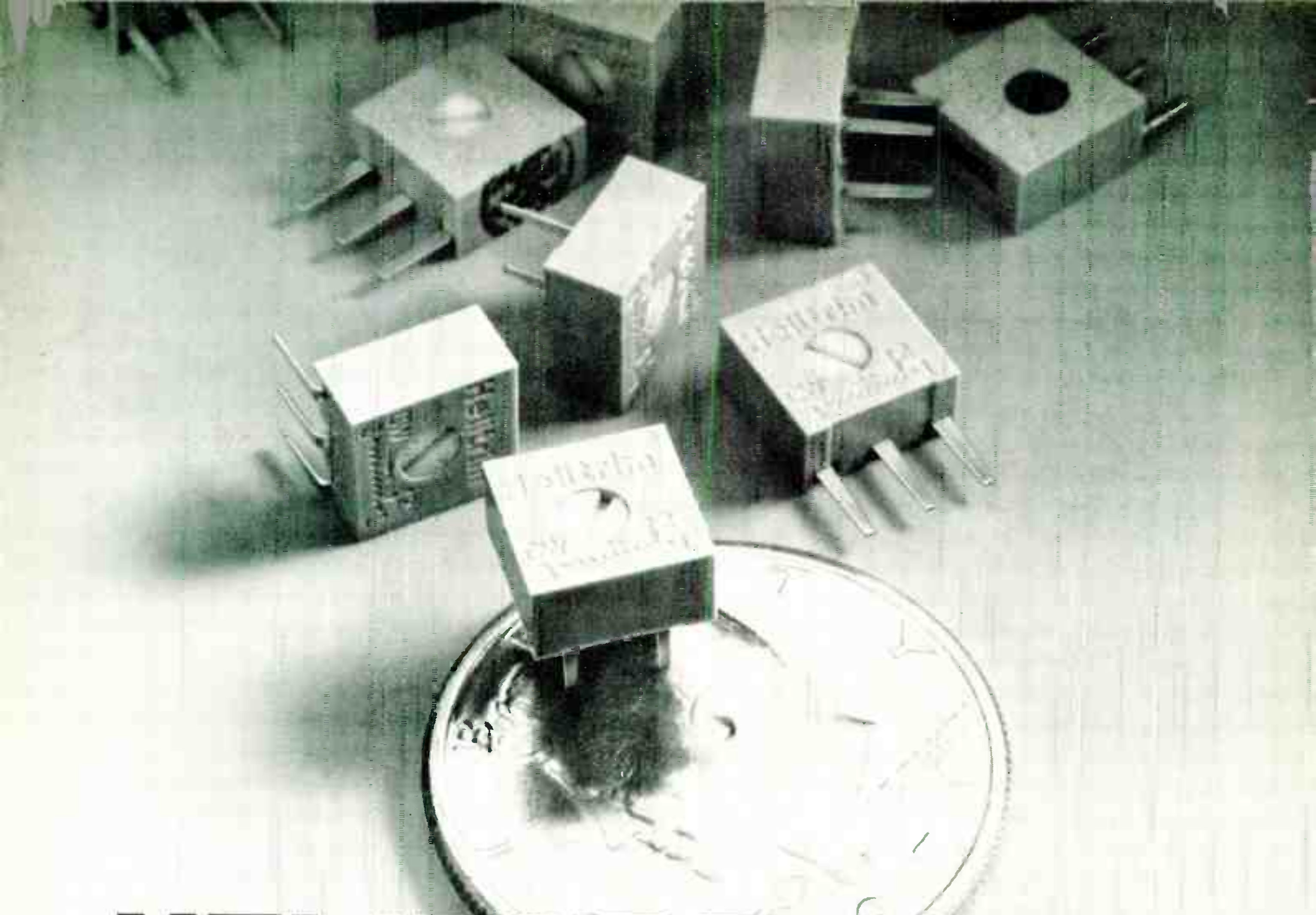

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Industrial electronics

Burn-in control is kept tight

Rack for semiconductors includes heat regulation, fault-detection circuits

Most burn-in racks for semiconductors are one-of-a-kind assemblies put together within a maker's or user's plant. The model LV, made by Wakefield Engineering Inc., is believed to be the first "off-the-shelf" unit, and it includes both temperature control and automatic fault-detection circuits to protect devices under test from damage.

The LV is modular, allowing the user to start small and add capacity as needed. The basic systems start at about $1,775, but even at the low end of the line a system accommodates 40 semiconductors, and it includes a liquid cooled plate holding either 40 or 80 25-watt emitter load resistors and simplified connection to remote test gear.

Contributing to the high reliability of the equipment, company engineers point out, is a combination of control electronics and a heat transfer system that involves no moving parts.

A key part of the Wakefield approach is that the systems are produced in volume—they cost less than the one-of-a-kind rack produced in-house, and are easier to repair. Finally, expansion of a system won't mean varying results from various parts, since the modules are part of a common line.

At the core of the system is a heating method that is derived from a cooling technique. Liquid-vapor cooling is an effective heat-sinking method, and—like running a refrigerator backward—the liquid vapor system can be made to generate heat.

In the model LV, a vacuum-sealed system has an electric heater at its base which generates vapor bubbles that rise through a finely machined pipe and carry the heating liquid along. There's a condenser and a heat exchanger at the top; they bring temperatures back to a preset norm. Temperature is controlled by metering the flow around this loop with a solenoid valve. As measured at the device mounts, which clamp to the pipe, the temperature is stable to within ±0.5°C, according to Wakefield. Temperature range is from 60 to 200° C.

Automatic fault-detection circuits protect both devices and the system itself against overpressure and coolant faults; the user need adjust only for overtemperature protection of his devices. If things get too hot, this control trips circuits that shut down the heater and remote dc power supplies used to test the semiconductors, and it lights lamps that show what went wrong.

Getting to and from the dc power supplies and electronic monitoring gear is simplified by a plugboard behind the hot pipe; the copper or aluminum device mounts—depending on the semiconductor package—come equipped with banana plugs to connect the device under test to remote electronic test gear through the plugboard.

The device holders will accommodate any package from a simple TO-5 to "press-pac" styles for rectifiers, diodes, or silicon-controlled rectifiers.

Wakefield Engineering Inc., Audubon Rd., Wakefield, Mass 01880 [371]

Data information system can also be annunciator

A solid state system called Datalert can be built to operate as an annunciator, a data information system, or a combination of both. When operating as an annunciator, visual displays indicate desired conditions. As a data information system, the visual displays will provide two status indicators for the different functions. Alarm and sequence operation can be quickly changed in the field. An internal plug board allows the user to program each individual input to accept high-threshold logic, open or closed relay or switch contacts, electronic switching devices, or TTL/DTL logic levels. Aero Systems Engineering Inc., 358 East Fillmore Ave., St. Paul, Minn. 55107 [378]

Annunciator displays alarms from up to 999 stations.

A solid state supervisory annunciator, using mostly integrated circuitry, provides visible and audio alarms from up to 999 reporting stations. The Supy 3 series recognizes alarm inputs such as voltage, contact opening, and contact closing. Specifications include 6 V dc power at 2.5 A, one-terminal input connection for each alarm point plus one terminal common to all alarms, and temperature range of 0°C to 60°C. International Electronic Research & Equipment Ltd., 1346 Clifton St., Winnipeg, Manitoba, Canada [376]

Temperature controller offers 0.03°C sensitivity

Direct settability, safety fusing, and solid state design are offered in the model 71A temperature controller. The instrument operates with a thermistor probe serving as one leg of an ac bridge. Control temperature is set as close as 0.01°C over a range of -10° to +120°C on three dials. With optimum probe placement, temperature can be held closer than the ±0.03°C sensitivity

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By JOHN J. COOKE
Senior Vice President & Secretary

zone. Price is $245. Yellow Springs Instrument Co., Box 279, Yellow Springs, Ohio 45387 [374]

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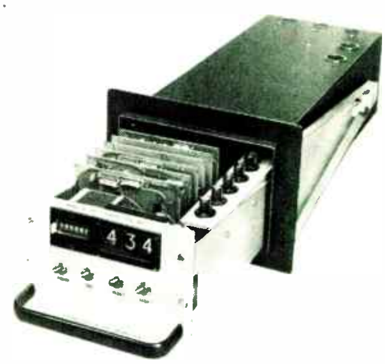

accuracy of 0.025% or better even on short runs, and flowmeter pulses can be calibrated into any desired liquid unit measurement. Other features include a readout of nine digits (six mechanical and three Nixies) and remote start, stop, and reset operation. Price is $795. H-B Industries Inc., 131A Route 36, Port Monmouth, N.J. 07758 [373]

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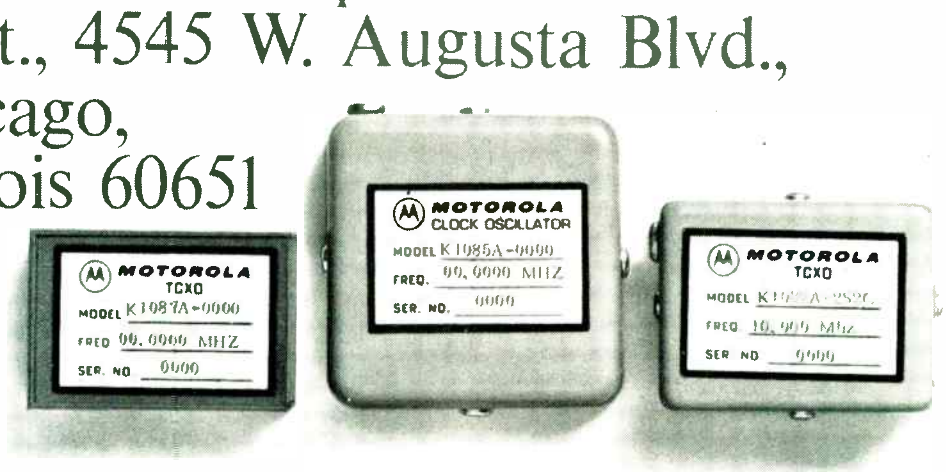


International Newsletter

October 25, 1971

Leningrad show raises hopes of Western companies

Cheered by the tremendous interest in their wares at the Leningrad computer and office equipment show [*Electronics,* International Newsletter, Oct. 11], Western exhibitors feel the Russian market for electronic hardware ranging from big computers to cash registers could run well above $100 million. Over 250,000 Russians visited the booths of 150 firms representing 12 nations, and Ralph R. Stafford, director of Eastern relations for IBM World Corp., calls the overall climate for U.S. business in the Soviet Union "clearly advantageous." The company's sprawling exhibit, which featured a 360/50 computer, was besieged by Russian scientists, planners, and engineers. And though IBM hasn't yet landed a substantial sales contract in the U.S.S.R., Stafford says, "We definitely plan to sell, including, hopefully, the 370 series computer."

A spokesman for Sweda, Litton Industries' Stockholm-based cash register affiliate, says he is "hopeful of getting the Soviets interested in automating retailing operations." And West Germany's Siemens AG says it is already talking to Eastern European groups about sales of its new 4004-150 computer.

Philips develops high-density process for bipolar ICs

The latest entrant into the hotly competitive bipolar IC process derby is Philips Research Laboratories, Eindhoven, the Netherlands. The new Philips technique eliminates the need for resistors on an IC chip, leading to very dense, low-dissipation logic and memory devices. Called Integrated Injection Logic, it uses pn diodes integral with the circuit's bipolar transistors. By using a switching level of only 0.7 volt for the diodes, charge carriers become available which are injected into the transistors; output is automatically limited. The lab has built an experimental IC with 1,100 gates on a chip only 10 mil^2. Power dissipation is less than 1 milliwatt at a clock frequency of 100 kilohertz.

French plan new space venture with Soviet Union . . .

France and the Soviet Union will study the aurora borealis through a new joint space undertaking. The Soviet Union's Intercosmos agency and the French space research agency signed a protocol setting up the experiment but fixing no launch date. France will furnish three spectrometers to detect the charged particles that are typical of the phenomenon; the Russians will mount them into a Cosmos satellite and carry out the launch.

. . . but get runaround on other shots

Meanwhile, French radio astronomers have been unable to get a straight answer out of the Russians on the fate of the Soviet Mars-3 space probe, which has a five-pound French radio receiver aboard. The Russians are more than a month late in the periodic reports they have been supplying the French since the probe was launched May 28. NASA also believes the probe has failed [*Electronics,* Sept. 27, p. 33]. The receiver was part of the French-conceived experiment to study sunbursts.

The French also are wondering what happened to their SRET-1 satellite that they shipped to Russia for launching several months ago. The launch originally was scheduled in June, but the Russians now say they hope to send it up by the end of the year. SRET-1 will test several types of solar batteries.

International Newsletter

Telefunken, Nixdorf near computer pact

A new corporate lineup in West Germany's computer arena is taking on definite shape. Apparently on the lookout for another partner, AEG-Telefunken has turned to Nixdorf Computer AG, and a joint venture between the two firms "could well be agreed upon within the next three to four weeks," a Telefunken spokesman says. The talks involve a jointly owned company for developing, building, and marketing large EDP systems ranging in price up to $3 million. With its 440 machine, Telefunken already has a leg up in large computer development. For Nixdorf, which thus far has concentrated on small and medium-sized systems, the new venture would mean rounding out the company's present equipment lineup.

Mullard, Ford build seat-belt interlock

Mullard Ltd., helped by Ford Motor Co. Ltd., has developed a car seat-belt ignition interlock system. A small piezoelectric ultrasonic transmitter, actuated by a multivibrator, is built into the belt webbing where it passes across the chest: its directional output is picked up by a pillar-mounted receiver. The seat has a switch closed by the occupant's weight. If both circuits are not actuated, a logic box cuts the ignition, except when the car is stationary, or in reverse or the lowest forward gear for servicing and maneuvering. Ford is interested because it thinks that interlocked seat belts, rather than air bags, may eventually become the compulsory safety item for cars in many countries.

German data trials hit 1 million b/s

Data transmissions at a rate of nearly 1 million bits per second—25 times faster than hitherto possible—have been conducted by IBM in West Germany. The transmissions, using pulse code modulation techniques, were carried out over a 3.5-mile stretch of ordinary telephone lines linking two IBM computer centers in Stuttgart. The maximum possible rate under the new system is said to be more than 2 million b/s. The company credits the PCM technique for the system's high speed. The interface between the computer and the telephone line is a prototype unit called the 3971 PCM data set, model 1.

Minicomputers to go on line at Japan's city halls

Many of Japan's 700 city halls soon may be equipped with minicomputers in a tax-billing net. The minis are Matsushita Communication Industrial Co.'s MAAC-7/S modified to operate with an IBM typewriter, a paper tape reader, and a tape punch. Takachiho Koheki Co., Japanese distributor for Burroughs, will add the basic and application software to the minicomputer systems.

Addenda

ITT's Components Group Europe is showing 32.768-kilohertz crystals to European watchmakers for use in electronic timepieces. The company has gotten the quartz crystal into a can only ¾ by $\frac{3}{16}$ by $\frac{3}{16}$ inch, but the watchmakers are pressing for an even smaller package. . . . The Japanese government has approved a cross-licensing pact between Sony and the 3M company of St. Paul, Minn., for video tape recording. It allows Sony to make and sell 3M's high-energy cobalt magnetic tape, while 3M will manufacture and sell Sony's U-Matic video cassette recording system. . . . Britain's Autonomics Ltd. has collapsed, the third such failure this year among British computer service bureaus offering sophisticated EDP services.

Ferranti goes to collector diffusion isolation

British company, evincing faith in bipolar technology, is taking the plunge into commercial CDI products

Britain has three native integrated circuit manufacturers. Plessey Co. has always concentrated on MOS and bothered little with bipolars. GEC Semiconductors Ltd. started off across the board and has now abandoned commercial bipolar activity.

Alone of the three, Ferranti Ltd. still makes DTL and TTL, but company men know that bipolars spell doom unless they can find something to give them an edge in the market. Hence Ferranti researchers have looked into every new technique, including tri-mask, base diffusion isolation, and collector diffusion isolation. CDI, they say now with their hands on their hearts, will give them their breakthrough.

Bell's CDI process [*Electronics*, Aug. 31, 1970, p. 87] cuts the number of masks needed for an ordinary npn IC transistor from between seven and nine to five. This pays off in lower costs and higher yields at the expense of lower breakdown voltage, higher inverse current gain, and higher collector-base and collector-substrate capacitances.

Obstacle. A big snag in Bell's original process was collector-base breakdown at only 3 volts, which limited CDI applications, and so far no U.S. company has picked up the method for commercial devices.

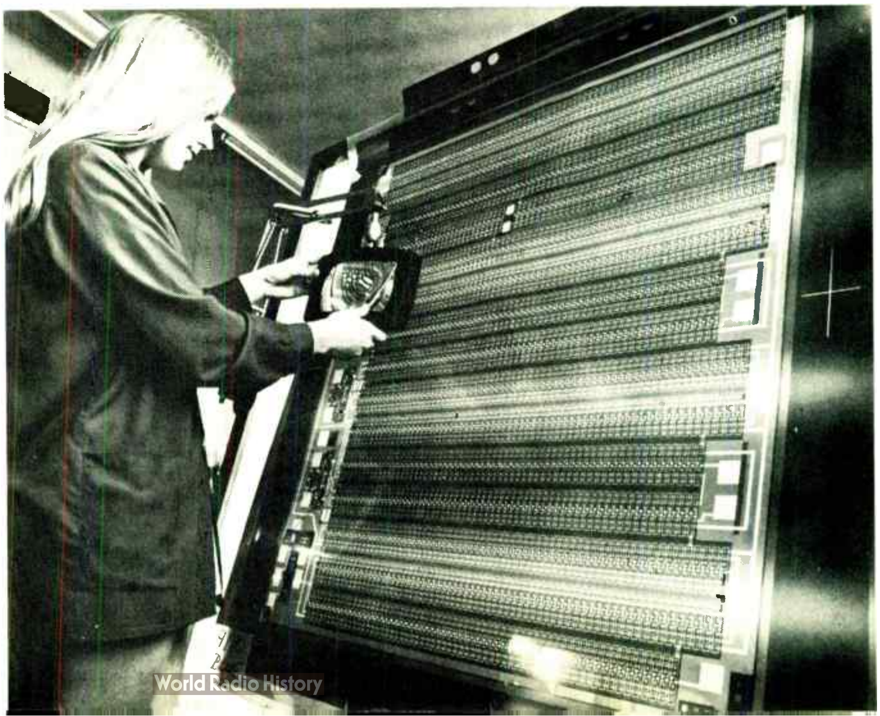
Ferranti men persisted, however, and they claim that their combination of epitaxial layer thickness—1.5 microns—and resistivity characteristics has pushed breakdown up to 7 volts, which means reliable TTL-compatible circuitry can be made.

The process, as far as Ferranti will reveal it, is to diffuse buried n^+ regions into the high-resistivity p substrate to define collector, p resistor isolations, and interconnect crossunders. They then grow a p epitaxial layer to form the base and any p resistors required. Then they diffuse an n^+ isolation ring and collector contacts into the p-layer. Nonselective p diffusion follows to lower the surface resistivity of the epitaxial layer. Finally they diffuse n^- emitters and any low value n resistors required, cut contact windows, and evaporate interconnect pattern.

Having solved, so they hope, the breakdown problem, Ferranti engineers say they are not too worried about the other snags. High inverse current gain—typically 20 along with a normal forward gain of 60—that would be a problem in logic gates using TTL action can be surmounted by using DTL action, says David Grundy, in charge of circuit development. Higher collector-base and collector-substrate capacitances per unit area are cancelled out in practice, he says, because the CDI transistor is smaller than its conventional bipolar equivalent.

Further, Ferranti's work shows that the feedback emitter as originally proposed by the Bell researchers is an effective solution to the problem of minority carrier storage, solved in conventional bipolars by gold doping. The feedback emitter is a second emitter connected back directly to the transistor base. When collector-base saturation occurs, the second emitter behaves like a collector, picking up charge injected by the actual collector and reducing base drive current accordingly.

Blow up. Ferranti, the only big-three British integrated circuit company active in bipolar work, is planning to use collector diffusion isolation in LSI.



In logic applications, Ferranti intends to use CDI only in LSI chips—not in simple or standard gates. Grundy says that in most LSI applications high speed and very low speed/power products are less important than price. Compared with an ordinary bipolar gate the CDI gate is smaller and allows higher packing density.

Costs. On top of this, the process is cheaper and permits higher yields. He thinks that chip costs can be cut enough to knock a significant amount off the price of a packaged circuit. With simple gates, however, the chip cost compared with packaging cost is too small to make any real difference to total cost.

The individual CDI transistor is bigger than an MOS transistor, but Grundy believes that LSI CDI manufacturing costs will be little greater than LSI MOS because more types of functional components are available. That means that CDI functions are simpler to make and, overall, are not bigger than MOS functions. CDI will score against MOS because it needs only a single, low-voltage supply rail as against high-voltage or multiple rails, because it can be combined on the same chip with linear functions— that's where Ferranti expects to make its biggest CDI sales—and because it can be faster and give a better speed/power product than MOS.

Grundy says intended applications include auto-electronics—a fuel injection controller on a single chip containing both digital and analog functions is being designed. Also being eyed are washing machines, analog-to-digital converters, and calculators and watches. In standard products, Ferranti will use CDI only in RAMs and shift registers big enough to justify it.

France

Automation scores a corking success in winemaking

The days when pretty girls from the Bordeaux vineyards squished grapes with their bare feet to make amusing French wines are long gone. Mechanical presses put them out of work decades ago.

Hands off. Automatic refractometer equipment in French winery replaces manual methods of determining grape's sugar content and potential alcohol content.

Now the French wine industry is taking another step into the 20th century, dispensing with guesswork and substituting an optoelectronic instrument to measure the potential alcoholic punch of the grape juice even before it ferments. At stake is money—the price a vintner gets for his grapes.

In about 25 cellars around France this fall, fresh-squeezed juice samples are being pumped through Sopelem automatic refractometers before the juice is bottled or barreled and hauled down into the old, dark caves for aging.

The refractometer measures the sugar content of the growers harvest in 40 seconds and provides a simultaneous visual and printed readout of the results.

This permanent printed record was a must among the characteristics that cellar operators put forth when they asked Sopelem to develop the instrument three years ago. Earlier methods of getting a reading on grape quality by using hand refractometers often ended up in fistfights as growers and buyers could not come to agreement on the exact degree of refraction.

Sopelem's new refractometer, just approved by the French government bureau of standards, can pinpoint the sugar content and from that calculate the probable fermented alcoholic degree on a range of 0 to 18 of alcoholic content. The error factor is claimed to be 0.5%. Nearing the end of the first grape harvest in which the refractometer was widely used, Sopelem says the growers and cellar operators are quite satisfied.

Cashing in. The price a cellar pays for grapes goes up about $1.50 per 100 liters for each degree of potential alcohol content—or per 17.5 grams of sugar. Thus, for a harvest of 10,000 liters, a wine grower's income varies $150 per potential degree of alcohol.

Sopelem feels it has just begun to penetrate the market. France has more than 1,000 cooperative cellars—all of them targets for Sopelem salesmen. The potential export market is only beginning to be explored by the company.

Sopelem, which also makes hand refractometers, admits that the small, portable viewer system was inaccurate. A drop of grape juice—usually extracted from a vat by a workman dunking his finger into the juice and letting a sample drip on the viewing plane—was impure due to its contacts with a person. Moreover, the temperature was not taken into account, sometimes causing serious—and costly—errors in evaluation.

The automatic refractometers solve the temperature problem by using an electronic thermometer which drives a motor to position a transparent grill. The grill is placed in the path of the refracted light beam, which varies according to the index of the color of the grape juice. A photoelectric cell then counts the lines illuminated on the grill, thereby measuring the angle of refraction. The number of lines counted corresponds to the precise color of the juice, indicating the sugar content.

Quality control is maintained by a system of rinsing before and after each sample is taken, to avoid mixing two samples of juice. The four-drawer machine is equipped with a plug to connect a printout device. It also provides an illuminated digital display on both sides of the box so that both operator and grower can see the result.

Great Britain

Evaporation technique cuts night scope size, weight

Light-intensifying night sights are a boon to the military. With the most successful intensifying approach—the fiber-optics-equipped crossover-focused intensifier—three tubes in sequence give a 30,000–40,000 sight gain. But with batteries and casing the complete unit weighs about six pounds, which is a lot of extra heft on a rifle.

Promising techniques for making smaller and lighter sights are channel electron multiplication, and replacing electrostatic focusing in the crossover intensifier with proximity focusing. Channel techniques have a noise problem that still has to be solved and the proximity-focused intensifier tubes made so far cost about $2,000 each—about three times the cost of a crossover intensifier—because manufacturing is complicated.

The problem is that to get adequate resolution by proximity focusing alone the photocathode and the phosphor screen have to be very close together—50 to 80 mils—which rules out ordinary manufacturing methods. In the crossover tube, cathode film evaporation equipment can be inserted between screen glass and cathode glass. What's more, it is far enough away from the cathode glass to lay down an even layer in vacuum after the bulk of the tube has been completed conventionally in atmosphere. This method just can not be applied with close spaced faces.

One way. In the U.S., Bendix has developed a technique in which the cathode is not moved into position until after the active layer—usually made up of antimony and the alkalis potassium, sodium, and cesium—has been laid down. This involves remote handling in vacuum. However, it cuts the length of a 1-inch diameter tube from over 2 in. to about 0.5 in., which more than halves the size and weight of a complete sight.

Now English Electric Valve Co. Ltd., under contract to the Ministry of Defence (Navy), has developed techniques for building up proximity photocathode layers with the glass in situ. John Woolgar, in charge of development, believes this will bring manufacturing costs down to crossover tube levels. EEVC has found a way of putting down antimony onto glass in atmosphere without degrading it, so that the antimony-covered plate can be brought close to the phosphor plate and the tube cold welded in atmosphere.

Vapors. Two holes are left in the periphery leading into the interplate gap, one of which is connected by copper pipe to a vacuum pump. Potassium and cesium vapors generated from heated alkali metal feed in through the other hole. Woolgar says these go down evenly onto the antimony, without using any expensive equipment. However, he can't do it yet with sodium.

Woolgar says the two-alkali tubes are as good as conventionally made tubes, with a sensitivity greater than 100 microamperes per lumen. However, without sodium they have no red response. Woolgar says he won't be terribly worried if he can't develop a sodium deposition process, because a good sight much lighter than present models can be made by mounting two proximity intensifiers in series behind a single crossover intensifier with a green phosphor screen.

In this case, the crossover tube will convert all the red input to green, all of which will be picked up by the proximity tubes, which have good response in green. Absence of a lens means that proximity-tube limiting resolution can never be better than about 70% of crossover resolution. But Woolgar claims this snag is counter-balanced by the absence of distortion because the crossover lens pulls out the picture corners to give a pin-cushion-shaped picture instead of a rectangle.

Japan

Plastic-film analog helps in optical link design

A team at the Research Institute of Electrical Communication, Tohoku University, led by Jun-ichi Nishizawa, is developing thin film optical transmission lines, another indication of the wide interest in optical communications in Japan.

Spatial, or free air, transmission systems using lenses were the earliest method proposed for optical communications. While losses are low, maintenance is a big problem, and work is now centered around glass guide systems. A continuous waveguide is flexible and essentially immune to external influences, and cost is low. Waveguides include glass fibers with continuous variation in index of refraction and rectangular films.

Loss in a glass transmission line is determined by the amount of impurities in the glass. Recently transmission lines with losses as low as 20 decibels per kilometer have been reported. Although much effort has been expended on developing materials with lower losses, a large amount of effort has also been spent on thin film transmission to reduce losses.

Guidelines. These guides consist of a film from several tenths to several hundredths of a wavelength thick. Light propagates along the guide as a surface wave with a large portion of the energy outside the guide—which reduces attenuation. If the guide is made one-sixth of a wavelength thick, the transmission loss falls to one-tenth what it would be if all the energy were to be contained in the guide.

A uniform film guide, though, does not have any convergence in the lateral direction. As the beam travels along the guide it twists and spreads and becomes scattered. The Tohoku team, therefore, is working along the same lines as Bell Laboratories in the U.S., in designing films that are thicker at their center, to constrain the beam to travel along the center.

Glass is undoubtedly the best material for the film. Nishizawa has already proposed a method for making glass films of this type, but it exceeds the present capabilities of his laboratory. Instead experiments are being performed with films of collodion and acrylic plastic dissolved in isoamyl acetate. Uniform films several hundred angstroms to several microns thick are obtained by dropping this liquid on the surface of water, removing it, and then drying it.

Drying out. An aspirator suction pump draws air over the film to dry it uniformly. To obtain the desired thickness distribution, nitrogen is blown on the center of the film to dry the center first, which causes the center of the film to become thicker than the edges. A typical film is 1,500 angstroms thick at the center. For these experiments a film 8 millimeters wide is made, although it should be possible to use a narrower film. Length of the strip is about 50 centimeters.

Using 4% plastic dissolved in isoamyl acetate, the team makes film at a speed of about 1.5 centimeters per second. To prevent dust from entering the film, the fluid is filtered five or six times.

In the experimental 1,500-angstrom film, the light beam spot size is about 50 times the wavelength, showing that the lateral focusing is sufficient. However, by changing the fabricating conditions, it should be possible to achieve an even smaller spot size.

There are several methods of injecting the beam into the film. One method is to focus the beam to a small spot by lenses and inject the beam directly into the end of the film. The injection efficiency is very low, though, because the film is so thin. Thus it was decided to taper the film so that it is several microns thick at the injection end by gradually changing conditions when fabricating.

Although the injected light is almost all scattered where the film is relatively thick, for the portion thinner than about 4,000 angstroms no scattering can be measured. Thus, it appears that if the film does not exceed this thickness, then almost all of the light that enters it is transmitted.

Another injection method is to use a prism to couple the beam to the surface wave. When complete internal reflection is obtained in a prism with a high index of refraction, coupling is obtained between the electromagnetic wave that leaks into the prism-film gap and the surface wave on the film. A type of optical tunneling occurs that excites a magnetic field in the film.

Sweden

Laser ceilometer checks cloud height

As any air traveller knows, the most relaxing part of a trip is definitely not those moments wondering when the plane will break through cloud cover on a landing approach. It's no easier knowing that the pilot and ground personnel are often just as much in the dark.

For some years, air traffic controllers and meterologists have been using a variety of ceilometers, most of which require two units in order to get cloud height by triangulation. Swedish electrical equipment maker ASEA has now developed a single unit laser ceilometer, which is designed for easy set-up and portability.

ASEA came out with its first laser ceilometer, using a ruby laser with 2- to 3-megawatt output, in the late 1960s, having developed it under Swedish military contract. This $15,000 laser unit, designed for meteorological use with a range of up to 3 miles, has been in series production since 1969, and has sold well, with many export orders, including one to the U.S. Air Force.

Solid state design. Now, ASEA has a new model for primary use at airports. Using a gallium arsenide diode laser, it is only about half the weight of the larger model. It has the transmitter and receiver in a single unit, which eliminates the problem of lining up the transmitter and receiver.

The range of the new unit is 65 to 1,600 feet, but ASEA military sales manager Aake Stenow says that they might increase the range to 3,300 feet. The unit is attached to a readout device—which would be in a meteorological office or air traffic control tower—by cable, which can be up to 3 miles long.

Readout is on graph paper. Stenow says that they could get digital readout, but controllers and meteorologists prefer the graph paper to see the configuration of the cloud base.

Accuracy of the unit is ± 16 feet, or 3% whichever is larger. The cloud ceiling is automatically plotted once a minute. ASEA says that even if the transceiver unit—which is built on a tripod base—is not set up perfectly level, reading error is small. For example, if it is off vertical by 10°, the induced error is only 2%.

The unit uses a 25-watt laser. ASEA will give no details of circuitry or components of the unit for proprietary reasons. Series production is just starting, and the units will be priced at $8,000 to $10,000.

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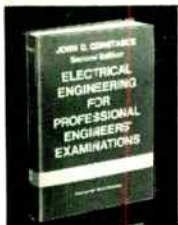

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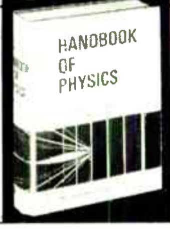

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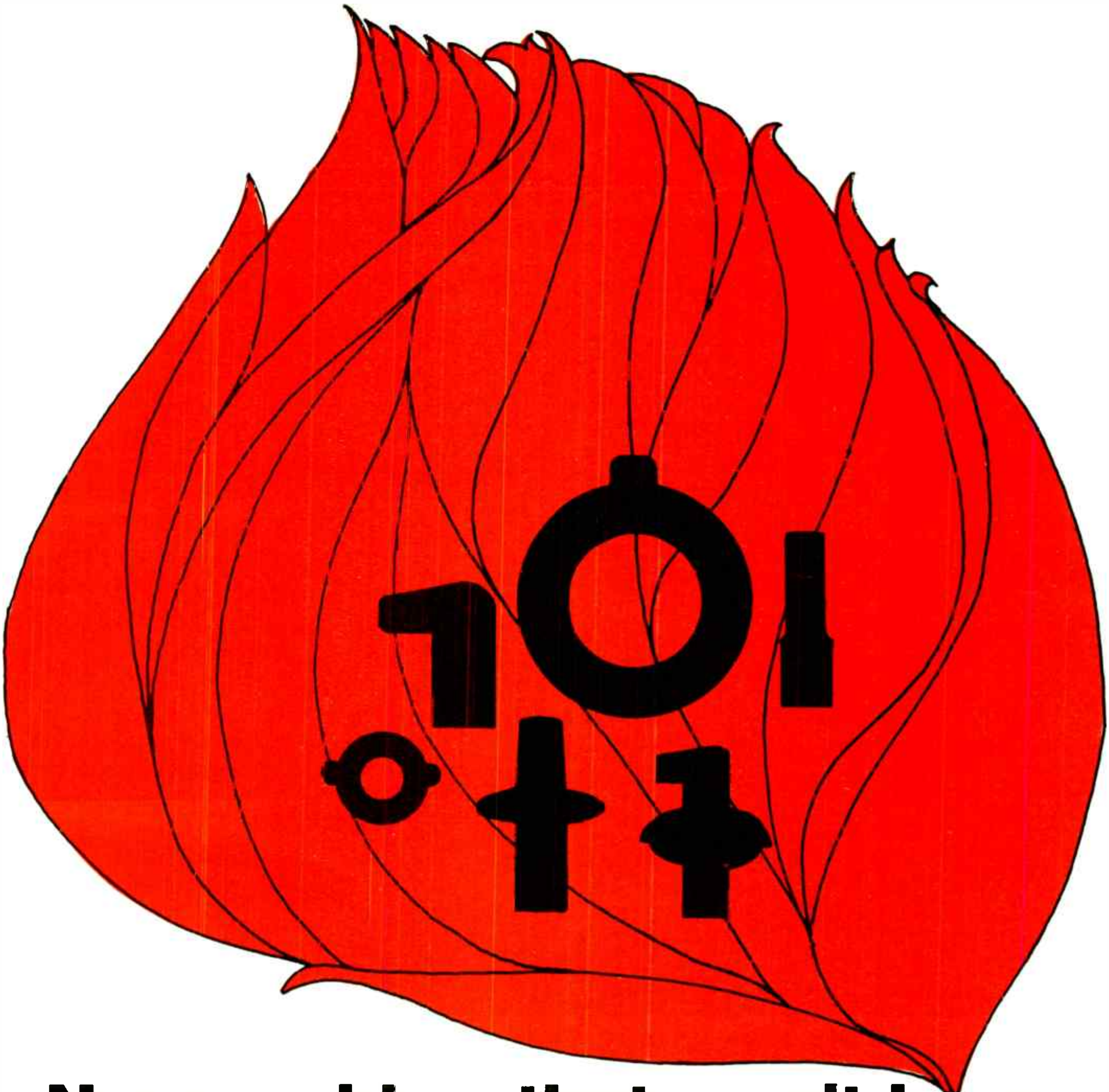

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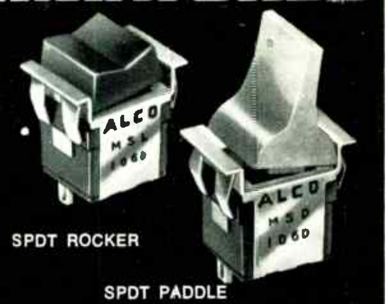

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ILLUMINATED

New brilliance in a miniature rocker featuring front panel lamp replacement. Entire switch simply snaps into .655" x .728" hole. Choice of 3 doublepole switching actions; 4 lens colors & 4 voltages. Replaceable lamp. Rated 6A @ 125 VAC.

ALCOSWITCH® MINIATURE SIZE
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ALCOSWITCH® ALSO AVAILABLE WITH WATERPROOF CASE
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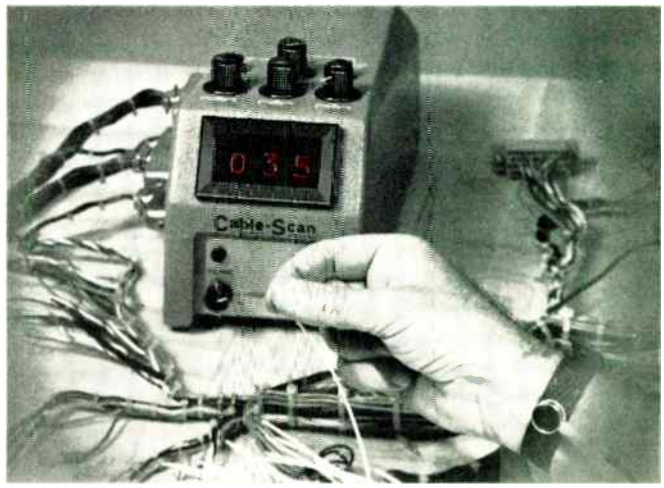

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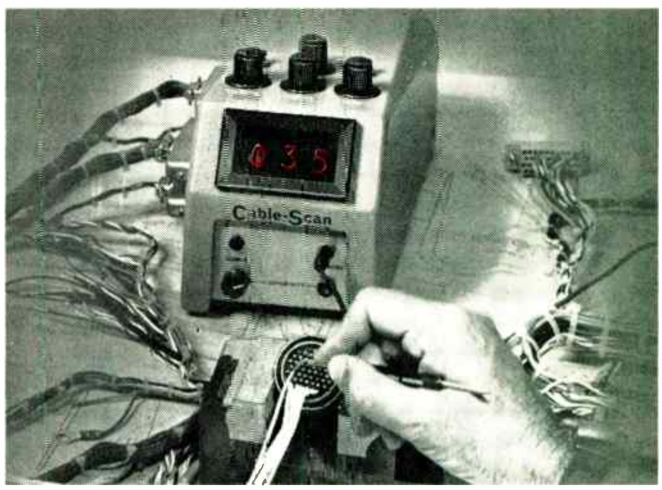

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Cable-Scan Inc.
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October 25, 1971

Electronics

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5	26	47	68	89	110	131	152	173	194	215	236	257	278	299	320	341	362	383	404	425	446	467	488	964
6	27	48	69	90	111	132	153	174	195	216	237	258	279	300	321	342	363	384	405	426	447	468	489	965
7	28	49	70	91	112	133	154	175	196	217	238	259	280	301	322	343	364	385	406	427	448	469	490	966
8	29	50	71	92	113	134	155	176	197	218	239	260	281	302	323	344	365	386	407	428	449	470	491	967
9	30	51	72	93	114	135	156	177	198	219	240	261	282	303	324	345	366	387	408	429	450	471	492	968
10	31	52	73	94	115	136	157	178	199	220	241	262	283	304	325	346	367	388	409	430	451	472	900	969
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12	33	54	75	96	117	138	159	180	201	222	243	264	285	306	327	348	369	390	411	432	453	474	902	971
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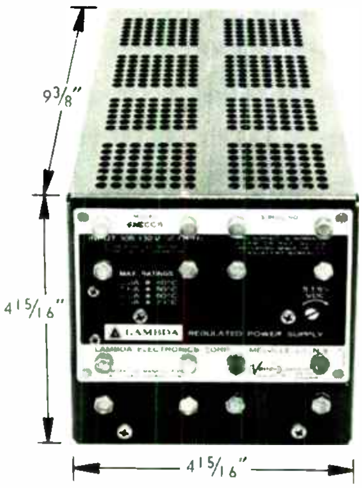

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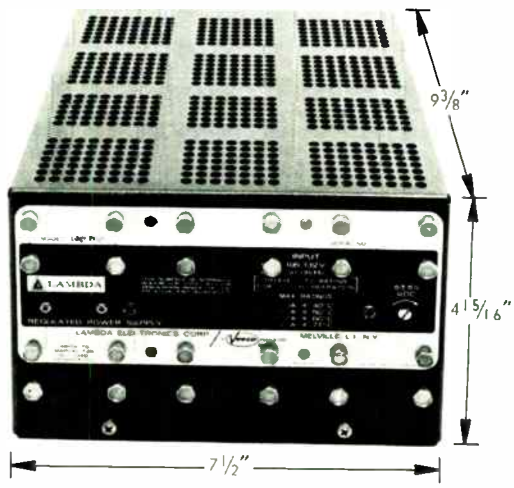

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LXS-CC-20	20 ±5%	7.7	7.2	6.5	4.4	190
LXS-CC-24	24 ±5%	6.8	6.4	5.7	4.4	190
LXS-CC-28	28 ±5%	6.0	5.6	5.0	4.3	190

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REGULATION: 0.1%
RIPPLE: 1.5 mV RMS
5 mV pk-pk

MODEL	FIXED VOLT. RANGE VDC	MAX. AMPS AT AMBIENT OF: 40°C	50°C	60°C	71°C	PRICE
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LXS-D-6	6 ±5%	26.5	23.4	19.8	16.0	235
LXS-D-12	12 ±5%	16.0	14.0	11.9	8.0	235
LXS-D-15	15 ±5%	14.0	12.3	10.4	7.5	235
LXS-D-20	20 ±5%	11.5	10.0	8.6	6.8	235
LXS-D-24	24 ±5%	10.0	8.8	7.5	6.0	235
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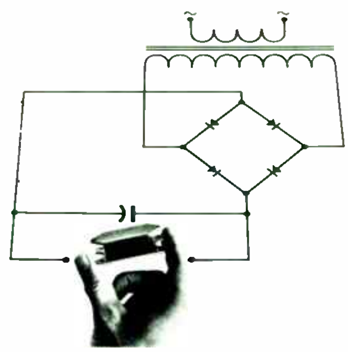

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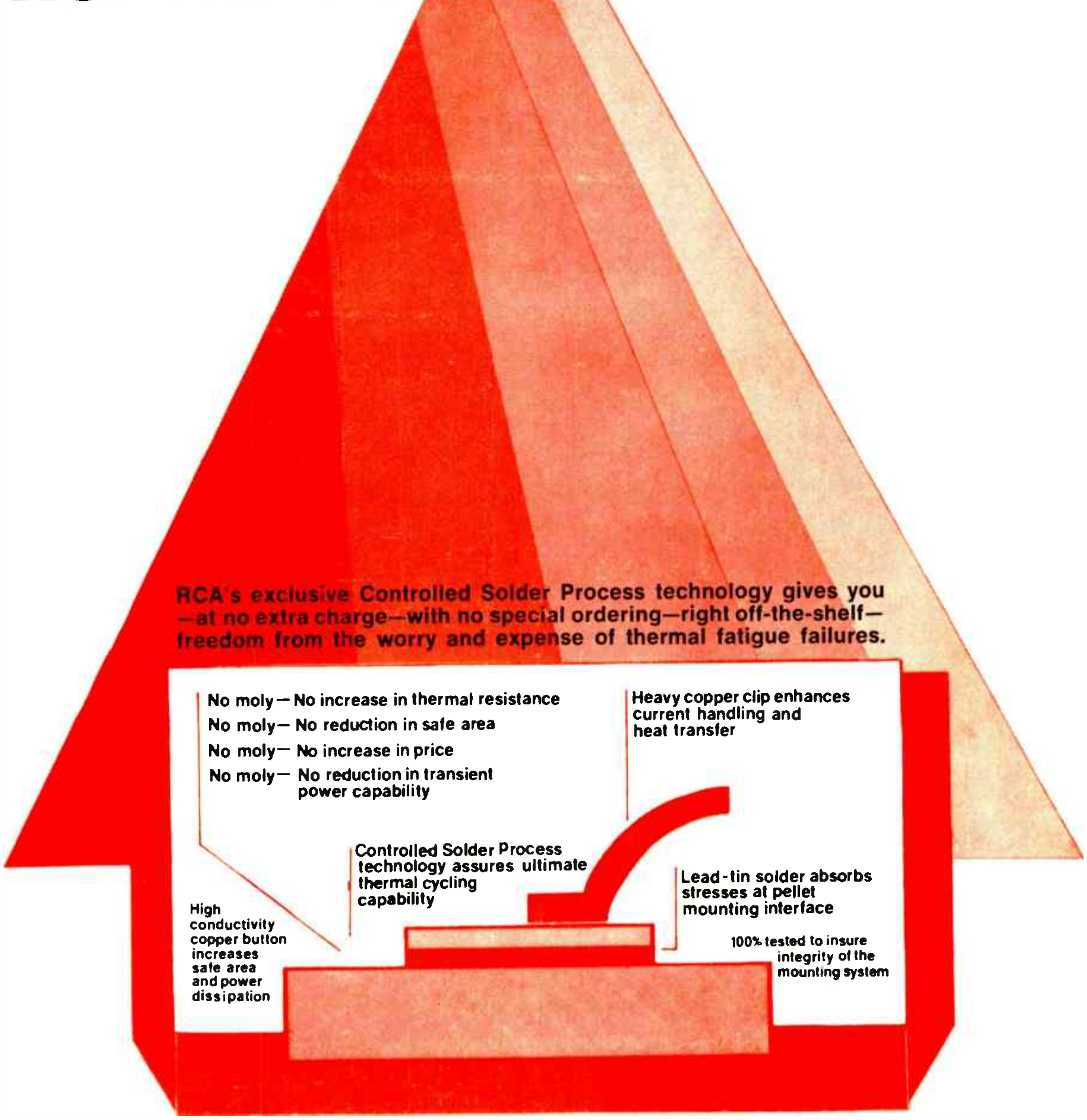

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