Electronics

Eliminating ground-loop errors: page 58
Fast, precise a-d converters: page 69
Air isolation for IC diode arrays: page 75

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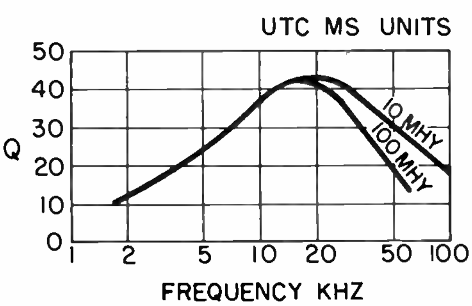

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*The maDC shown is for approximately 5% drop in inductance.

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Electronics

Volume 41, Number 9 April 29, 1968

News Features

Probing the News

Electronics Review

Electronics Abroad

New Products

Technical Articles

I. Design

II. Application

Departments

Electronics: April 29, 1968, Vol. 41, No. 9

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Readers Comment

Hardening isn't easy

To the Editor:

In our article "Skipping the hard part of radiation" [March 4, p. 122] it was intended that the information we presented be restricted initially to the task of selecting the most likely candidates for electronic components that would eventually be used in designing a hardened circuit. Although the technique described can be applied to predictions of circuit behavior, such predictions should by no means be considered as other than preliminary.

We make this point because we do not wish engineers to be misled into believing that we have set down the only requisite for hardening electronics in nuclear radiations.

Joseph T. Finnell
Fred W. Karpowich
Avco Corp.
Wilmington, Mass.

Receiver reinvented

To the Editor:

It looks as though my f-m receiver, using the wide band principle and a counter discriminator ["Mobile f-m broadcast receiver design," May, 1954, p. 130], is being reinvented. However, I hold U.S. Patent 3,018,371 on it.

During the 14 years since the article, my f-m receiver has reappeared, both here and abroad, in a number of guises and in papers that add nothing to my original work. For example, an article by Richard Sanguini [Electronics, May 16, 1966] corresponds to figure 5 of my article.

The most recent reinvention was described in February of this year in a paper delivered by L.L. Kossakowski of ITT Europe at the International Solid State Circuits Conference in Philadelphia. It is no more than what I indicated in figure 6 of my article.

The title I suggested, over a decade ago, was "A new f-m receiver free from multipath distortion." I still believe that title describes my work more accurately

New Bridge Design For Safe, Accurate, Easy Measurement of 'Lytic Capacitors

The Sprague Model 1W7 Capacitance Bridge introduces new, improved technical refinements as well as restyling for added attractiveness and ease of operation. Built *by* capacitor engineers *for* capacitor users, it incorporates the best features of bridges used for many years in Sprague laboratories and production facilities.

Precision Measurements over Entire Range from 0 to 120,000 μF
The capacitance range of the 1W7 Bridge can be extended to 1.2F with an external standard capacitor. The internal generator is a line-driven frequency converter, and detection is obtained from an internal tuned transistor amplifier/null detector, whose sensitivity increases as the balance point is approached. It has provision for 2-terminal, 3-terminal, and 4-terminal capacitance measurements, which are essential for accurate measurement . . . ±([1 + D]% + 10pF) . . . of medium, low, and high capacitance values, respectively.

No Damage to Capacitors
The model 1W7 Capacitance Bridge will not cause degradation or failure in electrolytic or low-voltage ceramic capacitors during test, as is the case in many conventional bridges and test circuits. The 120 Hz a-c voltage, applied to capacitors under test from a built-in source, never exceeds *0.5 volt!* It is usually unnecessary to apply d-c polarizing voltage to electrolytic capacitors because of this safe, low voltage.

Complete Specifications Available
For complete technical data on this precision instrument, write for Engineering Bulletin 90,011 to Technical Literature Service, Sprague Electric Co., 35 Marshall St., North Adams, Mass. 01247.

4SC-8116

New from Sprague!

5 Times the Resistance of a Conventional Metal-Film Resistor of Equal Size!

Type	Wattage Rating	Size	Maximum Resistance
Extended-Range Filmistor Resistor	1/10	.095″ D. .250″ L.	1.5 MΩ
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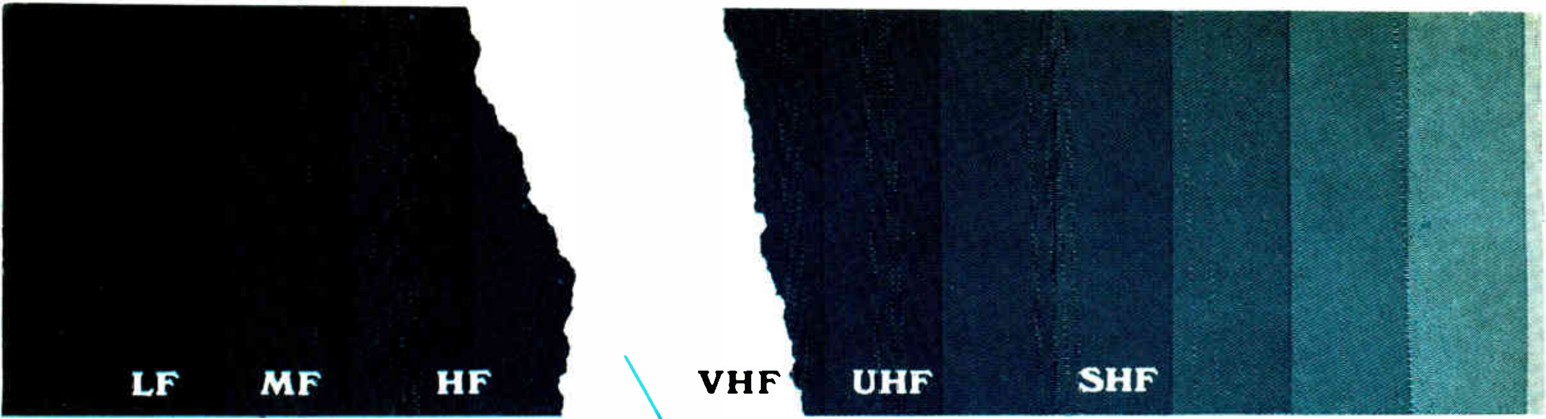

First counters to operate automatically across the VHF gap.

Until now you couldn't make simple, automatic frequency measurements from 100 to 300 MHz without a special VHF plug-in. The extra plug-in was clumsy in the lab. And when switching plug-ins was impossible—as in automatic console systems—the VHF gap was unavoidable. Now two self-contained Systron-Donner counters span the VHF gap, operating automatically from DC to the microwave region.

Non-stop DC to 12.4 GHz. The VHF gap is filled by a built-in prescaler in this new Thin Line counter. The instrument operates just like a simple frequency counter across the board from DC to 12.4 GHz. You merely connect the signal and read the final answer on the display. Built with IC's to take only 1-3/4" of rack space and operable by remote control, it is the ideal instrument for automatic systems.

Non-stop DC to 3 GHz. New ACTO® plug-in with built-in prescaler carries this counter across the VHF gap to 3 GHz with fully-automatic operation. The new broadband plug-in can be replaced by others to raise the frequency range to 40 GHz, to measure very noisy signals, to measure FM and pulsed RF, to read time interval, etc. This is the best available wide-range laboratory counter—the root of a system that can accomplish nearly everything possible with counter instrumentation.

...two more reasons to check with Systron-Donner before you buy.

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888 Galindo Street, Concord, California 94520.

than the title under which the article appeared.

Kerim Onder, M.A.
Fellow, IEE
Senior member, IEEE
New York City

The price isn't right

To the Editor:

The news item [March 4, p. 26] concerning a Post Office Department bid invitation for a new facer-canceler to replace Pitney-Bowes units now in use incorrectly quoted the unit price as $24,000.

The last order for 107 machines was negotiated at $16,500 each, delivered and installed.

F.S. Wardwell
Pitney-Bowes Inc.
Stamford
Conn.

▪ Electronics erred.

Revving up

To the Editor:

In the article, "Motor gives reverse twist to the Intelsat 3 antenna," [April 1, p. 71] the authors say that they have conducted a survey of different motors for this task and have concluded "brushless d-c motors have a higher reliability, but they would need a complex, low-efficiency analog driving circuit to achieve the required beam pointing accuracy."

This seems to indicate that their survey was not complete. This quote would apply to an electronically commutated motor, but not to a scheme which uses inductive elements for the commutation. At Philco-Ford SRS division a despin drive has been developed which uses a brushless d-c motor. This unit is lighter, consumes less power, and the electronic control unit is much less complex than the digital drive described in the article. Furthermore, the brushless d-c motor does not have the starting anomalies associated with a synchronous motor driven in a stepping mode.

Stephen H. Marx
Supervisor, Equipment Design
Philco-Ford Corp.
Palo Alto
Calif.

The authors reply:

We were aware, in our survey, of Philco's work on its d-c motor. However, we felt the stepper motor we selected satisfied our requirements better.

The d-c motor always operates at the peak point on the torque-speed curve. Any load change is then reflected as a speed change which the motor loop must correct for. In Sylvania's digital system, speed remains constant with load change but the antenna steps in phase to correct for the load disturbance.

Power consumption could be less for the d-c motor than for the stepper. But circuit drift with the d-c design becomes more of a problem. And while the Philco motor does not have the same starting anomalies as the stepper, it has another set of design considerations. It must operate first in a speed control mode, then switch over to a position mode. The complexity of the controlling circuitry could be comparable to Sylvania's starting circuitry.

Francis E. Donnelly Jr.
Reynold P. Graunas
John D. Killian
Sylvania Electric Systems
Waltham
Mass.

People

Until a few years ago, ships were designed piecemeal; space for the electronics equipment was near the bottom of a long list of priorities. The Navy is changing that; projects under consideration now undergo the same kind of systems approach as space projects.

Roderick

It's hardly surprising, then, that Litton Industries Inc. turned to a man with spacecraft experience when it needed a new president for its Advanced Marine Technology division. It chose Robert L. Roderick, 43, who has been manager of Hughes Aircraft Co.'s Surveyor project.

The division that Roderick heads works closely with another Litton division, Ingalls Shipbuilding, which is constructing a new yard in Mississippi. "Our function," explains Roderick, "is to get marine contracts, perform the systems engineering, and then turn the design over to Ingalls."

Whole package. Roderick has his hands full with new business. Litton won the contract-definition phase for the Navy's fast-deployment logistics ship, only to see the program cut from the fiscal 1968 defense budget. The fiscal 1969 request, however, contains $186 million for four of the ships.

Litton was also one of three winners in the contract-definition phase for the Navy's landing helicopter assault ship, and it's competing for a development and production contract. And the Advanced Marine Technology division will submit by April 30 its bid for the contract-definition phase for the Navy's new destroyer, designated DX.

Roderick, noting the broad transfer of his systems management experience from Surveyor to his new job, says, "This is valuable, especially in the DX competition, because of it high electronics content. There are 250 tons of electronic hardware in the DX."

The list includes sonars, air-defense missiles, tracking and search

People

radars, and antisubmarine missiles.

"These are all developed items," Roderick explains, "and our job is to pull them all together in the most effective way. We will design the command-and-control system."

Roderick says the Navy is sold on the systems approach, "and I think someone from the aerospace industry is likely to come up with a more imaginative approach than a marine designer, because the idea of going about it as a whole package—engineering and economics—is so new to the marine business."

Motorola thinks its European semiconductor operations have grown up enough to get along without direct supervision by the parent company. "We're ready to cut the cord," says C. Lester Hogan, vice president and general manager of the Semiconductor Products division.


Scalise

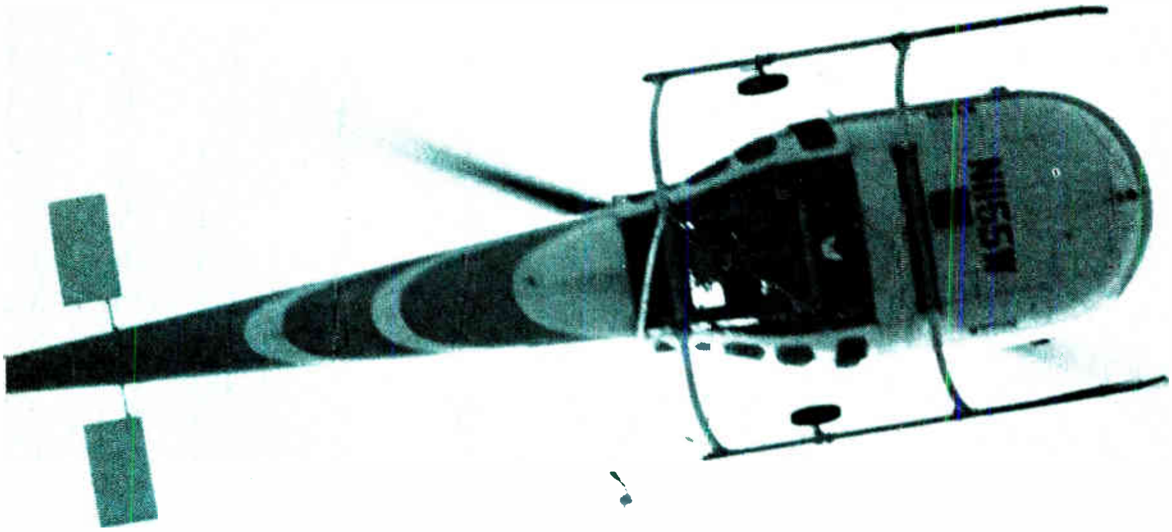
Hogan is turning over direction of all European production and marketing to George M. Scalise, 33, who'll work out of Geneva at first. Backing this move to give European operations more autonomy will be a 60,000-square-foot plant in Toulouse, France, to be dedicated May 1.

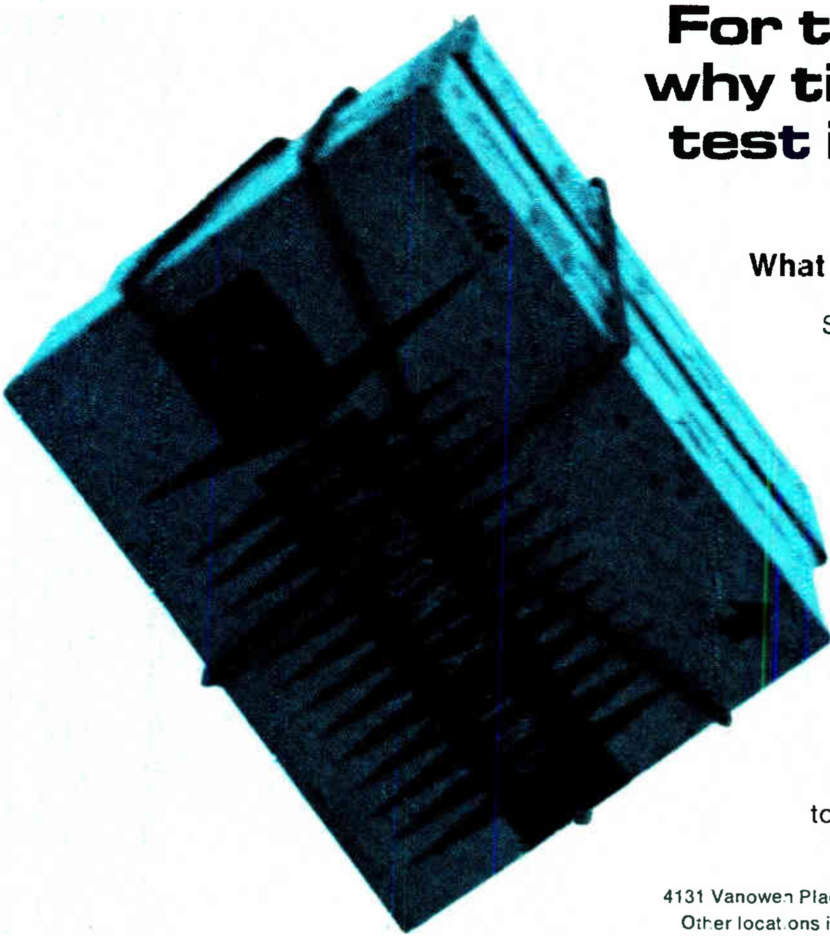
Start-up in June. Scalise says the plant will start assembling silicon transistors and integrated circuits in June. He expects full production —from diffusion to final testing—in 12 to 18 months.

"Our customers will be mainly in the computer and consumer business, and we'll be making the same kind of packages made in Phoenix, including plastics," he says.

Toulouse was chosen as the production site because the University of Toulouse is there and the city is the third largest in France, so it offers a good labor pool.

Scalise, who'll report to Hogan, has held several posts associated with IC production since joining Motorola in 1962. He was manager of manufacturing support operations in Phoenix.





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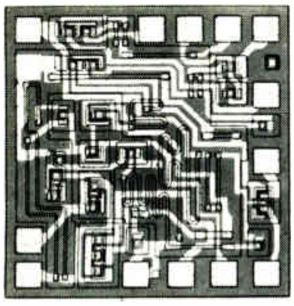


One name keeps cropping up as a source for integrated circuits— regardless of the type you are ordering.

Meetings

Quantum talks will focus on theory

There'll be a shift in emphasis at this year's International Quantum Electronics Conference in Miami, May 14 to 17. Attention will focus more on the theoretical areas, such as nonlinear optics, although there will still be a number of papers on lasers. The change stems from the establishment, last year, of a Conference on Laser Applications and Engineering.

In one session, two research teams working independently will report on methods for calculating with reasonable accuracy nonlinearities in crystals. Their work should aid in the search for materials that interact better with light. One of the papers, by Sudhanshu S. Jha and Nicolaas Bloembergen, both of Harvard University's engineering and applied physics department, will discuss quantitative results from the standpoint of Miller's indexes of crystallography. The other paper, by J. Ducuing and C. Flytzanis of the Institute d'Optique in Orsay, France, will deal with the magnitude of different nonlinearities, presenting experimental data for both harmonic generation and frequency mixing.

Light tuning. Five engineers from the Bell Telephone Laboratories, R. G. Smith, Joseph E. Geusic, Hyman J. Levinstein, Shobha Singh, and Le Grand Van Uitert, will contribute a paper on their work with continuously pumped optical parametric oscillators, work that makes it possible to tune coherent light through the visible spectrum down through the infrared [Electronics, April 15, p. 52].

Another paper on lasers covers work by F. E. Goodwin and T. A. Nussmeier, engineers from Hughes Aircraft Co. Their report will describe the development of a carbon dioxide laser system that beams a tv signal 18 miles [Electronics, April 15, p. 54].

Ali Javan, a physics professor at the Massachusetts Institute of Technology, will discuss phase-locking lasers to lower frequency sources to stabilize absolute frequency measurements in the far infrared.

For more information write R.W. Terhune, Ford Motor Co. Research Laboratories, Dearborn, Mich. 48121

Calendar

Symposium and Equipment Show, American Vacuum Society; Grand Hotel, Anaheim, Calif., **May 1-3.**

Human Factors in Electronics Symposium, IEEE; Marriott Twin Bridges Motor Hotel, Washington, **May 6-7.**

Aerospace Electronics Conference, IEEE; Sheraton-Dayton Hotel, Dayton, Ohio, **May 6-8.**

National Conference on Aerospace Meteorology, American Institute of Aeronautics and Astronautics; New Orleans, **May 6-9.**

Technical Conference and Exhibit, American Society for Quality Control; Sheraton Hotel, Philadelphia, **May 6-8.**

Appliance Technical Conference, IEEE; Columbus-Plaza Sheraton Hotel, Columbus, Ohio, **May 7-8.**

Industry and Communications Power System and Air Conditioning Joint Technical Conference, IEEE; St. Louis Gateway Hotel, St. Louis, Mo., **May 7-10.**

International Technical Communications Conference, Society of Technical Writers and Publishers; International Hotel, International Airport, Los Angeles, **May 8-11.**

Electronic Components Conference, IEEE and Electronic Industries Association; Marriott Twin Bridges Motor Hotel, Washington, **May 8-10.**

Electronic Components Technical Conference, IEEE; Everglades Hotel, Marriott Twin Bridges Motor Hotel, Washington, **May 8-10.**

International Quantum Electronics Conference, IEEE and American Institute of Physics; Everglades Hotel, Miami, Fla., **May 14-17.**

Pattern Recognition: the Retina and the Machine; University of Manitoba, Winnipeg, Canada, **May 15-17.**

(Continued on p. 16)

The CONNECTOR *Thing*

A periodical periodical designed, quite frankly, to further the sales of Microdot connectors and cables. Published entirely in the interests of profit.

Announcing the ~~interruption~~ of an important commercial for an even importanter one.

Our cage door was rattled last week by a harassed engineer type who was sprouting cables and connectors and holding a large sampler that was sloppily stitched with

LOVE FOR SALE

We quoted him section 404.5 of the penal code just to be on the safe side, and invited him in.

He said he was from the cable assembly department. And we said whose? And he said Microdot's. And we said Hmmm. And he said there's a lot of people that don't think of Microdot as a cable assembly house and he'd like to do something about it like write an ad.

So we said fine, what would it be about and he brought out a fat stack of papers and said here, and we said forget it, but if you could tell it to us like it is in about twenty seconds we'd tape it. So he did. And we were so impressed, we thought we'd play it back to you. It's darned interesting. Ready? (And remember, he's not a professional and he talks fast, but we think the points came across.)

TAKE ONE — **LOVE FOR SALE** — SIDE ONE

"Not enough people have thought of Microdot as being in the cable assembly business. But we are, because we make cables and connectors. We're also very experienced in cable assemblies.

"And we'll assemble all sorts of funny combinations. Our cables, somebody else's connectors. Some of our connectors with someone else's. Mix and match."

We turned off the recorder. "You mean we'll assemble competitive stuff?"

"Sure."

"Does the Pres know?"

"Sure."

"Okay."

TAKE TWO — **LOVE FOR SALE** — SIDE ONE

"Where was I. Oh, I was saying

MICRODOT IS IN THE CABLE ASSEMBLY BUSINESS AND AT CUT RATE PRICES.

The idea is we can assemble cables for a lot less than people who try to do it themselves because we know what we're doing.

There are no set-up charges. And we'll even make up one assembly. And we can really save people a lot of money if they use our connectors.

"Another thing, people not only save money, but they can be sure their assemblies will be right. We figure why should they take a chance on their learning curve and build, say thirty assemblies, and have ten maybe turn out not so hot? Our way you order thirty, you get thirty that work."

"You're running out of time."

"Okay. Real quick. *Hey out there. Why buy connectors one place, cable another, and assembly in a third? The cost in paper work alone would drive your comptroller grayish. With us it's one P.O. One big savings. We've cut costs on cable assemblies not the performance just the cost. How's that?"*

END OF TAPE

"Okay," we said, "but you didn't explain the Love for Sale bit. It was a sneaky way to get us interested in your pitch."

"Oh, it truly is love for sale. We love our work."

A guy with dedicated humor that crumby can't be all bad. We told him we'd see what we could do about spreading the word. So, to test if anyone is interested in low cost cable assemblies, we're running this microminiaturized RFQ. The whole idea seems to be worthy. If you agree, write in. We'll respond immediately.

MICRODOT INC.

MICROMIN RFQ FOR FAST FAST ACTION.
To Microdot Inc., 220 Pasadena Ave., So. Pasadena, Calif. 91030

Dear Pricecutters:

Please accept this abbreviated form as a gauntlet flang at you as a challenge, challenging your low, low assembly price claim.

☐ Job to quote on, attached.

☐ We have something in mind. You should get in touch.

Name ____________________

Company ____________________

Title ____________ Phone ____________

Address ____________________

City ____________________

State ____________ Zip ____________

Meetings

(Continued from p. 14)

Meeting of the Society of Automotive Engineers Committee on Electromagnetic Compatibility; Stardust Hotel, Las Vegas, **May 15-17.**

Pulp and Paper Industry Technical Conference, IEEE; Pfister Hotel, Milwaukee, **May 15-17.**

Symposium of the Association for Computing Machinery, National Bureau of Standards; Gaithersburg, Md. **May 16.**

Pollution Control Symposium, Analysis Instrumentation Division of the Instrument Society of America; Marriott Motor Hotel, Philadelphia, **May 19-22.**

Region 6 Conference, IEEE; Sheraton Motor Inn, Portland, Ore., **May 20-22.**

International Microwave Symposium, IEEE; Howard Johnson Motor Lodge, Detroit, **May 20-22.**

Short Courses

Selected applications of computers in engineering, University of Michigan, Ann Arbor, **May 20-31; $350 fee.**

Medical engineering, George Washington University's School of Engineering and Applied Science, Washington, **June 3-7;** $250 fee.

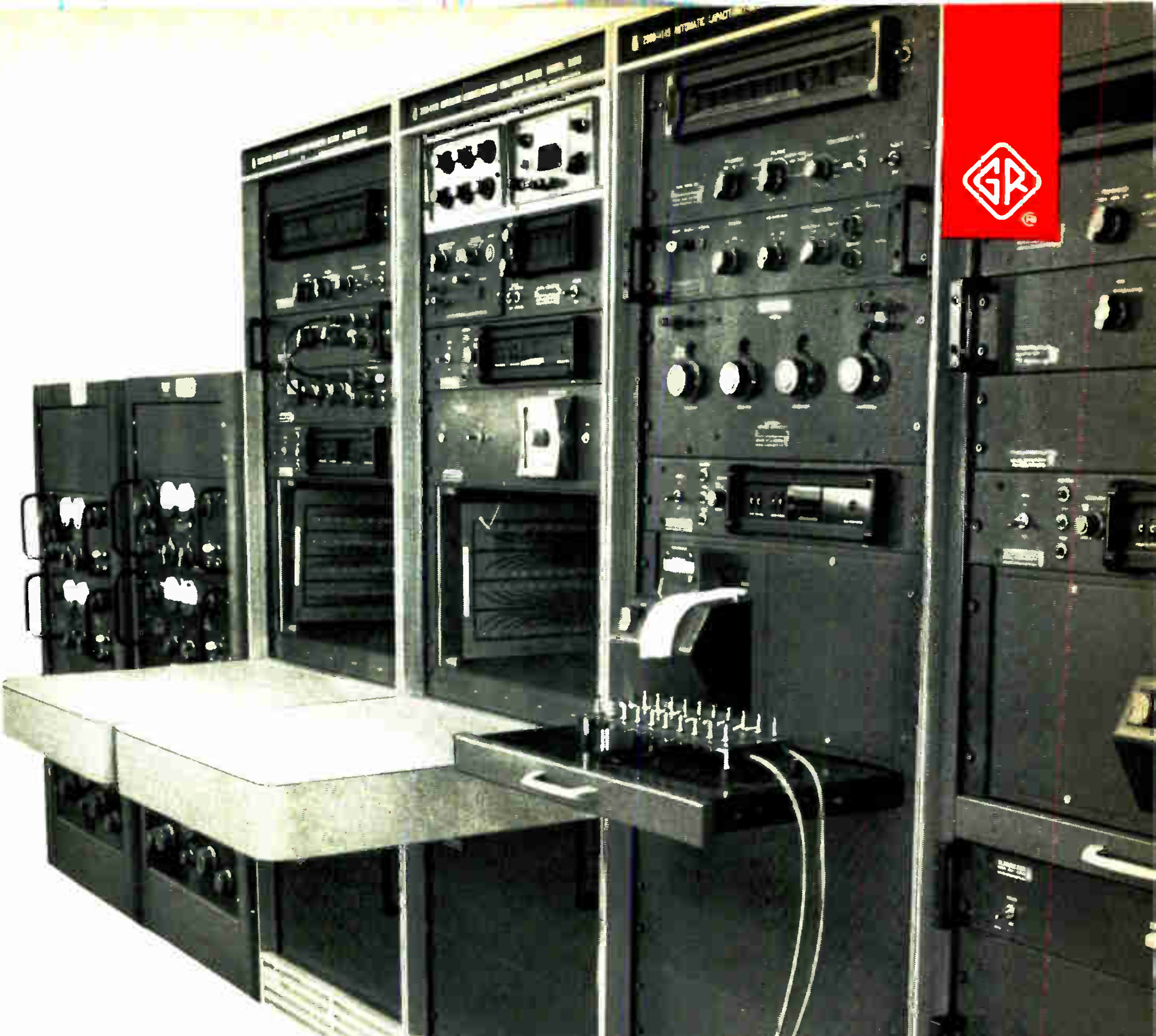
Structure of programing languages, Cornell University, Ithaca, N.Y., **June 4-8; $150 fee.**

Call for papers

International Antennas and Propagation Symposium, IEEE; Northeastern University, Boston, Sept. 9-11. **June 21** is deadline for submission of abstracts to Leon J. Ricardi, MIT, Lincoln Laboratory, P.O. Box 73, Lexington, Mass. 02173

U.S. National Committee Fall Meeting, International Scientific Radio Union; Northeastern University, Boston, Sept. 10-12. **June 1** is deadline for submission of abstracts to Leon J. Ricardi, MIT, Lincoln Laboratory, P.O. Box 73, Lexington, Mass. 02173

Applied Superconductivity Conference and Exhibition, Oak Ridge National Laboratory; IEEE and the American Physical Society; Gatlinburg, Tenn., Oct. 28-30. **Aug. 5** is deadline for submission of abstracts to W.F. Gauster, Oak Ridge National Laboratory, Building 9201-2, P.O. Box Y, Oak Ridge, Tenn. 37830



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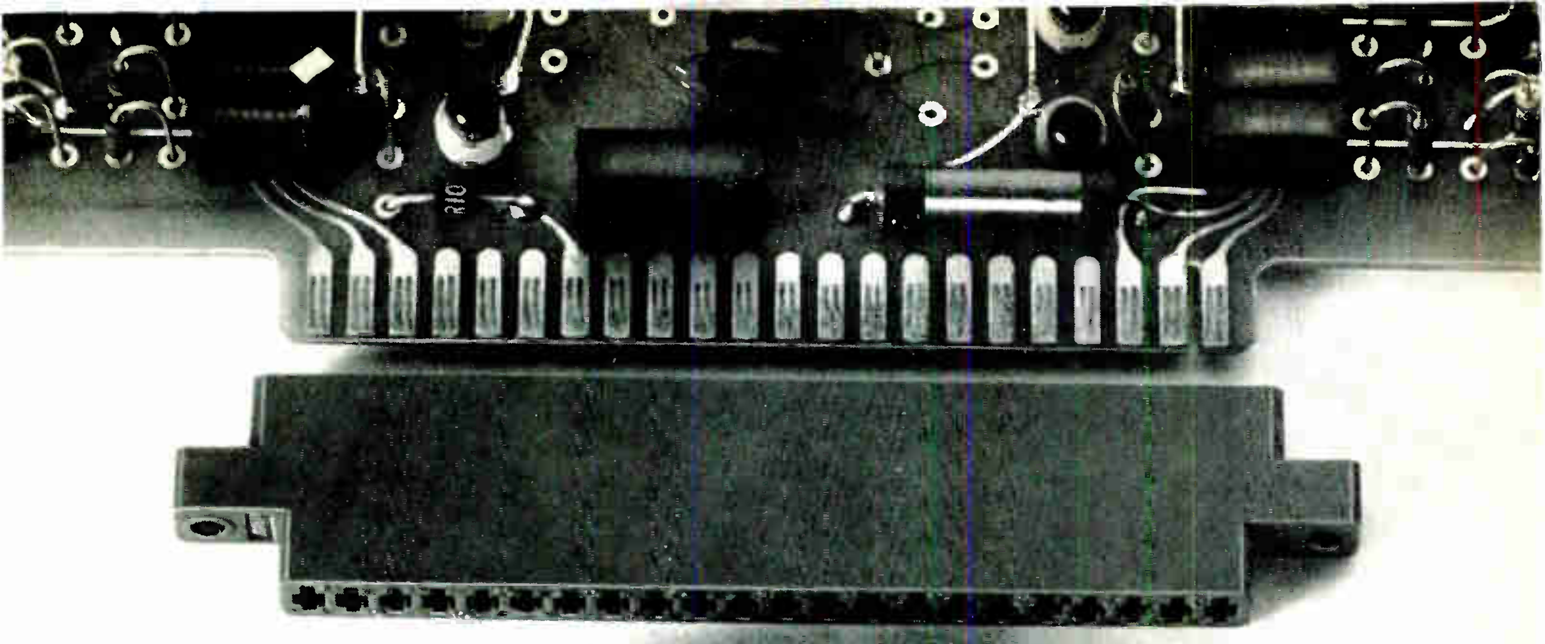

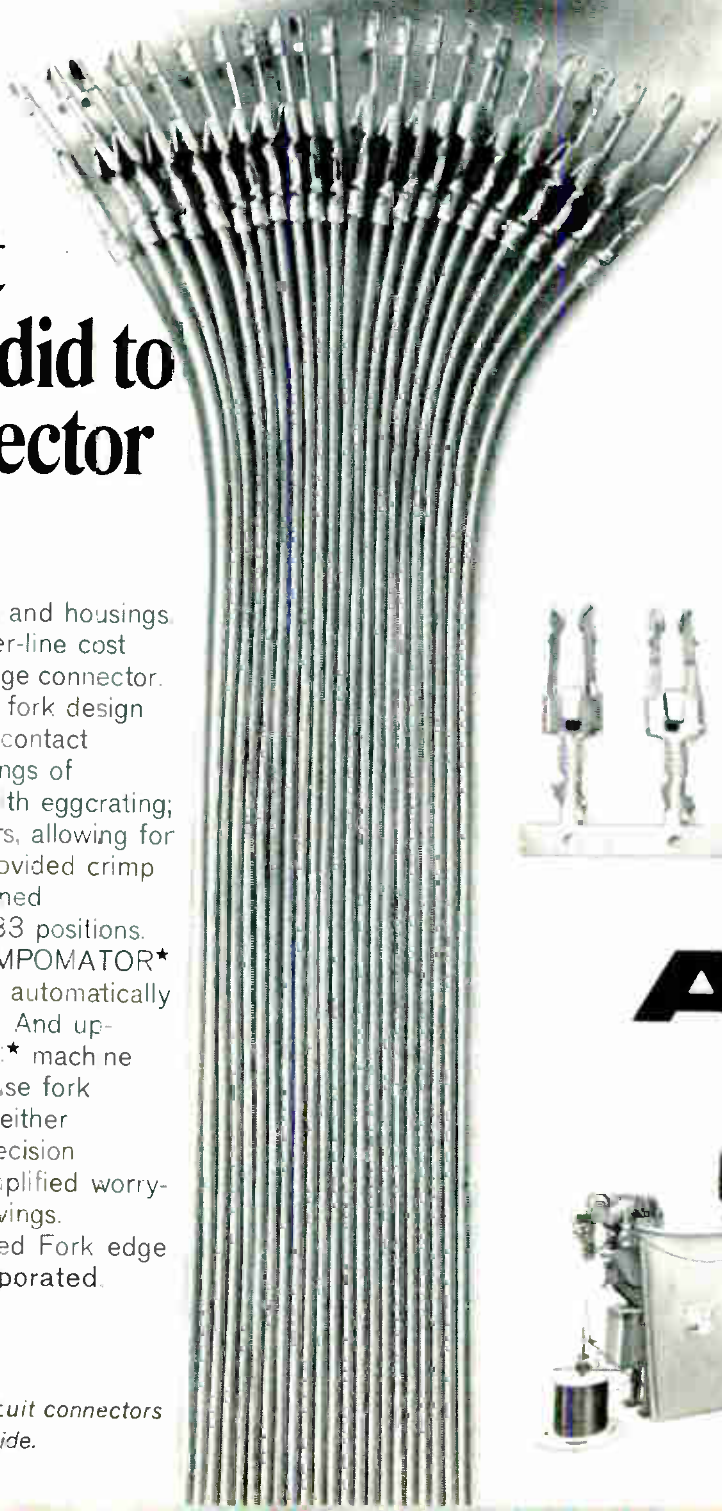

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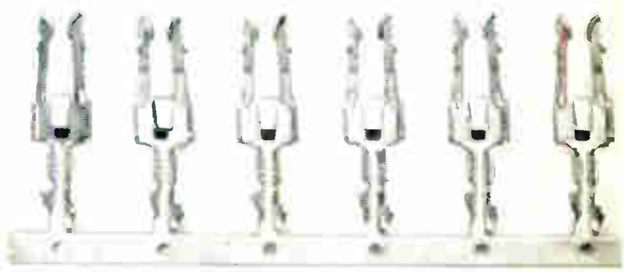

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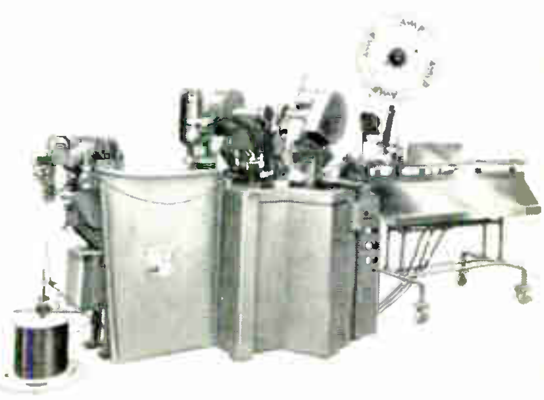

Editorial comment

McNamara's parting shot is almost on target

War is hell but, happily, wars do come to an end. In contrast, the Defense Department's battle with its countless suppliers goes on forever.

The electronics industry opened a new front recently with its criticism of the department's procurement procedures [March 4, p. 23]. Not only is that conflict continuing, it may have been exacerbated by Robert S. McNamara's parting shot—a memo to his staff in which he expressed his satisfaction with DOD procurement policies. True, he had misgivings about the way they were being applied, and urged his staff, in a number of specific recommendations, to assure that "fair and equitable practices cover the buyer-seller relationship."

But McNamara issued his memorandum almost at the moment he was leaving his post as Secretary of Defense and the electronics industry's suspicion that he waited too long may be justified.

Because of growing dissatisfaction by contractors, McNamara had assigned Thomas Morris, assistant secretary of defense, to sound out the views of executives at major defense companies on DOD practices and policies. Moreover, the defense agency had been keeping its ear to the ground for feedback from discontented suppliers. McNamara's memorandum, while defending his policies, notes the criticisms and seeks to answer them.

Morris reported nearly universal support for the procurement reforms (such as extensive use of incentive and fixed-price contracts and the use of weighted guidelines in profit negotiations), made during McNamara's administration. But he noted growing concern by contractors that the reforms, improperly applied, might cause them to assume "undue financial risk and cost penalties."

Replying to the charge of improper cost sharing, McNamara said he wanted to be sure that research and development performed for DOD at its direction is not subsidized by industry.

A frequent complaint of contractors concerns the careless dissemination of proprietary technical information among competitive bidders during the contract-definition stage. On that score, McNamara insisted that the department must ensure the integrity of its procedures "to preclude the transfer of one contractor's competitive advantage to another, thus reducing the eventual competition to a price basis only." Otherwise, he said, it will penalize the most efficient contractors and discourage their continued interest in doing business with the Government.

Other companies complained that sometimes work will be requested but contracts aren't written to cover it. McNamara called for a halt to the practice, and recommended that when inadequate contractual arrangements result in an increase or decrease in the contractor's cost, the Defense Department must provide "equitable adjustments in a timely manner."

Contractors have been particularly vocal when they have been required to accept firm, fixed-price contracts in areas where many development and production uncertainties exist. Calling for good judgment in the choice of contracts, McNamara said the emphasis on the higher-risk-type contracts should not be construed as a mandate for their use in inappropriate situations.

Often when contractors propose value engineering changes, they are mulled over for months at a time. Some are never acted upon, but others are made as normal engineering changes and the contractor does not benefit as he would if they were handled as value engineering changes. McNamara said those practices must cease, since they tend to deny the Government the benefit of good cost saving ideas.

The weighted guidelines are favored by many contractors, but criticism arises when the guidelines are manipulated to support a preconceived rate of profit. McNamara agrees that the guidelines are intended to "offer profit opportunity to conform with the degree of risk the contractor is called upon to assume."

The use of competitive and fixed-price contracts and the high degree of capital investment was designed by the defense agency to reduce the degree of contract supervision needed. But it doesn't always work that way. In some cases more government personnel are involved in administering contracts than during the era of cost-plus-fixed-fee contracting.

We applaud the ex-Secretary's admonitions that Pentagon personnel exercise careful judgment in applying existing policies. We hope that Secretary Clark Clifford will continue where McNamara left off. Without implementation, McNamara's memo will be no more than an admission that there is much room for improvement in the Defense Department's relationship with its suppliers.

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INDIANA GENERAL

Making Magnetics Work

Electronics Newsletter

April 29, 1968

Autonetics tickets Phillips for LSI job

The new assistant to the president at Autonetics—and **undoubtedly the man who will run the firm's large-scale integration facility when it swings into production later this year—is Alvin Phillips,** often referred to as the father of Sylvania Semiconductor's SUHL line of transistor-transistor-logic IC's. Phillips joined Autonetics April 22 as S.F. Eyestone's assistant after serving as general manager of Sylvania's integrated-circuit operation.

Autonetics, a division of North American Rockwell, has **often used the post of president's assistant to familiarize new executives with the company before assigning them more descriptive titles and more specific jobs.** C.F. O'Donnell, Autonetics' senior vice president for research and engineering, says Phillips has a solid background in engineering, production, and marketing—the kind of experience needed to convert the firm's engineer-dominated MOS microelectronics laboratory into a profitable production operation.

Relabeling IC chips saves face abroad

A big part of the growing business in unpackaged integrated-circuit chips [Electronics, April 15, p. 47] is the sale of IC's to British and Continental semiconductor makers for relabeling. These companies, lagging behind American technology in this field and pressed with demands for IC's from their customers, **are quietly buying diced circuits and whole wafers, packaging them, and putting on their own labels. And U. S. suppliers are going along with the face-saving subterfuge.**

Insiders guess that this relabeling business accounts for as much as 20% of the $15 million market for unpackaged chips. **And they expect this ratio to grow as U. S. firms develop more advanced transistor-transistor-logic and linear circuits.** Some smaller U. S. makers, especially those that are second sources, are also buying unpackaged chips for relabeling.

Litton computer to use wafers

In what may be a major step toward LSI computer design, Litton Industries' Guidance and Control Systems division is developing **a model of a navigation computer that would employ unpackaged 1½-inch-diameter semiconductor wafers containing 70,000 MOS transistors each.**

A block-oriented computer, the unit will be a parallel multiprocessor; each wafer will contain up to 36 arithmetic units and a central processor. Although the computer is still in the early design stage, Alden Stevenson, the division's vice president, says **the wafers may have contact pads around their perimeters to which bonds could be attached.** Epoxy may be used to encapsulate entire trays of wafers. The memory will also consist of MOS wafers.

Litton is developing the computer under a contract from the Avionics Laboratory at Wright-Patterson Air Force Base.

Beam-lead bipolars ordered for Mark 2

Autonetics is buying beam-lead integrated circuits for the Air Force F-111A's Mark 2 avionics system. The firm has ordered $285,000 of diode-transistor and transistor-transistor IC's, plus some beam-lead discrete transistors, from Raytheon's semiconductor operation in Mountain View, Calif. **This is believed to be the first major production order outside the**

Bell System for beam-lead devices. The devices will be furnished in chip form to Autonetics and will replace other bipoplar IC's Raytheon has been suppying for the program. The devices will probably go into hybrid circuits.

Fairchild won't be TTL second source

Despite the lure of a quick buck, Fairchild Semiconductor still declines to become an alternate supplier of transistor-transistor-logic digital IC's. **Fairchild apparently decided that it can make money with its TTL design and that its major production problems will be cleared up by year's end.**

Economic pressure has been building up in the company—after a year of belt-tightening—to copy Texas Instruments' 54/74 and Sylvania's SUHL series. But Fairchild claims that becoming a second source would ruin its image as an innovator. It has made a few SUHL and 54/74 chips on one or two occasions, though.

A Fairchild marketing spokesman conceded the risk in refusing to follow TI and Sylvania, **but said the TTL battle will be resolved not with the IC's available but with medium-scale and large-scale IC's.**

LTV gets contract to study solid state switching in planes

The Air Force and Navy are moving closer to a solid state system for handling all signal and power switching in aircraft. LTV Aerospace, which since 1960 has been investigating the feasibility of substituting semiconductor switching systems for present electromechanical techniques, has received an Air Force contract to design, fabricate, and evaluate a complete system for the A-7 attack plane. The firm earlier worked out a systems concept and developed hardware specifications under a Navy grant.

In the solid state approach, signal—or control—switching is kept separate from power switching to minimize the number of operations at the power level. **Information flows directly from source to the control logic, and power flows from its source—or electric bus—through a single device directly to the load.** This setup thus requires fewer and thinner wires than does an electromechanical arrangement, and permits the design of a system from three basic types of modules: signal sources, control logic, and power controllers.

LTV believes the solid state system will be five times as reliable as conventional switching. Weight of the distribution system could be 30% less, the firm adds, and the modular packaging could ease maintenance by as much as 40%.

Honeywell will sell rival's transducers

Instrumentation firms usually shy away from intercompany marketing arrangements. But on June 1, **Statham Instruments and the Test Instrument division of Honeywell will break tradition with an agreement under which Honeywell will market a line of industrial transducers designed and built by Statham.**

The pact will open an immediate market for Honeywell's test equipment, which can be used with Statham sensors to measure such things as pressure, load, weight, displacement, and acceleration.

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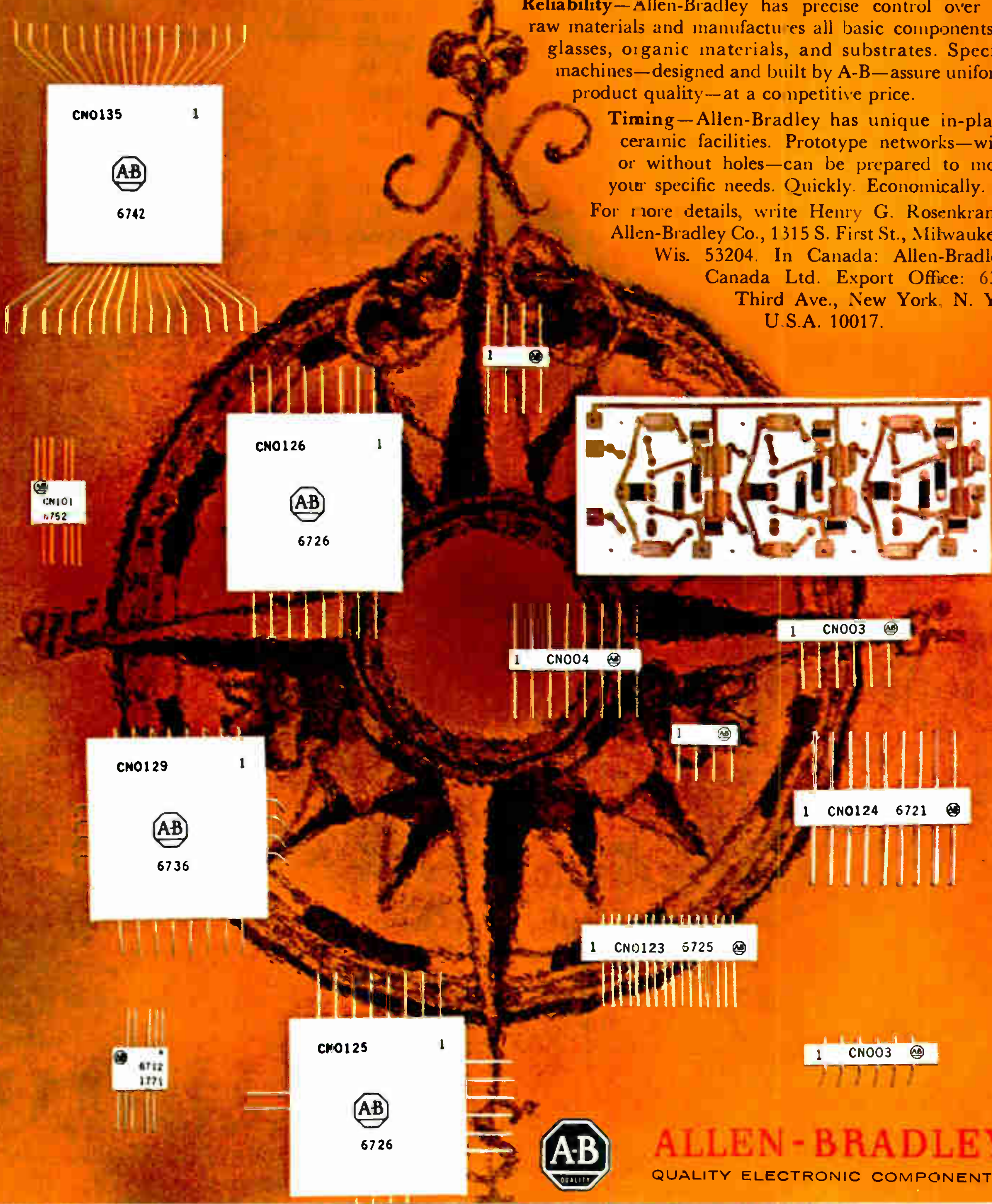

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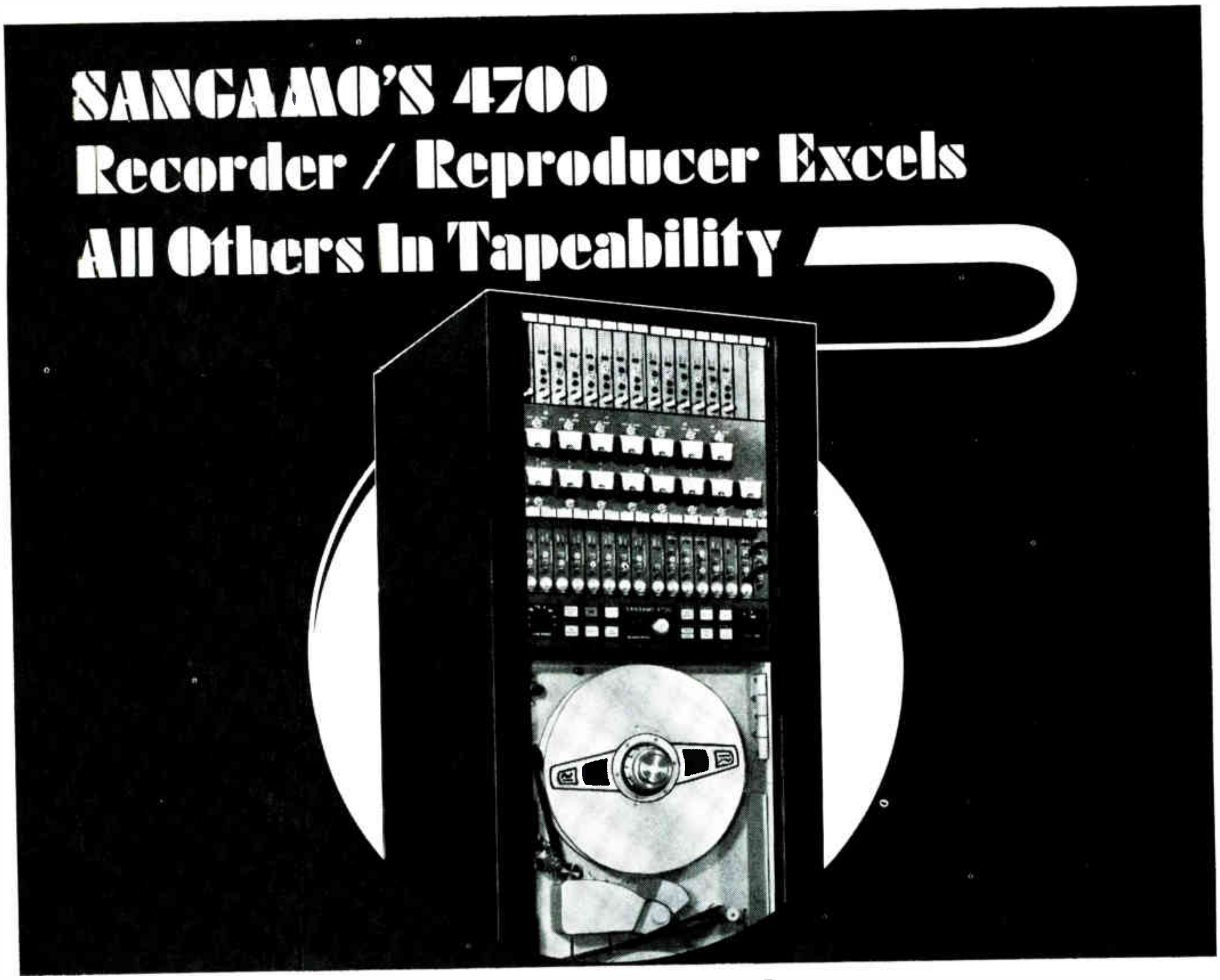

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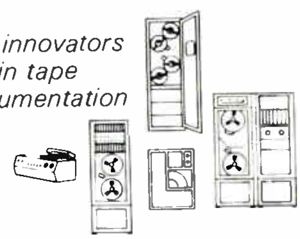

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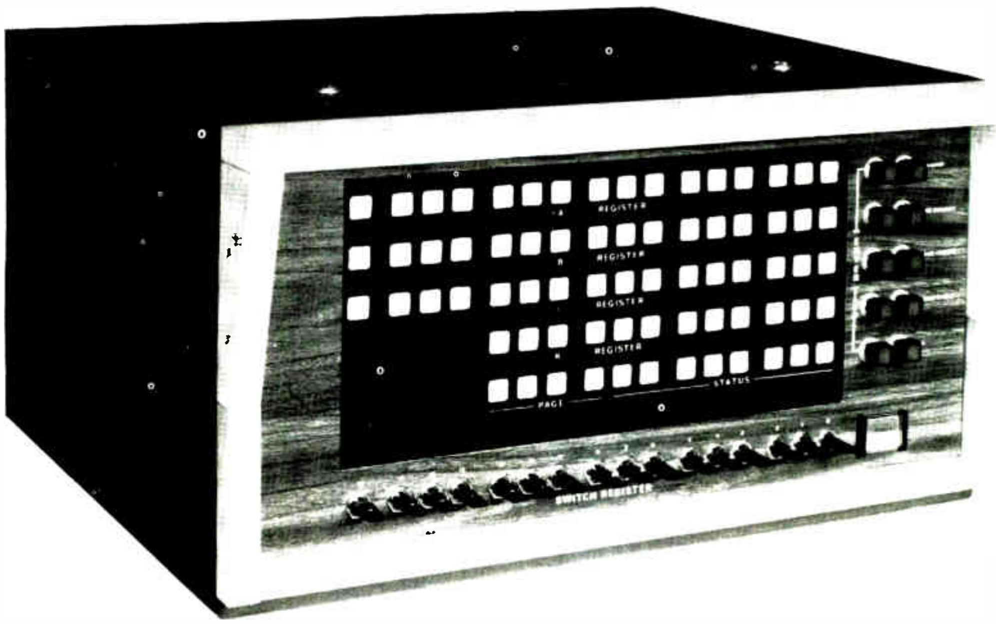

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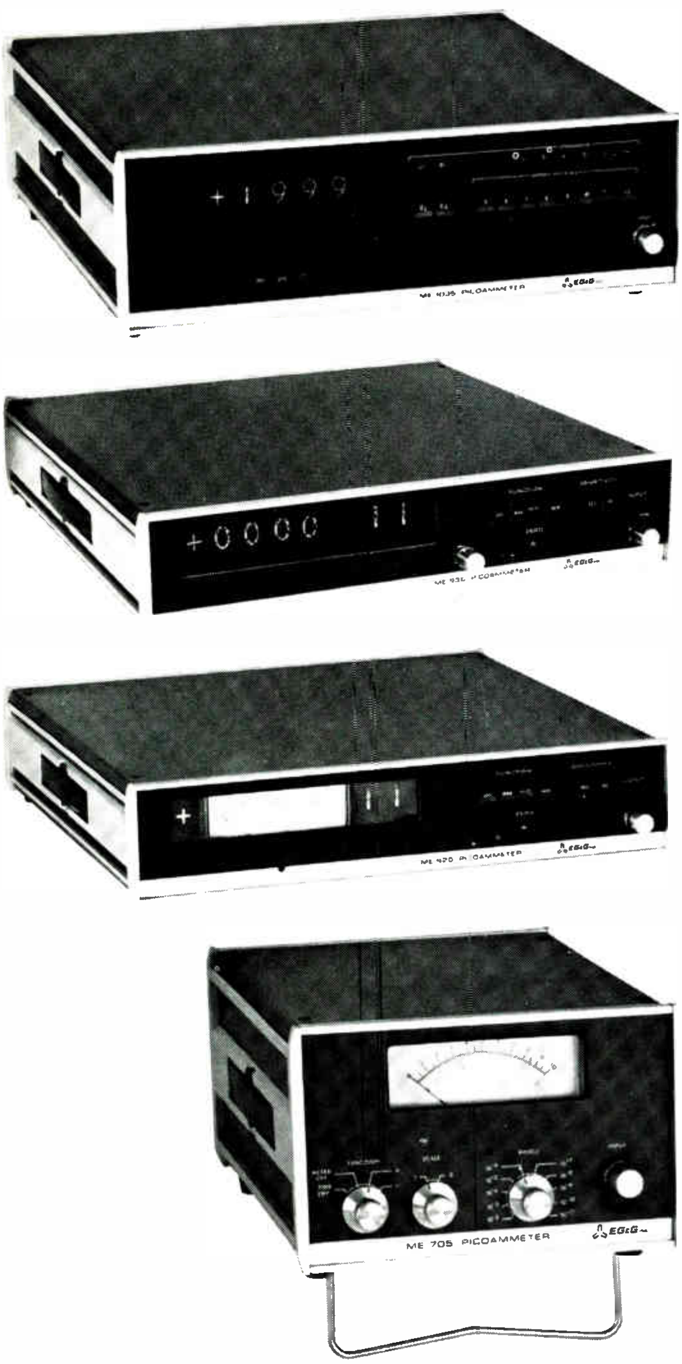

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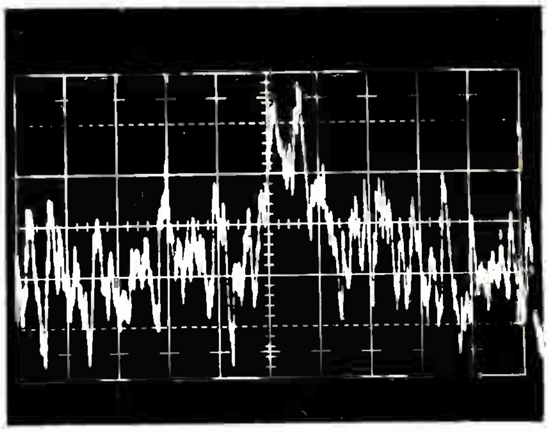

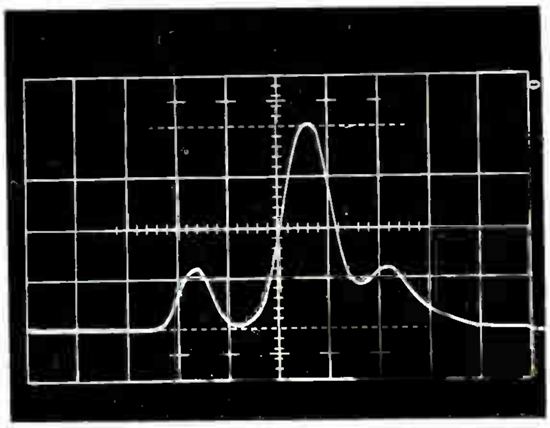

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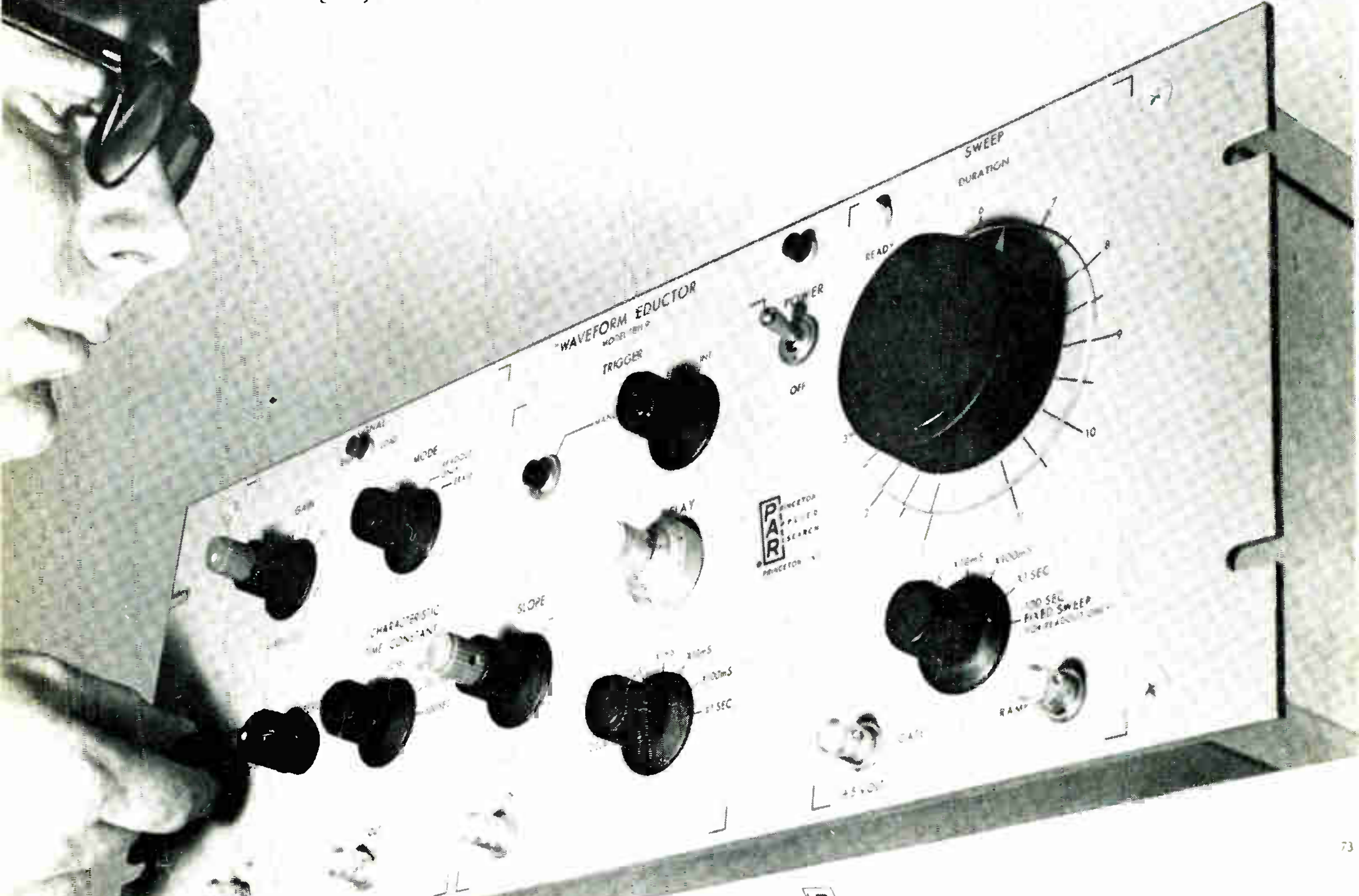

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Electronics Review

Volume 41
Number 9

Industrial electronics

Impatt impact

Impatt diodes, until now used exclusively in military hardware, may soon make themselves felt in the civilian market, and the price of this progress may turn out to be a traffic fine for speeding. The Bomac division of Varian Associates has developed a microwave radar "trap" using impatt diodes in place of an oscillator tube.

The first model of the system has just been delivered to the Muni Quip Corp., a subsidiary of the Duncan Parking Meter Corp., Elkridge Grove Village, Ind.

According to Muni Quip's chief engineer, Floyd Harwood, the new radar works at least as well as systems with klystrons. The Bomac system also promises to produce less spurious output, making the radar more accurate.

More expensive. The Bomac modifications were simple. Beginning with one of Muni Quip's standard radars, the engineers cut the power supply voltage by about two-thirds to get the 83 volts d-c required by the impatt. They also changed the power-supply regulation slightly and added a current control.

The modified unit has an output of 67 milliwatts at 10.5 gigahertz. In Bomac's parking lot, the engineers found that the system worked like a charm up to the maximum speeds tested, about 45 miles per hour.

However, other factors, such as life expectancy of the impatts, are still under study; tests will continue through this year at Muni Quip.

Also, the typical impatt costs more than $100 unmounted but the klystron tube is only about $90. The mount needed for the diode may easily raise the price of the combination to more than $200.

Muni Quip's executive vice president, William R. Shiry, estimates that adding an impatt would also mean adding a grand total of about $400 to the list price of the firm's standard unit, which costs $1,440. And thus he feels he'll have to wait for the price of impatts to fall before the device can get out of the lab—or the parking lot.

However, Shiry may not have long to wait. John Heiber, Bomac's director of microwave marketing, thinks that the impatt could soon be competitive with tubes. "Prices are high now because orders are for only a few units at a time. If we received an order for 1,000 oscillators, (diodes and oscillators), our price would drop below $100." He also points out that a power supply designed for the impatt—not a readjusted one as used in the experimental unit—could be cheaper than those now needed for klystrons.

Pull over. Varian's Bomac division has developed an impatt diode as the microwave power source for police radar traps. Solid state device shrinks system into two packages—meter and controls, on the left, and antenna, right. But its price—still a few hundred dollars more than conventional gear—is keeping it out of the market. One design is being tested by the Mini Quip Corp.

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Computers

Deficit mending

It's no secret that the General Electric Co. hasn't exactly been piling up profits from its computer business. In fact, industry rumors have it that GE's losses on its computer operation have run into the many millions of dollars, despite cutbacks in activities both here and abroad. A change may be at hand. The company this month named John W. Haanstra general manager of its Information Systems Equipment division, Phoenix, Ariz., the unit that produces commercial computers.

Big job. John W. Haanstra takes over GE's computer operations in Phoenix in a move evidently aimed at stemming the company's losses there.

Haanstra, known in the computer industry as an executive more interested in profits than technical breakthroughs, joined GE last summer after spending most of his professional career at International Business Machines Corp.

Great debate. Haanstra made a name for himself at IBM, where he is remembered as the man who almost single-handedly blocked the development of the System 360 series. He believed, at the time, that the advent of the 360 line would threaten the position of the General Products division, the operation he headed and the source then of some two-thirds of IBM's revenue.

Haanstra's first post at GE was as a consultant to J. Stanford Smith, who himself had only recently been brought in to revamp the faltering computer division. Last January, Haanstra was promoted to general manager of the Advanced Development and Resources Planning division, another unit of the company in Smith's charge. This appointment, quite interesting in its own right, becomes even more significant if changes are to be made in the computer division.

Now Haanstra is taking over the manufacturing and marketing side of the computer business from Louis E. Wengert, who becomes manager of GE's Constant Speed Drives division, the motors and motor-controls section of the company.

Remembering the MOS

A maxim in the electronics industry is, "You have to run hard to stand still." Memory Technology Inc., of Waltham, Mass., which has been doing well with its braided read-only memories [Electronics, Jan. 8, p. 52,] is beginning to learn first-hand how true this is. In planning a new product based on the technology, a universal bidirectional code converter, MTI has suddenly encountered competition from an unexpected quarter—semiconductor memories.

"When we first went into business a couple of years ago," says John J. Marino, president of MTI, "we had to sell prospective customers on the idea of using read-only memories. Now that these are a generally accepted idea, we can concentrate more on the advantages of braided memories over other kinds of read-only memories, such as speed and flexibility." But manufacturers of metal oxide semiconductor (MOS) memories have recently been making some rather broad claims about MOS, so that MTI has had to delay introducing its new converter until it can be sure what the MOS people are up to. No MOS memories have yet been delivered, says Marino.

Whirling disks. The only off-the-shelf converter now available, other than specially designed units, is a mechanical contrivance made by the Invac Corp., another Waltham company. Invac's device uses light bulbs, photo-sensors, and whirling disks driven by a motor. Marino says MTI's braid assembly could be sold for half the cost of Invac's device. He concedes that a 2,000-bit MOS read-only memory equivalent in performance to his braided memory could sell for a competitive price; and MOS has a definite size and weight advantage. However, the MOS memories are subject to a large masking cost that makes them quite expensive in small quantities.

The converter that MTI is working on is basically two braid memories connected end to end, so that one drives the other. The two braids encompass sets of core pairs instead of single cores.

The present breadboard model can convert between two eight-bit codes—any two, in either direction. It contains 32 U-shaped cores in two sets of eight pairs, and a single braid of 256 wires. Each wire in the braid threads a particular combination of eight core pairs, and a different combination of the other eight pairs, passing through one of a pair for a binary 1 and the other for a 0. The two combinations represent the two coded forms of a single character.

Bit position. A flip-flop register holds an eight-bit character that comes in on eight lines in parallel. The complementary outputs of each flip-flop drive selection coils on the two cores corresponding to that bit position. Because of the pattern of wires in the braid, these coils generate voltage pulses on every wire but one. The pulses reverse-bias the diodes connected to the braids; the one diode left unbiased admits a current pulse to its wire. This wire also threads a unique combination of core pairs in the other set; sense windings in that set pick up the corresponding code, which is amplified and precented to eight parallel output lines.

Changing braid. The converter is called universal because it can work between any two codes, simply by changing the braid. It can also work with three or more codes at once, with a longer braid and a set of core pairs for each code—as in a communications system that uses binary-coded decimal, Hollerith (punched card), and Baudot (teletypewriter) codes. The converter is also bidirectional, because the selection windings on the input side and the sense windings on the output side are identical. Current drivers and sense amplifiers are both connected to each winding, and biased on or off depending on the direction of conversion.

Consumer electronics

Microwave mini-oven

The American housewife is apparently happy cooking with electric heat or gas. The handful of companies that produce microwave ovens have been most successful in selling to restaurants and institutional kitchens. And all the major airlines use microwave ovens in their airborne kitchens.

But the Raytheon Co.'s Amana Refrigeration subsidiary is trying to change all that. It's introduced a small (23-by-17-by-15 inch) counter-top oven, called the Radarange, that operates from a standard 115-volt, 60-hertz power line and sells for $475.

The only other consumer microwave ovens available in the U.S. are part of large stoves and sell for more than $800.

Amana says the Radarange can bake a potato in four minutes, a hamburger in one minute, and a five-pound roast—well done—in 37½ minutes. Although the microwave mini-oven is new to the U.S., foreign electronics firms have been in the market for some time [Electronics, Sept. 4, 1967, p. 207] with such low-cost appliances for the consumer market.

Raytheon isn't alone in believing that microwaves will soon catch on in the U.S. Last month RCA said it set up a division to sell microwave tubes to oven makers.

What's cooking. Table-top microwave oven developed by Raytheon's Amana division will sell for $475. It plugs into ordinary house current. Most other U.S. designed microwave ovens are large or were designed for institutional kitchens.

Advanced technology

Bright idea

Television cameramen covering news and sports events have to guard against suddenly aiming their cameras at high-intensity lights without first "peaking" the tubes to accommodate the brightness. If they don't, the tubes are saturated and permanently damaged.

However, developmental work initiated at Bell Telephone Laboratories before 1967, and now in progress at both Bell Labs and Texas Instruments Inc., promises aid for the cameramen.

Bell developed a technique that replaces photo-conductive coatings (usually antimony trisulfide) in standard tv camera vidicon tubes with a silicon diode array. The array can handle sudden brightness without suffering fatigue. What's more, the array is said to provide higher sensitivity than the conventional coatings, without any loss of resolution.

Bell began the work for its Picturephone system, which is now being tested and involves the visible part of the light spectrum (0.4 to 0.7 microns). Last June, TI got permission from Bell to do similar work in the near-infrared region (0.9 to 1.1 microns) for classified military applications.

Standard tubes. A 540-by-540 array of 291,600 photo diodes on a thin silicon slice was made by Bell in its early work. Texas Instruments has since made similar sizes and, more recently, has developed a 600-by-780 format that measures 0.48 by 0.64 inch.

TI switched from the visible to the near i-r range by tailoring the diode spacing and thickness. Its present format has a center section 0.001 inch thick. A standard vidicon tube equipped with the TI array can be tuned across the spectrum from 0.3 to 1.2 microns.

To modify a standard vidicon tube, the silicon diode array is mechanically fitted into the front end just behind the front glass. Light passes through the glass and penetrates the silicon. The array is then scanned by an electron beam the same way the conventional tube is scanned.

"We get the sensitivity needed with silicon because it peaks at around 0.9 microns," reports Ward Paxton, manager of the advanced i-r systems components branch at TI. "The array is of low enough capacitance that it has few image smear characteristics."

Longer life. Using silicon instead of the glass plate may also extend the life of the modified tube; hydrocarbons and gases in the glass eventually poison the cathode. Frank Skaggs, an engineer on TI's project, says, "Most tv people now replace their tubes after 500 hours because the tubes begin to lag from fatigue. We think the array-equipped tube will have at least a 5,000-hour lifetime."

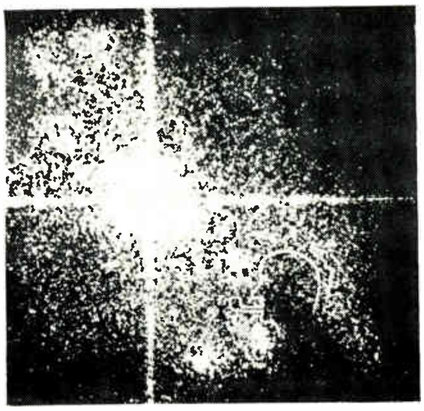
TI has used the arrays primarily in standard vidicon tubes, because these are the type used in military systems the firm is working on. Commercial-tv people often use orthicon tubes because of certain vidicon-tube limitations. Paxton believes, however, that array-equipped vidicon tubes could satisfy many commercial needs because these tubes span a wide range of the spectrum.

TI has produced several developmental systems for its military work, and Skaggs believes the silicon diode array technique will eventually break into the market for commercial camera tubes. For one thing, he points out, the array system has better red-light sensitivity than present tubes.

Seen from afar

Long-distance photography is only as good as the medium through which the picture is snapped. And obviously, the greater the distance the greater the distortion caused by the atmosphere. But a research team from Stanford University reported to the Air Force this month that holograms may be able to produce clear pictures despite atmospheric distortion.

Using a 1-joule ruby laser mounted on a 48-inch telescope, the researchers were able to photograph a man standing more than eight miles away at nighttime. Pictures were taken on a desert range near Holloman Air Force Base, New Mexico, under conditions of significant atmospheric distortion, the researchers said.



Far-out photo. Hologram taken from eight miles away. Note outline of man smoking pipe at lower right corner.

With further increases in laser power and film sensitivity, the technique promises the transmission of clear hologram pictures between the earth and satellites orbiting 100 miles or more away. Atmospheric distortion would be less a problem in this case than it is between points on earth.

Glassy-eyed. The Holloman experiment was the first practical demonstration of a laboratory test performed at Stanford more than a year ago. In that test, shower glass was used as the distorting medium.

A hologram is the product of the interference pattern created by the phase difference between reference beam and image beam. Since the effect of the wave distortion is the same for both, any distortion is, in effect, canceled out.

Another advantage of holography over conventional photography, notes Prof. Joseph Goodman of Stanford's applied electronics laboratory, is that it detects the image first before forming it, thus allowing for fine adjustments.

Several outstanding problems remain to be solved before effective long-distance transmission can be achieved, Goodman concedes. Signal-to-noise ratio must be boosted to at least 10, preferably to 100, by extending the dynamic range of the film.

Researchers must also find out how much more laser power it would take to ensure a strong signal at the receiver. The Stanford laser has 50 megawatts of power, producing 1-joule for 30 seconds. Goodman thinks a Q switched 20-joule ruby laser would be needed to produce a clear picture of a moving target at very long distances.

Different rig. Another advance might be to substitute foil-lined parabolas and a television camera for the telescope and film. Computer processing of the images would also sharpen results.

In the Holloman experiment, the telescope received the reflected laser light and focused it through a reflecting mirror and lens to the film. The man eight miles off stood in front of a flat, light-reflecting surface. Mounted a few centimeters above him was a retro-reflector—a triangular-shaped reflecting mirror—for the laser.

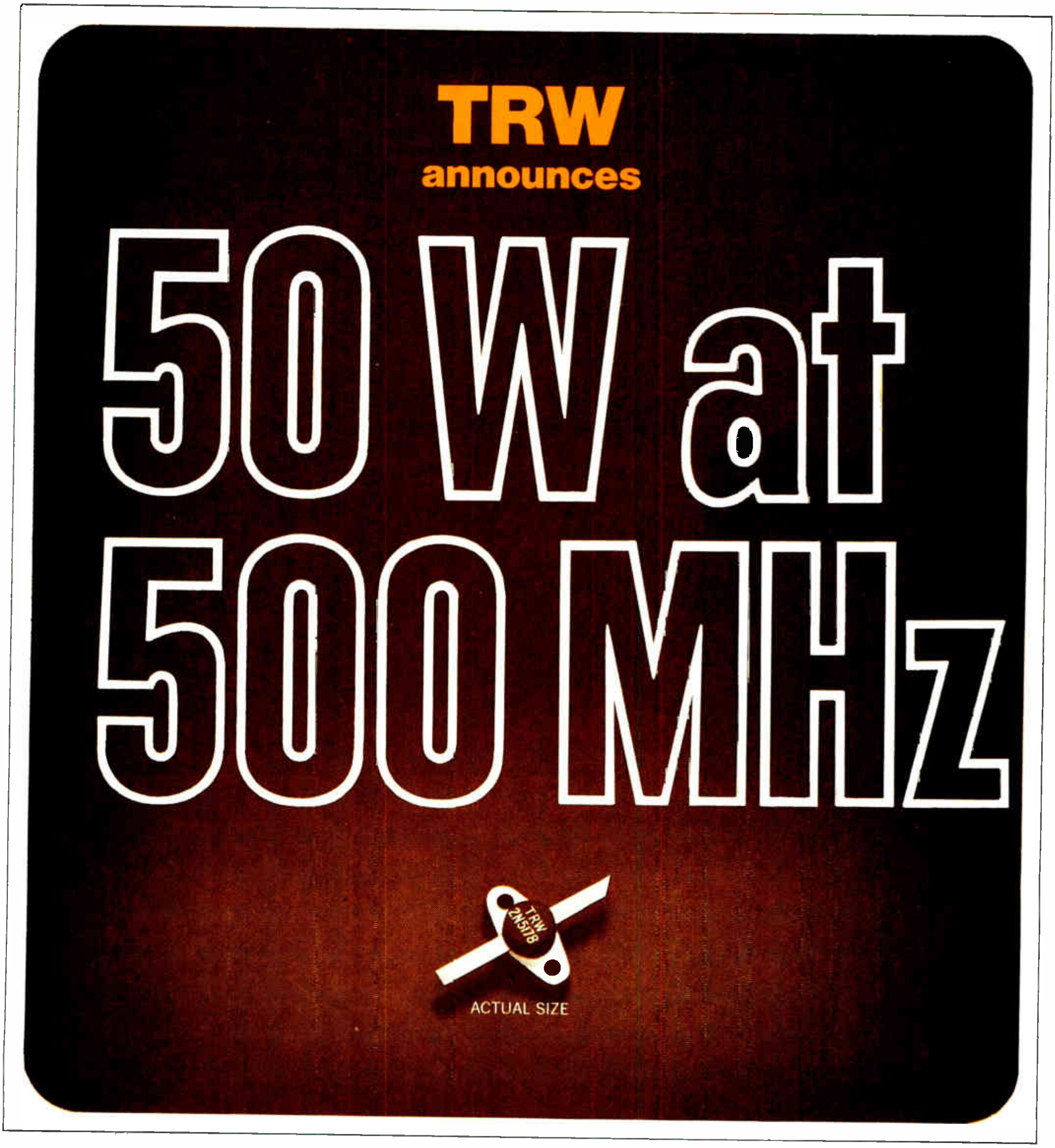
Although the picture was crude, the Stanford team considers it a significant step in an area of great promise. Further development will have to be conducted by the Air Force's Avionics Laboratory, though, Goodman comments, because "it's reached the stage where the university isn't the one to continue the research."

Medical electronics

Night watch

One of the most agonizing mysteries in medicine is the "crib death syndrome," which in the U.S. alone annually takes the lives of 10,000 to 20,000 infants in their sleep for no apparent reason. Various theories have been advanced, and while many have been ruled out, a few are now gaining attention.

One such theory, now being pursued by a research team composed of an engineer, a pathologist, and a surgeon at the Atlantic Research



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For evaluation quantities and complete technical details, contact any TRW distributor or TRW Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260. Phone: 679-4561, TWX: 910-325-6206. *TRW Semiconductors Inc. is a subsidiary of TRW INC.*

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division of the Susquehanna Corp., will soon be tested with microelectronic equipment.

The team believes the crucial element in the phenomenon to be the vagus nerve—the nerve that triggers the heart when it begins to falter. It believes that when an infant goes to sleep, heartbeat and pulse drop sharply, and that this slowing down of the heart continues as sleep deepens. If the process isn't interrupted, the researchers contend, the child can literally sleep to death.

Guardian. Pulse of sleeping infant is monitored to prevent "crib death." Band fits on infant's arm.

Close calls. A hiccup or cough or other cause of arousal in sleep produces a "vagal storm" that speeds the heartbeat and pulse. Says a member of the team: "If the theory is correct, a large number of infants in their first months have 'near misses' every night they sleep."

The first step in testing the theory will be to monitor the pulse of a sleeping infant. In conjunction with the Case Institute of Western Reserve University, the team has fashioned a breadboard "wristwatch" that uses a piezoelectric chip as a sensor and contains a simple transmitter made of discrete semiconductors that will transmit a wideband f-m signal. The monitoring system is now being tested on adults at Atlantic Research.

Remedy. Should the theory be correct, says Jack Spurlock, the team's engineer, the monitor could be used to trigger a remedial "control overtake," such as a vibrator, to stimulate the child's vagus.

In the early fall, the researchers hope to have a much smaller prototype monitor built with integrated circuits. Transmitter, battery, and sensor will be embedded in a thin nylon bracelet a child could wear without discomfort. The signal, at a frequency of 230 megahertz and a bandwidth of 35 kilohertz, would be received by a small broadband receiver in the home. From the home, it would be forwarded over landline to a central computer for analysis. According to Spurlock, the team's hypothesis will be proven or disproven in the next two years.

The project, which has been sponsored in-house by Atlantic Research, was recently granted funds by the Northern Virginia Heart Association.

Government

Grounding the middlemen

Although many electronics contractors maintain that the Federal Aviation Administration isn't the easiest Government agency to work with, many still are attracted by the business. But now, as a result of investigations by the General Accounting Office, much of that allure will fade.

The FAA has sometimes purchased test equipment only as part of a basic air traffic control or navigation system—even if the equipment was standard—but this is going to stop completely.

The FAA will now buy standard test equipment directly, instead of using the prime contractor as a middleman. However, when test equipment isn't standard, the FAA will allow the prime contractor to supply it.

In the purchase of the semiautomated terminal air traffic control system Tracon-C, for example, the contractors will supply the test equipment as part of the turnkey package supplied to each airport. Bids on Tracon-C are due May 28, but the FAA still has no definite idea of how many terminals its $14.5 million will cover [Electronics, Feb. 19, p. 155].

Double fares. The GAO found that in eight of the 20 cases investigated the FAA purchased off-the-shelf, standard test equipment through prime contractors rather than directly from the manufacturers. This meant, of course, that the FAA was paying for two companies' profits and for more overhead and handling. The GAO studied two contracts closely.

In one, the purchase price of the test equipment was $178,050. The prime contractor added $57,264, which included $25,205 in profit and 20,426 in general and administrative costs. The rest was for packing, shipping, engineering aids, and "materials variance."

In the second contract, the test equipment itself cost $240,995. The prime contractor charged an additional $62,790, of which $27,617 was profit, $15,905 was for material overhead, and $19,268 was for general and administrative costs.

Round trips. The GAO study disclosed that the FAA paid to have some test equipment shipped about 6,000 miles—from a manufacturer in Oregon to the prime contractor's plant near Boston, then back to the installation site situated near Los Angeles.

The GAO found a number of other cross-country treks for test equipment. So obvious was the waste of money that the GAO reported: "We made no effort to calculate the amount of additional transportation costs incurred by the FAA."

In addition, the GAO discovered that test equipment was being inspected and calibrated twice: once

on receipt by the prime contractor and again on receipt by the FAA at the installation site. Both were based on the manufacturer's manual. Of course, the prime contractor was charging the Federal Aviation Administration for its inspection and calibration services.

The GAO, an investigating arm of Congress, didn't identify the companies involved, in line with its policies of soft-pedalling reports [Electronics, Dec. 25, 1967, p. 107]. The FAA conceded that the charges were substantially correct.

Avionics

CAT by the tail

Much has been said in avionics circles about "belling the CAT," but clear-air turbulence remains the same menace to aircraft it was when the pun was considered funny. Of the many research efforts aimed at finding a means of alerting pilots to the presence of turbulence, however, one has finally resulted in a marketable system.

The Autonetics division of the North American Rockwell Corp. is taking the "experimental" tag off its air-turbulence detector and offering it to the airlines as a commercial product. Armed with statistics compiled in 372 hours of operation during 76 flights—30 in an Air Force C-135 and 46 in an Pan American World Airways Boeing 707 on regular passenger runs [Electronics, Nov. 27, 1967, p. 52]—Autonetics representatives have been presenting the case for the system to officials of American, Eastern, TWA, Pan Am, and United Air Lines.

The latest version of the detector —configuration number five—has three major parts: an infrared radiometer sensor, a data processor, and an indicator panel. The system operates in the far infrared range at the lower edge of the carbon-dioxide absorption band—between 14 and 16 microns.

Time to prepare. In the most recent Pan Am tests, conducted last December and January, the system operated for 157 hours and detected 14 areas of turbulence. It missed one and triggered five false alarms. Warning time averaged three to four minutes before the turbulence was encountered.

The latest version should be ready in about nine months, according to Edward Flint, manager of the program at Autonetics. It will incorporate a number of improvements over earlier models, which were prone to triggering false alarms. Flint notes, however, that the airlines are willing to live with some false alarms if they can be certain that no critical turbulence goes undetected.

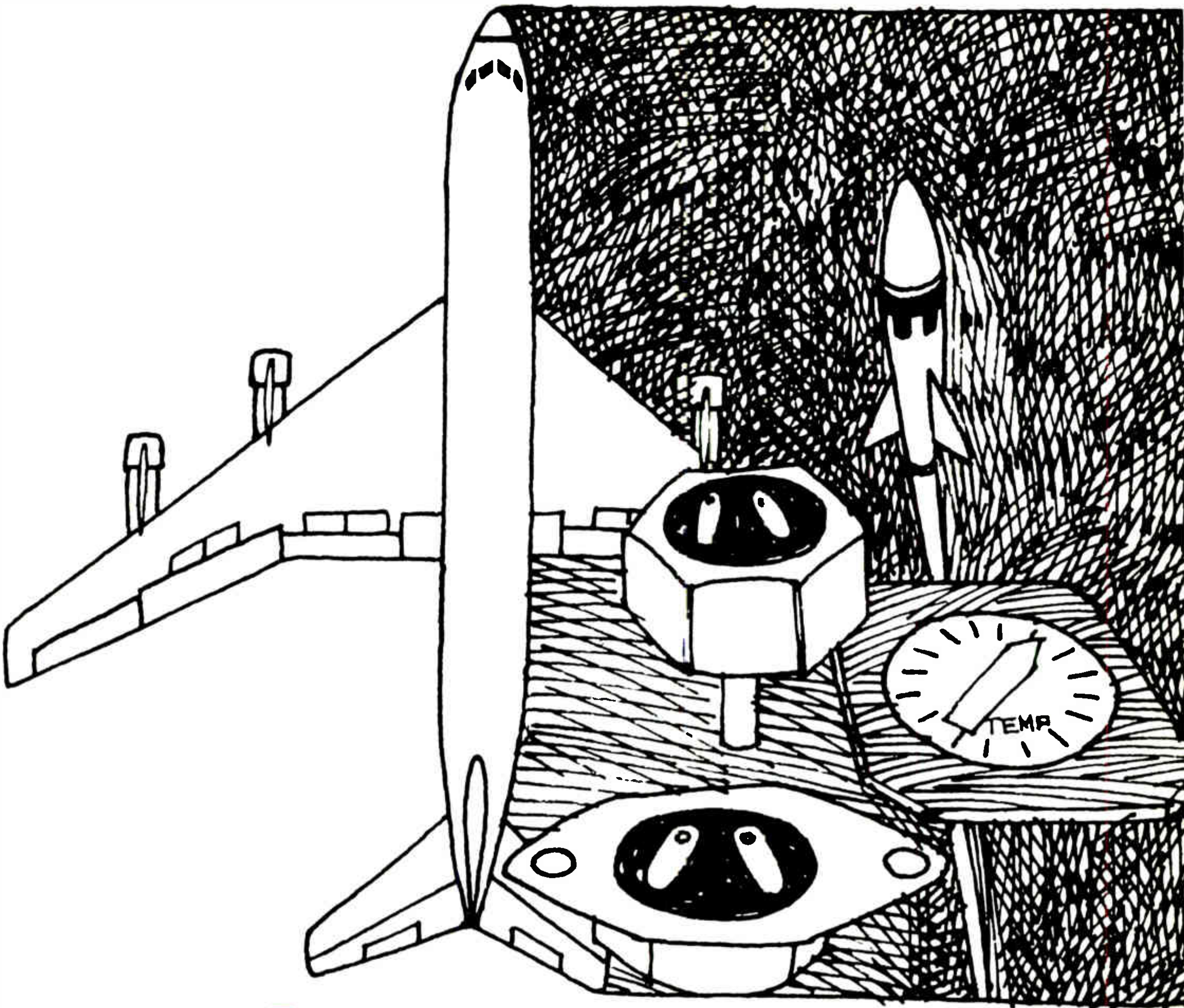
The i-r sensor beam is fixed to detect disturbances out to 50 miles ahead of the plane within a 2° vertical and 10° horizontal field of view. The fourth version of the system, the one used in the most recent Pan Am tests, was the first to employ a fixed beam.

Another refinement, first used in the third version of the detector, helps minimize false alarms triggered by the minor turbulence that results from momentary changes in the aircraft's attitude. This problem is licked by using a vertical gyro cutoff signal to turn off the infrared CAT sensor when the aircraft pitches down 1° or up 3.5° or rolls 4.5°.

Temperature change. During the Air Force flights, Autonetics engineers found that the presence of turbulence was signaled by a change in carbon-dioxide temperature, a change in carbon-dioxide density, and a change in ice-crystal concentration. The CO_2 absorption band was selected for the system on the basis of studies conducted by Autonetics that were started some eight years ago.

The system weighs under 50 pounds and requires less than 100 watts; both levels, Flint says, are lower than would be required by a radar detector. Besides CAT, incidentally, the detector can pick up turbulence caused by thunderstorms.

No price tag has yet been put on the system. It's designed for any aircraft that cruises between 25,000 and 41,000 feet, and Flint says it looks technically feasible, with a



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Space electronics

Fiddling with Symphonie

A paper on the use of a Luneberg lens in a mechanically despun satellite antenna drew an indulgent, and even faintly amused, response at an American Institute of Aeronautics and Astronautics conference in San Francisco this month. But Henning W. Scheel, a 26-year-old German electronic consultant, may have been aiming his ideas beyond his predominantly American audience.

Scheel and his associates are trying to influence the design of the Symphonie satellite, a three-axis-stabilized craft being developed jointly by Germany and France to provide television and telephone relays [Electronics, Sept. 4, 1967, p. 207].

Plans are to launch two satellites—one by 1971, the other in 1972. They're being designed to weigh less than 374 pounds, to permit launching by the ELDO-PAS vehicle. The two countries are putting up about $56 million for the project; requests for proposals went out in January.

Scheel says flatly that three-axis stabilization will cost twice as much as spin stabilization and be less reliable. He and a colleague, K. Rudzinski, convinced the influential German newspaper, Frankfurter Allgemeine Zeitung, to devote nearly a full page last month to their discussion of "unnecessary risks in the Symphonie project" and to Scheel's alternative.

Rudzinski said that no satellite with three-axis stabilization that weighed less than 660 pounds had yet been built. He said the three U.S. satellites with three-axis stabilization all required nearly as much money for one satellite as the Symphonie sponsors are prepared to spend for two.

Scheel made his case for the Luneberg lens as the antenna for a spin-stabilized satellite at the AIAA. Luneberg lenses are spheres filled with a nonuniform dielectric; the dielectric constant is 2 at the center of the sphere but only 1 at the rim, so that radio waves emitted from any source on the surface will be collimated on the other side of the sphere.

Despinning. The big advantage of this antenna is that it can spin with the satellite; only the antenna feed has to be despun. Multiple feeds can provide multiple pencil beams to illuminate specific areas of the earth.

The German Experimental Institute for Air and Space Travel Technique, near Munich, built and tested several Luneberg lenses under a program partly supported by the West German Ministry for Scientific Research.

Aperture efficiencies of better than 0.8 were obtained, Scheel says—far better than the 0.5 or 0.6 common with parabolic reflectors. Attenuation because of absorption in the dielectric was so small as to be unmeasurable; Sheel attributes this to the high frequencies used—4 and 6 gigahertz—and to a new polystyrene material.

The big argument against lens antennas, and the one that led many U.S. engineers who heard Scheel's paper to discount it, is that their weight increases with the cube of their diameter.

Also, to obtain narrow beams, large apertures are required. An 18-inch diameter Luneberg lens of pure polystyrene foam that produces a 10-degree beam at 4 Ghz weighs 35 pounds—"too much for certain space applications," Scheel admits. But, he says, lenses of the same diameter that weigh only 7 to 9 pounds are available—though the artificial dielectric used causes an absorption loss that cuts gain by about 1.5 decibels. "And it seems possible to fabricate lenses of only 2 to 3 pounds," Scheel predicts.

But Scheel's biggest weapon against weight is to increase the frequency, thus reducing wavelength and increasing the aperture-wavelength ratio.

Whether the Luneberg lens ar-

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Overheating of silicone rubber during sustained power overload often results in long-term leakage degradation.

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Controlled avalanche and permanently stable surface leakage characteristics. Hyperclean silicon surface fused only in hard glass. No oxides, silicones, or varnish are used.

ACTUAL SIZE

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JAN1N3612	400	2
JAN1N3613	600	2
JAN1N3614	800	2

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gument can convince the West German government—in the face of present plans and the existing technology for mechanically despun parabolic antennas—is problematical. Scheel still expects the devices to play a role in satellite communications. At least one U.S. representative at the AIAA meeting saw some future for the lens as a cheap ground antenna in a direct broadcast television system.

For the record

Millimeter tv. A point-to-point system capable of carrying 12 or more television channels at millimeter-range frequencies could save the CATV industry a lot of money by eliminating the need for underground cables. But even such advanced research houses as Bell Labs haven't been able to find an answer to the signal attenuation caused by heavy rain.

Now, however, the Chromalloy American Corp. and the Laser Link Corp. claim they have a system that not only can transmit up to 20 tv programs at one time over a 42-gigahertz carrier, but can guarantee excellent reception even in rain.

The secret of their scheme is being kept just that, a secret. Based on a proprietary modulation technique—the "quasi-laser" is what representatives of the two companies call it—the system is to be tested in the New York City area.

Happy landings. The Boeing Co. has purchased a military radar system that measures a plane's descent speed and landing velocity and plans to install it in its 737 civilian transport. The system, developed by the Ryan Aeronautical Co., is now being used in the F-4 Phantom jet fighter, the CH-46 helicopter, and the C-130 Hercules.

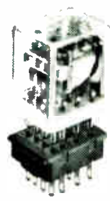
Scuttlebutt. In the wake of the Pueblo's seizure by North Korea, the Defense Department is studying the reliability of self-destruct mechanisms for electronic espionage gear.

Official weigh-in.

The first in a series of bouts as "the mighty mite," but as yet unheralded, M. "Tex" Aemco takes on all challengers to determine the championship relay and timer supplier of the world. Surprisingly, Las Vegas odds-makers have rated the match a tossup. Said one of them, "Little Tex packs all the punches of the big boy, so from here on the outcome looks like it will go to the man who can think fast and move quickly."

US vs THEM

YES 155 YES
5 and 10 Ampere 3 Pole
Industrial Relay



YES 156 YES
Miniature 4 Pole 3 Ampere
Industrial Relay

YES 157 YES
10 Ampere 3 Pole
Industrial Relay

YES 615 YES
Adjustable and Fixed
Industrial Time Delays

TEX

Thinks fast and moves quickly. Can match his opponent punch for punch. Lightning-like delivery. Scores best before tough judges. Great crowd pleaser because of his manner of charging in head first and not stopping until the battle is won. Clean fighter. Doesn't pull any punches.

POTTY BUTTERFELL

Has a lot of size going for him. Has done well in past. He's a nice guy.

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SPERRY RAND

MICROWAVE IC PROGRESS REPORT #1

Sperry PACT program carries avalanche transit time oscillator past 5,000 hours of life testing

Sperry's PACT (Progress in Advanced Component Technology) Program now offers more than 5000 hours of life test data on an X band Avalanche Transit Time Oscillator. With a test history dating from July 6, 1967, the device has not yet shown a measurable change in characteristics.

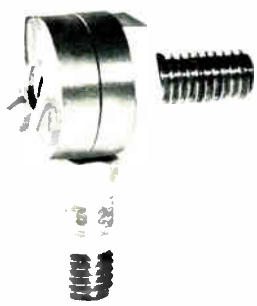
A direct result of PACT, Sperry's intensified effort to accelerate the development of microwave integrated circuits, the ATTO is believed to be the smallest device of this type available anywhere for the direct conversion of DC to a microwave signal. Its outline dimensions are identical with that of a DO-5 diode package.

In developing the device, PACT engineers attacked the following requirements:

- Relatively high power output in microwave IC size packages.
- Electronic tunability over 5 to 50% bandwidths.
- Frequency modulation capability without excessive spurious amplitude modulation.
- Minimum AM and FM noise characteristics.

Success of the project depended largely on Sperry's in-house capability for development and production of avalanching diodes. This capability met the challenge, and ATTO's are now produced entirely within Sperry's Clearwater, Fla., facility.

As soon as PACT had demonstrated its ability to deliver the diodes required, the other technical problems came under staff scrutiny. One of the first developments was an "upside-down" diode mounting technique which puts the heat dissipating region of the silicon mesa chip as close as possible to the heat sink. Resulting reduction of thermal resistance between junction and heat sink enabled



ACTUAL SIZE

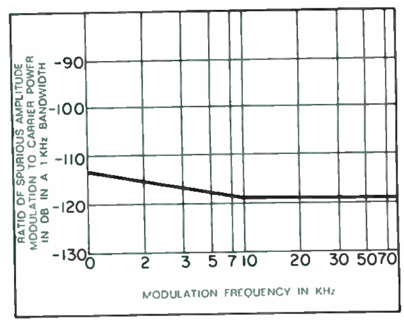
PACT engineers to handle current densities as high as 850 amps/cm^2. Power outputs have reached 380 mW CW.

Both frequency and phase locking techniques have been demonstrated.

Tuning requirements were met by utilizing mechanical, varactor or YIG techniques. Magnetic tuning across a 40% bandwidth is a reasonable expectation, and Sperry's experience in stalo design has permitted FM noise reduction by a factor of 30.

In summary, PACT has now demonstrated the feasibility of ATTO power output from 20 to 350 mW at specified frequencies between 5 and 10 GHz; inputs would vary from 80 to 110 VDC at 30 - 50 mA. These forerunners of true microwave IC's will deliver conversion efficiency as high as 5%, and

SPURIOUS AMPLITUDE MODULATION



frequency stability of 4.5 ppm/°C between −10 and +50/°C.

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Washington Newsletter

April 29, 1968

Telecommunications panel unlikely to ask for new Cabinet post

Prospects for a Federal Department of Communications are fading. The President's telecommunications task force now leans toward recommending that an agency similar to NASA be formed to cover the field of communications, but not at the Cabinet level.

James D. O'Connell, director of telecommunications management and vice chairman of the task force, has been instrumental in swaying the panel away from the department idea. **He's also against turning over the regulatory duties of the Federal Communications Commission to any new agency, and is just as firmly opposed to lumping communications with transportation under one Cabinet-rank department.**

Boyd in slow burn on fast-train delay

Transportation Secretary Boyd is ready to blow the whistle on contractors who have failed to get the high-speed rail service between New York and Washington into operation. The trains were supposed to roll last fall but have been delayed at least twice.

After the Budd Co. recalled 31 of the cars because of problems with control gear and stray voltages, Boyd appointed a task force to find out what was wrong and how to speed the project. The task force will report by May 17 and will probably recommend appointment of one prime contractor to oversee the entire project and coordinate efforts between Budd and the two firms building the electrical and control systems, Westinghouse and General Electric.

Some Washington sources say Boyd is so fed up with the delay that he's ready to publicly suggest hiring Japanese consultants to lead the project. Japan has had high-speed trains operating for several years.

More R&D cash for Post Office

Don't expect Congress to start the ball rolling toward changing the Post Office Department into a nonprofit Government corporation—something the President's Post Office Commission is expected to recommend in its report this week. But Congress is expected to pay more attention to the commission's urging that greater emphasis be given research and development to provide more efficient mail handling.

Likely to come out of this: another increase next year in the postal R&D budget, which grew from $16 million in fiscal 1968 to $23 million in fiscal 1969.

New missile studies point to a bonanza

Study contracts just awarded for an improved tactical all-weather, air-to-ground missile system—called AGM-X3—**presage hardware orders that may total more than $500 million over the next few years.** The $650,000 project-definition contracts have been issued to Hughes, Martin, and Boeing.

The new missile will supplement the Maverick, which uses television guidance and is limited to clear-weather daylight operation. The guidance system for the AGM-X3 hasn't yet been selected, but one prospect is a passive millimeter-wave radar. The Air Force is also asking the study contractors to investigate a combination optical-radar system using inertial guidance for midcourse corrections.

Washington Newsletter

Airlines may alone fund Comsat craft

The nation's airlines are considering the possibility of going ahead with Comsat on the aeronautical services satellite without waiting for Federal assistance. This line of thought, expressed by officials of the Air Transport Association, reflects worries that the oft-delayed project will be further postponed by a lack of Government funds [Electronics, March 4, p. 62], and has been spurred by recent Comsat statements that the company's charges or satellite services would come to "less than $100" per flight. This is about three times what the airlines now pay for communications on transatlantic runs, but they seem to feel that such added benefits as data relay might justify the higher price. The carriers still aren't happy, however, about Comsat's long-standing proposal that they pay a lump sum in advance.

One possible hitch in the approach being mulled is legal: Comsat's charter may not cover the independent operation of such a system.

A report on a national aeronautical satellite plan being worked out by the FAA, other Government agencies, and industry is due in two months.

Radiation roundup: Senate to hear calls for a tough bill . . .

It's beginning to look as if the radiation bill the Senate will pass will be sufficiently different from the recently passed House version to force a compromise.

Some key provisions of the tough Administration measure excluded from the House bill will be strongly urged by several witnesses at the Senate Commerce Committee's hearings on radiation. At the sessions—due to start May 6—consumer champion Ralph Nader, among others, is expected to demand that the Senate bill provide for Federal inspection of plants making radiation-emitting products and for the recall of faulty equipment—items dropped by the House [Electronics, April 1, p. 46]. And union representatives will probably push for inclusion of the Administration's call for constant monitoring of workshops where radiation-emitting goods are made.

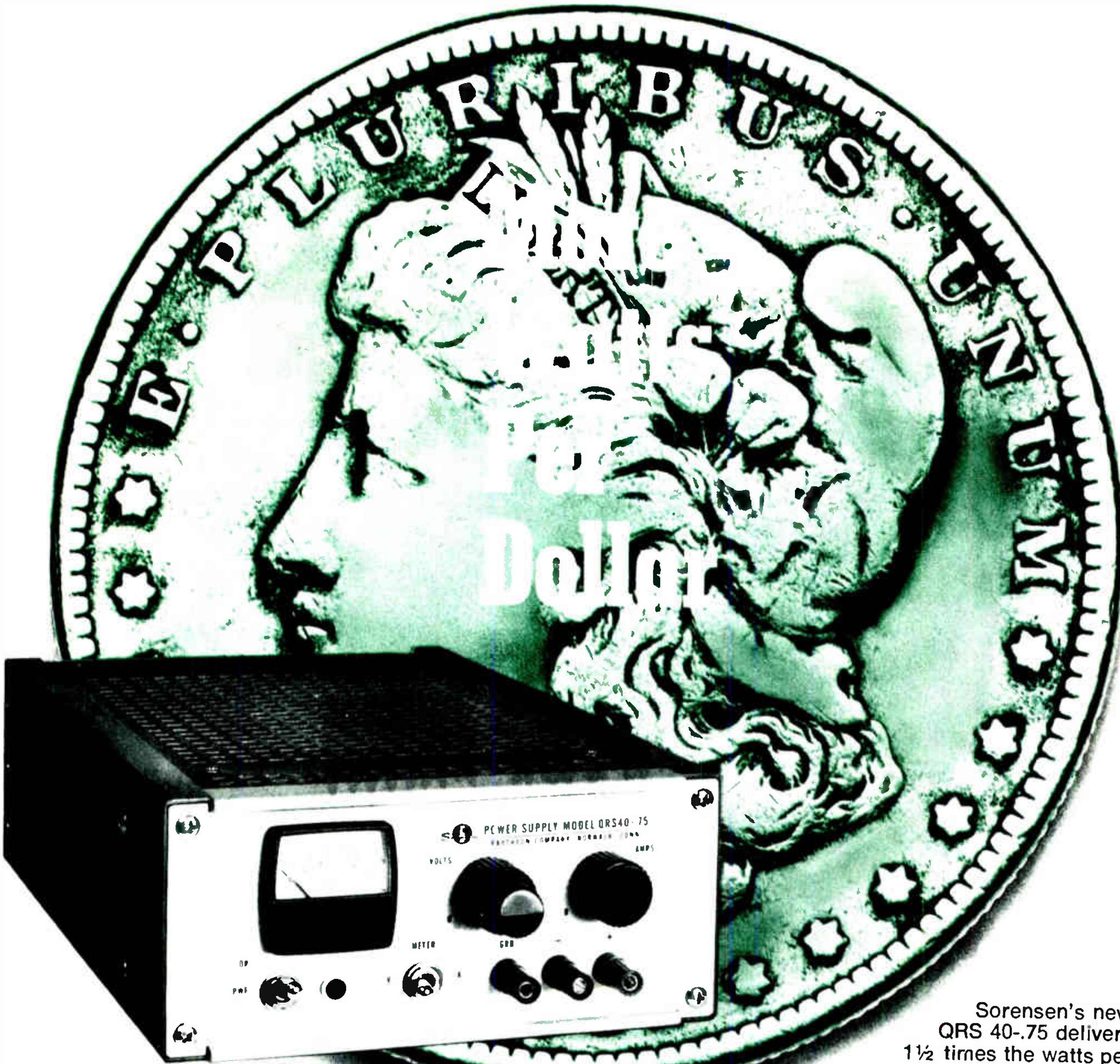
. . . as workers balk at radar overhaul

All the talk about the potential dangers of radiation-emitting equipment is having its effect in other places. **Concern over possible hazards may delay the FAA's plans to overhaul its radar antennas in a dozen locations.**

The FAA says there's no danger, but its technicians are refusing to work on antennas at Benson, N.C., while temporary radar equipment is in full operation 88 feet away. In past overhauls, the FAA turned off the airport radar and closed down the field, but at Benson—and other fields due for renovation—it's bringing in portable radars to keep the airports open during the overhaul period. **The National Association of Government Workers has asked the National Center for Radiological Health to investigate.**

F-m radio bill gets little House backing

Washington observers say Rep. Alvin E. O'Konski (R., Wis.) won't get to first base with a bill requiring that all radios imported or sold interstate be capable of receiving both a-m and f-m broadcasts. The bill has been referred to the Interstate and Foreign Commerce Committee, but chances are good that no hearings will be held this year. The House is not enthusiastic about the measure simply because f-m radios are selling well—their share of the home-radio market rose to 37% last year from 30% in 1966. And of the car radios sold in 1967, 10% were f-m, compared with 6.8% the year before. In all, about 15 million f-m receivers were sold last year.



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QRS 20-4	0-20	0-4.40	0-4.00	0-2.40	5¼	8	13¼	$255.
QRS 30-1	0-30	0-1.10	0-1.00	0-0.60	3½	8	13	$145.
QRS 40-.75	0-40	0-0.83	0-0.75	0-0.45	3½	8	13	$145.
QRS 40-2	0-40	0-2.20	0-2.00	0-1.20	5¼	8	13¼	$255.
QRS 60-.5	0-60	0-0.55	0-0.50	0-0.30	3½	8	13	$155.
QRS 60-1.5	0-60	0-1.65	0-1.50	0-0.90	5¼	8	13¼	$265.

Contact your local Sorensen representative or: Raytheon Company, Sorensen Operation, Richards Ave., Norwalk, Conn. 06856. TWX 710-468-2940.

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Burroughs

Circle 56 on reader service card

April 29, 1968 | **Highlights of this issue**

Technical Articles

Eliminating ground-loop errors
page 58

Ground-loop current plagues both the designer and user of electronic equipment. Separate grounding of electronic gear in a common system can cause hum in hi-fi systems or, more importantly, errors in data-measuring systems. A method that eliminates the problem uses two operational amplifiers connected as a differential circuit.

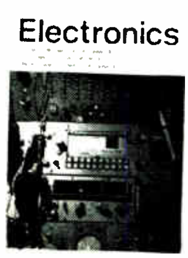
Speedier a-d converter adds integrating ramp
page 69

One way to waste the valuable time of a computer is to feed it an analog input through a slow a-d converter. Today's process-control and data-acquisition systems demand speeds up to 20,000 conversions per second with a resolution of 14 bits. A new development, the triple-ramp-integrating converter, not only does the job as well as the successive approximation technique, but does so at lower cost.

New isolation boosts performance of diode arrays
page 75

The advantages of discrete diode arrays (high forward conductance) along with the advantages of monolithic arrays (economy and uniformity) can be achieved using a new air-isolation process. The technique, an outgrowth of the "mesa" proposals of a few years ago, may be applied in the future to other types of integrated circuits.

Automatic checkout rides co-pilot
page 81



Avionics companies have been tackling the problem of getting cumbersome checkout equipment, now housed in huge ground vans that have to be brought up to the flight line, down to a size that will let it ride aboard the plane. Their aim is to give the pilot a constant reading of the performance of the many systems that today's military craft must carry, automatically detecting faults occurring while the plane is aloft. A survey of some of the approaches taken by avionics engineers indicates that on-board automatic checkout equipment may one day be as routine as a fuel gauge. The in-flight performance monitor designed by the Grumman Aircraft Engineering Corp. for the Navy's E-2A Hawkeye airborne early warning system is shown on the cover.

Coming

Testing integrated circuits

With the rising complexity of integrated electronic devices comes an increasing challenge in testing them. Manufacturers and users alike have developed ingenious methods to guarantee high performance and reliability in IC's.

Protecting data from the ground up

Error voltages that are created by circulating currents between pieces of separately grounded electronic equipment can be eliminated by using a differential data amplifier

By Robert I. Demrow
Analog Devices Inc., Cambridge, Mass.

Common ground may be the goal of diplomatic machinery, but it's the bane of data-measuring gear. Ground-loop currents running between pieces of equipment that are grounded at separate points to a common ground introduce voltages that can throw off the measurements.

There are ways to counter ground potential errors—the most practical and inexpensive of which is to use two operational amplifiers connected in a differential configuration as the data amplifier—but all the answers raise some questions of their own.

The ground-loop problem, of course, isn't limited to measuring devices. In an ordinary hi-fi installation, as on page 60, where signal source and power amplifier each has its own power supply, a 60-hertz leakage current flowing between the primary and secondary of the two transformers will be converted into a 60-hz noise at the power amplifier's input.

Dust and atmospheric humidity reduce the leakage resistance between primary and secondary transformer windings to a few megohms, and poor primary-to-secondary shielding places a substantial leakage capacitance in parallel with the leakage resistance. For example, 100 picofarads of leakage capacitance puts roughly 30 megohms reactance at 60 hz in parallel with the leakage resistance. These leakage paths set up currents that circulate between the amplifiers, developing spurious hum voltages that are applied with the signal to the output amplifier.

The leakage currents flow in parallel through the common ground and the signal lines connecting the amplifiers. Both paths have finite resistances, R_g and R_s, though they may be as low as a fraction of an ohm. In practice, plug-and-socket connections introduce appreciable resistance, especially if they're oxide-coated or loose.

The leakage resistance and reactance of the two transformers are lumped together as a leakage impedance, Z_L, connected in series with the source, V_L. If each transformer has a leakage resistance and reactance of 5 megohms, the two series-connected leakage impedances will total somewhat less than 10 meghoms. Since transformer leakage is by far the largest impedance in the ground-current path, the ground currents will be roughly equal to V_L/Z_L. With a 115-volt source and a 10-megohm load, for instance, the ground-loop current would be a nominal 11 microamperes split between the parallel paths provided by R_g and the series-connected resistances, R_o, R_s, and R_{IN}.

Hum at the speaker

Because the amplifier's input resistance, R_{IN}, is very high compared with the ground-conductor's resistance, R_g, most of this 11-μa ground-loop current flows through R_g. Hum voltage developed across R_g in this case would be 11 x R_g.

The author

Robert I. Demrow, a staff engineer at Analog Devices, has the job of finding new applications for operational amplifiers, evaluating the devices' performance, and checking out problems. He received his MSEE from Northeastern University in 1958, and has worked for GE, the Foxboro Co., and Honeywell.

If the ground path, including plug-and-socket connections, has a resistance of 1 ohm, the hum voltage, V_{BC}, across R_g will be 11 microvolts. This voltage is then applied to the series network of R_o, R_s, and R_{IN}, but because amplifier-input resistance is usually several orders of magnitude greater than R_o and R_s, almost the whole of the hum is developed across R_{IN}.

But if hum is a nuisance in a hi-fi system, the effects of ground-loop currents can be a disaster in a data-measuring system. The key specifications for a data amplifier include high common-mode and differential-input impedance, a high common-mode rejection ratio, good d-c stability, and in many cases, wide bandwidth, fast slewing, and fast settling time.

Data amplifiers are widely used to measure low-level signals developed by strain gages, thermocouples, biological probes, and other sensitive transducers. The transducer is often located at a remote test site, while the amplifier is housed in an instrumentation center. For example, signals developed by strain gages strung along a bridge structure would most probably be fed back to a data center at one end of the bridge. Similarly, thermocouple-temperature signals produced during tests on rocket engines would usually be fed to recorders and computers located in a well-protected blockhouse.

Separate sites for transducer and instrumentation mean separate grounds, and this creates a ground-loop problem.

Since the requirements for measuring millivolt signals developed by remote transducers aren't available in any one off-the-shelf op amp, the data amplifier must be designed from scratch. Key per-

Defining some op-amp properties

Parameter		Inverting	Non-inverting	Differential	Differential[4]	Differential[4]	Differential[3,4]
Signal Gain		R_f/R_i	$1 + R_1/R_2$	R_2/R_1	$1 + N$	$-R_3/R_2$	$\frac{R_5}{R_4}\left[1 + \frac{2R_1}{R_2}\right]$
Differential Input Resistance		NA	NA	$2R_1$	$R_{IN}\,[1+A]$	$R_1 + R_2$	$1 + \frac{R_2 A}{2R_1 + R_2}$
Common Mode Input Resistance		R_i	$R_{IN}\,[1+A\beta]$ Paralled by R_{CM}	$\frac{1}{2}\left[R_1 + \frac{R_2 R_{CM}}{R_2+R_{CM}}\right]$	$\frac{R_{CM}}{2}$	$\frac{R_1 R_2}{R_1+R_2}$	$\frac{R_{CM}}{2}$
Voltage Drift Referred to Input	Due to Voltage Drift[1]	$e_{os}\left[1 + \frac{R_i}{R_f}\right]$	e_{os}	$e_{os}\left[1+\frac{R_1}{R_2}\right]$	$2e_{os}$	$4e_{os}\left[1 + \frac{R_2}{4R_3}\right]$	$e_{os}\left[2 + \frac{1 + \text{GAIN B}}{\text{GAIN A}}\right]$
	Due to Current Drift[2]	$i_b R_i$	$i_b R_{source}$	$i_d R_1$	$i_b R_s$	$i_b\,[R_1 + R_2]$	$i_b R_s + \frac{i_d R_4}{\text{GAIN A}}$
CMRR Due to Resistance Deviations, K		NA	NA	$\frac{1 + G_{CL}}{4K}$	$G_{CL}/4K$	$1/4K$	$\frac{\text{GAIN A}\,(1 + \text{GAIN B})}{4K}$
CMRR Due to Amplifier's Gain Inequality		NA	$A/(A_2-A_1)$ As listed in data sheet	$A/(A_2-A_1)$	$\frac{A}{2(A_2-A_1)}$	NA	$\frac{A}{2(A_2-A_1)}$ in parallel with $\frac{A}{A_2-A_1}$ (GAIN A)
Combined Error, e_{cm}/V_{cm} $\left(\text{CMRR} = \frac{1}{e_{cm}/V_{cm}}\right)$		NA	$(A_2-A_1)/A$	$\frac{4K}{1 + G_{CL}} + \frac{A_2 - A_1}{A}$	$\frac{4K}{G_{CL}} + \frac{2(A_2-A_1)}{A}$	$4K$	$\frac{2(A_2 - A_1)}{A} + \frac{(A_2 - A_1)}{\text{GAIN A} + A} + \frac{4K}{\text{GAIN A}\,(1+\text{GAIN B})}$

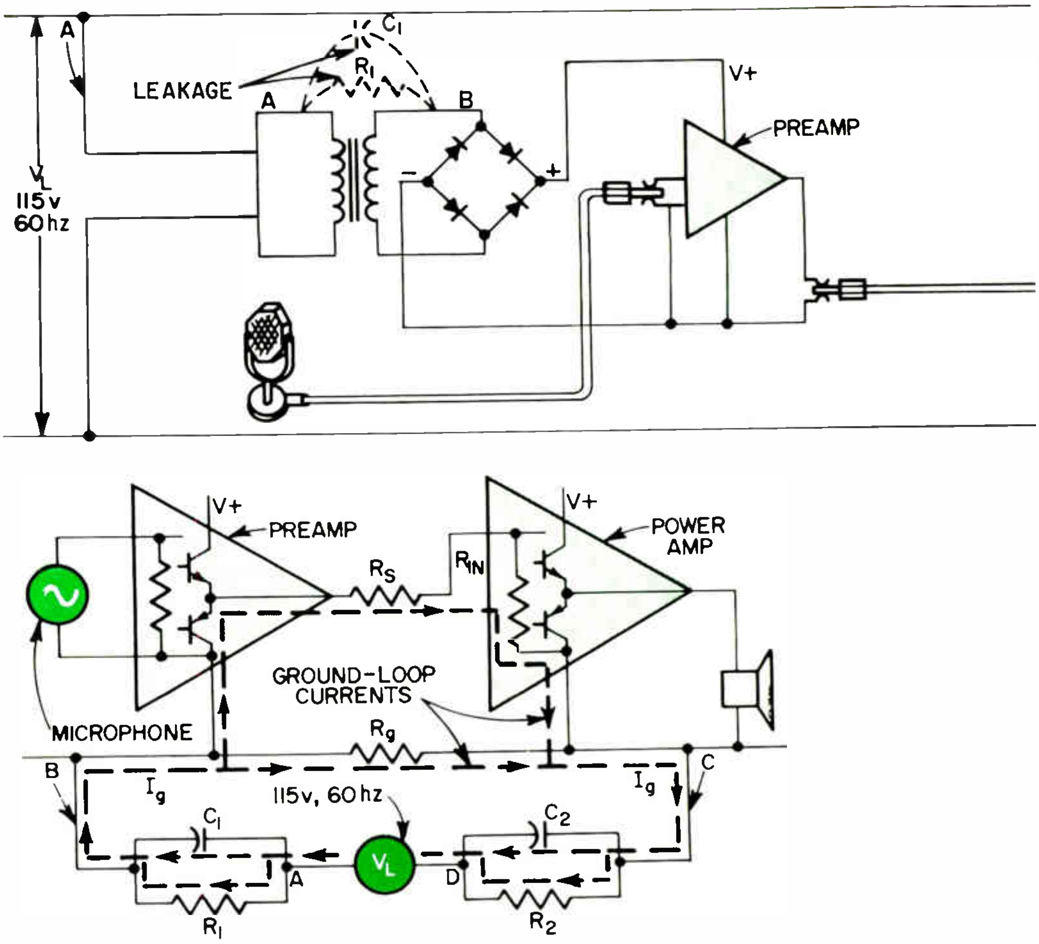
NOTES 1. e_{os} is the amplifier offset voltage drift due to temperature ie., $\left(\frac{\Delta e}{\Delta T}\right)\Delta T$.

2. i_b and i_d is the amplifier bias current drift and the bias difference current drift due to temperature ie., $\left(\frac{\Delta i}{\Delta T}\right)\Delta T$.

3. Calculations shown for $R_1 = R_3$

4. These amplifier parameters are assumed equal in magnitude but not necessarily of the same sign.

Around the loop. Transformer leakage sets up ground current I_g, which circulates between the two amplifiers via path ABCD (top). Ground-loop current flows through signal and ground lines connecting the two amplifiers (lower left), and creates hum voltage, V_h, at power amplifier's input terminals (lower right).



formance parameters have to be built in at a cost perhaps double that of a premium op amp.

Test-bed

In the data-measuring system on page 62, signals generated by a thermocouple placed in the stream of exhaust gases from a rocket engine undergoing test are fed over shielded cables to recording and data-processing equipment sheltered some 200 feet away. The difference in potential between the system's two ground points ends up as an error voltage applied to the amplifier along with its true input signals, a difficulty analogous to the hi-fi hum.

In extreme instances, ground potential difference at this test station could be as much as 5 volts; more typically, though, differences of 1 mv upwards are almost always present.

Typical sources of ground potential here include electrochemical effects, rectifier effects caused by soil crystals contacting buried metals and ores, thermoelectric effects created by temperature gradients in buried metals and soil elements, plus capacitive, inductive, and resistive coupling from power lines and charged clouds.

All these voltages can be lumped together into a single ground source, V_g, in series with the sum, Z_g, of all the ground impedances between rocket and blockhouse. As in the hi-fi case, it turns out that a substantial portion of this ground voltage is developed across the data amplifier's two input terminals.

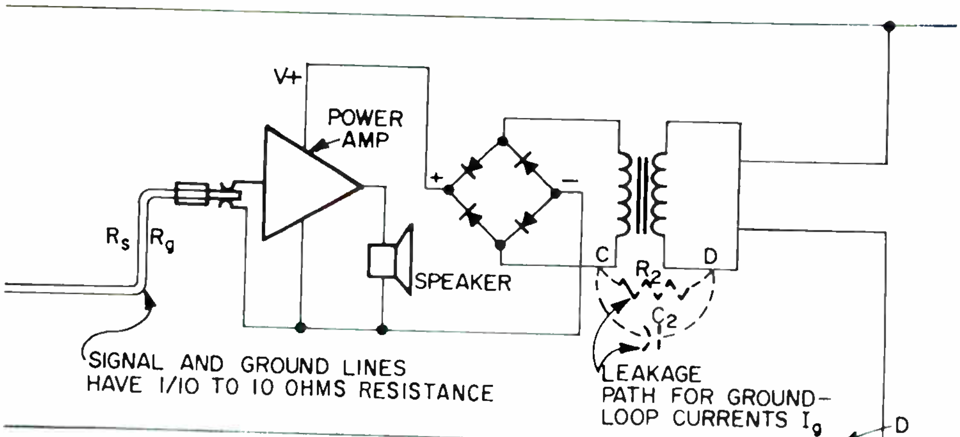
Impedance levels are different, however. Whereas it would be rare to find the earth's resistance exceeding about 1 ohm, it isn't unusual for 200 feet of connecting cable to introduce 20 ohms or more of resistance. Consequently, practically all the 10-mv ground voltage is applied across points A and B in the diagram, and in turn across the amplifier's input terminals.

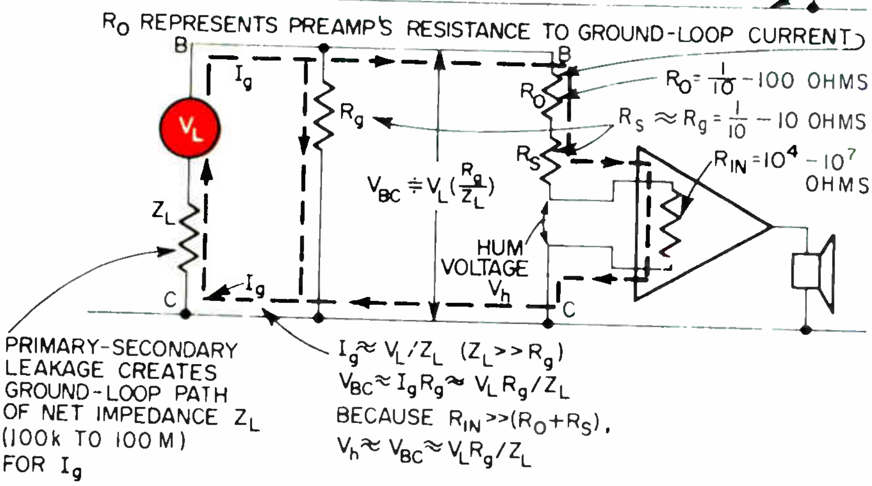
The thermocouple transducer acts as a low resistance, designated $2R_T$, split between the two separate current paths joining A and B. The thermocouple itself is represented for simplicity by resistance R_T in each ground-loop path.

Some remedies

Before discussing the use of an op-amp differential circuit to eliminate ground potential errors, it's perhaps worthwhile to outline alternative approaches sometimes adopted. Some are aimed at interrupting the continuity of the ground loop while preserving the path for transducer signals. Increasing the ground impedance value Z_g would be a step in this direction.

Another tactic—an expensive one—is to reduce the





resistance of ground conductor R_g so as to short-circuit the ground potentials, V_{AB}.

Yet another approach would break the ground-current path by operating the amplifier from an isolated power supply or by insulating the thermocouple from ground.

These methods are more easily described than implemented. For one thing, the amplifier is frequently used to feed signals into recorders, analog-to-digital converters, displays, and other data-handling devices, all of them likely to be separately grounded. In these cases, the ground loop is completed through the amplifier to ground via the additional piece of equipment, nullifying efforts to run the amplifier from an isolated supply.

For good thermal response, it's often necessary to weld the thermocouple to the structure monitored. And even if this extreme measure weren't required, the ionized gas issuing from the rocket motor would certainly provide a low-resistance path from thermocouple to ground.

In any event, the instrumentation engineer is usually presented with a pair of wires carrying signal- and ground-loop noise, and has no chance to make large-scale modifications in the over-all system. He must instead find ways within the limits of his instrumentation package to reject ground currents and the resulting error voltages.

One common method of interrupting ground-loop currents is to interpose an open circuit between signal source and amplifier, arranging for the open circuit to transmit signals while blocking ground-loop currents. This seemingly impossible job is handled by a transformer between the thermocouple and final amplifier, shown on page 63. A modulator-demodulator arrangement, the transformer responds only to signal voltage V_s and presents an open circuit to the ground voltage, V_g.

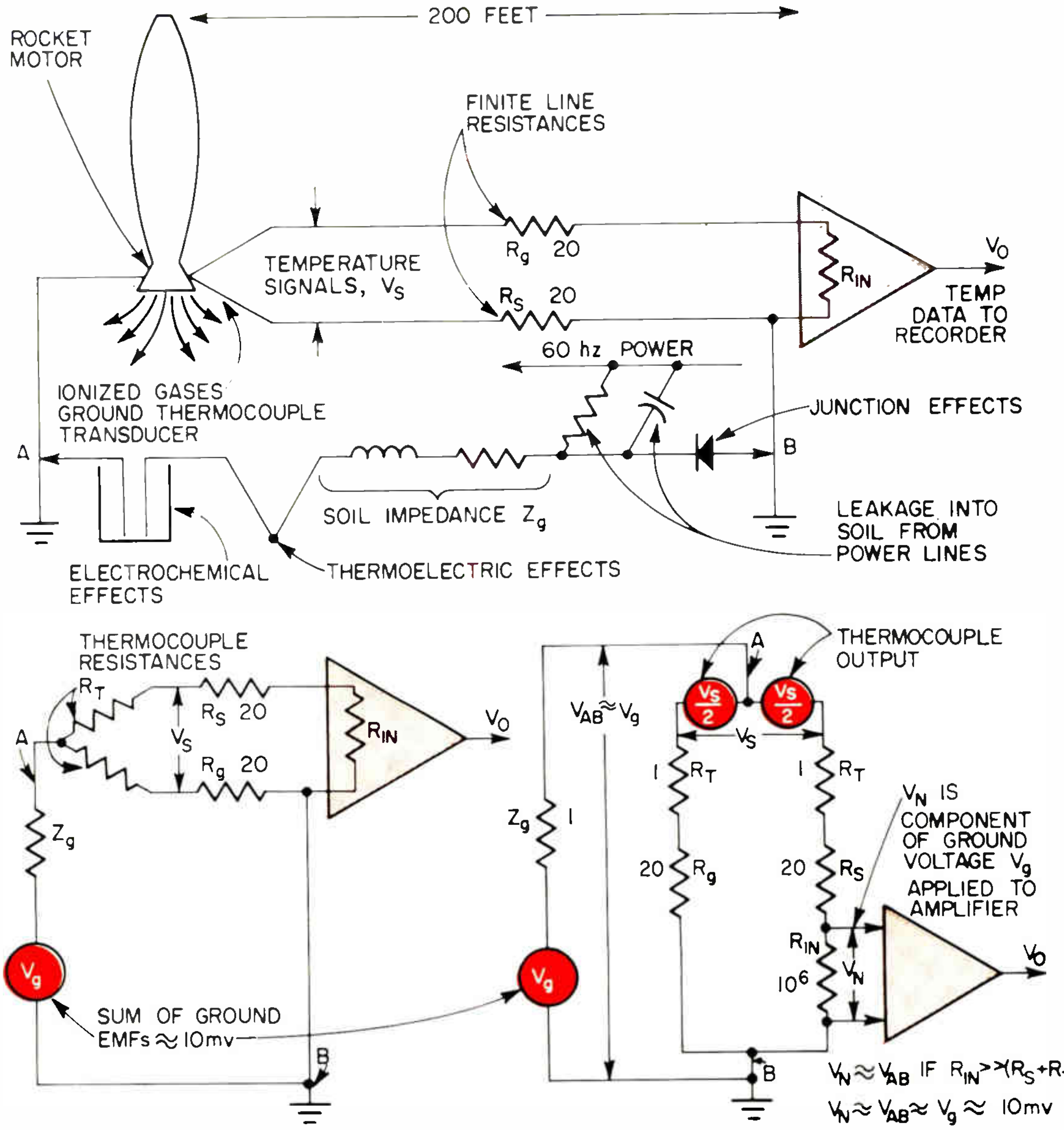
This circuit can handle very wide voltage differences between signal and amplifier grounds, or, when used with bridge and other differential sources, very high common-mode voltage levels. A further merit is that its error rejection is independent of any closed-loop gain setting—which is certainly not the case in the differential-circuit scheme.

Disadvantages include limited bandwidth, which can only be a fraction of the modulation frequency, and output errors created by intermodulation between the chopper and the signal. Another drawback is that error-reducing feedback cannot cover both modulator and demodulator without restoring a path for ground currents.

The switched-capacitor technique is an alternative way to break the ground-loop circuit. Similar in principal to the modulator-demodulator method, it tends to yield similar advantages and disadvantages, along with the added problem of poor frequency response.

Balancing act

The most widely applied method of minimizing ground-loop errors aims not to attenuate the current, but to apply identical fractions of ground-loop voltage to the inverting and noninverting terminals of a differential amplifier. The ground voltage is thus seen as a common-mode voltage when the transducer signal is applied differentially to the amplifier's input terminals, and if the amplifier has high common-mode rejection, it will ignore the spurious voltage and respond only to the valid input.



Vicious cycle. Separation of signal source and data amplifier can lead to considerable voltage difference between ground connections at each location (above). Ground voltage, reaching 5 volts in extreme instances, is represented as V_g in series with ground impedance Z_g (lower left). Ground-loop current set up by V_g develops error voltage V_N at amplifier's input terminals (lower right).

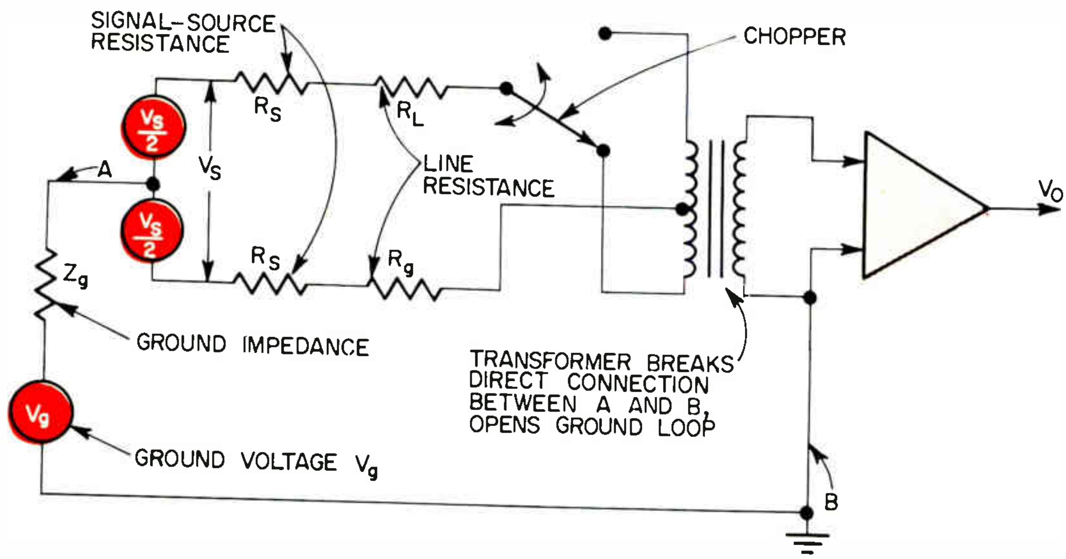
The ground-loop currents shown on page 64 flow through parallel paths APB and AQB, adding to voltages V_1 and V_2 at the amplifier's input terminals. If the signal source were removed, these voltages would be created solely by the ground-loop currents. Accordingly, it's possible—for d-c errors at least—to adjust the balance resistor, R_B, so as to make V_1 exactly equal to V_2. The equal voltages become a common-mode input for the amplifier, which ideally develops no output for identical voltages applied to its inverting and noninverting input terminals.

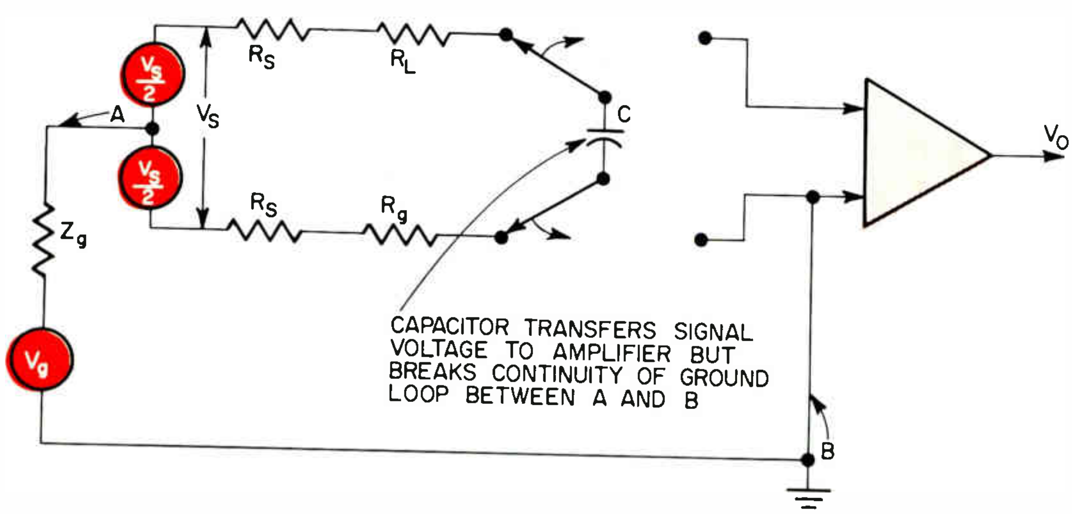
Commercial amplifiers are available with common-mode rejection ratios of 10^6 or more; these can reduce every volt of common-mode input to a microvolt of equivalent common-mode error, making over-all accuracies of 100 ppm feasible.

This setup handles only d-c common-mode errors, but the principles of balancing a-c inputs are similar.

So far, the op-amp differential circuit has been described only as an economical way to overcome ground-loop problems in high-accuracy data-measurement applications. However, it should be noted that the differential arrangement can be used for data measurements in which the transducer's signal is differential rather than single-ended.

Strain-gage elements, for example, are usually connected in Wheatstone-bridge arrangements, and develop push-pull output signals perched on relatively high levels of common-mode voltage. Even when the strain-gage elements are isolated from ground by as much as leakage capacitance permits, the amplifier must invariably be a differential one





Blocking grounders. Magnetic coupling between transformer's primary and secondary breaks direct connection for ground-loop currents and transmits signal as equivalent a-c voltage (above). Alternative technique breaks direct ground-loop continuity with a switched capacitor that alternately charges to signal voltage V_s and then passes this voltage to the amplifier.

to extract millivolt signals from several volts of common-mode carrier. Biomedical measuring instruments, too, invariably require differential amplifiers to extract information from high levels of 60-hz pickup.

Picking a pair

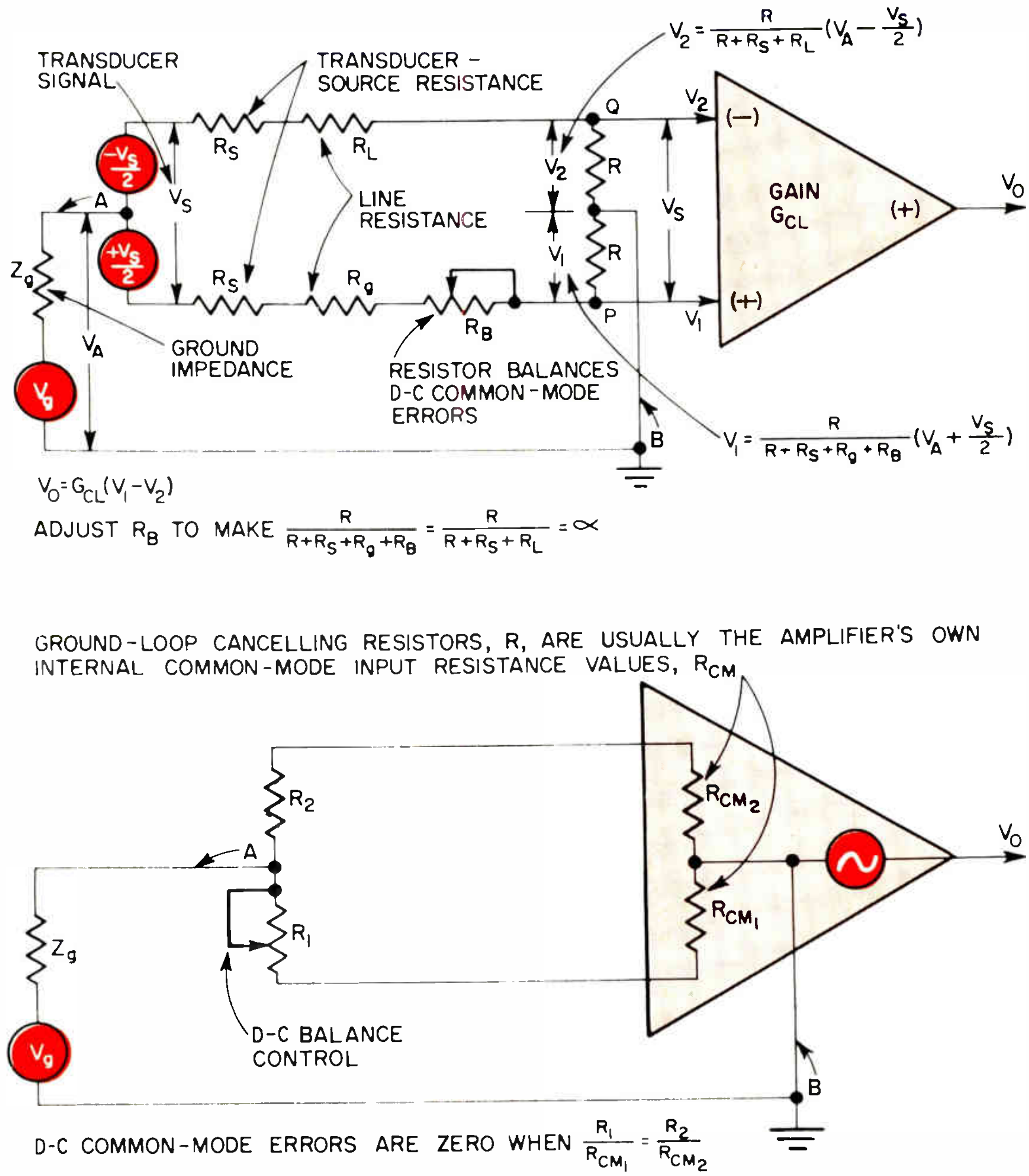
Having established that a circuit that has to measure millivolt signals in the presence of several volts of common-mode or ground-loop noise must have low drift, high CMRR, high input impedance, fast response, and variable gain, the next step is to see how conventional operational amplifier circuits fulfill these basic requirements.

The need for impedance levels of 1,000 megohms or more rules out a differential amplifier based on an inverting circuit whose input impedance is equal to the circuit's input resistance; a noninverting circuit can provide adequate input impedance when used as a differential amplifier.

D-c stability depends on the drift of the two op amps selected for the differential circuit. Chopper-stabilized op amps are out of the running because they require special power supplies to offset their single-endedness. But some conventional operational amplifiers have the necessary d-c stability, along with good response and input impedance.

The closed-loop gain and gain linearity that an amplifier can provide depends upon the amount of open-loop gain available for use as negative feedback.

The relationship between closed-loop gain stability, % $\Delta G_{cl}/G_{cl}$, and open-loop gain variation, % $\Delta A/A$, is $\Delta\%\ G_{cl}/G_{cl} = \%\ \Delta A/A \times 1/(1 + A\beta)$



Identical twins. Ground-loop errors can be reduced by converting ground-loop voltage into common-mode input voltage. Equal parts of V_g are applied to inverting and noninverting terminals and their effect is scaled down in proportion to amplifier's CMRR (above). In practical circuit, high-value balancing resistors, R, are replaced by amplifier's common-mode input resistances, R_{CM}. Although this setup handles only d-c balancing, the same principles are applicable to a-c ground-loop and common-mode errors.

where β is the fraction of open-loop gain used as feedback. Because $1/\beta$ is very nearly the same as closed-loop gain G_{cl}, and $A\beta >> 1$, the equation simplifies to

$$\% \Delta G_{cl}/G_{cl} \approx \% \Delta A/A \times G_{cl}/A$$

If the data amplifier must provide 2,000 volts/volt gain for d-c signal scaling, and specifications call for 0.5% gain linearity, the stability equation can be manipulated to give the nominal value of open-loop d-c gain A in terms of the amplifier's expected open-loop gain variation, % $\Delta A/A$.

For example, if open-loop gain varies by 25% due to loading, aging, or the effects of temperature—that is 100% $\Delta A/A$ = 25%—then 0.05% $\approx$ 25% $\times$ 2,000/A. So the minimum open-loop gain under these conditions is 25 $\times$ 2,000 $\div$ 0.05 = 10^6, or 120 db—a bit beyond the range of op amps with the required stability.

Chopper-stabilized amplifiers could handle it, but, as noted earlier, they need elaborate power-supply arrangements when used in high-impedance differential circuitry. Thus, high closed-loop gain, input impedance, and common-mode rejection with low drift make off-the-shelf op amps impractical for this kind of differential circuitry.

Circuit design

Designer's casebook

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

FET's resistance change trips heater control

By Emanuel Elad
University of California, Berkeley

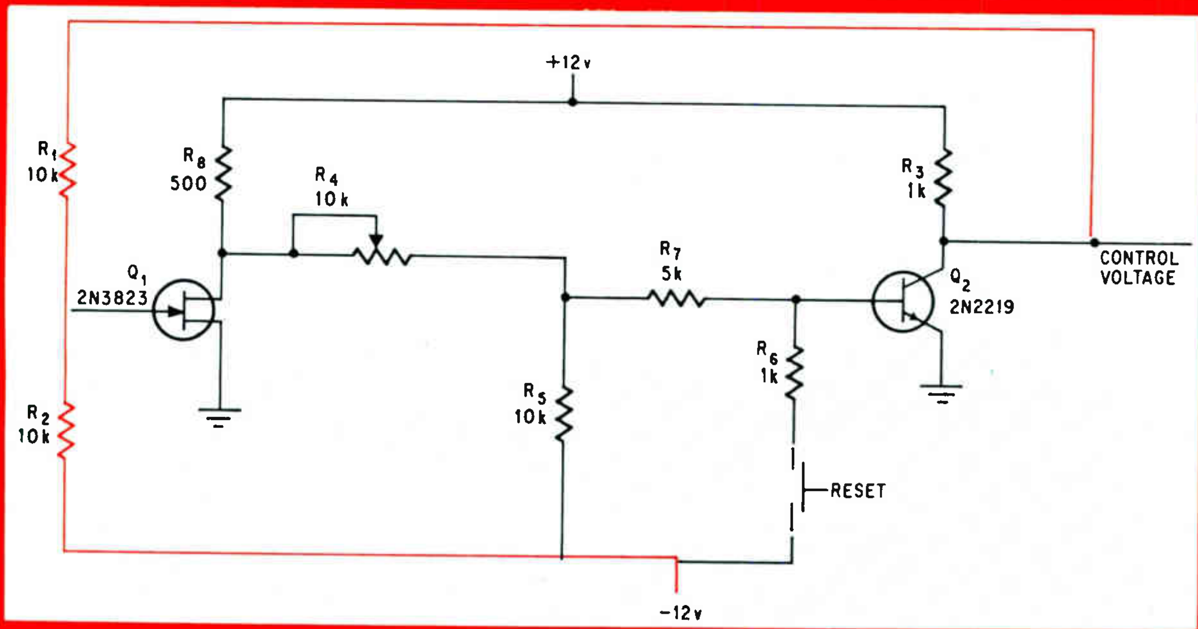
Transconductance in a field effect transistor is a parameter that can accurately establish the high-temperature cutoff in a heat chamber. As the temperature in the chamber rises, transconductance drops, causing a bistable circuit composed of the FET and a bipolar transistor to switch. In switching, the bistable circuit opens the line between the chamber's heating elements and the supply. By adjusting a potentiometer between the FET and the bipolar, the cutoff point is determined for any temperature between 35 C and 65°C.

Closing the reset switch allows a negative voltage to appear on the other side of R_6 at the base of Q_2. This strongly biases Q_2 off, establishing a 1-milliampere current flow through R_3, R_1, and R_2. The potential drop across R_3 causes an 11-volt d-c level on Q_2's collector, which is used to control the heater's supply line.

Voltage division by R_1 and R_2 results in −0.6 volts at the gate of Q_1. Drain-to-source resistance in the FET is low at this gate voltage, and consequently high current—in the milliampere range—flows through Q_1 and the drain resistor R_8. Only microamperes flow through R_4 and R_5—the two resistors paralleling the FET—making for a negligible voltage drop across R_5. The high negative voltage that is therefore present at the base of Q_2 keeps it off despite the opening of the reset switch.

As the ambient temperature increases, drain-to-source resistance in Q_1 increases, thus deflecting current flow out of Q_1 into R_4 and R_5. The voltage drop across R_5 increases until a level is reached—dependent on the setting of R_4—where the base of Q_2 becomes positive with respect to its emitter. Enough current flows through the limiting resistor R_7 to bias Q_2 into saturation, and the increase in Q_2's beta resulting from the rising temperature makes it easier to switch that transistor on. This places the collector of Q_2 close to ground potential, thus removing the heater control voltage.

Resistors R_1 and R_2 now divide the −12-volt sup-



Temperature dependent feedback. When Q_1's drain-to-source resistance increases at high temperature current through R_4 and R_5 increases. This biases Q_2 into saturation which in turn moves Q_2's collector from −12 volts to ground. Bias at Q_1's gate changes from −0.6 volts to −6 volts.

ply. The gate voltage is therefore −6 volts—which is above the FET's pinch off—and current flow in Q_2 is mere microamperes.

After the ambient temperature falls below the circuit trip point, the reset switch must again be closed.

The circuit can be made to trip at low temperatures by placing the reset switch between the gate of Q_1 and resistors R_2. It's preferable for reasons of accuracy, however, to use a p-channel FET and a pnp transistor in that application.

SCR helps video signal gate a-c power line

By Wayne Simister

University of Utah, Salt Lake City

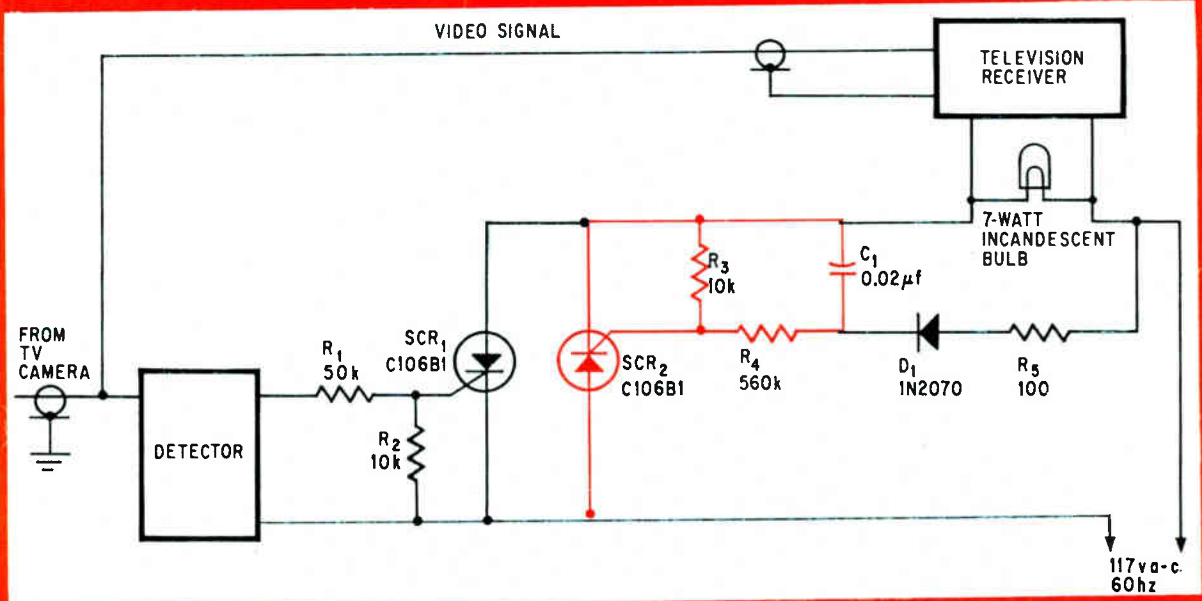
Television receivers scattered throughout a closed-circuit system can be turned on by video signals from a camera. These signals—usually only 30 microamperes—are able to switch on the 117-volt line because the SCR circuit they gate helps in the switching.

When no signal is present at the gate of SCR_1 resistor R_2 maintains the gate and cathode of the SCR at the same potential. Resistor R_3 at the gate cathode of SCR_2 does the same thing. Consequently the a-c line between the receiver and the 117-volt supply is open.

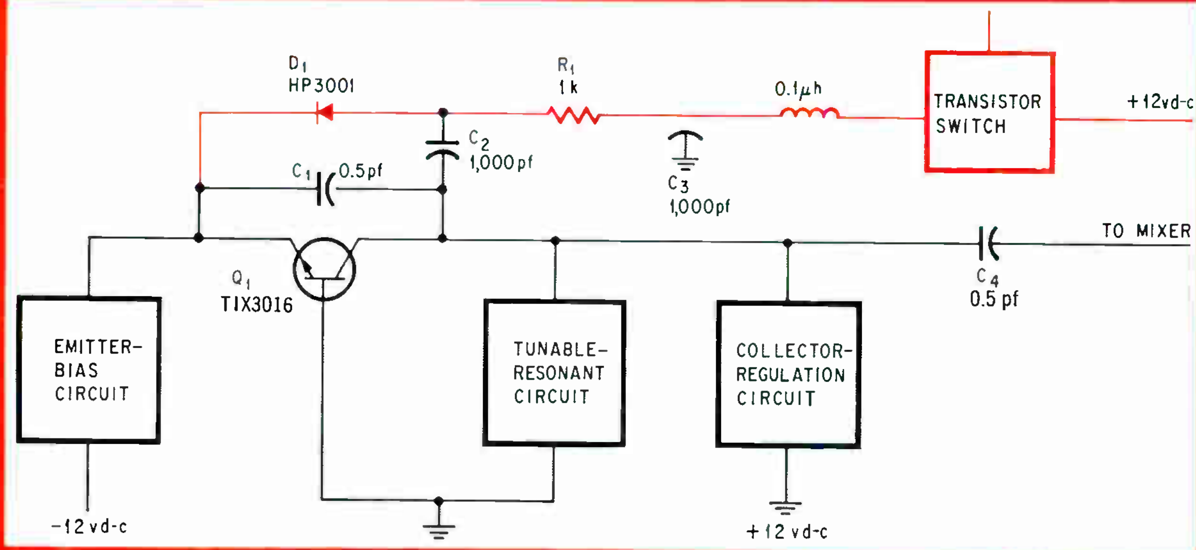
When a detected video signal reaches R_2, SCR_1 is gated into conduction. When the positive part of the a-c voltage appears it is passed through SCR_1. Power is delivered to the receiver's d-c supply and capacitor C_1 charges through to D_1 and the current-limiting resistor R_5, the positive cycle's peak voltage. After the positive cycle returns to zero, C_1's discharge through R_4 and R_3 gates SCR_2 into conduction. Although SCR_2's gate voltage isn't present during all of the negative cycle, it stays on until the peak voltage is reached. Anode current in the interval between the peak and zero points keeps the SCR on.

As long as the detected signal is present at the gate of SCR_1, each succeeding cycle will be coupled into the receiver's supply. The values of R_1 and R_2 must be selected with care, since a low R_1 and high R_2 will make the SCR's gate sensitive to line transients. Conversely, a high R_1 and low R_2 weaken the gate signal so much that it doesn't work.

The 7-watt bulb connected across the line absorbs any inductive kicks that might occur in the receiver's filter network. A spike, resonating between capacitor C_1 and internal inductance, prevents SCR_2's from turning off. If the circuit is used to control an electric motor instead of a tv receiver, the incandescent bulb must be larger to absorb the inductive phase shifting.



Domino theory. A small signal gates SCR_1 into conduction during the a-c's positive swing; SCR_2 is gated on during the negative swing. Capacitor C_1 charges to the line voltage when SCR_1 is conducting, as it discharges through R_4 SCR_2 is gated on.



Waiting for the gun. A transistor with a forward-biased p-i-n diode across its collector-emitter junction acts as a d-c amplifier. Opening the switch lets the diode return to its natural high resistance, causing oscillations to begin

P-i-n diodes turn on microwave bands faster

By August Barone

Airborne Instruments Laboratory, Deer Park, N.Y.

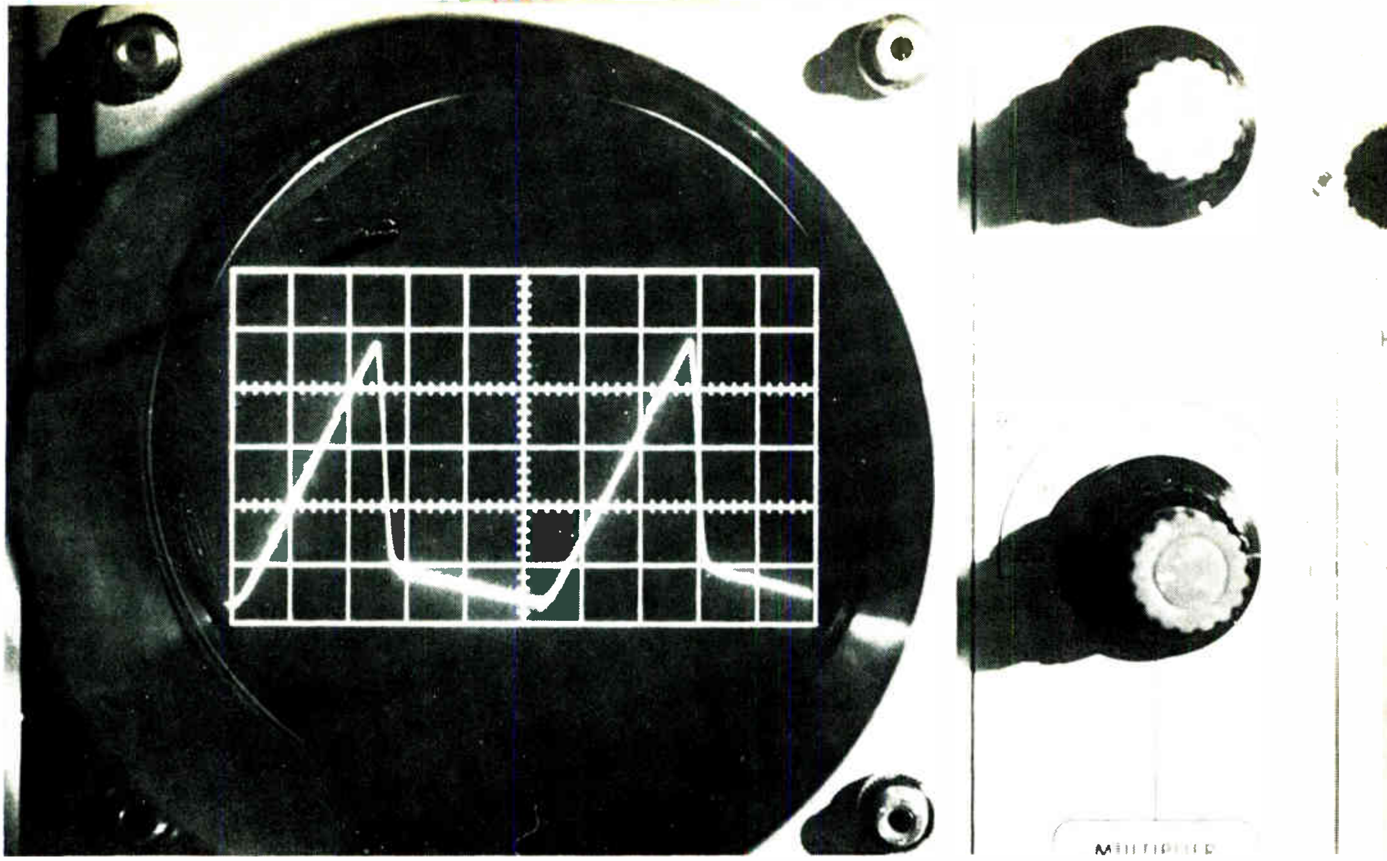
Discrete frequency bands—necessary in wide-spectrum communication equipment—are generated by several tunable oscillators in a receiver. These oscillators must turn on immediately so the operator won't lose time in sweeping the bands in search of a signal. If the junctions in the oscillators' transistors are kept at 50°C, full oscillations begin 50 milliseconds after the turn-on signal appears. Collector current maintains this high junction temperature, and a p-i-n diode in each oscillator is used for switching in and out of a-c operation. Conventional systems stop oscillations by removing the d-c bias from the transistors. Unfortunately this lengthens the turn on time of the oscillator because the junctions start their temperature rise from a low temperature. The obvious drawback in the conventional system is the long waiting times necessary while switching through the different bands in the receiver. These waiting times are long enough to cause the operator to miss distress signals.

P-i-n diodes are nonrectifying semiconductors used extensively as switches in microwave circuits. Unbiased, the diode has naturally high resistance and low capacitance because of the intrinsic region, where carrier lifetime is long. When forward-biased by a d-c voltage, the intrinsic region has a high conductivity.

A p-i-n diode connected across the collector-emitter junction of a transistor offers a high impedance while a band-command trigger holds the line open between it and the +12-volt d-c supply. Consequently, regenerative feedback can be coupled through C_1 from the oscillator's collector circuit into the emitter's tank circuit. Oscillations occur and are coupled out through C_4 until a command signal opens the d-c line.

When this line is opened, current through D_1 reduces its resistance to about 10 ohms. Any a-c voltage that might appear in the collector circuit won't have the type of phase relationship that causes oscillations, because the low resistance lets the current flow back to the emitter circuit. When the operator turns on an oscillator by closing the d-c line, the oscillations begin in 50 milliseconds and the frequency is within 4% of nominal value.

Short lead lengths are necessary on all the components of this circuit, especially the bypass capacitor C_3. At microwave frequencies the added inductance resonates with the bypass capacitor. The p-i-n diode must also be carefully located and have a minimum lead length, since any inductance resonates with the isolating capacitor C_2. Instead of using C_1 as the feedback capacitor the circuit designer may wish to make use of the p-i-n diode's capacitance. Circuit operation is not changed if this method is used. The capacitance in the diode which is low when no d-c current is flowing is shorted out when the p-i-n diode is forward biased by the closed command switch.



Industrial electronics

Triple play speeds a-d conversion

Designed for high-performance applications, triple-ramp converter does the job 85 times faster than dual-integrating-ramp circuits

By H. Bent Aasnaes and Thomas J. Harrison
Systems Development Division, International Business Machines Corp., San Jose, Calif.

The high performance demanded of today's process-control and data-acquisition systems require analog-to-digital converters capable of speeds up to 20,000 conversions per second and a resolution of 14 bits. A new technique, triple-integrating-ramp conversion, not only does the job as well as the successive-approximation technique, but does so at a lower cost.

Unlike the successive-approximation converter, the triple-ramp circuit doesn't require expensive component precision. Instead, it operates on the voltage-to-time principle of the relatively inexpensive dual-ramp converter. This principle involves the conversion of an input voltage to a time interval, which is easily measured with digital methods. But the third ramp makes the big difference—putting the new converter in the same high-performance class as the successive-approximation circuit.

An experimental triple-ramp converter is now undergoing tests at the International Business Machines Corp.'s San Jose, Calif., facilities.

The new circuit achieves its high speed by converting the integrated measured analog voltage—the first ramp—during two subsequent ramps, one coarse and one fine. The coarse ramp rapidly converts most of the input voltage by using less-than-full resolution. During the fine ramp, the remaining voltage is converted for full resolution. Total conversion time is about 1/80th that when converting the full value at full resolution.

Even though the voltage level at which the converter switches from the coarse to the fine step may not be precisely known, any error is included in the third, or fine, ramp, where it is resolved and added to the converted value obtained during the second, or coarse, step.

Building blocks

In single- and dual-ramp converters, the input-signal amplitude is changed to a time interval as an intermediate step in obtaining a digital value. And during this interval, pulses are counted—with the total pulse count corresponding to the unknown voltage.

The single-ramp circuit compares the analog input signal, V_{in}, with a ramp voltage, $V_r(t)$, which is produced by a function generator. Because the slope of the ramp is constant, the time interval between $V_r = 0$ and $V_r = V_{in}$ is proportional to V_{in}.

Single-ramp converters have long been used in low-cost, low-performance industrial applications. Accuracy in this type of converter primarily depends on the linearity of the ramp generator, and the stability of both the clock frequency and the comparator threshold voltage. Moreover, the circuit is sensitive to any noise on the input signal during the instant of comparison of V_r and V_{in}, and its conversion time is directly proportional to the value of the input voltage.

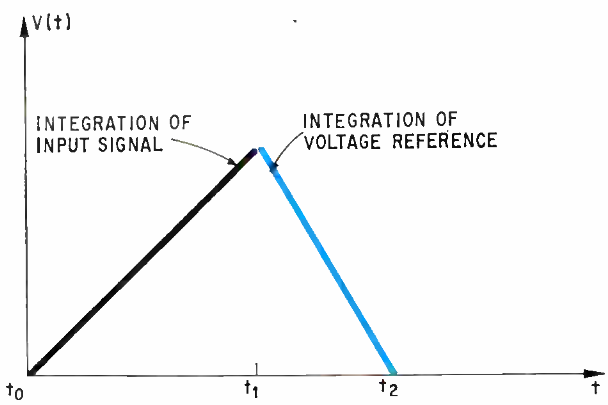
In an n-bit binary converter with a clock frequency, f_c, in pulses per second, the maximum number of pulses is 2^n, so the conversion rate is limited to $f_c/2^n$ conversions a second. Therefore, a 12-bit converter using a 10-megahertz clock can only provide about 2,500 conversions a second. These factors generally limit the single-ramp converter to applications requiring fewer than 12 bits and to speeds from 5,000 to 10,000 conversions a second.

The double-integration or dual-ramp technique doesn't depend on a highly stable ramp and clock for conversion accuracy. The input signal to the dual-ramp converter is first integrated for a fixed time interval, set by counting a number of clock pulses. The integrator voltage at the end of this interval is proportional to the input signal averaged over the integration time. A reference voltage of polarity opposite to the input signal is then integrated for the time it takes to reduce the integrator voltage to its initial value. A binary number proportional to the average-signal value is obtained by counting clock pulses during this second integration period.

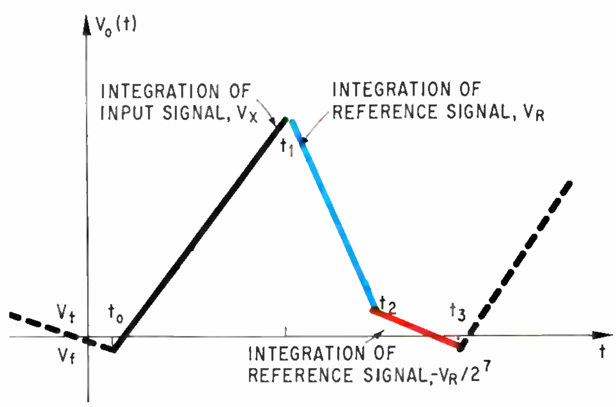
This up-down integration makes the dual-ramp converter inherently more accurate than the single-ramp converter and results in an over-all conversion linearity superior to that of the integrator. Since the digital number is independent of the integrator's time constant, precision resistors and capacitors with low temperature coefficients aren't required. Moreover, with the same clock measuring both the first and second integration intervals, a precision clock is unnecessary. Noise error is minimized because the input signal is integrated, and the actual analog-to-digital conversion occurs during the second integration period—after the input signal has been disconnected from the converter.

However, for all the dual-ramp converter's advantages, there is a price to be paid in speed. A total of 2^{n+1} clock pulses is normally required for an n-bit full-scale conversion. With a 10-Mhz clock and a 14-bit resolution, which is feasible using inexpensive components, a rate of only about 300 conversions per second can be obtained.

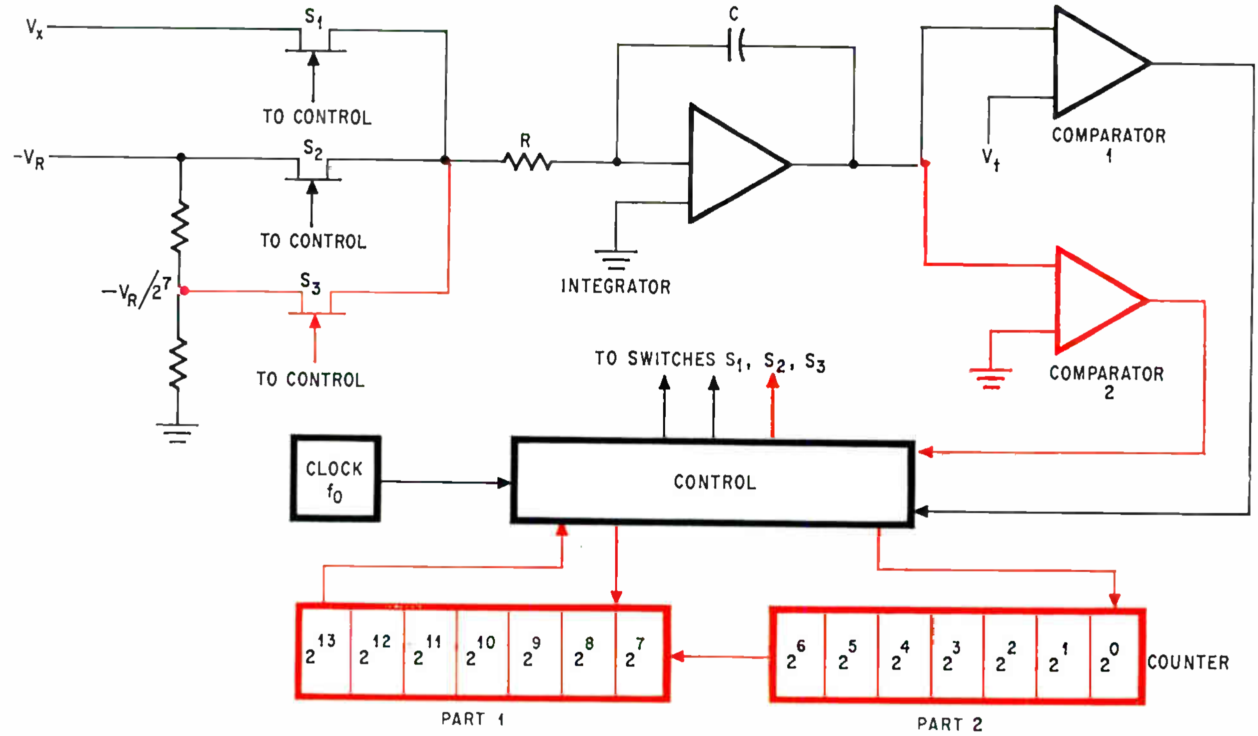
Although this 14-bit conversion rate is adequate for some instrumentation systems, many process-control and data-acquisition installations require higher rates. The successive-approximation a-d converter commonly used for such applications is capable of 14-bit resolution at 20,000 conversions a second. This type of converter, however, is sensitive to noise, and is expensive—primarily because its design doesn't lend itself to integrated circuits.



Only two. In dual-ramp converter, the unknown input signal is integrated for a fixed time, t_0 to t_1. Then, integration of reference voltage yields a time interval, t_1 to t_2, which is proportional to input signal.



Added step. Output of triple-ramp analog-to-digital converter is integrated twice. Then a third ramp, from t_2 to t_3, provides vernier action for high-speed, high-resolution conversions.



Precise split. Like a dual-ramp integrator, but with one more comparator and switch and a two-part counter, the triple-ramp converter provides fast 14-bit conversion.

A triple-ramp converter with the same 14-bit resolution contains a two-part binary counter, two comparators, an analog integrator, control logic and three switches, and a pulse clock. The circuit differs from the dual type in that the dual's second ramp is broken into the two ramps—coarse and fine. The converter's three main analog signals are the input voltage, V_x, a reference voltage, $-V_R$, and another reference $-V_R/2^7$. The control logic determines which signal becomes the integrator's input.

Converting by parts

When the integrator output reaches a predetermined threshold, V_t, comparator 1 changes state. Although the value of V_t isn't critical, it must be at least slightly greater than the absolute value of $V_R/2^7$. In a similar manner, comparator 2 responds when the integrator output reaches ground. The counter, divided into two parts having seven bits each, is connected so that overflow pulses from part 2 (2^0 to 2^6) proceed into part 1 (2^7 to 2^{13}). Sequencing the converter's internal operations is the control circuit.

The conversion cycle consists of three time-based operations: integration of V_x for a fixed time interval, integration of $-V_R$ until the first clock pulse after the integrator output reaches the threshold, and integration of $-V_R/2^7$ until the first clock pulse after the integrator output causes comparator 2 to change state. During the first two integrations, clock pulses accumulate in part 1 of the counter and, during the third, pulses accumulate in part 2.

A conversion cycle starts at time t_o. The initial integrator output voltage is:

$$V_o(t_o) = -V_f \quad (1)$$

where $-V_f$ is an offset voltage resulting from minor time delays in the circuits. Each part of the counter is at zero. The control logic closes S_1 and opens S_2 and S_3, thereby connecting analog input voltage V_x to the integrator. Then V_x is integrated for the fixed time interval

$$(t_1 - t_o) = \frac{2^7}{f_c} \quad (2)$$

determined by the time it takes for part 1 of the counter to count 2^7 clock pulses. The last pulse resets part 1 to zero. The integrator output voltage at this time is

$$V_o(t_1) = V_f + \frac{V_{x\,avg}}{RC}(t_1 - t_o) \quad (3)$$

where the integrator is assumed to be ideal and $V_{x\,avg}$ is the average value of the input voltage over the time of integration.

Immediately, the second-ramp operation starts. Reference $-V_R$ is connected to the integrator by closing S_2 and opening S_1; S_3 remains open. This reference voltage is equal in magnitude to the maximum allowable V_x but opposite in polarity. Integration proceeds until t_2, the time of the first clock pulse after comparator 1, changes state. The comparator changes state when the integral of $-V_R$ equals V_t. Then, comparator 1 changes state. During the integration of $-V_R$, only part 1 of the counter is running. It receives clock pulses at the 2^7 stage. At t_2, the number in the counter is

$$N_1 = 2^7 f_c (t_2 - t_1) \quad (4)$$

Since each clock pulses enters the counter at the seventh bit, 2^7 counts per pulse are added.

The integrator output voltage at t_2 is

$$V_o(t_2) = -V_f + \frac{V_{x\ avg}}{RC}(t_1 - t_o) - \frac{V_R}{RC}(t_2 - t_1) \quad (5)$$

Counting precisely

At this point, only S_3 is closed and the third-ramp operation is triggered. Integration of $-V_R/2^7$ takes place between t_2 and t_3, where t_3 is determined by the first clock pulse after comparator 2 fires. This occurs when the integrated voltage reaches $-V_f$. During this interval, part 2 of the counter is running. At t_3, the number of pulses in the counter is

$$N_2 = f_c(t_3 - t_2) \quad (6)$$

Any counts in excess of 2^7 overflow into part 1.

At t_3, the integrator's output voltage is

$$V_0(t_3) = -V_f + \frac{V_{x\ avg}}{RC}(t_1 - t_0) - \frac{V_R}{RC}(t_2 - t_1) - \frac{V_R}{2^7RC}(t_3 - t_2) \quad (7)$$

Because of the integrator offset and the time delay through comparator 2, this voltage isn't zero. However, as long as the converter runs continuously, $V_0(t_3)$ equals the initial voltage $-V_f$. Equation 7 is then reduced to

$$V_{x\ avg}(t_1 - t_0) = V_R(t_2 - t_1) + \frac{V_R}{2^7}(t_3 - t_2) \quad (8)$$

which, combined with equations 2, 4, and 6, yields

$$V_{x\ avg} = V_R\frac{N_1 + N_2}{2^{14}} = V_R\frac{N}{2^{14}} \quad (9)$$

Thus, the number N in the counter at the end of conversion is the 14-bit representation of the average input voltage over the interval t_0 to t_1.

Faster by far

The triple-ramp converter, like the dual-ramp type, doesn't require the resistor, the capacitor, and the clock to be precise or highly stable. Both types minimize noise-induced errors by averaging the input signal, but the new converter is much faster.

Since 2^7 pulses have to be counted in each of the three integration periods for a full-scale signal, V_x, the maximum conversion time for a 14-bit triple-ramp converter is $(3 \times 2^7)/f_c$—about 85 times faster than a 14-bit dual ramp's $2^{15}/f_c$. With a 10-Mhz clock, the triple-ramp unit operates at about 26,000 conversions a second, compared with 300 for the dual-ramp device. In general, the triple-ramp converter is faster than the dual-ramp type by a factor of $3/2(2^{n/2})$.

Conversion accuracy isn't affected by the value of V_f. Since $-V_R/2^7$ is switched into the integrator at t_2, an increase in V_f may result in one less pulse being applied to part 1 of the counter. But this pulse is equal to 128 pulses applied to part 2, so the final count accommodates the error. This means that V_f need not be highly stable, and that the delay and offset voltage of comparator 1 are of little consequence.

Delaying response

Although an offset is the result of a constant delay and only changes in this delay produce an error, the switching circuitry and the integrating amplifier must be quite fast. Since the integrating amplifier has a finite bandwidth, a delay exists from the time a signal is applied at the integrator input to the time the output appears. A delay also exists between the time the control logic applies a signal to the input switch and the time the inputs actually switch.

A tolerable conversion error would be one bit, that is, an uncertainty in the value at the 2^0 stage. During one clock pulse period, 128 counts can enter the counter. Since the clock period is 100 nsec for a 10-Mhz clock, each count is equivalent to 100 nsec divided by 128, or 0.7 nsec. Therefore, each 0.7 nsec increment in the delay due to time or temperature results in a 1-bit error.

Long on options

The triple-ramp method is by no means limited to a 14-bit converter. Changes in the counter's word length and in the reference voltage-divider resistors make it possible to trade speed for resolution. At a given clock frequency, speed is doubled for each two-bit decrease in resolution. A 12-bit converter, for example, operates in excess of 50,000 conversions a second with a 10-Mhz clock frequency.

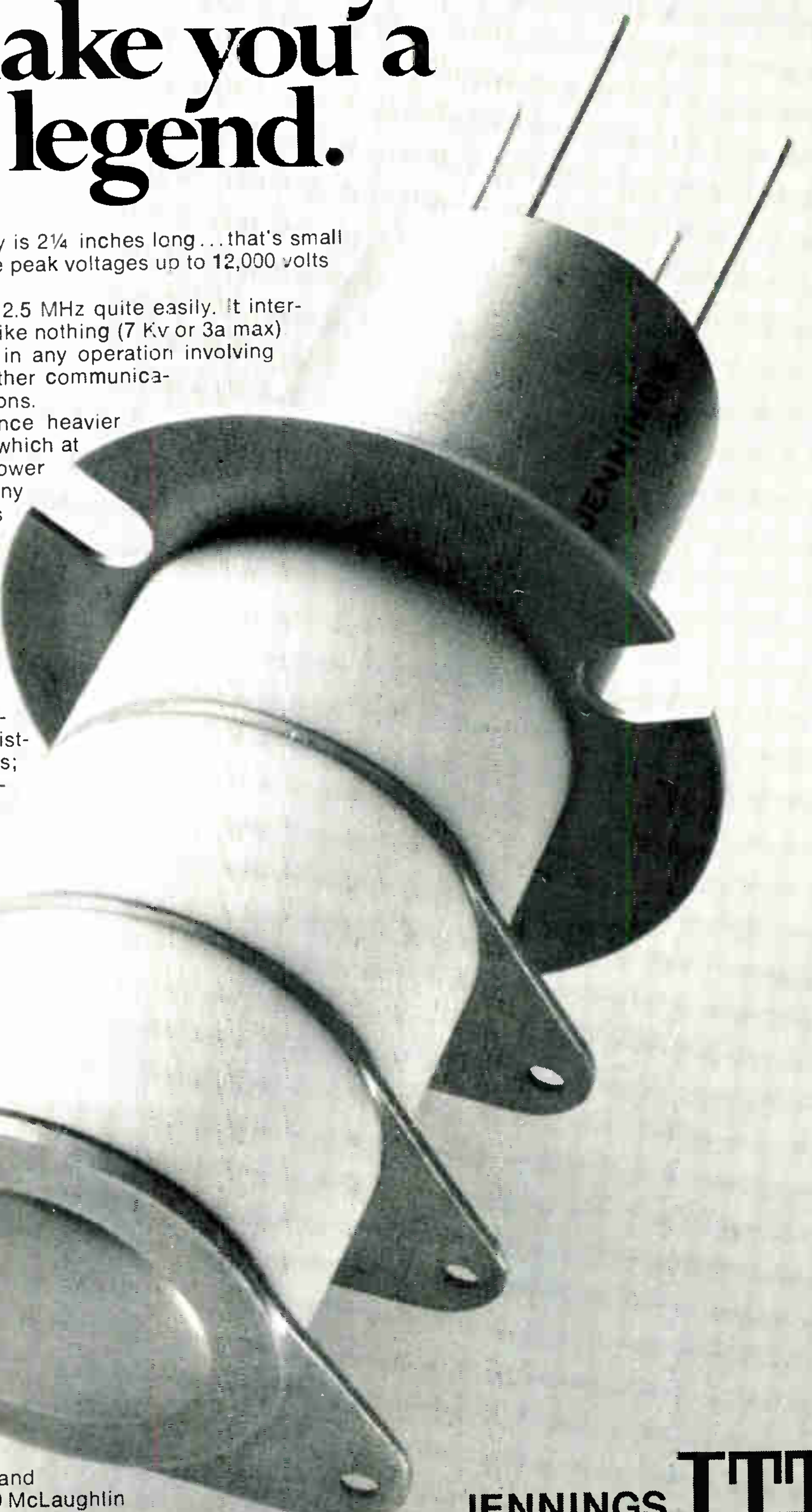
An offset voltage added to the integrator input enables signals of both polarities to be converted. This shifts the sum of the inputs to the positive range. Since an extra bit is required in the counter, conversion speed is reduced. The most significant bit in the counter is the sign bit; if zero is written as 1000 . . . 0, negative signals are represented in a 2's complement code.

The authors

H. Bent Aasnaes, a senior associate engineer at IBM's Systems Development division, specializes in the development of analog circuits for process-control computers.

Thomas J. Harrison, with IBM since 1958, is manager of analog technology for process control at the systems division's laboratory in San Jose, Calif.

This little relay can make you a living legend.



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Integrated electronics

Isolation problems get an airing

Planar air technique gives more reliability and design freedom than the solid method, and is being used for diode arrays

By Hal Clausen and Roger B. Rusert
Fairchild Semiconductor Corp., Mountain View, Calif.

Isolating the elements of an integrated circuit so they'll behave like discrete components has long been one of the most stubborn problems in designing and manufacturing IC's. In the most widely used dielectric isolation technique, a thermal oxide layer envelops the element islands and a polycrystalline substrate provides support. Now, however, another technique—planar air isolation—has been developed to the point where it's being commercially used in diode arrays [Electronics, April 15, p. 25]. This air isolation "challenger" has several advantages over the solid method:

- Two layers of protection instead of one, giving greater reliability.
- Compatibility with standard processing techniques, which may lead to higher yields.
- Greater freedom of design, because of the shorter lead paths, easier access, and fewer wire-crossover restrictions.
- Higher forward conductance in the diode array, because of shorter lead paths.
- Easier manufacture, because isolation is accomplished after element fabrication and the surface is flat, without the bumps encountered when the solid method is used.

Many other methods have been tried over the past decade, but none worked out well enough to be put in high-volume commercial production. Some of them, such as beam-lead, have been produced for in-house use. The others have been relegated to even lesser roles, in a few custom "ultra-performance" IC's or as laboratory curiosities or subjects of conference papers.

Planar's parents

Like the solid method, planar air isolation is making its commercial debut in the form of diode arrays. It's an offshoot of the 1964-66 proposals for mesa and handle-wafer isolation [Electronics, March 20, 1967, p. 91].

In the mesa method, transistor elements and interconnections were formed in the conventional way. A substrate was then joined to the wafer surface by a glass wafer. Excess material was removed and the elements were isolated by selective etching.

In the handle-wafer scheme, standard active elements were protected by thermal-oxide layers. Mesas containing the devices were then etched out. A glass-coated silicon handle-wafer was then fused to the mesas, and the wafer was isolated by lapping the material. Glass was formed around exposed mesas by backfilling, and then the handle-wafer was etched away.

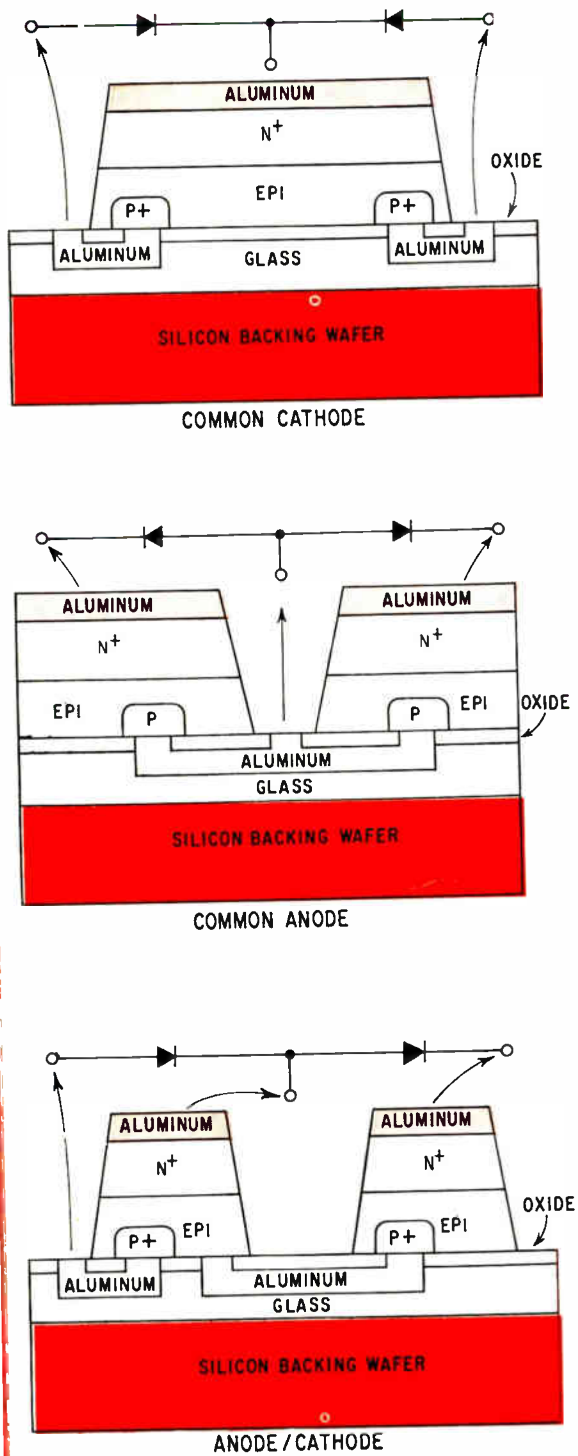
Both processes were basically compatible with standard production techniques but required too fine a control and were relatively costly. Prototype runs suffered from low yields of usable IC's and inconsistencies from unit to unit. Still, both the mesa and handle-wafer techniques showed enough promise to merit additional research, and it was this further work that led to planar air isolation.

What was needed at first was a marriage of the mesa and handle-wafer techniques. This yielded

The authors

Hal Clausen is senior marketing engineer in specialty products at Fairchild. He has a B.S. in education from the University of Illinois and nearly 12 years of experience in semiconductor work.

Roger B. Rusert received a B.A. in physics from Carleton College in 1964 and an M.A. in physics from the University of California at Berkeley in 1966. He's a research engineer at Fairchild and a specialist in isolation.



Interconnections. Air isolation applied to three diode arrangements. In these simplified array segments, the only change from one interconnection scheme to another is that of the mask; the order and arrangement of each "layer" remains the same. This advantage has been put to use in the fabrication of commercial 16-diode and dual 8-diode arrays.

better contacts with the elements; contacts could be made directly to the n+ region, through the "back door." Long paths weren't necessary.

Second, the original mesa idea called for a critical thinning step, done by etching. This was imprecise, often leaving unwanted silicon areas. The problem was solved by switching to a lapping technique—again done from the back.

Third, the glass material used left a lot to be desired. It didn't sufficiently resist acids, its thermal coefficient of expansion differed from that of silicon, and its melting point wasn't very much below the alloy temperature of the silicon and aluminum parts. Engineers finally developed a glass material that was sodium-free and had the right melting point resistance and thermal coefficient. The glass is sedimented by a centrifuge technique using a specially constructed wafer press that maintains a constant temperature during fusion, thus preventing irregularities in the glass layer.

Designers saw that bonding directly to the pads would require removal of the unwanted oxide during the contact cut step. They previously had removed oxide after the isolation step, but this increased mask and diffusion requirements.

Finally, production became possible when IC makers became more adept at maintaining close tolerances.

Why be discrete?

The electrical performance of planar air-isolated devices is as good as that of discrete arrays. Air isolation seems to have achieved discrete characteristics that were beyond the reach of pn-junction isolated IC's: high breakdown voltage, reduced parasitic effects, and uniform parameters from element to element, among others.

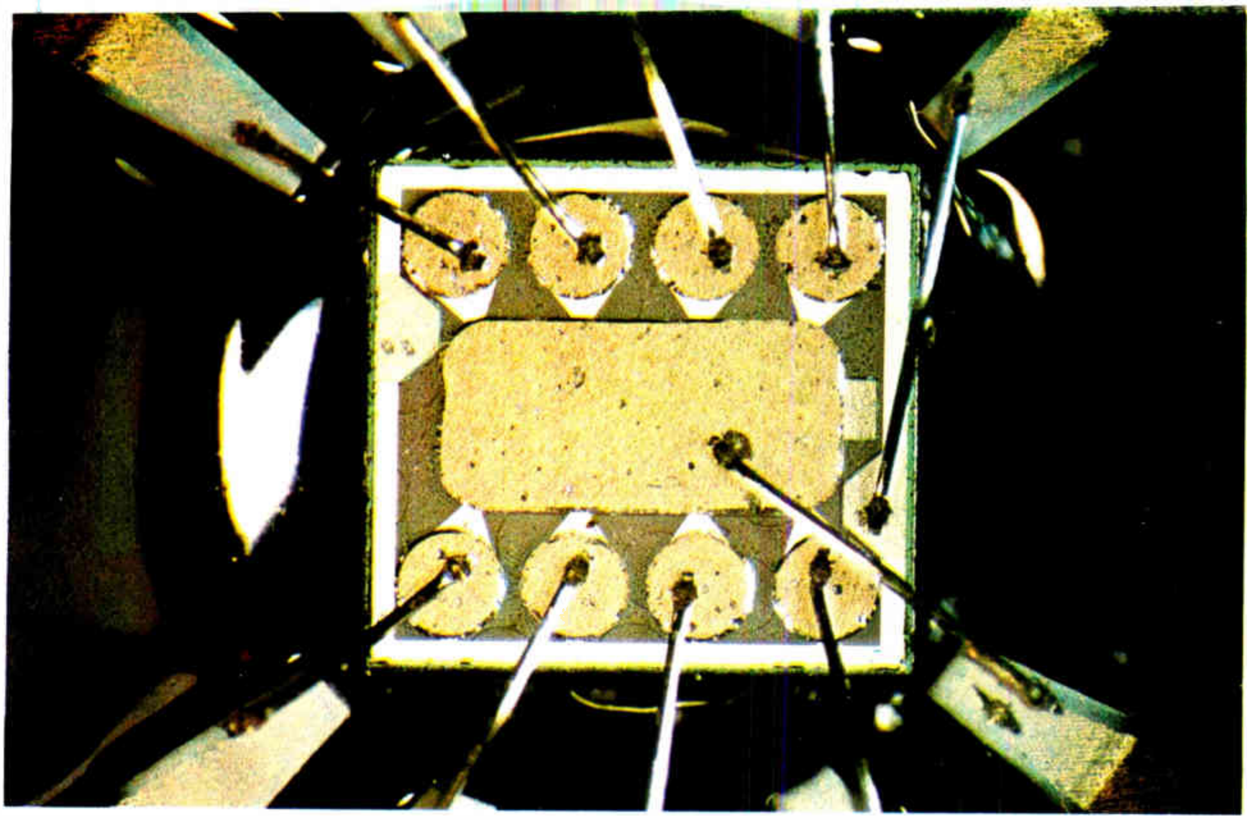
The new technique provides double protection for all junctions: oxide passivation and encapsulation in glass. Compared with other forms of isolation, it requires fewer assembly operations, die attachments, and bonds. It accommodates volume production methods through batch processing. And, because it requires no special masks or expensive materials, and little in the way of new production equipment, planar air-isolated IC's will be sold at regular prices.

Illustrations of the step-by-step manufacturing cycle appear on page 78; the entire technique is straight-forward and easy to visualize.

How it's made

After the elements have been diffused, a phosphorus-doped n+ region is diffused as a bordering ring around the p+ element areas. This is to prevent channel-type inversions, which cause excessive leakages and shorts. The step, commonly called the phosphorous channel cutoff diffusion, is often applied in solid-isolation processing, and occasionally in low-leakage discrete devices as well [Electronics, April 1, p. 59].

A contact cut is then made. Next, a thick alumi-



Sixteen diodes. Ceramic flat-pack mounted array fabricated with air-isolation. Large moat in center is common-cathode contact; eight circular moats are anode-to-cathode junction point contacts; trapezoidal area is common-anode contact. The cement-like gray portion around the contacts is the oxide.

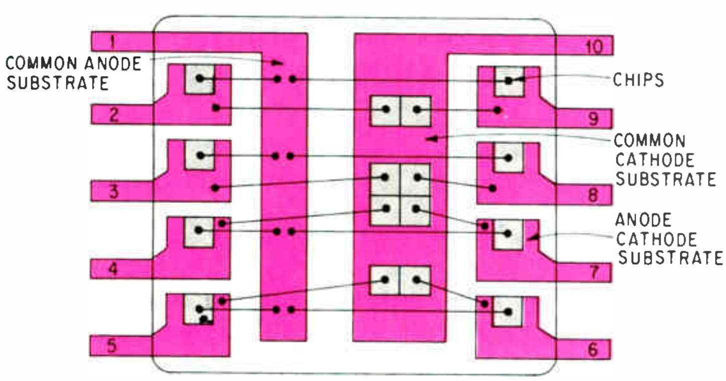
num layer is evaporated and etched to form interconnections. A finely divided glass, five microns thick, is then sedimented from a suspension, over the aluminum and onto the front of the wafer. A support wafer—six mils thick—is placed over the glass layer and against the device wafer. The glass is fused under heat and pressure to join the wafers permanently.

The back of the device wafer is then lapped and etched, until its thickness reaches 20 microns. Next, an aluminum film is evaporated on the back, minimizing diode resistance drop at the die's extremities. Then an isolation mask, aligned with the patterns on the front of the wafer, is placed over the aluminum. The aluminum is etched, and then the silicon parts are etched down to the thermal oxide layer. At this point, the IC consists of mesa-like substructures, each surrounded by moats of insulating air.

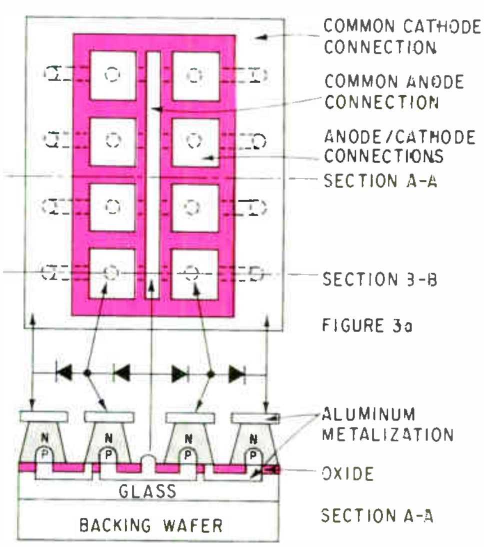
Padding exposed

Because oxide cuts have been made beneath the aluminum contact pads and the silicon has already been etched, the aluminum pads are exposed. Bonds can now be made to the back of the aluminum, which itself is firmly attached to the fused glass. Thick aluminum lead conductors are then attached. Since these may be attached on both

Arrays: Hybrid vs. monolithic



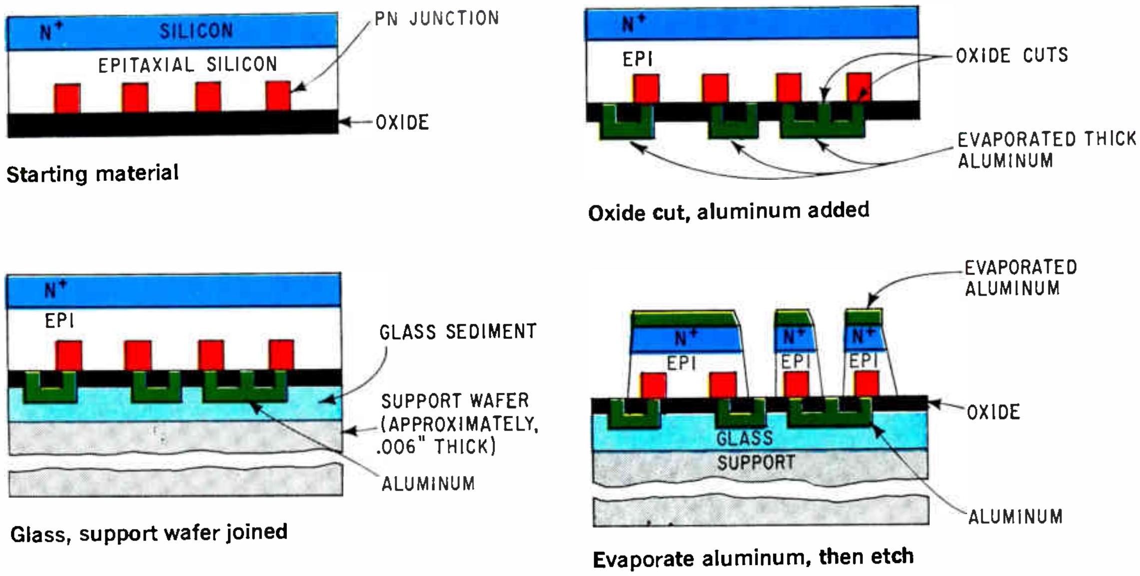
Chip-and-wire



Air-isolated

Contrasting diode arrays. Hybrid technique (above) involves many chips, more bonds, and has wire-crossover restrictions. Planar scheme uses only one chip, has fewer bonds, and easier pin arrangement.

Planar air



Isolation. Step-by-step processing of a planar-air-isolated diode array. In final form, mesa-like active elements are surrounded by air moats.

sides of the die, resistance drops are relatively low and complex interconnection schemes are easily accommodated.

Bumpy path

Solid isolation has a number of drawbacks. It provides only normal oxide protection; there is no supplementary glass coating. And because solid isolation is done before the circuit's elements are diffused and metalized, it requires a nonconventional processing cycle.

One must contend with the "bumps" on the dielectrically isolated wafer surface. The oxide layer arrangement doesn't always permit easy access for the lead paths. As a result of the occasional long lead paths—particularly evident in large matrices—forward conductances of the elements are relatively poor. The processing cycle itself is so involved (for example, the thinning step) that only one semiconductor manufacturer has mastered the method sufficiently to enjoy broad commercial success [Electronics, Jan. 22, p. 44 and April 1, p. 25].

Chipping away at hybrids

The new method also provides better isolation than the chip-and-wire technique of hybrid IC construction, which is a popular way to make arrays in small packages.

A typical hybrid version of the 16-diode array and its air-isolated monolithic equivalent appear on page 77. In the former, two electrically isolated metalized substrates are used, each with two chips of eight diodes mounted on it. One substrate has a p-on-n common cathode die, and the other an n-on-p common anode die. These chips have been fabricated in blocks of eight junctions to facilitate handling and to increase the net yield. Even if four of the junctions are rejects, four usable junctions remain. Note that lead-wire crossover problems might arise if the good junctions aren't on the same die plane.

In any event, four separate die attachments and 28 lead bonds are required for each array. But if planar air isolation is used for the same type of 16-diode array, only one die attachment and 20 bonds are needed. One chip, instead of two, is required. Double protection—glass encapsulation as well as the oxide passivation—is provided. There aren't any wire-crossover problems. And, of course, there are the other general advantages cited earlier.

In the typical diode array the interconnection scheme determines the arrangement, but with air isolation only two junctions are required in each case. Thus, for a common anode, all the anodes are connected to a common point, and for common cathode, all cathodes are so connected. For anode-cathode arrays, anodes are connected to cathodes in a series string.

These alternative schemes are accomplished by merely changing the isolation and metalization masks. Larger arrays may be fabricated by simply building more junctions.

As for packaging, the new process is compatible with all three major practices—TO-5 can, flat-packs, and plastic dual-in-line packages. The bonding arrangement uses aluminum wire that is ultrasonically bonded to the chip, yielding greater reliability and strength than standard gold-ball bonding.

Planar air isolation has been incorporated—in prototype quantities—in linear IC's and in ultrafast digital circuits. Volume production of these monolithics is expected later this year.

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Big job. Close to 1,000 points will be monitored in flight aboard the A.r Force's C-5A, giant cargo and troop transport built by Lockheed-Georgia that is the world's largest airplane.

Avionics

Testing on the wing

Automatic airborne systems for monitoring avionics performance in flight are a must for today's—and tomorrow's—fast, complex military aircraft

By Alfred Rosenblatt

Avionics and space editor

A military pilot used to have a relatively easy time keeping track of his plane's electronic instruments. There weren't many to worry about, first of all, and each piece of avionics equipment performed an essentially independent function. Checking his instruments, the pilot could decide whether the displayed readings for altitude, velocity, and bearing were reasonable, and he used this data to perform such operational tasks as navigation and bomb delivery.

Not so today. Present—and planned—military aircraft are so fast and complex that the pilot is out of touch with the workings of his avionics and, in a sense, with the outside world. With the speeds and altitudes at which missions are currently flown, sightings from the cockpit may be of small value. And the sophistication of modern avionics has made for an interdependence among the instruments. For example, navigation is now performed by a doppler radar, an inertial platform, and a computer, with the operation of each piece of equipment depending on information supplied by the others. And while this gear is bringing the plane in on its target, related avionics systems are aiming and firing off weapons and keeping tabs by radar on the enemy's response.

A strike mission may involve more than 150 different modes of operation, and all functions—and combinations of functions—must be handled precisely if the sortie is to succeed. Ground maintenance can't ensure this degree of reliability, nor can pilot or crew. Hence the need for continuous, automatic in-flight checkout of avionics equipment. The aim of a considerable effort now is the development of systems that cannot only spot faulty operation, but can diagnose and isolate it, and can switch the operation to an alternate mode. Such systems would be able to predict failures, too, and would alert the pilot of the status of his avionics.

Setting the sights

All new military aircraft feature some degree of automatic, computer-controlled monitoring; the newer the plane, the more self-test and maintenance equipment it will carry, and the more previously ground-based checkout gear will be built into its avionics. But the sort of systems envisioned by engineers now won't be flying until the mid-1970's.

functioning at full capacity, and, finally, it will display the monitored data to the pilot or another crew member.

There are, of course, problems—some very basic ones. The most obvious is the question of how all this complex monitoring circuitry is to be engineered into a plane. Another difficulty is that most of the avionics systems now being developed employ subsystems already designed. Engineers must thus build new self-checking systems around existing test points and cannot apply an integrated approach to monitoring.

Completely integrated monitoring setups will certainly be possible in the future, though, and the problem of space is largely being solved by ad-

For openers. First extensive in-flight performance monitoring in an operational aircraft was developed by Grumman for the five-place E-2A Hawkeye used for early warning, command, and control.

vances in electronics miniaturization. A more fundamental question concerns the over-all approach to in-flight checkout.

"What we're after is dynamic monitoring of the craft's total avionics system," says Greg Foster of Autonetics' Strike Avionics division.

The features of such a monitoring system are listed in a paper to be presented at next week's National Aerospace Electronics Conference in Dayton, Ohio, by Helgi Heinzmann, a senior design engineer at the General Dynamics Corp.'s Convair division. First, says Heinzmann, it will be able to perform all preflight, in-flight, and postflight testing, producing a no-go signal when it discovers a faulty subsystem. Second, it will trace the fault down to the level of line-replaceable units (LRU's). It will further record all this data to aid in maintenance and to provide a basis for failure predictions, and will be able itself to recognize gradual performance degradation. It will, as noted earlier, be capable of switching operations from a degraded mode to one

There are currently two schools of thought about the role of the central computer in a monitoring system. Paul Tracy, a program engineer at the General Electric Co.'s airborne early-warning radar department, puts it this way: "Should each piece of equipment evaluate itself, or should the evaluation be made at a central computer site?" In the first case, the go/no-go decision would be made on the spot and the computer would receive only a status report.

"In-flight monitoring at this point is not a well-shaped program," concedes L.M. Puckett, an associate technical director for avionics systems at the Naval Air Systems Command. "However, we're quite conscious of its necessity and are incorporating various degrees of performance monitoring and failure warning into all Naval avionics projects. Quite a bit more development in philosophy is needed before an over-all point of view can be imposed on all systems.

"Depending on the aircraft," Puckett continues. "part of the monitoring is being done on a systems basis, part on an equipment basis. Some projects have already used a central computer for diagnostic routines—creating a stimulus to the equipment and evaluating the response to determine operational status.

"We're trying in most cases to integrate the performance-monitoring capability that's there, and also to get these concepts into new equipment early in the design process," he says.

Several paths

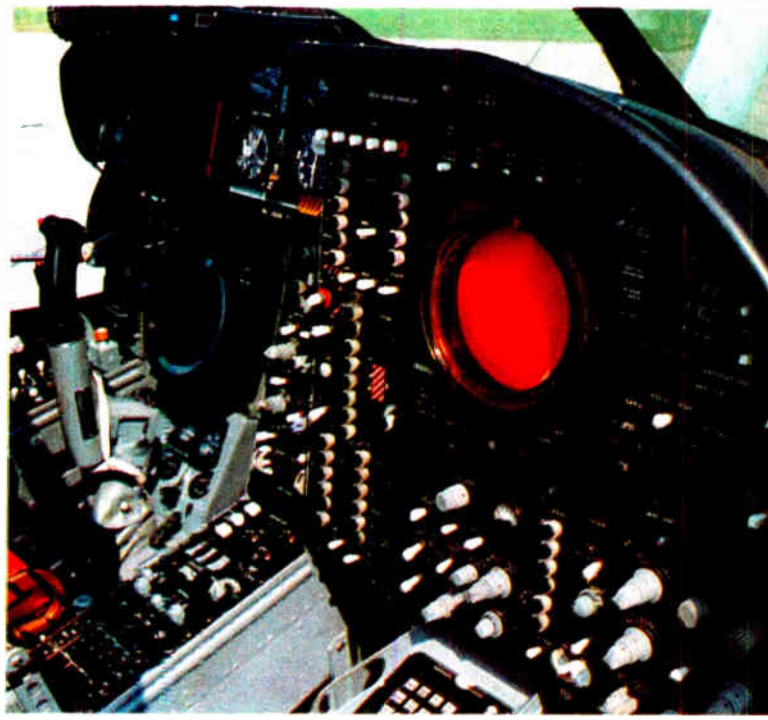
Enough new systems have already been designed to give an indication of where things are headed. As could be guessed, they've been heading in several different directions since the first extensive in-flight monitoring arrangement became operational three years ago aboard the Navy's E-2A Hawkeye airborne early warning, command, and control craft, a plane developed by the Grumman Aircraft Engineering Corp.

One basic approach is represented by the Mark II avionics now being integrated for the FB-111 and F-111D fighter-bomber by Autonetics, a division of the North American Rockwell Corp. The Mark II system uses the central computer not to compare preset limits with performance data but simply to program tests; the testing and evaluation are done right in the avionics boxes.

Another approach is taken in the Malfunction Detection, Analysis, and Recording (Madar) subsystem developed by the Lockheed-Georgia Co. and now being produced by the Lockheed Electronics Corp. for the Air Force's huge C-5A transport. Madar ties almost 1,000 test points dispersed throughout the airplane into a central fault-monitoring and diagnosis system that digests raw analog signals sensed in the individual black boxes, quantizes this data, and compares it with the limits and references stored in a central computer. The computer indicates on a console any malfunctions in the aircraft's subsystems and directs the flight engineer to the source of the trouble, right down to a line-replaceable module.

Other aircraft

Besides the Mark II and Madar projects, various kinds of self-testing and checkout arrangements are being integrated into such helicopters as the Lockheed-California Co.'s AH-56 Cheyenne, and the IHAAS and ILAAS craft. Built-in test equipment is also a feature of the A-New avionics going into Lockheed's P-3C patrol plane. A Univac general-purpose computer derived from the Model 1230 will perform the tests on the P-3C, and a high-speed printer, a cathode-ray tube, and an audio system will provide warnings of any malfunctions.

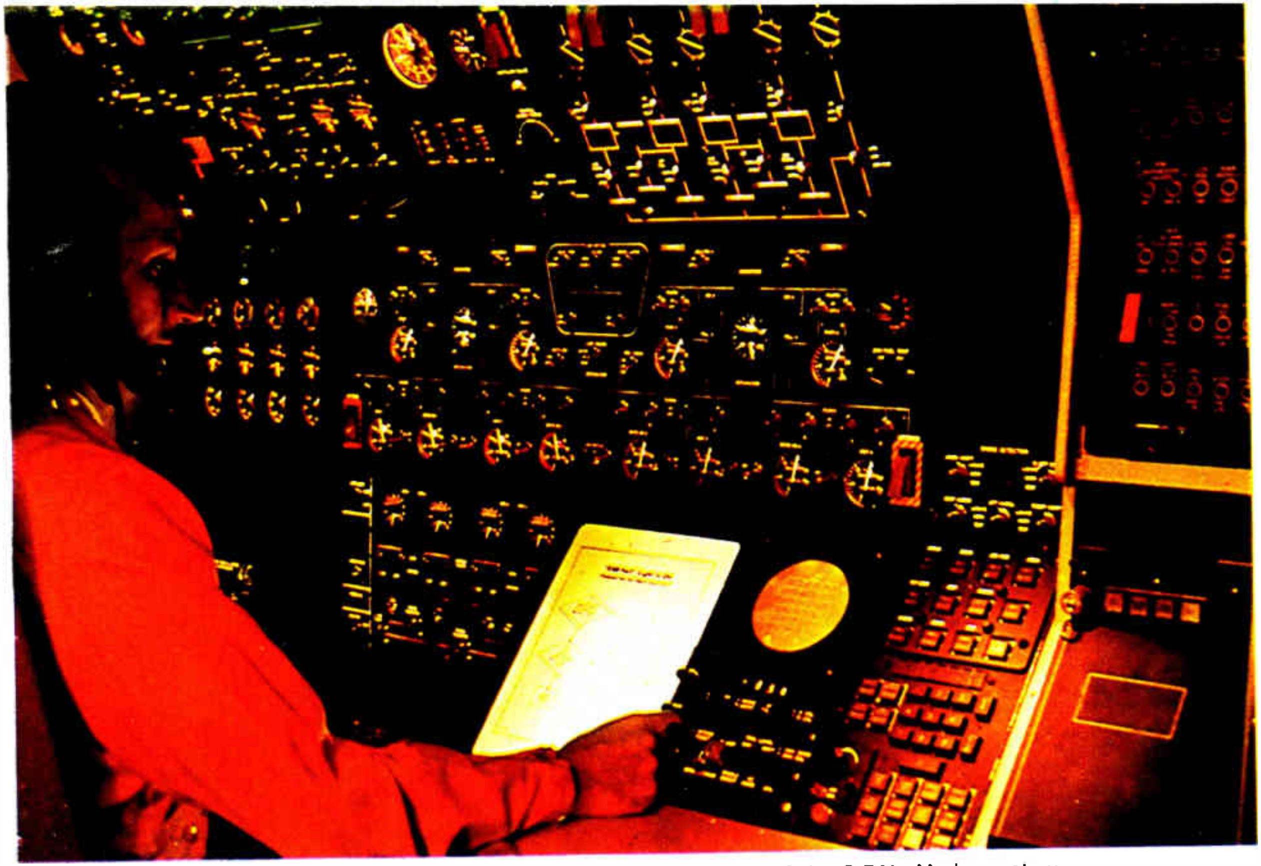


Dual role. Displays in the cockpit of the A-6A are now also used for in-flight checkout of the avionics' operation.

Systems integrators are now introducing self-check capabilities into aircraft originally designed without them, such as Grumman's A-6A Intruder. And the International Business Machines Corp. is studying the possibility of adding what the company calls Automatic System Self-Test (ASST) to the A-7D/E Corsair. IBM is integrating the A-7's avionics, as well as supplying the on-board digital computer.

Several companies, among them Autonetics, GE, and the Boeing Co., apparently sense a retrofit market in the making here. They're working to develop standard interfacing modules with which in-flight

Intruder. The avionics' systems integrator for the A-6A added computer-aided checkout features after each subsystem had been designed.



Diagnosing console. Subsystem malfunctions displayed on the console of the C-5A's Madar system can be isolated with the help of a random-access film store and oscilloscope.

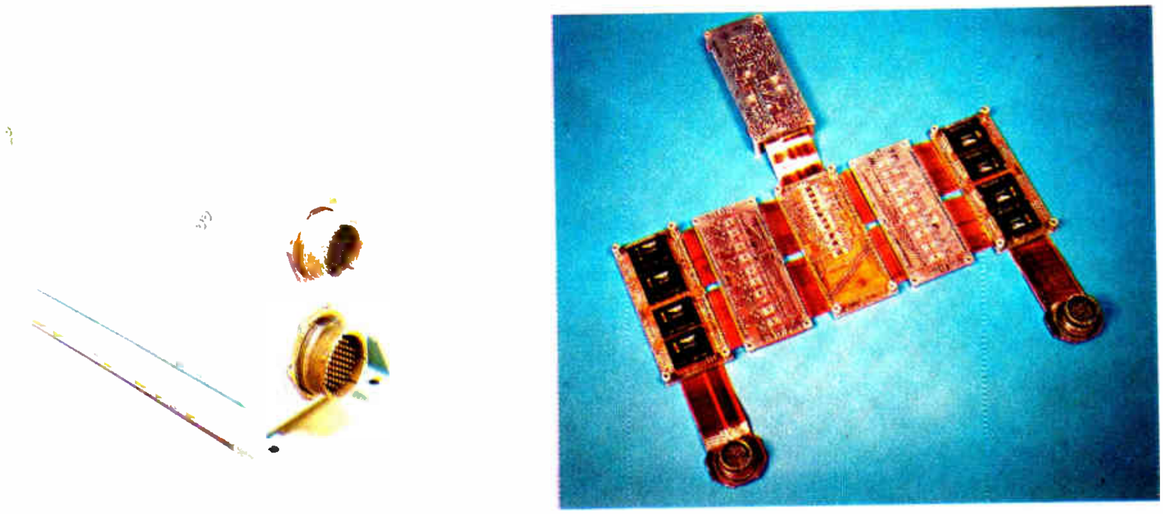
monitoring features could be easily added to a plane's avionics.

Shape of the future

The Mark II avionics system contains many of the features projected by Heinzmann for the total system of the 1970's. Among these are automatic switching from a degraded mode to an alternate by computer, and the production—on paper tape—of permanent fault data to aid in maintenance.

Harvey I. Hylton, the computer design engineer in the F-111 project office at Wright-Paterson Air Force Base, Dayton, Ohio, notes that the Mark II system was designed specifically to reduce ground maintenance work and speed the F-111's turnaround time between missions.

Test circuitry is built into all the LRU's in the avionics, Hylton says, so that each unit undergoes end-to-end internal self-testing. Any malfunction is signaled to the central computer, which addresses each LRU over a serial digital channel. The computer then flashes a light on a specially designed status board to alert the pilot to the problem. The status board, as well as the maintenance-data recorder, was built by the Kearfott group of General Precision Systems Inc.



Information gatherer. Remote acquisition unit in Madar senses test-point signals. A one-piece multilayer cable is used to interconnect its circuitry. Signal conditioning circuitry—the black packages—takes up a large amount of space, may be left out of unit being considered for advanced Madar design.

Signals from the avionics equipment go to a box that combines the functions of multiplexing and analog-to-digital conversion. Most of the information is already in digital form, Hylton explains, but synchro-type equipment does produce analog data.

All self-testing and limit-comparison is done in the LRU's themselves. The digital computer merely scans the signals from the units to determine whether there has been a malfunction, and to decide, if necessary, to which alternate mode to switch the operation.

This monitoring of LRU status requires no more than 5% of the on-board computer's memory capacity, Hylton points out.

With one exception, failure thresholds in the subsystems are set by hard wire in the factory. The exception: the limit conditions for the multiplexer-converter's self-test, which are set in digital registers within the converter by a code word from the computer.

Comparing the capabilities of the Mark II avionics with those of the Mark I in the F-111A's now flying out of Thailand is like comparing a Cadillac with a Model T. Although the Mark I system includes built-in-place test equipment, there's no central computer directing the monitoring nor is there any recording of fault information. Lighted lamps on subsystem control panels indicate malfunctions but ground personnel must isolate the faults. However, a malfunction in the terrain-following radar, the first such system operational in a tactical fighter, is displayed on the aircraft's caution panel.

Checking out a giant

Lockheed's Madar is designed for automatic or manual step-by-step, troubleshooting by an operator while the plane—the C-5A—is in flight. Indicator lights linked to the 10 major subsystems aboard the huge craft are displayed on one side of a three-part console.

When a malfunction occurs, step-by-step maintenance procedures, such as would be found in a maintenance manual, are selected from a 10,000-frame random-access film store and are projected on the other side of the console.

Also included in these frames are pictures of the waveforms that should be found at the various test points. Based on the information in the frame, the operator can call for a live waveform from any of the manual test points in the system and display it on a two-channel oscilloscope that is also part of the console. Following the directions given him by the film store, and using the waveforms presented on the scope as a guide, the operator can quickly trace the fault to a specific LRU. He can then decide how to remedy the problem or how to operate around it.

Madar operates through 32 remote signal-acquisition units installed throughout the plane. Twenty are scanned automatically and 12 are tied into a manual on-demand system controlled by the operator as he checks the equipment. Each acquisition unit scans 30 test points, multiplexes the analog signals—ranging from d-c to 400 hertz and up to 200 volts peak-to-peak—and feeds them, in a standard ±5 volts peak-to-peak range, to a central multiplex adapter. This adapter then multiplexes the incoming signals through a common analog-to-digital converter to a digital computer.

Each remote acquisition unit weighs about 3½ pounds, dissipates 3.75 watts, and measures 4½ by 9 by 5 inches. A flat multilayer cable developed by Lockheed and manufactured by Sanders Associates Inc. eliminates the need for connectors in the package; the unit's elements, mostly silicon monolithic integrated circuits, are flow soldered to the cable.

Metal oxide semiconductor field effect transistors are used in the multiplexing unit, principally because a junction FET would remain closed if power failed, thereby interconnecting all the test points.

All 600 automatically monitored test points are scanned at a 10-kilohertz rate. A Nortronics 1060A computer is used solely to store limits and fault data and to control the scanning system. The central multiplexing unit controls a magnetic recorder for storing changed or out-of-limits data, a crash data recorder, and a paper-tape printer that presents the flight engineer with a numerically coded statement of what's gone wrong.

Within limits

The Lockheed engineers had to work, in some cases, with existing subsystems in designing their in-flight monitoring systems, observes Joseph Barrett, Madar program manager. In the communications subsystem, for example, the LRU's were already designed and Lockheed had to go with those test points that were available. However, the multimode radar was specially developed for the C-5A, and Lockheed could specify, in this case, where it wanted the test points.

A next-generation version of Madar has already been proposed for a NASA space mission, Barrett says. In this system, each remote acquisition unit will have its own a-d converter. The central multiplexer will scan waveforms at such a high rate that there'll be no need for the oscilloscope display; the amplitudes will be stored and processed in the digital computer memory.

Lockheed is investigating hard-wire storage of limits data in a fast ferrite-core memory. The company also wants to reduce the size of the signal-acquisition units and place them closer to the LRU's. To achieve this, engineers are working with low-power MOS devices and thick-film interconnections between hybrid and monolithic circuits. The goal, according to Leonard Merel, chief design engineer for Madar, is to put an eight-channel signal-acquisition unit—with its own a-d converter—into a 2-inch cube.

Upgrading

Grumman is planning to redesign its in-flight monitoring system for the next version of the Hawkeye. In the E-2A monitor shown on the cover, up to 77 alarm channels feed directly in from built-in-place test equipment circuits at various points in the avionics to energize indicator lights at the top of the console. Using a cross-bar switch, the operator can select live waveforms from the appropriate test points for oscilloscope display; voltage values at other points can be read out on a digital voltmeter. Then, following the instructions in a manual of fault-diagnoses routines, the operator can isolate the fault and choose alternate modes of operation.

There's no computer in the E-2A monitoring setup, but all the test gear in the advanced Hawkeye will be linked to a stored-program digital processor.

"The new system will have a flexible machine with a large core-memory capacity," says Julius Cohen, Grumman's E-2 program manager. "We've learned from experience with the E-2A what additional points should be monitored. Diagnostic procedures will be able to trace faults to even lower levels than the LRU's."

Monitoring limits will be set in the computer, says Cohen. Grumman is trying to decide now whether to build a-d conversion circuitry into each subsystem or use a separate signal-conditioning unit. Also under consideration is a multiplexing system to cut down on the wiring.

The primary alarm readout being studied for the advanced system is an alphanumeric message displayed on cathode-ray tubes at each of the three crew stations in the Hawkeye. There will also be a panel of lights similar to the one in the E-2A but much smaller, a test oscilloscope, and a digital volt-ohmmeter at the radar operator's console. The light panel will indicate malfunctions in the central computer and the equipment-cooling system—faults that could prevent an alphanumeric message from being displayed.

Each crewman will be able to call for alphanumeric readouts of system status and to initiate tests. Only the radar operator, however, will be able to examine a waveform from a specific test point or get a reading on the digital volt-ohmmeter.

In the case of its A-6A, Grumman has added a self-monitoring capability to an avionics system originally designed without it—"and without adding equipment," according to Grumman's George A. Walz. "We used equipment supplied to us by the subcontractors," he says.

The company inserted diagnostic routines into the drum memory already on board the aircraft, and hooked the whole system into display equipment already on hand. "Data such as airspeed and pressure altitude coming in from the air data computer can be presented on digital readouts already in the cockpit," says Walz.

Fundamental split

All discussions of automatic in-flight checkout come back to the basic question of whether evaluation should be done by a central computer.

In the technique exemplified by the Mark II avionics, both test and evaluation circuitry is designed right into each piece of equipment. A self-contained monitor in a radar, for example, circulates its own test signals through the subsystem, and such parameters as time, amplitude, and pulse width are compared to references set up within the subsystem. Operational capability is assessed on the spot by calculating, say, signal-to-noise ratio, subclutter visibility, and detection sensitivity.

When questioned by the central computer, the built-in circuitry simply reports its own evaluation of its operational status. The computer, of course, is programed to take action in the case of a malfunction—warning the pilot and initiating a diagnostic procedure.

In much of the Madar system, the test-stimulation hardware is built into the equipment to be monitored, but the evaluation capability is not. Evaluation is the function of the computer, which periodically addresses all of the test points in the system. The tolerable limits for the parameters checked at these points is stored in the computer, and from these it determines when performance is falling below standards. It also isolates the faults and keeps track of trends in equipment operation. The degree to which a computer could actually forecast failures is, according to GE's Tracy, "limited only by the imagination of those designing the data-evaluation system and the programing."

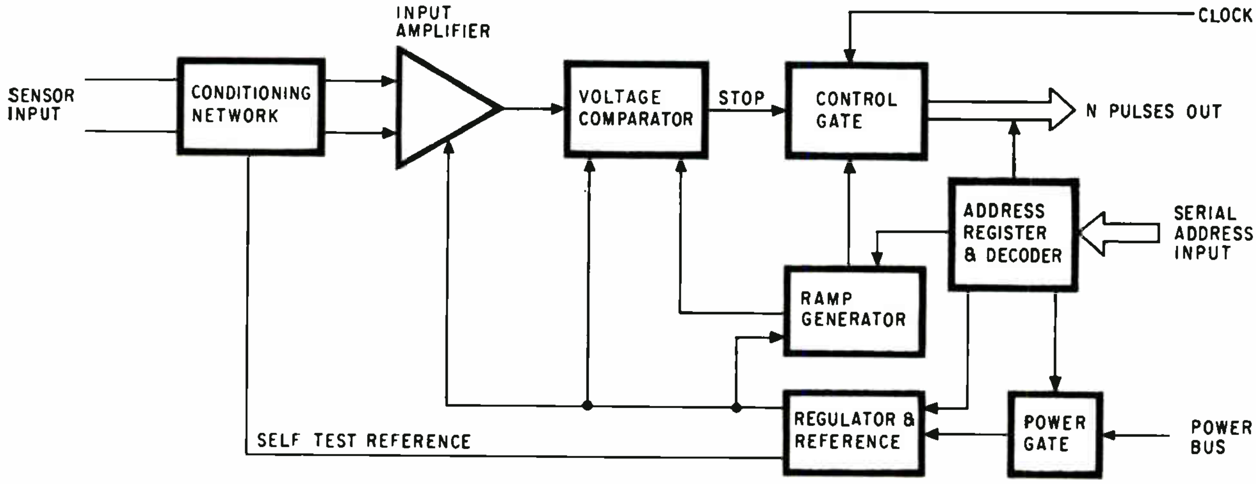
Process control

Autonetic's Foster predicts that the computer in the systems of mid-1970's will set the tolerances and limits for the test points throughout the avionics. But the Air Force's Hylton contends that "we don't know if there's really a need for such set-point control to be done by the computer. It would be just like a process-control computer setting limit points on the basis of what's going on inside the process. For in-flight monitoring, it's quite possible that setting the limit points by hard-wire—tailoring a resistor network, for instance—may be adequate."

Hylton maintains that "there isn't a need to change limit points so rapidly," and warns that "you might need more complex circuitry in the LRU. You'd need holding registers for storing the limits. The great advantage, of course, would be the flexibility; you could tighten or loosen set-point tolerances based directly on operational experience."

Other systems problems complicate the basic question. Tracy points out that the operating speeds and complexity of radar systems have reached the point where it would be just about impossible for an external computer to assess a radar's performance. Analog-to-digital conversion of signals to measure amplitudes, timing, and pulse width would require fantastic bit rates, he says, "especially with the 100-to-200-nanosecond resolution required in the coherent radars we're designing."

The answer, Tracy states, "is a happy mix of both techniques, even within the same piece of equipment. Radar test signals have to be circulated anyway during interpulse periods to tweak up the system. Better to use these signals for self-monitoring instead of converting them to digital form and transmitting them to a computer."



Conversion. Circuit proposed by RCA would sense the levels of analog signals at remote test points and send digital data to a central computer.

As Tracy sees it, "The computer would monitor the results of these self-tests and at the same time make detailed assessments of the performance of less complex subsystems based on limits stored in its memory."

Challenge and burden

The job of implementing the complex new monitoring systems is falling increasingly on the integrating contractor. Eventually, says Convair's Heinzmann, he will specify all airborne monitoring requirements, much as he now specifies weight and power.

Autonetics' Foster agrees. "A subcontractor in future won't just be told to supply a radar that contains a monitor," he says. "He will be told to supply a radar that performs specific and exacting self-tests."

But the management techniques needed for the procurement of these systems have yet to be developed. Engineers connected with the Air Force's Airborne Warning and Control System (Awacs), for example, are frankly concerned about the gigantic procurement task that faces them. One estimates that as many as 10,000 test points will be monitored in this system, more than 10 times the number in the C-5A. It's clear that the systems managers in charge of the monitoring will have to get busy very early in the design phase.

This kind of designing from the ground up is fine for future avionics, but the military may also be interested in retrofit systems. The Air Force is reported to be considering retrofitting the C-141 and B-52H, and several companies are developing circuitry to do the job.

Autonetics has something called Focas, for Fast Operational Checkout Avionics Systems, a group of sensors that will interface between test points in the subsystems and a central monitoring unit. Silicon-on-sapphire and MOS circuitry will be used in the signal-conditioning section. Autonetics hopes to add Focas sensors to the avionics carried aboard such tactical aircraft as the F-4 and the F-105.

The company's aim is to eliminate the need for ground-support equipment on the flight line. Because Focas monitors down to the LRU level, a faulty black box can be replaced on the flight line; maintenance crews won't have to tear down the whole system.

Data from Focas' sensors is sent through a signal-conversion network to a central computer or several separate processors, where it is evaluated on a go/no-go basis. Norman Gortz, one of the system's developers, says the test sensors can monitor any signal at the interface between the connector and the LRU—"a-c, d-c, synchro, low-level noise, whatever is desired."

A recording device, perhaps located in the aircraft's bomb bay, stores data on the condition of the various avionic subsystems for later analysis. If a monitored LRU malfunctions and the problem is of concern to the pilot, a light flashes on his control panel. Focas has a self-testing capability to determine if it, rather than the avionics gear, is inoperative, Gortz notes.

In addition to its avionics-monitoring ability, the unit can be applied to such other aircraft systems, as hydraulics, fire control, and the engine. Once monitoring is begun, it continues throughout the mission.

GE, too, is developing a family of general-purpose sensors. "We're trying for a whole shopping list of basic sensing modules," says Tracy. "These will be in chip and thick-film form, with go/no-go limits tailored, for example, by hitting taps on a voltage divider network before the unit is attached to a monitor point. A half-dozen modules could meet the majority of testing requirements, and 1 cubic inch per module is the design goal."

In another paper to be presented at the NAECON meeting next week, Donald Bowie, a research engineer at Boeing, will discuss another development effort in this field. Bowie stresses the need for great care in selecting the additional test points required to give a fault-detecting system the capability to isolate the cause of a malfunction. Locations should be determined on the basis of failure-mode and failure-effects analyses carried out in the initial design phase, he says.

The test points should be conditioned to provide standard indicator signals, and Bowie suggests the use of high-density packages, such as flatpack differential amplifiers and single-chip shift registers to minimize the effect of this conditioning on overall equipment size.

Bowie's paper especially emphasizes the need to keep the fault-isolation system as separate as possible from the operational systems. To this end, Bowie recommends that the signal-conditioning circuits, as well as the stimulus generators for initiating tests, be contained within the LRU. With internal conditioning, the operational signals don't enter the monitoring system; access is only to the conditioned test points.

Describing the Boeing project, Bowie says both test and operational signals would be fed into what the company calls a RAU—for remote access unit. Located adjacent to the LRU, the RAU converts the signals to digital form and time-multiplexes them on common transmission lines to a digital computer. A multiplex control and computer buffer provide power, timing control, and synchronization for the unit, Bowie explains. Test points would be both sequentially and randomly accessible.

Boeing has actually built a RAU-type unit using MOS FET components. Bowie predicts that the application of large-scale integration techniques can bring the size of the RAU down to 1 cubic inch, and estimates that the unit will consume about 1 watt of power.

Bowie observes that removal of the remote access unit wouldn't alter the operating characteristics of the LRU; the line-replaceable unit could thus be used in avionics systems without integrated self-testing.

Way out

The Aerospace Systems division of RCA is considering the development of standard signal-sensing packages for on-board monitoring and maintenance during long-term space missions in the 1970's.

For a projected orbiting laboratory that would carry 10 or 11 people for five years, RCA is studying what it calls an Adaptive Dynamic Analysis and Maintenance (Adam) system. Adam would check all the spacecraft's critical parameters against limits stored in a central computer, according to Richard R. Schellenbach, senior staff scientist at the Aerospace Systems division. "Spares would be carried on board or ferried up from earth," he adds.

"We estimate there'll be roughly 5,000 points monitoring the health of the craft and taking data from experiments," Schellenbach says. "Another 3,000 points will be needed to isolate a fault to an LRU. To make our design problems easier, we're looking at a mix of sensing modules that will handle analog, digital, and discrete parameters."

Thus far, Schellenbach has studied the power-supply and communications subsystems that might be aboard the spacecraft to determine what points should be monitored and what test-stimulus generators should be employed to isolate a fault. He found that by using the test points by themselves and in combinations, not every module in the supply would have to be tapped.

"Of the 360 separate circuit modules in the supply, only 250 sensor points would be needed to determine which module failed," Schellenbach says. "Only 10 stimulus generators would be needed to exercise the various parts of the system."

It would also be possible, he says, to use stimulus generators already built into the operational part of the subsystem. "Frequency synthesizers in the communications set could be used as generators in other parts of the equipment, and reference voltages could be used in making limit checks."

Studies by Schellenbach have shown that d-c and a-c analog voltage monitoring would account for roughly 90% of the instrumentation. A standard analog module, on page 87, would be addressable by the central digital computer, and monitored amplitudes would be fed digitally back to the computer. The goal, again, is a 1-cubic-inch module, Schellenbach indicates.

Monitored new world

If monitoring subsystems in a craft orbiting a group of scientists around the earth for five years sounds pretty far out, consider the closing statement in Heinzmann's paper on future systems:

"Automatic integral checkout will be part of all future vehicles. Even the automobile will have its share. A future designer may well specify LRUs with one of several standard checkout features. But the technique will not stop with the LRU: why should the SST pilots' physiological parameters not be monitored? And why should a comprehensive checkout system merely display and record a fault?

"Automatic repair action, initially perhaps limited to substituting good components and manipulating variables, is certainly within the grasp of our technology. A faltering propulsion plant may be restored to satisfactory operational condition by fast, automatic manipulation of the fuel and ignition systems. If the engine must fail, the future automatic checkout system will at least select the optimum degraded mode operation. Much work lies ahead, but the results cannot fail to be interesting and rewarding."

In the next issue

Developing a system to monitor the performance of modern avionics in flight is especially complex when the process and equipment are to be integrated throughout the aircraft. In the next issue, F.H. Hardie and G.E. Simaitis of the International Business Machine Corp.'s electronics systems center in Owego, N.Y., describe how they've tackled the job with the Automatic System Self-Test (ASST) design.

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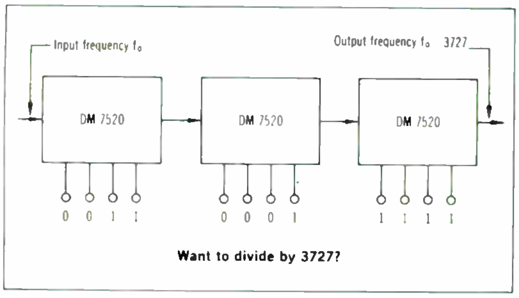

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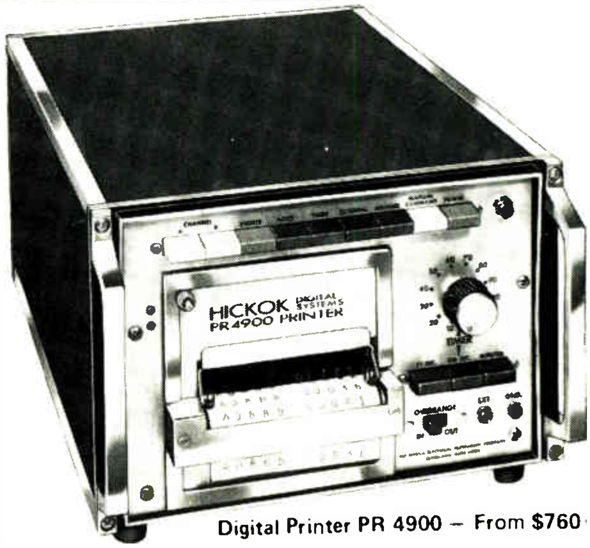

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The arts

Signal gains for electronic music

The one-time ugly duckling of the arts shows signs of becoming a swan of sorts as serious composers work with random-sound effects, computers, and synthesizers

By Peter J. Schuyten and Stephen W. Fields
Assistant editors

Electronic music is reaching the point where little Johnnie, instead of enduring a weekly piano lesson, may soon be learning to switch his signal sources and vary voltages on a synthesizer.

Right now, the bleeps, blaps,

Composer Douglas Leedy adjusts

screeches, and oogahs produced by sine-wave generators, frequency synthesizers, and even computers are forcibly arresting the attentions of skeptical purists from the world of serious music.

Reprise. Less than a decade ago, electronic music was largely the province of a few establishment outcasts splicing tape and working with crude reproduction equipment. Their efforts were generally treated with indifference or scorn. But in recent years the medium has gathered momentum; it is now heard in concert halls, on records, at World's Fairs, and in television commercials. And a sizable number of respected institutions in the U.S. and overseas have made substantial investments in electronic equipment.

Today, a composer dissatisfied with conventional musical instruments and techniques can turn to electronics. His only problem is deciding whether to use computers,

frequency generator to get tone that

synthesizers, or a mixed bag of electronic gadgetry that can produce only random sound.

Body and soul

Random sound, one of three principal forms in the world of electronic music, is variously produced. Alvin Lucier, a composer who directs Brandeis University's Electronic Music Laboratory in Waltham, Mass., has devised one of the more exotic methods. He attaches electroencephalogram electrodes to his head and blinks his eyelids rapidly to produce brain waves that are converted into sound.

In another vein, Max Neuhaus, a freelance percussionist and composer of electronic music from New York City, has invented what he calls the Max-Feed, an "instrument" that produces random sounds somewhat easier on the ear than the output of Lucier's system. The Max-Feed houses a transistor

is mixed to form a complete measure.

radio, an amplifier, and a microphone in a transparent plastic box. The microphone picks up an audio signal from the radio and feeds it into the amplifier, which sends the signal back into the radio. The output—a function of the original broadcast signal—is chance music, a highly random sound that Neuhaus says, "expands our perception of the world around us. Put 100

For love — and money

Although electronic music is still largely a noncommercial proposition, some composers are using their talents to good account in the business world.

For example, Morton Subotnick, a free-lance composer, recalls when he would do electronic music for one-minute commercials and settle for only $50 a spot. "I've wised up now," he says. "If I need a $5,000 four-track tape recorder, I work very hard for a couple of weeks turning out only a few 60-second spots. And I have it." Subotnick's credits include the theme music for the Columbia Broadcasting System's program The 21st Century, and background music for the Western Electric and Vote toothpaste broadcast ads.

And Ferretti-Lay Inc., an MIT spinoff that set up shop a year ago, is bent on selling visual and aural presentations for radio and television broadcasts as well as backgrounds for dance and drama productions. Equipment is still being installed at the firm's Newton, Mass., facility, but the company hopes to start looking for outlets soon.

Max-Feeds in a room and they create a symphony."

Organization men. But other composers feel that there is more to electronic music than pure chance. J. W. Beauchamp, a member of the engineering faculty at the University of Illinois and a composer of electronic music, says: "Music is more interesting if it is built around a logical framework. Although music should be full of surprise and variety, it's still the organization of the sounds that counts."

Ercolino Ferretti, co-founder of Ferretti-Lay Inc., Newton, Mass., a spinoff from the Massachusetts Institute of Technology that produces electronic music for profit, bristles at the idea of randomness for its own sake: "There are two sides to human behavior, randomness and redundancy. Unless randomness is used within highly limited bounds, it is pretty useless. If I have a handful of marbles and I throw them down 100 times, you might find one pattern that is pleasing, but what about the other 99? I can't prove that random music is a point of no return, but until something tells me different, random sound will continue to be just one of the parameters of my music."

State-of-the-art muse. Also at odds with the random-sound school are computer composers. Using highly complex equipment, they must laboriously program five sound parameters for every note: timbre (the quality of tone distinguishing instruments or voices), attack (initiation of performance, especially with respect to the degree of unanimity with which a phrase is begun by several instruments), pitch (a musical tone determined by the frequency of vibration of the sound waves that strike the ear), decay (decrease in quantity, volume, or force of sound), and rhythm (regularity or flow of movement). To hear what he has created, the composer must connect a digital-to-analog converter with frequency and envelope generators, as well as modulators, to his computer outlet.

While such music can be controlled to the nth degree, most would-be composers find that trying to justify computer time for such applications at today's prices is a tough proposition.

Calculated disks

However, things are looking up for the computer composer. Several years ago the Bell Telephone Laboratories developed two programs—Music IV and V—that a composer can use in working up his own piece. Written in Fortran, the Bell programs are based on a pulse-code-modulation sampling scheme. Comparable software is in various stages of dress and undress at other computing centers around the U.S., including the University of California at Santa Barbara and the University of Illinois in Champaign-Urbana.

Overseas, too. Sweden's government-owned Radio Stockholm is now debugging a $500,000 electronic music studio that Jon Appleton, head of Dartmouth College's recently opened Griffith Electronic Music Studio, says "is a good 10 years ahead of its time."

Among other things, the Swedish

facility features a special-purpose computer designed solely for music composition. The machine has a selective memory and analog converter that automatically stores on tape what is being composed, making playbacks a simple matter. A composer can also store the completed portions of his work on magnetic tape when he's through for the day, leaving the entire memory free for other composers to work with.

Another indication that computer-composed music is starting to come into its own is that the International Federation for Information Processing is holding a competition for such works. The three top entries will be played at the IFIP Congress in Edinburgh, Scotland, this August.

Medleys

Synthesizers are the third route being taken by composers of electronic music. Such machines are a series of modules controlled by fixed or varying voltages. The modules combine frequency or tone generators, electronic switches or sequencers, modulators, band-pass filters, and amplifiers to produce an audio signal that's piped into a speaker system.

The audio signals originate with a set of voltage-controlled oscillators whose input is a signal from a keyboard or other voltage divider network.

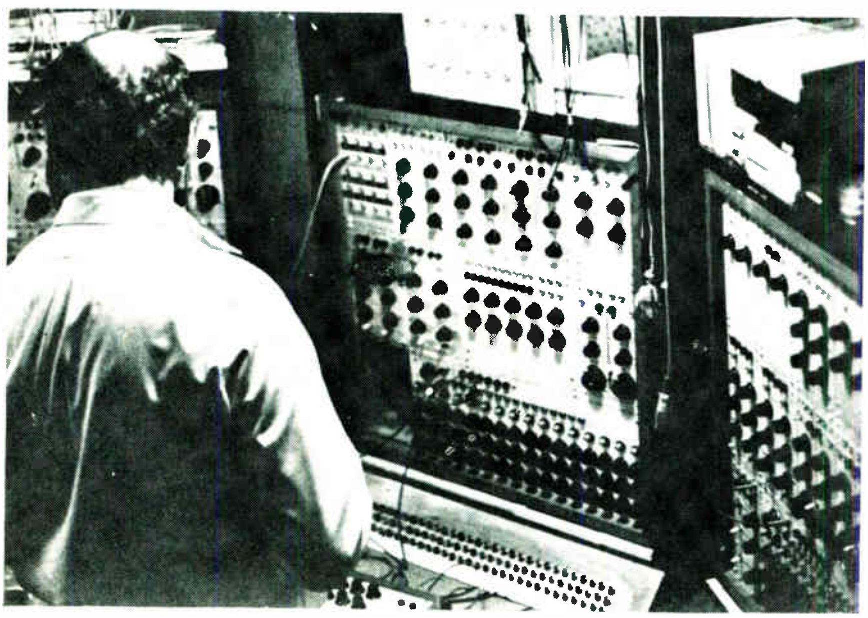
The output is a single frequency tone, or range of frequencies, if the oscillator is being swept. The output is fed to an amplifier, a switch, a modulator, a mixer, or combination of such devices. Since the switches are controlled by a voltage signal, the rhythm they set can either be varied or held constant.

The output from the switches is then combined with other signals and further shaped and processed by the modulators. The shaping sets both the attack and decay time of the sounds.

Hark. After a final mixing of the various signals from still other modulators, mixers, and oscillators, the end product—music—finally reaches a waiting world through speakers.

In theory at least, a synthesizer can create almost any imaginable sound, including those of standard musical instruments. "But it's pointless to duplicate the sound of a conventional symphony orchestra on one," says Gerald Strang, chairman of the music department at California State College in Long Beach and himself a composer of electronic music. "The real value of electronic music lies in the creation of new forms that can't be reproduced any other way."

White elephant. During the early 1950's RCA built one of the first synthesizers. Strictly a commercial proposition, the Mark II was designed to save the company's Vic-



Face the music. Morton Subotnick, a free-lance composer, works with a Buchla synthesizer at New York University's electronic music center.

Technology's offbeat offspring

Music isn't the only lively art to be touched by electronics. Technology's impact is now being felt in the visual media and even in literature.

A number of research institutions, including Bell Labs and the Lincoln Lab, are experimenting with computerized animation, using light pens, on-line color oscilloscopes and plotters, digital and analog generators of lines and symbols, and other peripheral gear. An off-line movie camera is usually used to record the computer's output, but Bell Labs has been able to put output directly onto microfilm in real time with a Stromberg-Carlson 4060 processor and a cathode-ray-tube display. And holography, still in the early stages of development, seems to have exciting possibilities.

Goodbye to the stone age. In the plastic arts, electronics has provided the means for a new medium of expression, kinetic sculpture. Using servomotors, stepping relays, silicon-controlled rectifiers, amplifiers, light-sensitive semiconductors, sequence timers, and flip-flop circuits, sculptors are now creating vibrant and sometimes explosive forms.

In literature, the attempts to produce computer-written poetry are rarely taken seriously, but computers may be of great value in critical studies of meter and rhyme.

tor division the time and trouble of hiring musicians and songwriters. The machine was supposed to turn out new material as well as provide background music for pop standards. Eventually, however, the idea came a cropper to the tune of about $100,000. "The sound was too tinny and the rhythms too precise for the human ear. Frankly, it just wasn't pleasant to listen to for very long," says James Seawright, technical advisor to the Columbia-Princeton Electronic Music Laboratories, where RCA sent the Mark II on "permanent loan."

With early synthesizers, editing was one of the most important steps in producing a finished piece of music. Equipment was only able to produce one sound at a time. Once the desired sound was made, it was put on tape and the synthesizer was reprogramed for the next

Two for the role. Ercolino Ferretti and Michael Lay, former MIT professors, have set up a company to produce electronic music on a commercial basis.

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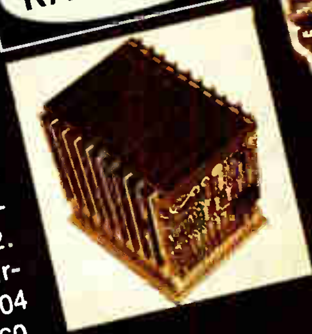

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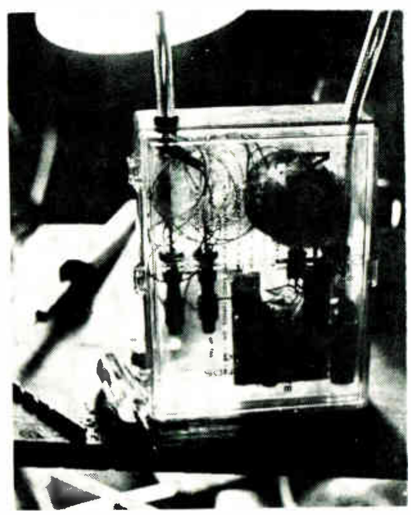
. . . the new synthesizers are on-line machines . . .

output. The process continued until all of the sounds were taped. Then the editing began. Each sound had to be put in its proper place. Sounds that were to be used more than once, were duplicated and mixed in later. Such work was more a scissors-and-tape proposition than an electronic process.

Noteworthy. But modern synthesizers can be programed to produce a complete composition. And whereas the RCA machine produces only one note at a time, the new devices are on-line. The real-time feature allows the composer to hear what he is composing immediately and eliminates the need for heavy tape editing.

Another attractive feature of the new machines is their portability. The R.A. Moog Co. in Trumansburg, N.Y., is now selling a device that can be carried around by pop music groups to augment the sound of their electric guitars and rhythm sections [Electronics, March 4, p. 41].

In Moog equipment, most of the interconnections between modules are made internally. In its simplest version, the device sells for around $1,500. Robert A. Moog, founder and president of the company, says: "The time will soon be upon us when people will start buying them for the home instead of an electric



Off the shelf. The Max-Feed produces random sound, one form of electronic music. Set's output is obtained from transistor radio and feedback network.

organ or a piano."

Playing jacks. The only other commercial synthesizer is made by Buchla Associates of Berkeley, Calif. The basic model—15 modules and a keyboard—sells for $2,400. In the Buchla unit all the modules are independent; interconnections are made by plugging patch cords into input and output jacks on the front panels. Operating the Buchla thus requires a thorough knowledge of the many knobs and input-output jacks on the panels. Once mastered, though, the equipment is able to produce a greater range of sound dynamics than the Moog.

There is a drawback to the synthesizer—it has no memory. Although this can be partially compensated for by the addition of a tape recorder, such an arrangement is cumbersome for both composers and performers.

Hookup. "One solution to the synthesizer's memory problem would be to connect it to a small general-purpose computer," says Richard Friedman, a systems programer at New York University's Courant Institute Computing Center. "This would satisfy everyone. Not only would it lower composing costs considerably, but it would give the random composer as much freedom as he wants." Friedman, who is also a composer, thinks machines like the PDP-8S are suitable.

Douglas Leedy, faculty composer and assistant professor of music at the University of California at Los Angeles, feels that improvised concerts represent the real future of the medium. A musician who has played the French horn with several leading symphonies, Leedy is interested in the entire range of electronic music. His philosophy: "We live in a throwaway society. People aren't interested in preserving conventional art forms any more, but are trying to create new artistic experiences for today. Electronic music has taken what was once a very distant art form out of the hands of the elite and placed it within the reach of almost everyone."

Contributions to this report were made by Bill Bell in Los Angeles, Robin Carlson in Boston, Peter Vogel in San Francisco, and Bruce Cross in Chicago.

Second-source IC's on firm footing

Since device users generally insist on alternate suppliers for volume buys, semiconductor houses make a virtue of necessity and duplicate best sellers

Imitation, once considered the sincerest form of flattery, is becoming almost as important as innovation in the field of integrated circuitry. Most IC customers prefer to have second sources, and semiconductor houses—for a variety of reasons—are generally anxious to oblige.

However, "generally" is the operative word in this context; even the industry's big three—Motorola Inc.'s Semiconductor Products division, the Semiconductor division of the Fairchild Camera & Instrument Corp., and Texas Instrument Incorporated—differ in their attitudes toward second sourcing. Motorola embraces the concept wholeheartedly; Fairchild professes, except in rare cases, to be disinterested; and TI occupies a middle ground.

Insurance policies. Realistic pricing and delivery protection are the big factors in customers' insistence upon second and even third sources for IC's. "Strikes, fires, dyspeptic engineers, or acts of God at suppliers can wreak havoc with production schedules," says Larry Steele, director of procurement at the Military Communications division of the International Telephone & Telegraph Corp. "Besides, the Government likes dual sourcing; it's the American way."

"With multiple sources of supply, prices are lower," says Winston R. Willmert, manager of purchasing at Honeywell Inc.'s Electronic Data Processing division. "I'd rather have at least two parties fighting for my business. With a sole source, you might get better device performance, but never more realistic price or delivery." His colleague, Robert R. Leonard, group director of circuits and hardware, points out: "During development of our 4200 and 8200 computer lines, we were paying through the nose for an IC supplied by a single source. When we began purchasing in volume from a number of suppliers, the circuit's cost dropped by a factor of three or so."

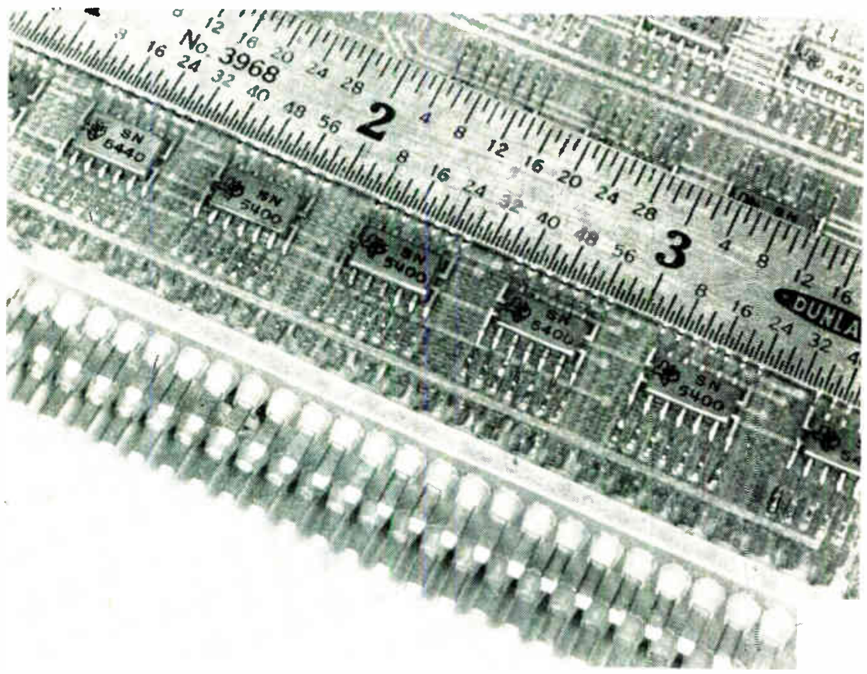
Fat copycats

Profits motivate IC houses to produce competitors' devices. "Second-sourcing gives our salesmen more to work with and affords us a marketing edge," says Thomas J. Connors, vice president and director of marketing at Motorola's semiconductor unit. "We don't worry about the not-invented-here aspects. And since we don't have the time, money, or facilities to innovate everything, we'll try to duplicate any assembly that's created a market."

At the moment, the company offers just about every commercially available digital assembly, including resistor-transistor logic, diode-transistor logic, and three different versions of transistor-transistor logic. With the exception of its emitter-coupled logic series that was developed in-house, Motorola entered all of these markets as an alternate source.

Connors warns, however, that there are three prerequisites for a supplier's becoming a second source. First, there must be a sizable market; second, the company must be able to compete in high-volume, low-cost situations. And third, entry must be carefully timed. "If you get in too early, you'll watch your investment go down the tubes for a while," he says.

Nudging. Connors notes customers often urge his division to become an alternate source for a new IC family. "If the big suppliers haven't made a device, their customers beat on them to become second sources. And the smaller the sole-source supplier is, the harder the customers lean on the leaders to get into the business and provide



Choice item. Best-selling IC's like those in this digital assembly from TI are widely copied by other semiconductor houses.

. . . customers call the shots on duplication of characteristics . . .

a back-up delivery capability."

Strategem. The Semiconductor division of Sylvania Electric Products Inc. furnishes an interesting example that IC makers are also mindful of such considerations. "There was a time when we feared that TI would push its 54/74 series by lining up a second source and signing up some potential customers for our SUHL (Sylvania Universal High-Level Logic)," says Harry M. Luhrs, IC marketing manager. "Transitron was not as good a second source as we would have liked. Buyers tended to think of them as a specialty or quick-reaction house rather than a volume producer. We wanted Motorola and hoped, too, for Signetics. So we went out and lined up accounts and got them looking for second sources. We then offered limited engineering advice, some masks, and a selection of chips to Motorola. They went for it. Soon after, the dam broke and Westinghouse, Philco-Ford, and Raytheon as well as Transitron also came into the fold. Our SUHL was on firm ground."

There's still no hard-and-fast corporate policy on second-sourcing at Sylvania. "We'll do it if it seems profitable, but we prefer to innovate. In this industry if you don't, you are continually playing 'catch up,'" says Luhrs.

Sylvania second sourced Fairchild's 930 DTL line for a time, but dropped it after the field became overcrowded and profits harder to come by. Interestingly enough, the company is now turning out TI's 54/74 assemblies for the International Business Machines Corp. "With a single, big customer, we have only one set of specs, deadlines, and qualification procedures to meet," says Luhrs. "And since we don't push our second-sourcing, we avoid confusion."

Reluctant dragon

Texas Instruments also prefers to be an originator but is always ready to go after targets of opportunity. Ed O'Neill, IC marketing manager, estimates that about one-third of the company's IC business is in second-source items. Most of this volume is in DTL lines. In TTL and other complex circuits, TI does almost no second-sourcing; its assemblies are, however, extensively copied. One reason for this may be that the geometry and configurations developed for TTL represent a feeder technology for medium-scale-integration and large-scale-integration assemblies as well as flip-flop circuits and gate work. As a result, TTL has caught the attention of engineers throughout the electronics field.

O'Neill cautions that there are no guarantees in second-sourcing. "Even the best are bound to flop occasionally," he says. "A house depending entirely on second-sourcing will be hit harder by a miss than one with balance—the more established a line is, the lower will be prices and profits."

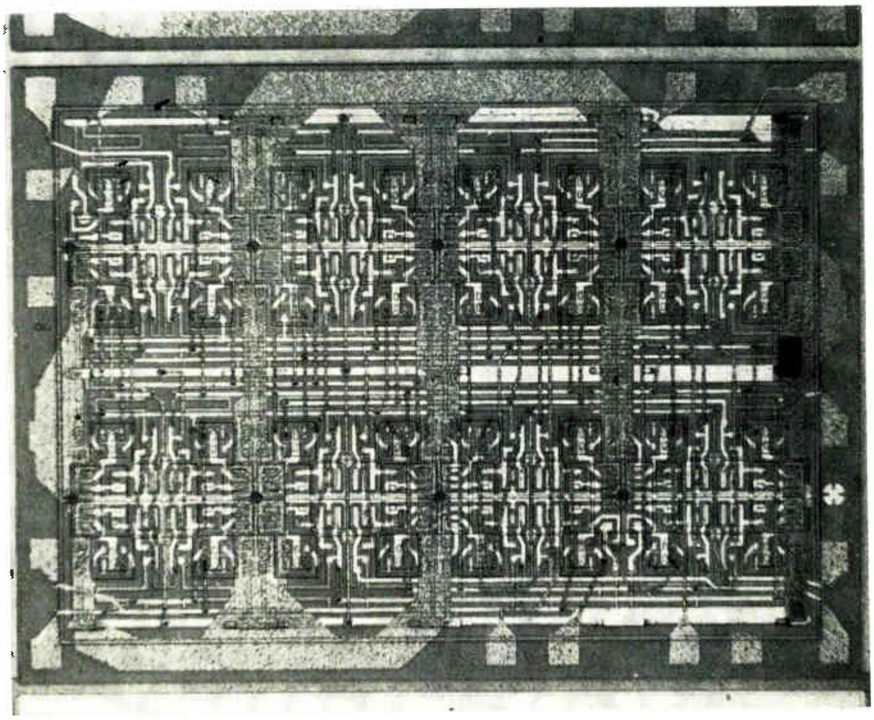
Customers usually call the shots on ensuring duplication of characteristics by maintaining elaborate testing facilities, O'Neill says. He doesn't consider this a real problem for a company with resources, but admits the difficulties are considerably more complex with IC's than discrete components.

Consuming interest

Users of IC's agree—albeit warily—that most second-source assemblies stack up pretty well against those from originators. "There's a fairly close match on characteristics and packaging," says Richard Stewart, manager of the advanced technology department in the Data Systems division of the Hughes Aircraft Co. "However, we still have to guard against 'specmanship' by the marketing departments of second sources. At times, they push assemblies that aren't compatible with our requirements. We look closely at our originals and decide what criteria our alternate suppliers will have to meet."

Similarly at the General Dynamics Corp.'s Pomona division, there is a policy that all systems be so designed that at least two IC sources can be used. In cases where there is no time or money to run proofing tests, the company will struggle along with its prime supplier. "We've found variations occur even on licensed devices, so we run proof tests on all suppliers," says Robert Martin, group engineer. "How the device performs in a system is the key to its acceptability."

Field trials. The Autonetics division of the North American Rockwell Corp. uses second sources for IC's because of Government and in-



Tough act to follow. Fairchild hopes to discourage would-be imitators by developing more complex devices; this 32-gate LSI unit is an example.

house requirements that back-ups be available. "There are no particularly divergent patterns in the performance of IC's from originators and second sources," says Arthur Lowell, assistant director of Autonetics' Research and Engineering division. "Most of our suppliers work both sides of the street, and we make a pretty thorough facilities evaluation check on all of them. This is important in the case of small specialty houses when a large volume of devices is required."

Although most IC users make a virtue of the necessity of riding herd on their suppliers, some doubt the efficacy. "There's always some difference between a prime and second-source product," says William R. Rodrigues de Miranda, senior reliability engineer at the communication and data processing operation of the Raytheon Co.'s Equipment division. "To get complete matches, we would have to define all measurable parameters which might affect operating characteristics. They aren't exactly common knowledge, though. Manufacturers are still trying to relate parameters—and not just those you find on a spec sheet—to actual performance."

An equally tolerant approach is taken by James Mintern, senior components engineer, at Raytheon's Space and Information Systems division. "The need for second sourcing depends on one's primary sources and on the nature of the product," he says. "Second sources are always preferred on standard IC's, but often individual situations make this impossible or even undesirable. Highly individualized specifications or ultrahigh reliability call for so much emphasis on information exchange between user and vendor that second-sourcing becomes an encumberance—even more so when the user must try to protect the secrets of individual vendors while getting equal performance from them. In such cases, you give one man all the business. Make sure he knows it, and usually, he'll come through for you.

"In the case of an S-band power amplifier for the lunar module portion of Apollo, I insisted on a single source," says Mintern. "We needed reliability and quality. And this was an instance where there was no justification for price shopping."

Trouble. Most users have at least one horror story to tell about using a sole source. The experience of LTV Electrosystems Inc., a subsidiary of Ling-Temco-Vought Inc., is typical. "We used a metal oxide semiconductor IC as a 50-bit shift register in a recent piece of equipment," says C. F. Turrentine, director of materials at the company's Garland division. "Only one supplier produced it and we felt we had to go with him. But we ended up getting into all kinds of trouble. The source ran into delivery problems and we had to stop our production lines on a number of occasions. We scoured the industry for an alternate supplier, and while some came close to meeting our requirements, we would have had to invest extra money on design to work with them. We finally had to stick with the sole source and help overcome the difficulties."

Stranger than fiction. In the main, however, semiconductor houses are convinced that their IC customers need and want second sources of supply. And a marketing aide at one IC maker even admits to having printed one of his own company's data sheets on the letterhead of a rival concern just to give a potential buyer the impression that there were two suppliers. The ruse worked. Subsequently his company bought the second which then began to turn out the circuits.

Above the strife

Some IC concerns, notably Fairchild, disparage second-sourcing. Says Jerry Sanders, the Semiconductor division's marketing manager: "If everyone second-sources, we'll cannibalize our industry. All we'll do is drive the cost per gate down and down. I'd like to see the dollars wasted in solder, printed circuit boards, overhead, and the like put into 'vertical integration' to guard against pricing ourselves out of business. Otherwise, we'll give more and more for less and less until we eventually fly up our own tails."

Refusing to second-source is the company's way of protecting its own contributed value. Fairchild wants to integrate more and more of the system onto the chip, maintaining its contribution and keeping prices at a high level.

Fairchild, of course, is an innovator and still a leader in the IC field. But not every concern can afford to be so aloof. Raytheon's Semiconductor division, which got a late start in the business, furnishes a case in point. "We've been second-sourcing since our inception," says Paul Sullivan, IC marketing manager. "It's a good business, per se, but we've also gained the know-how to turn out products of our own design."

Back door. Similarly, ITT Semiconductors' IC output is 100% in second-source items. Robert F. Graham, the division's director of marketing, considers such a role a natural for latecomers with resources. "The phenomenal growth of IC's, together with the industry's poor record on deliveries, makes for excellent opportunities," he says. "Technical talent can be found anywhere; manufacturing and marketing skills have now become the keys to success."

The company has done well hitching rides. It caught the crest of the DTL wave and is now setting its sights on TTL and MSI assemblies.

In another vein, Intersil Inc., a small specialty IC house formed last year by Jean A. Hoerni, inventor of the planar process, is embarking on its corporate life with a refreshing *chutzpah.* It intends to reverse the field's normal procedures and convince one or all of the big three to make its volume proprietary circuits as they are developed. As for second-sourcing, Ward Gebhardt, the company's director of marketing, says: "Our role will be to contribute to the store of new products. But we have no hang-ups about second-sourcing, and if it helps our customers, we'll do it."

Second class. One of the reasons for the smaller houses' obvious reluctance to build reputations in second-source operations is the fear that making good could ultimately do harm. "Second-source houses will not attract the engineering talent they need to put them into the innovation markets," says William Berg, marketing manager at the Signetics Corp., a subsidiary of the Corning Glass Works. However, Signetics recognizes customers' need for alternate

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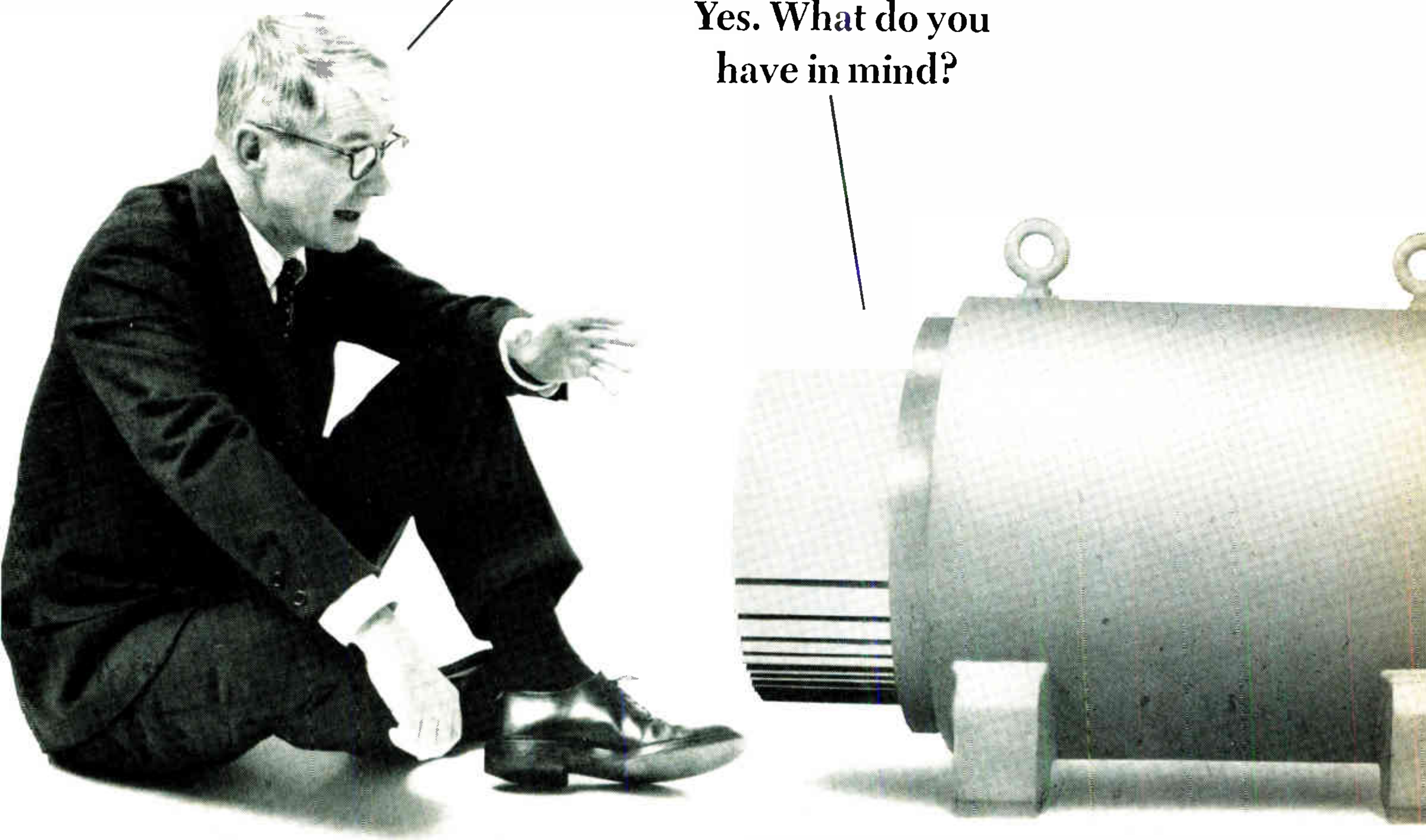

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suppliers, and has an exchange agreement with the Sprague Electric Co. "They use the same masks," says Berg. "And for all practical purposes, Sprague and Signetics IC's are interchangeable."

And the National Semiconductor Corp., also espouses the second-source concept with enthusiasm. In the IC business only a year, National has a surprisingly well-balanced and profitable product line that includes both original items and best-selling alternates. "We've concentrated most of our design talent on up-for-grabs markets like the linear and MOS fields and chosen to second-source TTL in the digital area," says Don Valentine, the company's marketing manager. "This way the money comes in fast, and we can apply the profits to other areas with good potential."

Teledyne Inc.'s Amelco Semiconductor division is also working both sides of the IC street. About 25% of IC dollar volume is attributable to second-source items. But Amelco also makes its own 809 op amp and 58 different logic devices.

Isolated case. In a few instances, IC makers can come up with devices that defy imitation. In this category are the dielectrically isolated assemblies built by the Microelectronics division of Radiation Inc. High-cost markets, where low to medium volume is required, are the company's prime targets. But being in a class by one's self has drawbacks as well as advantages. Says William Weir, director of marketing: "We have a problem finding second sources for our more complex IC's. The Government and original-equipment manufacturers want back-ups. But if you're making a device that others can't duplicate profitably, the customer has to pay for it." Weir concedes that the widespread availability of technical talent will eventually intensify competitive pressures. "But right now, our process know-how separates us from the rest of the pack, and we have no intention of peddling it away for the few dollars it might bring in," he says.

Contributions to this report were made by Walt Barney, Peter Vogel, and Bill Arnold in San Francisco; Lawrence Curran and Bill Bell in Los Angeles; James Brinton in Boston; Marvin Reid in Dallas; and Mark Leeds, Howard Wolff, and Peter Schuyten in New York. It was compiled by Eric Aiken.

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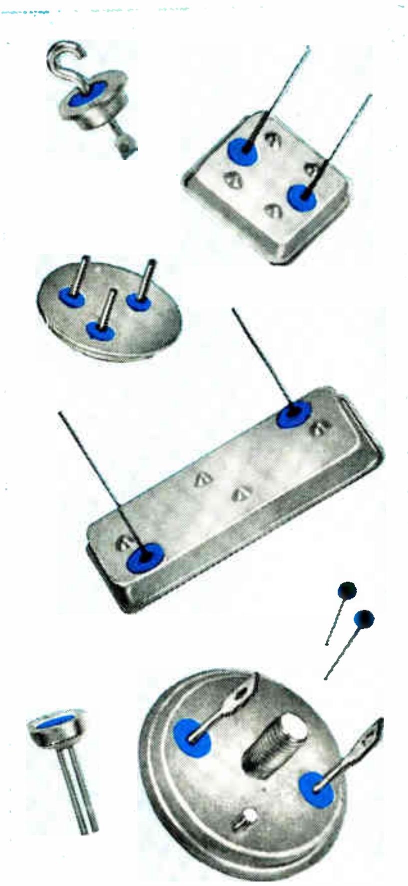

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Components

IC's poaching on op amp preserves

But assemblies with discrete components are still thriving in applications where design specifications are demanding

Don't count out the discrete operational amplifier! It may be losing some ground to the monolithic integrated-circuit device, but assemblies with discrete components are still making their way.

"Op amp applications are certainly expanding, and so far IC's are having an impact in medium-high-frequency, low-power, and low-voltage areas," says Jim Balderson, linear IC product manager at Texas Instruments Incorporated, Dallas. "But when specifications get tight, IC's can't compete. This is where the smaller producers of op amps will have to take refuge. They'll have plenty of room for growth, but will find the range of their market is smaller."

Versatility is at the root of op amps' growing popularity. They can do just about any kind of computing job—addition, subtraction, integration, differentiation, sign and scale changes, calculation of fractional and higher-order powers—and can control, compare, process, regulate, and detect both linear and nonlinear signals.

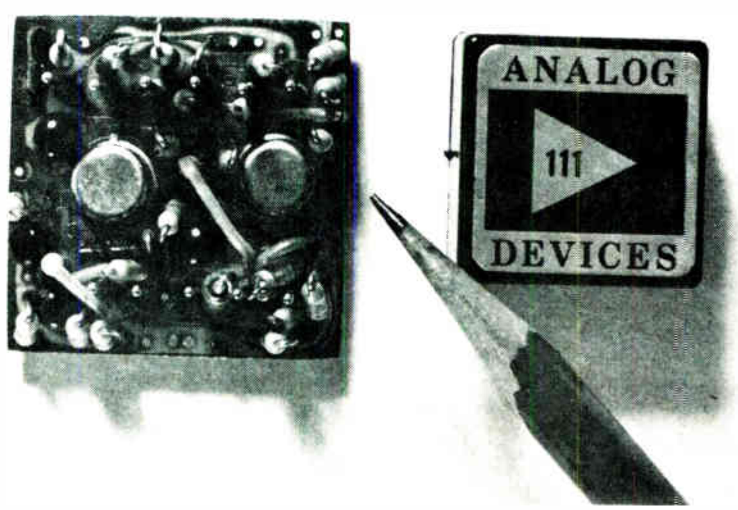
Open road

Although precise data isn't available, op amps appear to be climbing into the very-big business category. Dale Dukes, manager of management information and services at the Burr-Brown Research Corp., Tucson, Ariz., pegs the 1968 market at \$90 million, about \$20 million ahead of last year's. Jerry Metzger, product manager at the Fairchild Camera & Instrument Corp.'s Controls division, estimates monolithic units' share at \$30 million—up 20% from 1967's record. And by the early 1970's says Dukes, IC op amps may be ringing up sales of over \$100 million a year.

Might have been. "I can't help but wonder what would happen if the IC had been a few years late. We'd probably have a \$100 million market on our hands," says Ray Stata, marketing vice president at Analog Devices Inc., Cambridge, Mass., a firm with 40 or so conventional op amps in its catalog. "The advent of IC's poured cold water on our dreams, but the fire's not out yet."

"Op amps with discrete components and hybrid arrangements with IC's will be around for a long time," says David Ludwig, director of engineering at Philbrick/Nexus Inc., Dedham, Mass., a division of Teledyne Inc. "It's always possible to reach much higher levels of technical performance with a unit you can adjust. So, for the best common-mode rejection, highest input impedance (without having to resort to Darlington inputs), lowest offset current, highest input voltage, maximum frequencies, and the like, users will continue to specify units with discrete components."

Analog Devices' Stata isn't ready to throw in the towel. "Companies



Shrinking. Op amp with discrete components at the right is Analog Device's cheapest model at \$13. Company saves both space and money in modules like the 420A multiplier at left by using an IC op amp. This assembly sells for \$165.

. . . op amp companies will never be plowed under by the IC houses . . .

like ours will never be plowed under by the IC houses," he says. "We'll always be one step ahead, applying our best units and improving on them. At the very least, we'll supply the design engineering needed to use circuits in the most elegant way." As evidence, Stata cites the company's model 420A amplifier, which has two μA-726 monolithic dual-transistor pairs on a temperature-controlled substrate.

Where it's at

Integrated circuits, however, are continuing to make significant inroads at the low end of the line—devices selling for $10 to $18 each. "There are a number of unsophisticated assemblies at this level that will be displaced in the next year or so," says David Taskett, marketing manager at Zeltex Inc., Concord, Calif., a firm that offers 60 different versions of op amps. Fairchild, for example, dropped its low-cost ADO-47 op amp because it couldn't compete with IC's. Similarly, all of the company's chopper-stabilized devices have been discontinued. But Fairchild is readying a hybrid assembly to take their place. Called the ADO-70B, the unit has an IC input stage.

Arresting gear. "The 709-type monolithic units have cut into the growth of our AD5 and SQ5 op amps that sell for under $10," says Daniel Sheingold, a staff consultant at Philbrick/Nexus. "However, unit sales continue to climb by as much as 10% because of follow-on orders." Fairchild's Metzger also notes the impact of repeat business.

With IC's chipping away at the low end of the line, Philbrick/Nexus is turning to larger, more complex op amps like its recently introduced model 1003, which has a field effect transistor input. "This device has only a few picoamps leakage and a temperature coefficient of 1 microvolt per degree Centigrade, and it has no IC's," says Ludwig. "We haven't abandoned the IC and are looking at unpackaged chips and discrete components on ceramic substrates. This would give us some of the size advantages of integration. But we'll do this only if we don't have to add too many components to get the IC's operating parameters up to snuff."

Examples of Philbrick/Nexus' more complex units are the Meter Mates introduced at last month's IEEE show in New York. Presently, there are two versions—a high-impedance input device and a unit that converts a zero-center meter into a null-center meter that reads logarithmically on either side of center. The first a-c Meter Mate is expected to be available next month; it will yield root-mean-square, peak-to-peak, or full-wave rectified average voltage from an audio-frequency input. Both linear and log readouts will be offered.

Burr-Brown's Dukes says discrete op amps tend to offer more design flexibility than IC's and thinks that design fundamentals still favor discrete components where performance is critical. "But in standard production-line op amps where costs and size count most, IC's are superior," he states.

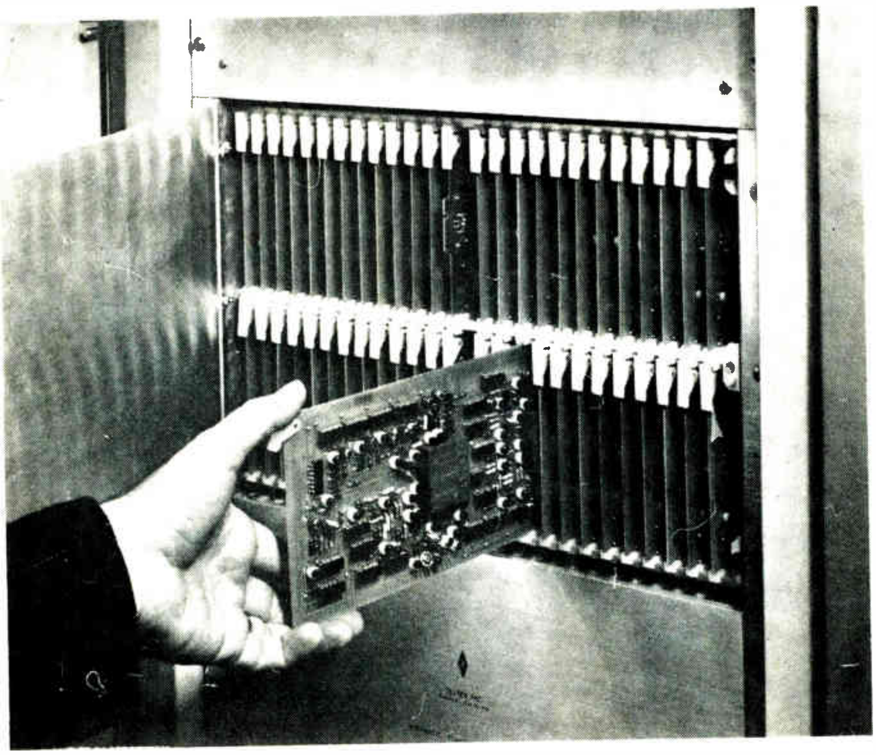
Magic number. Fairchild's Metzger agrees with the proviso that 100,000-unit runs are a minimum requirement to make the monolithic-unit production economically feasible. Analog Devices goes so far as to steer customers to IC's when they seem appropriate. "If a purchaser's application permits loose specs and he's ordering in volume, we point him toward IC's. We're casting our bread upon the waters against the time he'll need tighter parameters," says Stata.

Long haul

Over the long run, technology will force change in the character of op-amp outlets. Future assemblies will be largely modular amalgamations of IC's and discrete components. Moreover, products will increasingly be specified in terms of their function within a system rather than as an operational or differential amplifier with given characteristics.

Stata says Analog Devices plans to take advantage of the best the IC houses have to offer, and then, by outboarding components and building larger modules, to improve on their offerings. "As far as the market is concerned," he says, "the winning companies now are making the correct guesses as to which modules to work on now. Active filters are obviously a good bet as are the multipliers and chopper-stabilized amps."

But the inbred nature of the op-



Hedged bet. Zeltex, an op amp maker, is diversifying its product base by adding wares like this element for hybrid/analog function generator.

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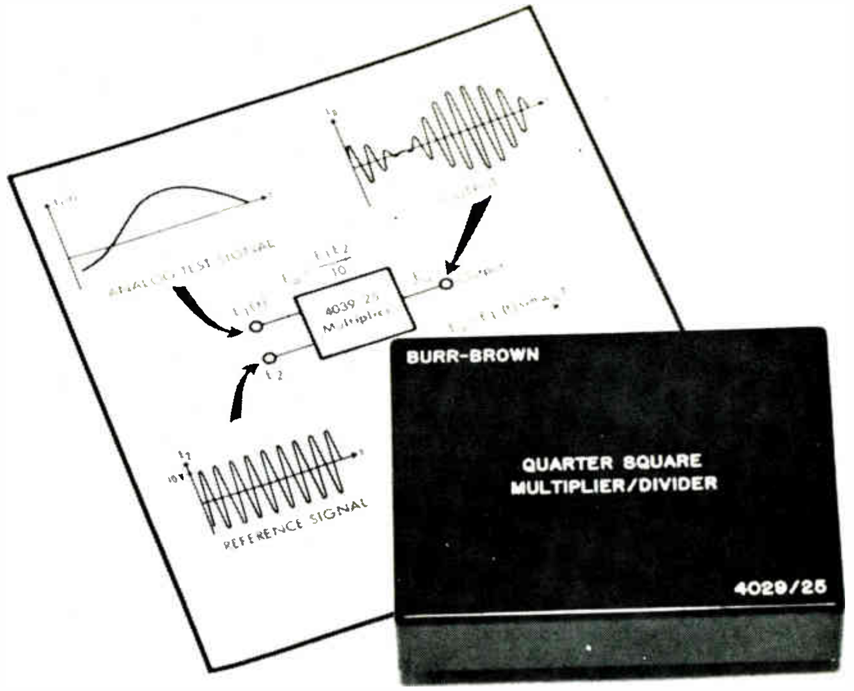

It figures. This quarter square multiplier introduced by Burr-Brown has a rated output of ±10 volts at 5 milliamps; unit cost is $195.

amp business is a danger, says Stata. Companies are looking over their shoulders and second-guessing like mad. "If Burr-Brown brings out a gidget, or if we do for that matter, it sets off ripples throughout our industry," he says.

Repeat performance. "Market planning is tough right now; it's very hard to get opinion on samples because customers haven't been exposed to the sort of devices we look forward to selling," says Stata. "It's almost like the situation in the 1950's when General Electric tried to estimate the (now profitable) market for the unijunction transistor and found none since nobody knew what the company was talking about. They didn't have applications data either, and we face almost the same situation now."

Some companies are now making data amplifiers with rack mounts and selling them for $500 to $600. Stata believes his company should be able to do the same thing in a miniature package for about $225. Analog Devices model 601, which includes a μA-726 temperature-controlled transistor pair, represents a step in this direction.

"We recommend the 601 for use as a bridge amp, a thermocouple amp, or high-impedance differential amp among other applications," says Stata. "The 601 has a common mode or rejection of about 120 decibels over a band of d-c to 60 hertz, and a bandwidth of 30 kilohertz. The 601's potential looks good to us, and there will be 602 along in the middle of this year to broaden our coverage here."

Burr-Brown is concentrating on specific functions rather than universal modules, says Dukes. "We're interested in the market for specialized versions of general-purpose, building-block devices."

"Our high-cost, high-performance op amps get a large part of our engineering effort. Complexity is rising along with price in this area," says Philbrick/Nexus' Ludwig. "Our list of customers shouldn't change much; we'll just be selling them a larger part of the system."

And with the advent of Meter Mates, it is only natural for the company to expand into instrumentation. "We'll be looking for holes in the instrumentation field left untouched by the Hewlett-Packards and the General Radios, but which present real customer needs," says Ludwig. The company has already introduced two 5000-series measurement devices, essentially specialized Meter-Mate modules with panel meters and controls.

Contributions for this report were made by Peter Vogel in San Francisco, Bill Bell in Los Angeles, Marvin Reid in Dallas, and James Brinton in Boston. It was compiled in New York by Eric Aiken.

Integrated circuit package sealing application centers opened by GTI

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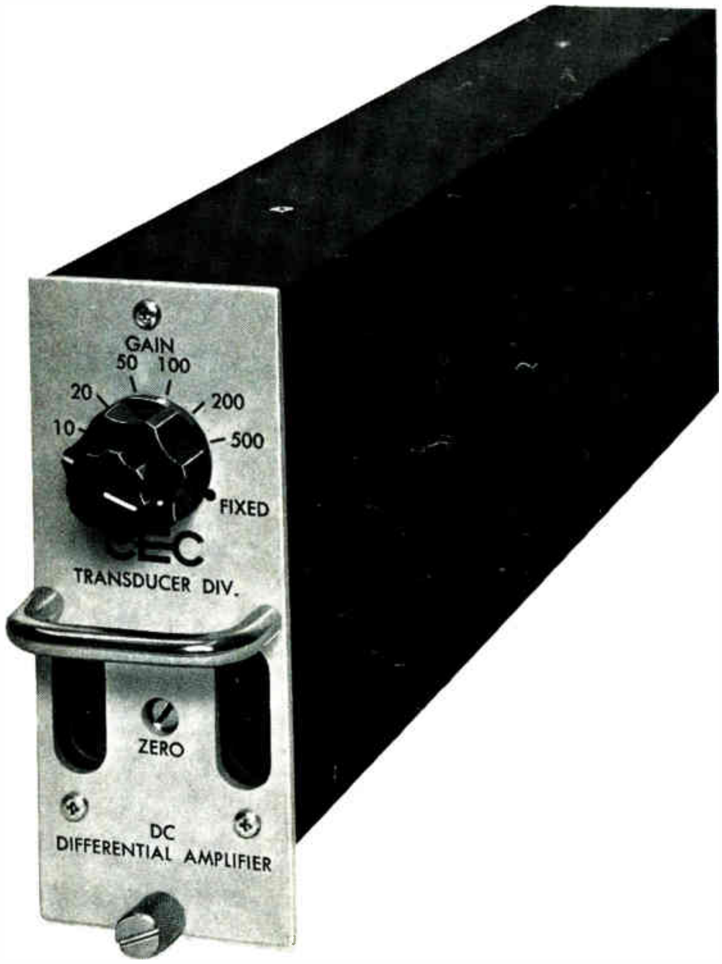

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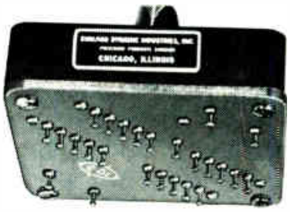
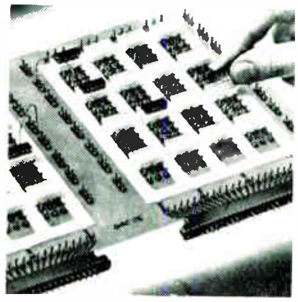
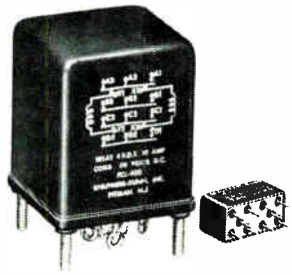


Adjustable-stop, single p-c wafer rotary switch type RS275 has a switching matrix of 20 inputs and 5 outputs. It meets applicable portions of MIL-S-3786. Applications include computers, checkout equipment, test equipment, and programing. Price is approximately $130; delivery, 30 days. Chicago Dynamic Industries Inc., 1725 Diversey Blvd., Chicago 60614. [341]

Miniature coaxial cable, with a 0.150-in.-diameter shield, has an inductance of only 0.061 μh per ft measured at 100 khz. The center conductor has an o-d of 0.059 in. and dielectric is solid polyethylene. Cable's attenuation is 18 db per 100 ft at 400 Mhz, and operating temperature range is −55° to +85°C. Times Wire and Cable, 385 Hall Ave., Wallingford, Conn. 06492. [342]

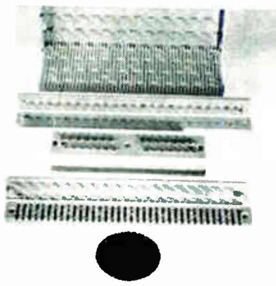


IC breadboard panels in the Omny-Pac series feature advanced laminar bus bar-capacitor design and 16 or 32 dual in-line IC sockets. Each socket is designed for easily inserting 14-pin IC's. The MBB-1000 (16-circuit panel) measures 6½ x 8½ in., and the 32-circuit panel MBB-2000 is 13 x 8½ in. Methode Mfg. Corp., 1700 Hicks Rd., Rolling Meadows, Ill. 60008. [343]

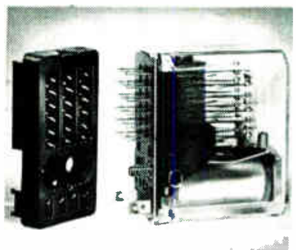


Military grade aerospace relays models FCL-400 and FCL-1 save energy by using power just to transfer the contacts, not to hold them. The 10-amp FCL-400 operates on as little as 35 mw-sec; the 2-amp, half crystal can size FCL-1, on 2 mw-sec. Once transferred, contacts remain in the last operated position with zero power drain. Struthers-Dunn Inc., Pitman, N.J. 08071. [344]

R-f filter type 550 is suitable for use in communications equipment, aircraft instruments, etc., which may be interfered with or damaged by high power radio energy. It gives average attenuation of 75 db of r-f energy in a range from 1 Mhz to 20,000 Mhz. It comes in 1 amp, 0.45 amp or 0.3 amp ratings. Elliott-Automation Ltd., Airport Works, Rochester, Kent, England. [345]



Solderless gas-tight connectors are for connecting flat cable or individual conductors to wire wrap or solder posts and to various types of p-c board contact systems. The contacts make up to 63 connections simultaneously, and can handle wire sizes from No. 30 Awg to No. 22 Awg stranded. 3M Company, 3M Center, St. Paul, Minn. 55101. [346]



Miniature relay series AZ430, with a 6 Form C contact arrangement, is designed for multipole switching applications. It is available with low-level bifurcated, 2 amp or 5 amp silver alloy, heavy duty contacts. Coil voltages range from 6 v to 115 v d-c. Over-all size is 47/64 x 1 13/32 x 1 3/16 in. American Zettler Inc., 697 Randolph Ave., Costa Mesa, Calif. 92626. [347]

Card-edge connectors series 6309 are designed for high packaging density (mounting on 0.300-in. centers) in programed wire wrap applications. They are suited for mounting on chassis, p-c boards and metal plate assemblies. They incorporate contacts spaced on 0.100-in. square grid, and accommodate 1/16-in. p-c cards. Elco Corp., Willow Grove, Pa. 19090. [348]

New components

Semiflexible cable turns the corner

Right-angle connector has vswr under 1.15; precision casting of outer shell reduces bend radius to 1 inch

Match up. The connector can join two semiflexible cables, or a semiflexible to a standard cable.

Bending brings out the worst in semiflexible cable. The inner conductor and the solid aluminum outer conductor crease and the inner conductor goes off-center. Reflections appear in the line and the voltage standing-wave ratio goes up.

Engineers at the Times Wire and Cable division of the International Silver Co. found that the vswr rose when the radius of the bend was less than 10 times the diameter of the cable. They developed special tooling, and were able to get the bend radius down to four times the diameter of the cable.

But much of Times' semiflexible cable was going into aircraft systems and bending the cable still took up too much room. So the com-

. . . air used as the dielectric . . .

pany developed a right-angle connector with a 1-inch bend radius and a maximum vswr of 1.15—about the same as that of the cable.

Into the turn. Ralph Kragle, manager of connector operations at Times, says the bend is made as a smooth coaxial transition by precisely casting the connector's outer shell. Bends have normally been made by drilling, in a solid casing, two holes that meet at a 90° angle. So when the inner conductor was inserted, it was bent sharply. The inner conductor of the Times' connector is a solid piece of beryllium copper that bends smoothly in the casing, and the dielectric is air. Short sections of low-loss dielectric are at each end for compensation. Kragle says the key part of the connector is the Teflon bead that supports the conductor. "The bend is very smooth, and the bead is almost reflectionless."

The cutoff frequency depends on cable diameter. Connectors are available for diameters from ¼ to ⅞ inches. For the largest diameter, the cutoff is 4 gigahertz, and for ½-in cable, the connector's vswr stays under 1.15 up to 12 Ghz. Insertion loss is low; for a ¾-in connector, it's 0.2 decibels.

Highly eligible. The unit can mate with semiflexible cable at both ends, or it can be fitted to mate with type N, type C, or the General Radio Co.'s type GRL-874 connector.

The unit was first used on Lockheed Aircraft Corp.'s C-5A cargo plane, and has been sold to Pan American World Airways, Inc.

The company says the connector will be useful wherever high isolation and low loss aluminum-sheathed semiflexible cable is needed. Principle applications are now in aircraft, missile, and submarine systems. Times expects the use of semiflexible cable to increase in commercial communication systems, like cable tv.

Prices are $50 to $100 for small quantities. Connectors for 50-ohm systems are available within a month, and units with other impedances can be designed.

Times Wire and Cable Div., 358 Hall Ave., Wallingford, Conn. 06493 **[349]**

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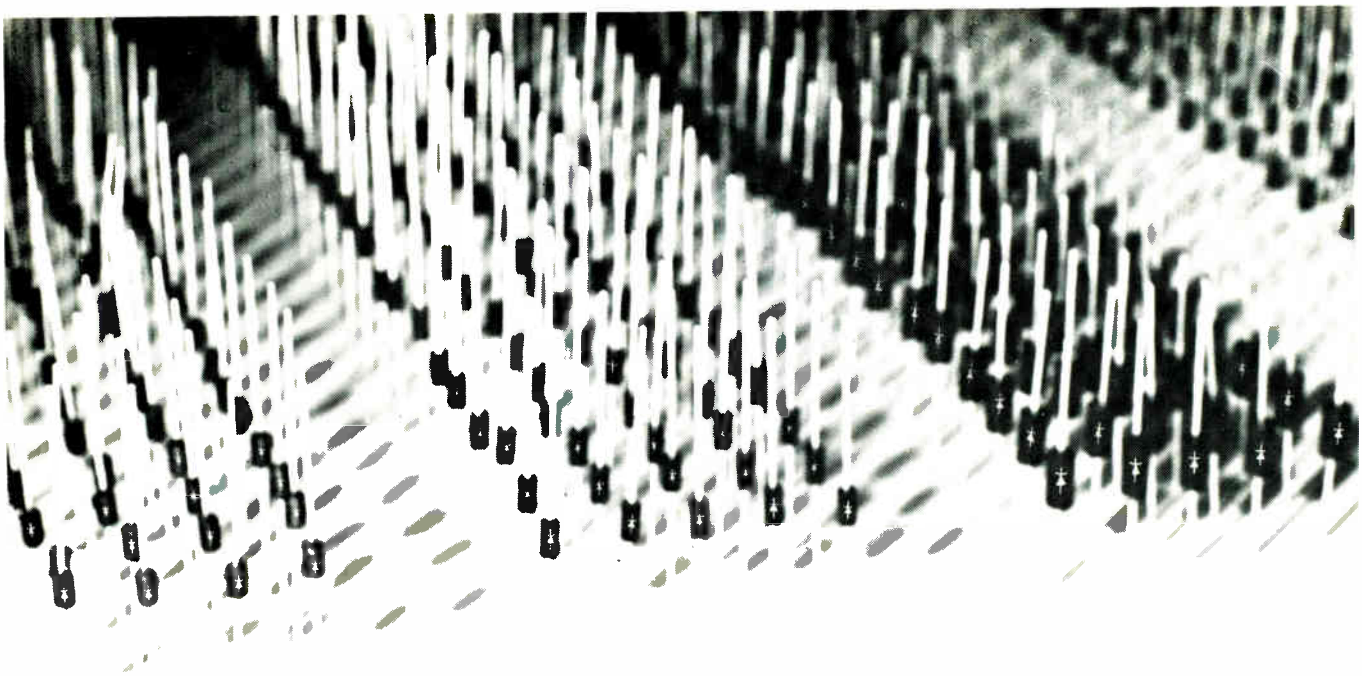

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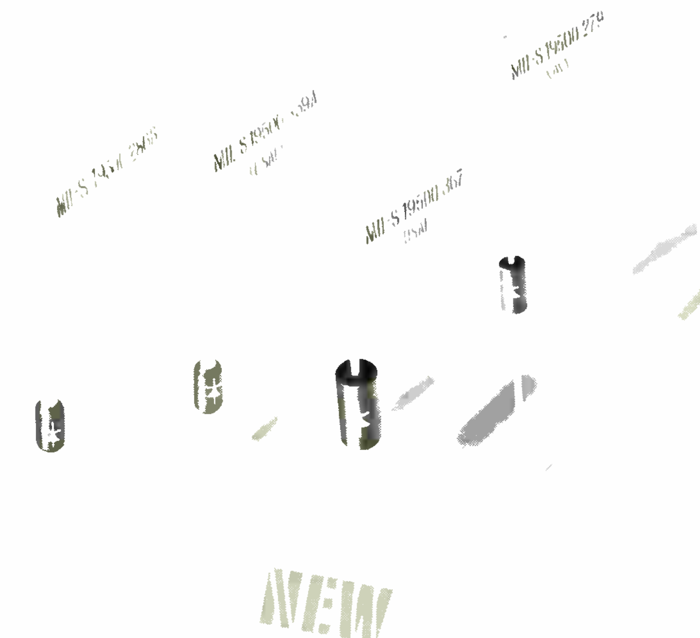

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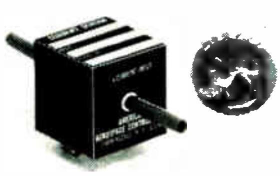
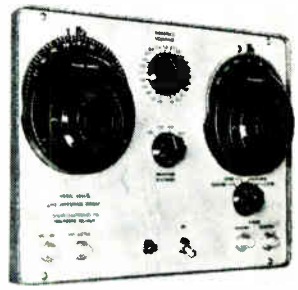
New Instruments Review



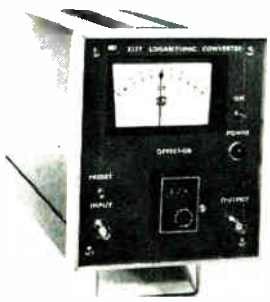
Current sensors 2006H utilize magnetoresistors to detect current in ranges from 0 to 25 amps to 0 to 300 amps a-c or d-c. Output from the sensor is suitable for remote transmission in automatic checkout equipment. Price is $298.50 each in lots of 1 to 9 and delivery is 2 to 4 weeks. American Aerospace Controls Inc., 129 Verdi St., Farmingdale, N.Y. [361]

Digital readout, universal measuring bridge type 8-150 is for both laboratory and production use. The 24 ranges of measurement include inductance 0.15 μh to 120 henrys, capacitance 0.2 pf to 1,200 μf, resistance 0.002 ohm to 12 megohms, with an over-all accuracy of 1%. A 1-khz oscillator is included. Whittaker Corp., Gencom Div., 80 Express St., Plainview, N.Y. 11803. [362]

Pressure transducer model 434/534 covers pressure ranges from 1 psi to 5 psi with high accuracy during 35 g vibration. The 434 covers absolute pressure ranges, while the 534 covers various differential and gage pressure ranges. Power rating is 1 w at 165°F. Insulation resistance is 50 megohms at 200 v d-c. Bourns Inc., 6135 Magnolia Ave., Riverside, Calif. 92506. [363]

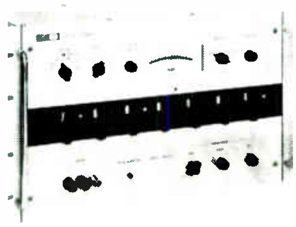


Line impedance bridge 6363-2 is for measuring r-f impedance and phase angle without direct connection to power line. Two current transformer probes couple to unknown impedance providing measurement magnitudes from 0.3 to 1,000 ohms and phase angles ±180° from 15 khz to 30 Mhz. Price is $1,365. Solar Electronics Co., 901 N. Highland Ave., Hollywood, Calif. 90038. [364]

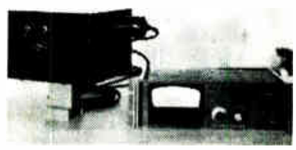


Logarithmic converter model 2277 provides accurate db measurements of complex waveforms or d-c voltages. Features include 120-db dynamic range, bipolar input, and d-c to 200 khz frequency response. Applications include oscilloscope preamp, logarithmic null voltmeter, and production comparison voltmeter. Optical Electronics Inc., Box 11-140, Tucson, Ariz. 85706. [365]

Automatic circuit test set model AP-502 is a completely portable unit (weighing less than 40 lbs) that will make up to 1,200 continuity or insulation tests per minute. The automatic sequencing and simple controls permit operation by unskilled personnel. Price is $4,950; delivery 45 days after receipt of order. Teleproducts Inc., 351 New Albany Rd., Moorestown, N.J. 08057. [366]



Meter calibrator 760A reads percentage error directly of any a-c/d-c, ampere, or voltmeter on its own front panel meter. D-c accuracy is ±0.1% from 0.001 to 1,000 v. Current range is 1 μa to 10 amps with ±0.25% accuracy. Resistance is 0 to 10 megohms, accurate to ±0.1%. A-c accuracy is ±0.25%, 0.001 to 1,000 v. John Fluke Mfg. Co., Box 7428, Seattle, Wash. [367]



Absolute reflectance transmittance photometer model 209 is for narrow band measurements between 1,650 Angstroms and 2.4 microns. It is a double-beam a-c null balance photometer to be coupled to a monochromator or narrow-band interference filters. The double-beam system permits rapid scanning. Kaye Scientific Corp., 39 Manhattan St., Stamford, Conn. 06902. [368]

New instruments

Oscillator serves many functions

Nyquist plotting, spectrum analysis, and digging a signal out of noise are just a few applications

A programable filter oscillator has bobbed up Down Under and the maker, AIM Electronics Ltd. of Melbourne, Australia, claims it's the only one of its kind available. The oscillator is the newest addition to AIM's modular instrumentation system.

The unit, PFO 166, has a variety of operating modes, including filter accept, filter reject, and oscillate. Variation of the applied programing voltage between 1 and 5 volts alters the oscillator output frequency by up to 400:1 within an available frequency range of 15 to 50 kilohertz.

When used as an oscillator or accept filter, it also gives a quadrature output (an identical frequency 90° out of phase). The quadrature signal in a feedback loop means the equipment will phase-lock a lock-in amplifier or a tracking filter. It also permits the unit to be used for automatic Nyquist plotting.

In spectrum analysis, the unit can be either a conventional oscillator or a filter. Two PFO 166 units can be used to inspect the electrical characteristics of circuits or equipment: one as an oscillator with programable frequency driving the input of the circuit under test, and one as a filter at the output to assist examination of the resulting frequency spectrum. A third PFO may be used as a reject filter to reject the dominant harmonic of the input signal and reduce its distortion to less than 0.1%. The resulting signal may be displayed on a meter, oscilloscope, or an x-y recorder. For display purposes, a ramp waveform must be used as a time base and as the programing voltage.

In the presence of noise, the PFO 166 can also be applied in signal recovery where an amplifier is required to lock to an unknown frequency and phase. The technique requires a local phase-locked reference generator, consisting of a phase-sensitive detector and the voltage programable filter. The PFO generates a reference signal and adjusts its frequency automatically to the incoming frequency. A phase-sensitive detector referred to the quadrature output provides an error voltage that is applied to the PFO to maintain the phase-lock.

In Nyquist plotting, the unit is used to generate a variable frequency sweeping through the full 400:1 range. The in-phase quadrature outputs are connected to two phase-sensitive detectors, and these resolve the signal from the system under test into two components. These can then be automatically displayed on an x-y recorder or oscilloscope.

Other possible applications are as a tracking filter and as a programable comb filter where several units are used in combination.

AIM Electronics Ltd., Melbourne, Australia [369]

New instruments

Place on panels sought for meters

French-made digital unit displays voltage, current and resistance readings

Not content with manufacturing Europe's lowest-priced digital multimeter, France's Schneider Radio

Television has now come up with the Continent's lowest-priced digital panel meter. Called the VT-100, the meter displays digits from 0000 to 1999 and is priced in the neighborhood of $175. U.S.-made panel meters cost about $295.

Schneider is aiming the new instrument at the original-equipment market. "We wanted to develop as inexpensive a meter as possible so that equipment makers wouldn't have to raise their prices," says Martin Birnbaum, head of the company's Professional Electronics division.

The company has yet to set a price for the meter in the U.S. and still hasn't decided on a distributor. Honeywell Inc. distributes Schneider's multimeter, called the Digitest, in this nation. Priced at $300 in Europe, the Digitest sells for $525 in the U.S.

Gallic display. The VT-100 panel meter reads out to 1999.

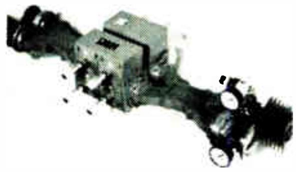
Several ranges. The VT-100 measures voltage, current, and resistance; it reads out d-c voltage over three ranges, d-c current over five ranges, a-c voltage over three ranges, a-c current over three ranges, and resistance over five ranges. The instrument's input impedance is 1 megohm, and its measuring cadence is one per second. Resolution is 1 millivolt.

Part of VT-100's circuitry is made up of diode-transistor-logic integrated circuits, with the rest discrete solid state components. Birnbaum says the whole unit could have been made with IC's, but this would have meant a higher production cost.

The unit measures 5.8 by 2.9 by 7.8 inches, and features automatic zeroing. It was exhibited for the first time at the annual Paris Components show last month.

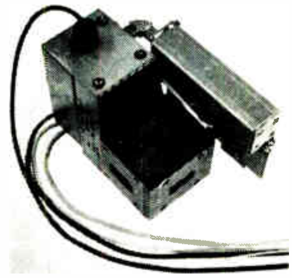
Schneider Radio Television, 12 rue Louis Bertrand, Ivry, France [370]

Custom-engineered zero return-loss diplexer is basically a narrow-band bandpass filter, but it terminates out-of-band signals into an internal load rather than reflecting them back to the input. Over the 2.97-3.13 Ghz passband, insertion loss is less than 0.9 db. At 2 and 4 Ghz, insertion loss is greater than 40 db. Sage Laboratories Inc., 3 Huron Drive, Natick, Mass. 01760. [401]

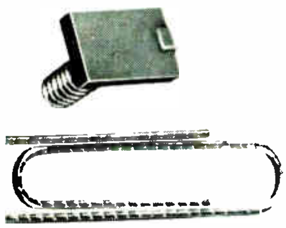


C-band tunable filter model 51-923-1 comes in a waveguide assembly consisting of cylindrical cavity resonators, power dividers, and high power loads. It is designed to eliminate the rfi problem in an operational weather radar system. Tuning range is 5.45 to 5.65 Ghz, bandwidth 20 Mhz, power handling 400 kw peak, and vswr 1.5:1 max. AAI Corp., Cockeysville, Md. 21030. [402]

C-band beacon antenna DMAQ-200-1 will survive heat pulses to 3,000°F and will operate for 5 minutes in a 1,000°F environment. It weighs 5 oz, is 1.5 in. long and has a 1.13 in. diameter. Frequency range is 5.4 to 5.8 Ghz, vswr less than 1.5:1 and power handling capability 1 kw peak, 10 w average. Dorne and Margolin Inc., Veterans Memorial Highway, Bohemia, N.Y. [403]

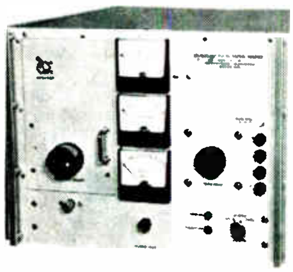


X-band preamplifier model APX-2, designed for radar applications, is a fixed-tuned parametric amplifier providing a 50-Mhz bandwidth anyplace in the 8.5 to 12 Ghz range. Noise figure is 3.5 db max with 16 db of gain. The unit handles up to 200 mw c-w input without damage. It measures 4 x 5 x 6 in. Melabs, 3300 Hillview Ave., Stanford Industrial Park, Palo Alto, Calif. 94304. [404]

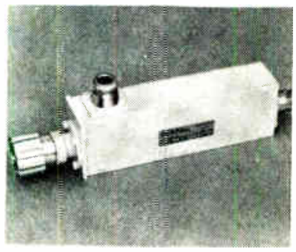


A line of 20-w stripline terminations features a metal-film element deposited on a beryllium oxide substrate. Model 125-20W-T is for insertion in ⅛-in. stripline. Vswr rating is 1.1 or better below 1 Ghz and 1.25 or better below 4 Ghz. Dimensions are 0.250 x 0.375 x 0.065 in. Price is $35; delivery, 2 to 3 weeks. EMC Technology Inc., 1133 Arch St., Philadelphia, Pa. [405]

High power limiter operates over the frequency range of 2 to 8 Ghz. The device can limit peak r-f input powers up to 500 w and average power up to 5 w. Maximum r-f power output is 100 mw. Low power insertion loss is 1.25 db maximum and input vswr is 1.75 to 1. The unit comes with OSM or TNC connectors. Micro State Electronics, 152 Floral Ave., Murray Hill, N.J. [406]



Microwave pulse signal source 03-54-00 provides up to 40 kw peak power output and tuning range of 700 to 850 Mhz. The instrument offers stable frequency, variable pulse width, repetition rate and power output as well as external and internal pulse synchronization which permits separate use of modulator. Applied Microwave Laboratory Inc., Andover St., Andover, Mass. [407]



Directional couplers covering 200 Mhz to 12.4 Ghz provide high accuracy coaxial measurement. They are suited for broad-band swept reflectometer set-ups or constant vswr monitoring systems. Minimum directivity for the 5 couplers that cover the band ranges from greater than 40 db at the low end to more than 30 db at the high end. Emerson Electric Co., Calabasas, Calif. [408]

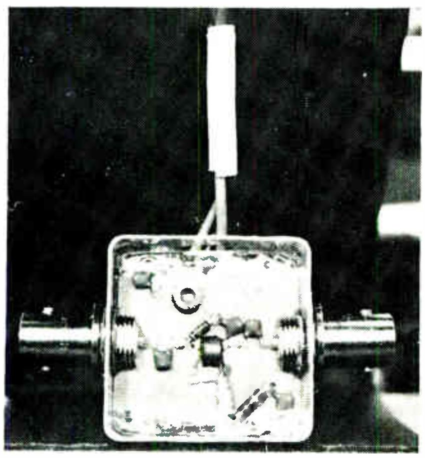
New microwave

Tiny tee in attenuator increases range

Voltage-controlled unit, with ferrite hybrid junction, has phase shift under 5°, operates from 50 to 2,000 Mhz

"It seemed as though Lady Luck were on our side. Every time we thought our designs were going to be stymied, along came the hardware that could do the job." That's how Allen Podell, director of development at the A-R Anzac Electronics Co., described how Anzac engineers came up with a voltage-controlled attenuator (VCA) that offers high performance from 50 to 2,000 megahertz.

Anzac's first attempt to make a VCA was hindered by isolation and phase-shift problems. Company engineers built a device but it was



Down to 20 db. Since the ferrite magic tee (in center of attenuator) is small, phase shift is low.

flat only up to 8 decibels.

It's magic. Podell thought of using a magic tee—a four-port junction—in the attenuator because of its high isolation. He wanted two ports for the input and output and, across the other two ports, he intended to connect adjustable resistors. But when he analyzed the system, he found that for a low voltage standing-wave ratio, the resistance at one port must increase when the other resistance decreases. He saw no way to do that.

Then, along came the p-i-n diode, a device whose resistance goes up with increasing d-c current. Podell put two p-i-n's in series across the two ports, and, by biasing one diode, he could control the attenuation and, at the same time, keep the vswr down.

But the dynamic range was still low because of large phase shifts. Then, along came ferrite magic tees, five-millimeters thick. Podell, by putting one in the VCA, reduced the attenuator's electrical length, cutting phase shift to under 5°.

Anzac's attenuator has a dynamic range of 0 to 20 db, and a maximum vswr under 1.2. Insertion loss is 1.0 db for low frequencies, and 1.5 db at higher values. For a given control voltage, the plot of attenuation versus frequency is a line with a slope of 0.000025 db per Mhz.

On the level. Anzac expects its VCA to replace mechanical attenuators, popular because of their flat attenuation over broad frequency bands. "We're close to them in performance now," says Podell. He claims there is no other VCA that can match its performance under 1 gigahertz.

Anzac hopes to sell to the military and to makers of sweep generators. One use suggested by Podell is matching the outputs of a pair of antennas tracking the same object.

The VCA could also be used to regulate the output of a sweep generator.

If more than 20-db attenuation is required, the VCA's can be cascaded. The devices are normally controlled by a current source, 5.8 milliamps for 0 db to —0.58 milliamps for 20 db attenuation.

The cost is about $200 and delivery time is four weeks.

A-R Anzac Electronics Co., 121 Water St., Norwalk, Conn. 06854 [409]

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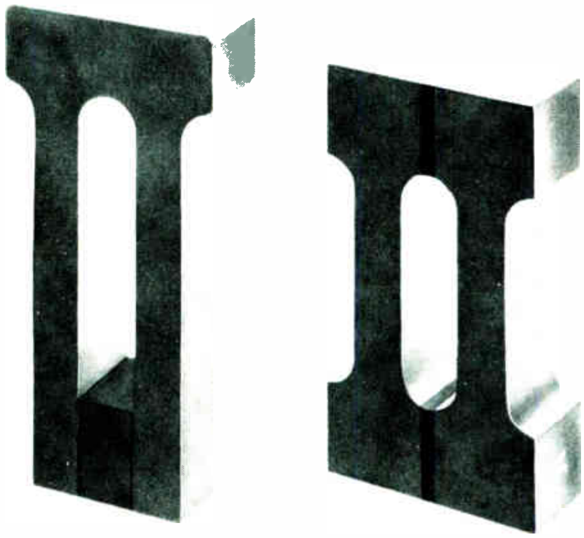

π type　　　　NA type

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Tokin VIBROX is supplied in two shape-types with nominal frequencies ranging from 15 to 100Kc. Termed NA and π respectively, both make use of associated permanent magnets to totally eliminate the need for DC bias — despite the fact that VIBROX is magnetostrictive.

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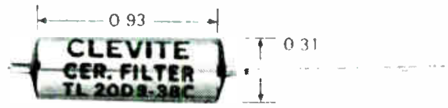
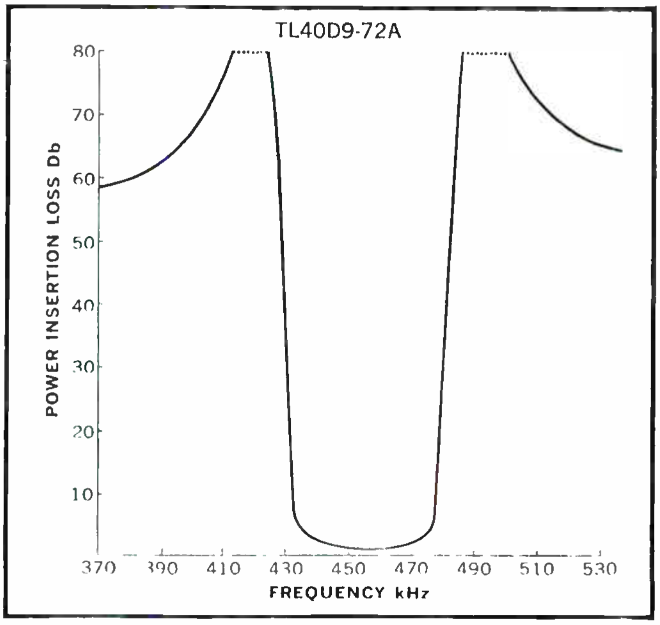


less than $15 with Clevite's compact ceramic ladder filter.*



Here's the smallest (less than 0.07 cu. in.), most rugged fixed-tuned filter on the market today!

Clevite's 9-disc miniature filter is packaged in a hermetically-sealed cylinder, exceeds all military environmental specifications, is ideal for transistorized i-f amplifier circuitry in AM and FM sets plus many other applications that call for a fixed-tuned filter. Stop band rejection: 50 db. Center frequency tolerance: ± 3kHz. Stability: within ± 0.2% for 5 years; within 0.2% from −40°C to +85°C. Impedance (in and out) 2000 ohms for B/W less than 12 kHz; 1000 ohms for broader bandwidths.

Following models standard at 455 kHz (A) or 500 kHz (C) (custom models on special order):

Model Number	B/W min. @ 6db	B/W max. @ 60 db
TL10D9-20 (A or C)	10 kHz	20 kHz
TL16D9-32 (A or C)	16 kHz	32 kHz
TL20D9-38 (A or C)	20 kHz	38 kHz
TL30D9-57 (A or C)	30 kHz	57 kHz
TL40D9-72 (A or C)	40 kHz	72 kHz

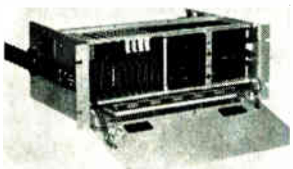
***PRICES:** 1—$25 ea; 25—$20 ea; 100—$17.50 ea; 500—$15 ea; 1000—$13.75 ea; 2500—$12 ea.
(Prices subject to change without notice)

Send order or request for Bulletin 94021 to: Clevite Corporation Piezoelectric Div., 232 Forbes Rd., Bedford, Ohio 44014, U.S.A. Or: Brush Clevite Company, Limited, Southampton, England

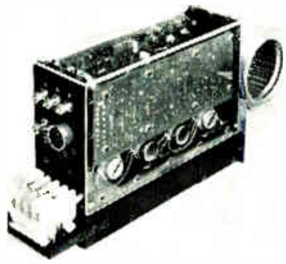
CLEVITE

Circle 125 on reader service card

New Subassemblies Review

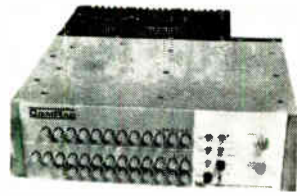


Read-only transformer memory systems series LBS have bit capacity ranging from 32,768 to 262,144 bits. The nondestructive read-only cycle time is 300 nsec. Access time is 250 nsec. The system provides a parallel readout of up to 128 bits. Operating temperature range is 0° to +50°C. Memory Technology Inc., 223 Crescent St., Waltham, Mass. 02145. [381]

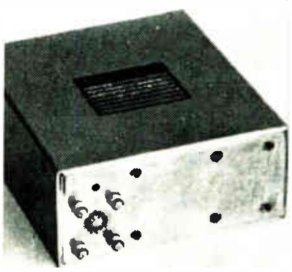


D-c servo amplifier model A505 can provide a 70-amp peak pulse output at 40 v d-c for fast acceleration and deceleration of high-response d-c motors. It has an integrally mounted blower to provide for adequate cooling and increased steady state rating. Voltage gain is 50. Power supply can be 28 or 40 v d-c. Westamp Inc., 1542-15th St., Santa Monica, Calif. [382]

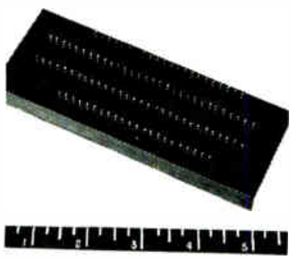
Active low-pass filter type 171 is designed to reduce noise, restrict bandwidth, and provide data correlation. Cut-off frequencies from 2 to 2,000 hz with Butterworth, Bessel, or gaussian characteristics are available by switch selection. Input impedance is greater than 100 megohms. Price is $590. Neff Instrument Corp., 1088 E. Hamilton Rd., Duarte, Calif. 91010. [383]



Core memory systems in the Com Rac series will be available in several models. Model 100 exhibits a cycle time of 1 μsec, an access time of 0.45 μsec, and is available in capacities up to 4,096 words by 24 bits or 8,192 by 12 bits. The memory is packaged in plug-in assemblies 7¼ x 9¼ in. Information Control Corp., 1320 E. Franklin Ave., El Segundo, Calif. 90245. [384]

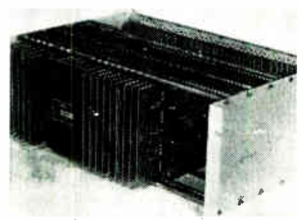


A-c/d-c power modules series RA-80 are adjustable from zero to max. output and externally programable in several modes. They come with outputs of 0-10 v to 0-160 v d-c, power to 1,000 v. Regulation and ripple characteristics are good, and efficiency up to 80%. Units operate at base temperatures to 80°C. Technipower Inc., Benrus Center, Ridgefield, Conn. 06877. [385]



High-reliability 100-tap delay line model BF-14-419 is especially designed for memory systems. It features a maximum rise time of 30 nsec, for a delay of 1,000 nsec, with distortion at the taps held to less than 5%. The unit is available from stock at an impedance of 93 ohms. Custom-engineered units are also available. Bel Fuse Inc., 198 Van Vorst St., Jersey City, N.J. [386]

Power supply model 5002-10 delivers up to 2,012 v d-c and up to 10 ma. Highly regulated, its output varies only 0.0025% or 2 mv for a 100% load change or 10% line change. The unit can operate at either positive or negative polarity with a temperature coefficient less than 50 ppm/°C and stability of 0.005%/hr. Raytheon Co., Richards Ave., S. Norwalk, Conn. 06856. [387]



Integrated circuit memory system model CE-150 is available in capacities of 4096, 8192 and 16,384 words with word lengths variable in 4-bit increments from 8 to 36 bits. The random access unit has a full cycle time of 1.5 μsec and an access time of 750 nsec. It has application in small computers. Lockheed Electronics Co., 6201 E. Randolph St., Los Angeles 90022. [388]

New subassemblies

Three-wire design speeds up memory

Smaller cores and combined sense-inhibit line permit nanosecond access with conventional 3-D organization

A large ferrite-core memory that has the cost advantages of three-dimensional design but attains unusually high speeds by using smaller cores will be shown this week at the Spring Joint Computer Conference in Atlantic City, N.J. The memory is the Ampex Corp.'s new model 3DM-750 unit, which has a 750-nanosecond cycle time and a 300-nsec data access time. These speeds—perhaps double those of the usual large 3-D memory—are made possible with cores only 18 mils in diameter threaded with three wires.

Three wires for speed. New 3-D memory fits in 19-inch rack.

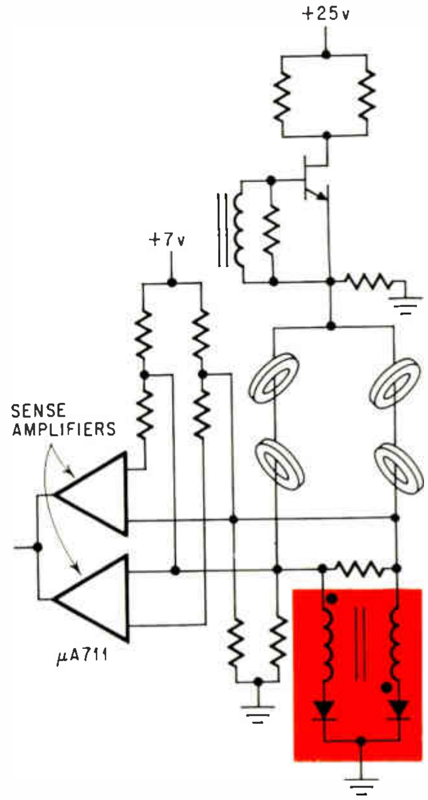
Conventional 3-D memories use 22-mil cores and four wires—for x-select, y-select, sense, and inhibit functions. Most high-speed ferrite-core memories—such as Ampex' last major development, the model RM [Electronics, Nov. 13, 1967, p. 201]—are 2-D or 2½-D. But these cost more than the 3-D because they require more electronic drive and sense circuits in proportion to the amount of information they can store.

The basic 2-D memory has two orthogonal sets of wires, one set containing a wire for each word and the other a wire for each bit in a word. At each intersection of the two sets, a word wire and a bit wire pass through the hole in a toroidal ferrite core. A third set, the sense wires, is parallel to the bit wires.

To read data from a 2-D memory, a current strong enough to switch to 0 all the cores that it threads flows along a single word wire. Cores that switch from 1 to 0 generate voltage pulses in the sense wires. To store data, a current, half the magnitude of the read current, passes through the word wire in the reverse direction, and another half current passes along those bit wires threading cores that are to store 1's. The two currents combine to set the proper cores to 1 where only the half-current flows, the cores don't switch.

The conventional 3-D memory is a series of stacked planes, each containing one bit of each word in the memory. In each plane two orthogonal sets of wires permit any core in the plane to be addressed; the corresponding wires in all planes are connected in series to select all the bits of a word. In each plane a sense wire detects the change in magnetization of any core, and an inhibit wire opposes the current in one of the two select wires to store a 0.

To read data from a 3-D memory, a half-current passes along one wire in each of the two orthogonal sets, in such a direction as to switch to 0 all cores that the two wires thread. Cores that switch generate voltage pulses in the sense wires; where only the half-current flows, the cores remain unswitched. To write data, a half-current runs through each of the two wires in the opposite direction,



switching cores to 1 except where the inhibit current opposes them.

Because the larger cores take longer to switch, and because the longer wires are accompanied by more parasitic effects that tend to reduce speed, the speed of the 3-D has generally been thought to be limited. Getting four wires through 22-mil cores is difficult; nobody has seriously considered trying it on a production basis with smaller cores. But Ampex engineers sidestepped both difficulties by designing a 3-D memory with only three wires through each core, combining the sense and inhibit functions on a single winding.

The key to the design is what the designers call an antibalun transformer. This is a transformer with a 1:1 turns ratio, whose two coils are connected with opposite polarities to the two sides of the inhibit line, as shown above. These two sides, as in conventional 3-D memories, pass in parallel through adjacent rows of cores, exchanging positions at the center of the row; this arrangement minimizes the noise picked up while data is being read out. If the resistance of both sides of the winding is exactly equal, the same amount of current flows through both coils of the transformer. If for some reason the current through one side tends to increase, the transformer generates a back voltage on that side to hold back the current and an opposite voltage on the other side to increase the smaller current—thus tending to keep the two currents equal. Because the currents in the two coils tend to remain equal and in the same direction, the connection is called an antibalun.

Because the two coils have opposite polarities, the two currents see a low common-mode impedance in the antibalun and build up quickly when the transistor switch at the top of the diagram turns on. When it turns off, if the currents haven't been equal, a correcting flux has built up in the transformer, creating circulating currents in the sense-inhibit line. Because the resistance of the line plus the transformer coils is only a few ohms, the ratio L/R in the winding is high and the time constant is long—so that these circulating currents could continue for many microseconds. To increase R and reduce the time constant, two diodes at the bottom of the antibalun pass normal inhibit current with hardly any resistance but increase the resistance to circulating currents to several megohms.

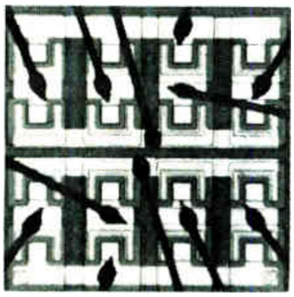
With the circulating current thus quickly decaying and the transistor switch turned off, the inhibit line is effectively floated electrically at the end of the inhibit cycle. The differential voltage generated during a sense cycle sees a very high impedance in the antibalun, providing a maximum input to the sense amplifier.

The basic module in the new memory contains 16,384 words of 40 bits each and is packaged in a unit that occupies 5¼ inches vertically in a standard rack 19 inches wide. Smaller memories are available in the same package. Any word count that is a multiple of 4,096 is available, and the word length can be anything from four to 40 bits. Up to eight of the 5¼-inch modules can be stacked, building a memory as large as 65,536 words of 80 bits each—more than 5 million bits. The price range is $12,000 to $250,000, including the drive and sense circuits.

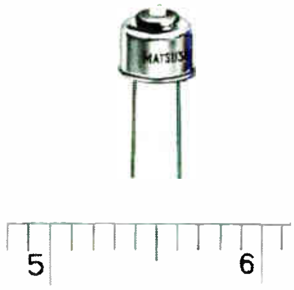
Ampex Corp., 401 Broadway, Redwood City, Calif. 94063 [389]

New Semiconductors Review

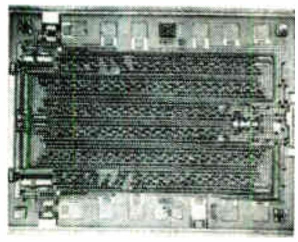
Silicon rectifier diodes series BYX are for heavy industrial use. The BYX25 controlled-avalanche units are used from 600 to 1,000 v at 20 amps average current. The 600-v units have avalanche breakdown ratings from 750 v to 1,830 v. For 1,000-v diodes, minimum avalanche breakdown rating is 1,250 v; maximum, 1,880 v. Amperex Electronic Corp., Slatersville, R.I. 02876. [436]



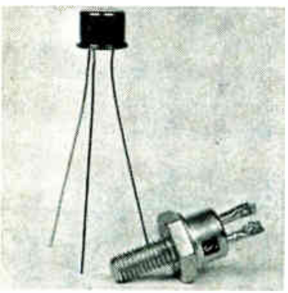
Single-chip diode array RDA-10 is for core driver applications. It shrugs off surge currents to 1,000 ma with a steady state forward current of 200 ma. The device features working inverse voltage of 30 v, and provides max. reverse recovery time of 20 nsec, even at extreme switching conditions. Rated power dissipation is 400 mw. Radiation Inc., Melbourne, Fla. 32901. [437]



Pressure-sensitive diodes employ impurities that are highly sensitive to semiconductor stress effects. Variation of resistance is 10^3. Sensitivity increases in proportion to the impurity concentration (atoms per cm^3). Operating temperature range is −30° to +60°C. Rated working voltage is 20 v d-c max. Matsushita Electric Corp. of America, 200 Park Ave., N.Y. 10017. [438]

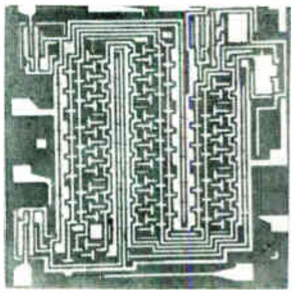


Dual 50-bit dynamic serial shift register MEM 3100 is constructed on a single monolithic chip utilizing 656 MTOS P-channel enhancement mode transistors. It utilizes 4-phase operation and requires only two external clocks. Features include low power dissipation, high noise immunity, and input data selection. General Instrument Corp., 600 W. John St., Hicksville, N.Y. 11802. [439]



Pnp silicon power transistors in TO-111 cases (SDT3301-4) and TO-5 cases (SDT3321-4) have breakdown voltages of −40, −60, −80 and −100 v respectively. Minimum gain is 10 at collector current of 5 amps, and gain range is 40-120 at collector current of 2 amps. Gain-bandwidth product is 40 Mhz min. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. 33404. [440]

Silicon, step-recovery power varactor diodes provide 17 w of output power at 2 Ghz (P_{in} = 30 w). Type MV1809C offers a minimum doubling efficiency of 52% at 20 w input power, and the MV1809C1 guarantees a 58% minimum efficiency at 25 w in. Both units are available in the standard cartridge package. Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. 85001. [441]



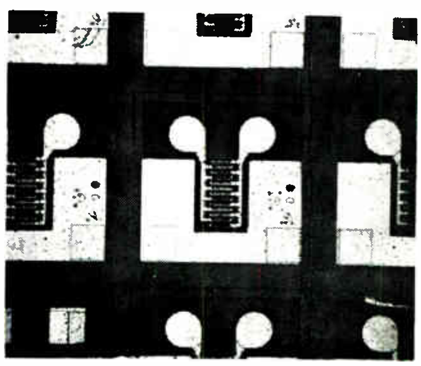
Static shift register 3300 is a serial access, 25-bit MOS IC. It operates on 1.5 mw per bit at 250 khz and has 25 flip-flops arranged serially in 16-, 8-, and 1-bit strings. There are over 200 components in the 70 by 75 mil chip. In a temperature range of −55° to +85°C, price is $27 each in lots of 1-24. Fairchild Semiconductor, 313 Fairchild Dr., Mtn. View, Calif., 94040. [442]

X-band and Ka-band Schottky barrier detector diodes D5754, D5691, and D5733 feature high burnout resistance (typically 5 to 10 w peak pulse power). Small junction areas permit tangential signal sensitivities in excess of −50 dbm at X-band and up to −45 dbm at 40 Ghz. Prices (1 to 9) range from $12 to $50. Sylvania Electric Products Inc., 730 Third Ave., N.Y. 10017 [443]

New semiconductors

FET reaches for the high ground

Higher operating frequency and reduction of static-charge problems are the principal features of a new transistor



Math counts. Change in geometry resulted in a higher operating frequency for FET.

A specialist in field effect transistors has decided to respecify the devices so an engineer knows what he is dealing with. At the same time, Siliconix Inc. has developed a [illegible] that reaches the gigahertz range.

Designed for low-noise amplifiers, oscillators, and mixers, the 2N5397 has a minimum gain of 15 decibels and a maximum noise of 3.5 db at 450 megahertz. Its competitors, one of which Siliconix second-sources, are rated at 10 db gain and 4 db noise and 13 and 4 db, respectively, both at 400 Mhz.

The FET's improved performance is partly due to changes in geometry that the designer, J.B. Compton, senior engineer, considers proprietary.

Customer's man. According to Compton, "We tried to spec the device the way the customer will use it." Minimum transconductance is 5,500 micromhos measured at a drain current of 10 milliamps. Competitors claim 4,500 micromhos at zero bias.

"Transconductance specified at zero bias will not necessarily yield a usable transconductance at that value in a practical circuit," Compton says. He cites a competing device that would probably yield a transconductance of 3,400 micromhos at an operating current of 5 milliamps, even though it's rated at 4,500. He says the 2N5397 reaches 6,500 micromhos at zero bias.

"This kind of specification tells the circuit designer more," Compton asserts. Typical circuits would be in two-way radios, military telemetry systems and low-noise microwave amplifiers.

By the chip. The cutoff frequency of the 2N5397 is not higher than other FET's, but it's limited to 900 Mhz by its package, a TO-72 can header, Compton says. The device has a maximum usable frequency of 1.5 gigahertz in chip form. Siliconix also plans to sell chips individually for higher-frequency hybrid applications.

Being a junction FET, the 2N5397 is less subject to the handling problems of metal-oxide semiconductor high-frequency FET's. MOS FET's are commonly subject to static-discharge problems around the gates, causing them to burn out.

Climbing up. With a chip peaking at 1.5 Ghz., higher ranges must be near. Compton thinks there's a good chance of 3 Ghz in 18 months. Improvements in photomasking techniques should raise cutoff frequencies even higher, without any fundamental breakthroughs, Compton believes. However, he does see a materials limitation for silicon FET's at about 10 Ghz.

Prices are $5.70 in lots of 100 or $8.50 apiece for the 2N5397 and $4 and $6 respectively for the 2N5398 industrial version.

Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. 94068 **[444]**

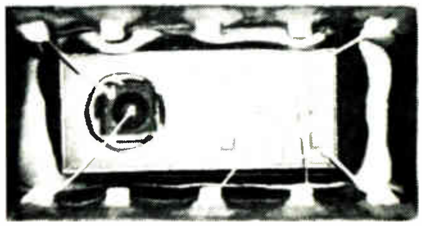
New semiconductors

Optics aid pulse amplifier

Photo diode and light sensor form input stage for IC amplifier

A new semiconductor technology using optical coupling to obtain complete electrical isolation within a standard integrated circuit package has led to the development of an optoelectronic pulse amplifier by Texas Instruments.

Designated the SNX1304, the device is being offered for engineering evaluation and consists of an IC feedback amplifier with an input from a light-sensitive diode in the silicon chip. Fixed to the surface of the chip is a gallium-arsenide pn-junction light emitter. This is placed on top of the diode.



Applications include transmission of a-c or d-c signals across computer-subsystem interfaces where circulating currents prevent interconnection of ground leads, and where rejection of common-mode noise at the end of a long data-transmission line is required. The high input-to-output isolation (±100 volts) of the optical coupling allows the device to function as a broad-band pulse transformer with response extending from d-c to 100 kilohertz.

The device has a forward input threshold current of 4 milliamps and a forward input voltage rating of 1.2 volts. Its off voltage is 5 and its on voltage is 0.2 volt. Rise and fall times are 250 and 350 nanoseconds respectively, and it comes in a standard 10-lead TO-89 flat pack.

Texas Instruments Inc., Dallas, Texas **[445]**

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(Picture is #5000-2S.)

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New Books

Solid Statements

Fundamental of Silicon Integrated Device Technology, Volume II—Bipolar and Unipolar Transistors
R.M. Burger and R.P. Donovan
Prentice-Hall Inc.
480 pp., $15

The two pillars of integrated-circuit technology, bipolar and unipolar (junction and surface) transistors, are discussed from the simple models of their d-c operation through their more complex relationships. The authors include second-order effects, such as drift currents and small parasitics.

Sections on bipolars include carrier and current theory, capacitance, parasitics, small-signal and large-signal behavior, structures, and topological design. The authors compare the IC and discrete versions and provide data on metalization, multiple structures, diodes, and complete IC design.

The discussion of junction and surface elements includes static and dynamic characteristics, noise, temperature effects, stability, and design. Among applications covered are linear and logic circuits, radiation effects, and IC construction.

The material can be grasped easily by those who haven't read Volume I of this series, which covers oxidation, diffusion, and epitaxy and is geared to processing rather than final design.

The book has two minor drawbacks: the minimal treatment of passive elements and the overabundance of tutorial presentation.

Fielder's choice

FET Applications Handbook
Jerome Eimbinder
Tab Books
288 pp., $12.95

To this compilation of articles on field effect transistors which originally appeared in the EEE magazine, Jerome Eimbinder—the managing editor of that publication—has added a number of papers presented at applications clinics and seminars sponsored by his magazine.

Through this technique, a variety of topics is covered by more than 20 experts. The reader gets a fairly thorough discussion of FET theory, substantial design information, and numerous examples of FET application. But, despite its considerable merits, this anthology does not fulfill the promise of its title nor can it be used as a single source of information on FET applications.

The anthology approach is self-defeating. With each of the contributors expressing his special point of view and using his own terminology, there is the inevitable loss of a unifying perspective and continuity. This is particularly evident when the reader comes upon different symbols for identical terms or repetition of material he has already read in a slightly different form earlier in the book.

The editor has organized his material so that basic FET characteristics and simple applications are presented first. This permits the reader to make his way through to the more complex sections without too much difficulty.

Included in this survey of field-effect technology are discussions of a-c and d-c amplifiers, attenuators, r-f amplifiers, limiters and choppers. Also covered are complementary FET's, FET biasing, oscillators, FET noise, and preamplifiers as well as switches, serial arrays, commutation, photo-FET's and electrometers.

The magnificent seven

The Art of Computer Programing
Volume I: Fundamental Algorithms
Donald E. Knuth
Addison-Wesley Publishing Co.
634 pp., $19.50

Computer programing is an art that has grown from the cameo to the heroic. Donald E. Knuth decided in 1962 to bring together most of the writings on computers. He envisioned a book of 12 chapters.

But before long he knew he would need a seven-volume work. "Fundamental Algorithms" is the first of the projected seven.

Knuth packs into the first 120 pages all the mathematical derivations of computers, allowing an engineer who knows them to skip that section. But then he presents his feeling that there are "intriguing connections" between computers and the abstract mathematics that is his forte.

To back up that idea, he discusses computers and their ties to algorithms, mathematical induction, sums and products, permutations and factorials, binomial coefficients, and harmonic and fibonacci numbers.

Knuth has created an imaginary computer he calls "MIX," and a machine language to go with it. He applies MIX programs to his discussions of permutations and programing techniques such as subroutines, co-routines, interpretive routines, and input and output.

Other subjects covered, for which Knuth has prepared examples and graded practice exercises, are allocation, lists, trees, and multilinked structures. A working understanding of calculus and advanced algebra is necessary to appreciate this work, which might best serve as a graduate-level text.

Stephen Strell

Recently published

Introduction to Calculus, Donald Greenspan, Harper & Row, 439 pp. $9.95

Treats derivatives, integrals, differential equations and other fundamentals of calculus; also develops theory, techniques, and applications relating to discrete functions, difference quotients, finite sums, and nonlinear difference equations.

Applied Mathematics for Electronics, J.H. Westlake and G.E. Noden, Prentice-Hall Inc., 608 pp., $12.25

Covers the important middle ground between basic mathematics and the sophisticated topics associated with modern electronics—such as computers, filters and amplifiers. As each new principle is introduced, its application is discussed and illustrative examples are presented.

Electrochemistry, C.W. Davies, Philosophical Library Inc., 234 pp., $20.00

Gives an up-to-date and concise account of the principles of electrochemistry. Is suitable for novices and for the industrial scientist who is looking for guidance in this field. Covers electrolytes, ionization, surfaces, cells, and kinetics.

Technical Abstracts

By wire

Field distribution of plated wire memory elements and its effect on memory characteristics
Judea Pearl
Electronic Memories Inc.
Hawthorne, Calif.

In a plated wire memory, the way the magnetic field is distributed on the surface seriously affects several important factors: adjacent bit interactions, drive currents, and sense signal amplitudes. An analysis shows that there is a characteristic length associated with the applied field and the magnetic properties of the wire that defines the shortest length in which the magnetization can be localized.

For a wire of diameter, d, and film thickness, t, and with a hard-axis susceptibility, x, the length is equal to the square root of the product of d, t, and x. In a typical plated wire, the characteristic length varies between 0.020 and 0.025 inch, which corresponds to a maximum bit density of 40 to 50 bits per inch.

With these results, universal curves also can be plotted that give the required word current for the geometries chosen.

Presented at the 1968 Intermag Conference, Washington, April 3-5.

Pcm for privacy

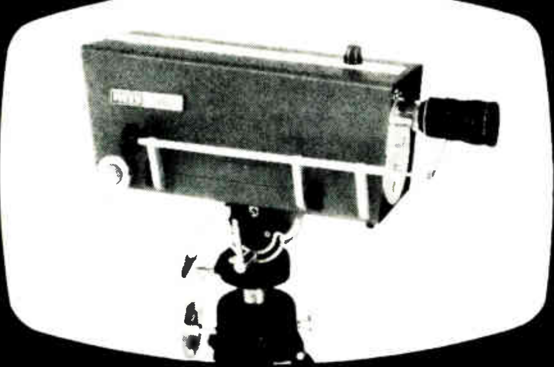
Transmission performance of telephone networks containing pcm links
D.L. Richards
Post Office Research Station, London

Military men and others worried about eavesdropping can relax a little. A new pulse-code modulation coder-decoder designed to fit inside a telephone set can be used to digitize and scramble voice signals before they get on a line, making it difficult to tap in. The new device also permits large offices to economize on wiring by carrying all internal calls on wide-band digital circuits.

One such coder-decoder, using integrated digital-logic circuits in 40 flat packages and analog thin-film circuits, takes up only four cubic inches. Its power dissipation is less than 500 mw.

Analog-to-digital conversion begins when a narrow pulse opens a sampling gate, whose pulse amplitude output then excites a damped tuned circuit. The result is a decaying wave with an initial amplitude proportional to the sampled analog voltage. A Schmitt trigger generates an output pulse for each peak until the wave's amplitude falls below a set threshold. Thus, the number of pulses for each sample is a measure of its compressed amplitude. A standard binary counter then keeps track of the number of pulses, and a shift register converts the parallel output from the counter to the pcm train.

The decoder generates a fixed-amplitude pulse with a width that's proportional to the incoming line pulses. The same sort of counting techniques used in the coder determine the pulse length. Next, the



pulse is applied to an RC network that charges twice as fast as it discharges. The network's voltage is sampled for a fixed time that equals or exceeds the pulse width, producing the expanded decoder output, which is proportional to the original coder input.

Advantages of the pcm coder-decoder include a minimum amount of analog circuitry, the acceptance of positive and negative signals without the need for inversion or rectification, and a threshold level high enough to minimize drift.

Presented at the Colloquium on Pulse-Code Modulation, London, March 4.

Telltale heat

Infrared analysis of second-breakdown modes in power transistors

A.S. Dostoomian
Raytheon Co.
Wayland, Mass.
M.F. Nowakowski
NASA
Huntsville, Ala.

Testing a transistor for second breakdown without destroying or degrading the device has long been a problem. Now a system that senses the imminence of second breakdown through thermal tests with a fast-scan infrared microscope eliminates this problem; the destructive effect of second breakdown is never reached. Thus, there is no permanent damage to the device.

The transistor is energized by a pulse that is synchronized with the microscope's scan cycle. This pulse can be delayed to allow the detector's instantaneous field of view to be phased to the infrared flash caused by second breakdown, at whatever point it might take place. As the transistor is scanned, the system's display shows a pulse, whose amplitude depends on the intensity of the hot spot, and a thermal map of the area scanned.

A complete raster scan of 150 transistors was taken at the second-breakdown current level, at half that current, and at two-thirds that current. For almost all lower current levels, the location of the initial hot spot occurred at the same point as the heat peak observed during second breakdown. At the full second breakdown current level, about 30 transistors showed hot spots; second breakdown in these transistors occurred at a lower current level than the other transistors. Transistors that showed hot spots when scanned at current levels less than the rated maximum tended to go into second breakdown at lower current levels than units that exhibited no hot spots.

When testing for second breakdown in the forward- and reverse-bias directions, about half of the transistors showed hot spots occurring at the same point. The probable reasons for hot spots differing are the presence of more than one anomaly, and the temperature increase during testing.

After infrared testing, a number of transistors were again subjected to second breakdown. In the units that failed, melted areas occurred at the points where the initial heating was observed with the infrared microscope.

Presented at IEEE International Convention, New York City, March 18-21.

New Literature

Single channel terminal. Lenkurt Electric Co., 1105 County Road, San Carlos, Calif. 94070. A flysheet describes the 46A single channel terminal that furnishes a voice channel with choice of in-band or out-of-band signaling. Circle **446** on reader service card.

Videotape recorder. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. Bulletin V158 contains features, specifications and a description of the VR-1200A high-band color and monochrome videotape recorder for broadcast and sophisticated closed circuit tv use. **[447]**

Reed relay. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, has issued a bulletin on the model 7001 Microreed relay, a single-pole double-throw unit designed to be driven by transistors. **[448]**

Miniature terminals. Robinson Nugent Inc., 802 E. Eighth St., New Albany, Ind. 47150. A six-page catalog illustrates 94 different miniature and subminiature terminal styles. **[449]**

Antenna system. Andrew Corp., 10500 W. 153rd St., Orland Park, Ill. 60462. Bulletin 266 covers a 350-450 Mhz remote controlled receiving antenna system. **[450]**

Microwave equipment. Microwave Systems Co., 6915 Lakewood Place, Denver, Colo., 80215, offers a product line catalog describing large passive repeaters, guyed and self-supporting towers, and microwave accessories. **[451]**

Shielding materials. Russell Industries Inc., 96 Station Plaza, Lynbrook, N.Y. 11563. Catalog No. 70 covers the full spectrum of shielding materials for electromagnetic and radio-frequency interference problems. **[452]**

Heterodyne mixer-oscillator. Weinschel Engineering, Gaithersburg, Md. 20760, has published an illustrated catalog sheet on the model HO-1 heterodyne mixer-oscillator. **[453]**

Elapsed time indicator. ENM Co., 5306 W. Lawrence Ave., Chicago 60630, has issued a catalog sheet describing the series T5B economy model elapsed time indicator. **[454]**

Wirewound resistors. Kelvin, 5919 Noble Ave., Van Nuys, Calif. 91401. Bulletin HR400-20-4 outlines the specifications and test procedures set up by the company to approach the maximum in reliability goals for precision wirewound resistors. **[455]**

Electronic tachometers. Airpax Electronics, P.O. Box 8488, Fort Lauderdale, Fla. 33310. Bulletin F-11 describes the Tach-Pak, an electronic tachometer that converts rpm, speed or frequency into an output current or voltage linearly proportional to the input signal usually generated by the motion of a rotating component. **[456]**

Xenon flashtubes. Torr Laboratories Inc., 2228 Cotner Ave., Los Angeles 90064. A four-page brochure describes the Torrlite series of xenon flashtubes. **[457]**

Power amplifier. Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634. Data sheet 68266 covers the unity voltage gain model 821 power amplifier, a unit that can increase power output of IC operational amplifiers as much as 40 times. **[458]**

Incremental shaft encoders. Disc Instruments Inc., 2701 S. Halladay St., Santa Ana, Calif. 92705. The use of Rotaswitch shaft encoders for automatically

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Circle 139 on reader service card

New Literature

controlling the positions of industrial work-tables is described in Bulletin 454. [459]

Chemical etching equipment. Western Technology Inc., 220 W. Central Ave., Santa Ana, Calif. 92707. An eight-page brochure describes a complete line of precision laboratory and production chemical etching products. [460]

Power supply. Analog Devices Inc., 221 Fifth St., Cambridge, Mass. 02142. A one-page data sheet describes a low-cost, p-c mounting power supply for operational amplifiers. [461]

IC telemetry receiver. Defense Electronics Inc., Rockville, Md. 20854, offers a bulletin containing engineering features, performance specifications, functional block diagram and outline data on an IC telemetry receiver for ground-based, special airborne, mobile and portable applications. [462]

Audio connectors. Switchcraft Inc., 5555 N. Elston Ave., Chicago 60630. Catalog C502a provides the engineer and designer with an up-to-the-minute guide to the latest in audio connectors. [463]

Tone transmitter and receiver. Quindar Electronics Inc., 60 Fadem Rd., Springfield, N.J. 07081. Bulletins 1007 and 1008 cover the QT/QR-50 tone transmitter and receiver. [464]

Tuning fork oscillator. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343. Model TF-120 silicon transistorized tuning fork oscillator is illustrated and described in a single-sheet bulletin. [465]

Spark gaps. ITT Electron Tube Division, Box 100, Easton, Pa. 18042, has available a brochure describing its line of two-electrode spark gaps, which protect circuit components from damage by overvoltages. [466]

Test equipment. Beckman Instruments Inc., 89 Commerce Rd., Cedar Grove, N.J. 07009. Insulation test equipment, electronic test and measuring instruments, high-voltage power supplies, and automatic component testers are comprehensively covered in 40-page Catalog 31. [467]

Wave filters. ADC Products, 6405 Cambridge St., Minneapolis 55426. A 14-page catalog contains a general approach to wave-filter design and a discussion of the problems encountered in writing wave-filter specifications. [468]

Pressure switch. Control Products Inc., East Hanover, N.J. 07936, has issued a bulletin illustrating and describing the P-6000 pressure switch. [469]

Rectangular connectors. ITT Cannon Electric, 3208 Humboldt St., Los Angeles 90031. Catalog 2D-D covers a line of double density "D" rectangular connectors. [470]

Rfi components. Filtron Co., 131-15 Fowler Ave., Flushing, N.Y. 11355. A complete line of filters and components for suppressing radio frequency interference is presented in 24-page Catalog P-68. [471]

Ferrite material. Krystinel Corp., Fox Island Road, Port Chester, N.Y. 10573, has available a specification sheet on the K-940 advanced, high permeability ferrite material that permits the miniaturization of magnetic components. [472]

Time-delay relays. Plessey Airborne Corp., 1414 Chestnut Ave., Hillside, N.J. 07205. The "UltDelay Economini" time delay relays are described in two-page illustrated bulletin PS-19. [473]

Power supplies. Raytheon Co., Sorensen Operation, Richards Ave., Norwalk, Conn. 06856, has issued short-form catalog 68A covering its d-c power supplies and a-c line regulators. [474]

Strip-chart recorders. Foxboro Co., Foxboro, Mass. 02035. Bulletin C-14 describes the ERB series of electronic strip chart recorders. [475]

Resin dispenser. Hardman Inc., 600 Cortlandt St., Belleville, N.J. 07109. A catalog sheet describes the Triplematic 700 resin dispenser for microminiature shots. [476]

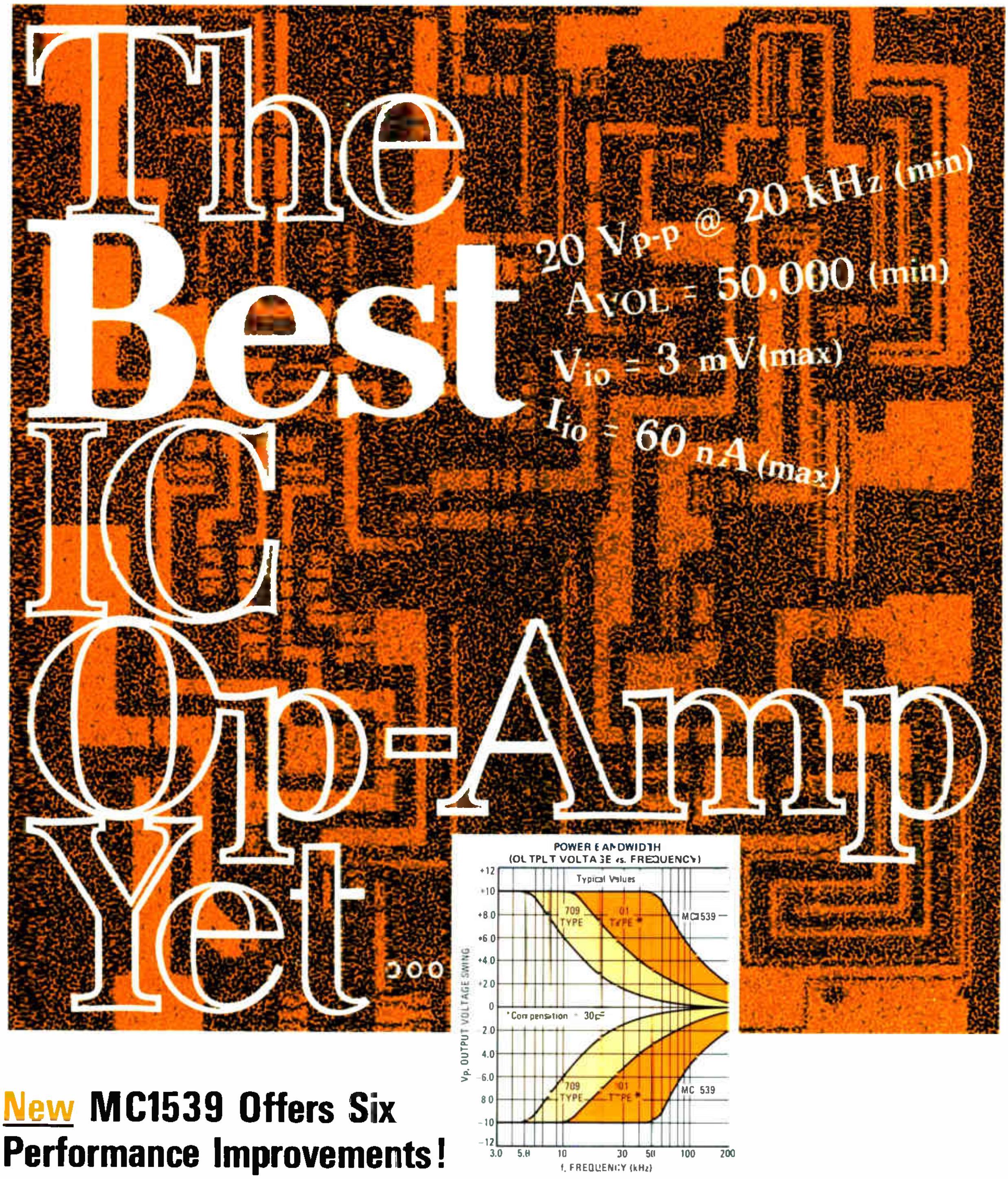
Terminal blocks. Thomas & Betts Co., 36 Butler St., Elizabeth, N.J. 07207. Eight-page, illustrated bulletin 500.2 describes a new line of terminal blocks and their accessories. [477]

Electronic components. Switchcraft Inc., 5555 N. Elston Ave., Chicago 60630. A 25-page booklet covers such major product categories as jacks, plugs, switches, connectors, indicating devices and audio accessories. [478]

Subsystems. Reeves Instrument Division Dynamics Corp. of America, Garden City, N.Y. 11530, offers a 24-page brochure detailing subsystems in such areas as telemetry, digital ranging, airborne radar, tactical radar, satellite and spacecraft tracking radars, analog computers and aerospace ground equipment. [479]

Coil bobbins. Gries Reproducer Co., 400 Beechwood Ave., New Rochelle, N.Y. 10802, has published a pocket-size booklet covering the advantages and design features of its precision molded thermoplastic coil bobbins. [480]

Tear-off and file for future reference . . .



New MC1539 Offers Six Performance Improvements!

Our engineers say the MC1539 integrated circuit operational amplifier is "the finest I/C Op Amp available today. Period." The six advantages below and the specs on the next page offer strong supporting proof:

1. Input Offset Voltage — 2.0 mV lower than comparable circuits . . . requires less input bias compensation.
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3. Output Short-Circuit Protection and Input Over-Voltage Protection — built-in to provide "accident-proof" operation and transient suppression.
4. Guaranteed minimum gain over full temperature range — twice that of previous types . . . for higher performance — with stability.
5. Power Bandwidth — typically an order of magnitude better (See Inset).
6. Slew Rate — typically 34 V/μsec at $A_V = 100$ . . . twice as high — for extremely fast comparator applications.

Best of all, the MC1539 (and, a low-temperature range version, MC1439) are 100-up priced at a low $12.00 and $7.50, respectively, in the 8-pin (TO-99) metal package. And, the pin configuration is the same as the 709 and 101.

TURN PAGE

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Newsletter from Abroad

April 29, 1968

Europe ponders place in space

West European space officials face a round of harsh decisions now that Britain has decided to call it quits on two key international programs—the Europa rocket and the proposed European television-relay satellite.

The British move puts the fate of Europa, a joint effort by the seven countries in the European Launcher Development Organization (ELDO), up to France and West Germany. **They need the rocket for their Symphonie communications satellite and most likely will find a way to keep the program going after Britain drops out in 1971.**

There's scant chance, though, that France and Germany can convince other ELDO governments to help them pick up Britain's share of the tab—a hefty 27%. So far, about $400 million has been allocated for the project. Italy was losing interest in ELDO even before Britain adopted its new stance toward prestige space projects. Nor can Symphonie's promoters expect any substantial help from Belgium and the Netherlands; both have tight space budgets.

ELDO's sister space body, the 13-nation European Space Research Organization (ESRO), has its own woes, even though Britain will boost her contribution to ESRO's work slightly over the next three years. ESRO, set up to handle scientific programs, has been switching its emphasis to communications satellites. **Britain's decision not to support a tv-relay satellite is a setback for ESRO, which seemed likely to be named project manager.**

Europe's space ministers will meet in Bonn this July and may attempt a salvage effort then. The eventual result could be a single program combining the projects that survive.

Australia uneasy over F-111 order

A row is in the offing in Australia over the two dozen F-111C fighter-bombers ordered from the U.S. Defense officials in Canberra have let out that the **cost of the 24 swingwing aircraft will likely come to $270 million, some $79 million more than the government's original estimate.** What's more, the opposition Labor Party has been raising a fuss over the decision to buy the planes every time a U.S. F-111 has been lost.

Defense Minister Allen Fairhall will air the government's stand on the F-111C order in late April or early May. Because of the spiraling costs for the initial 24 planes, **the government almost surely will drop its plan to buy an additional six F-111's fitted out with special electronic reconnaissance gear.**

Japan clearing up patent picture

Japan's electronics industry is moving fast to straighten out its patent position regarding color television and integrated circuits.

Insiders say eight **of the country's dozen color-set makers have asked the government to approve a deal that would license them to use the basic color-tv patents held by the Hazeltine Corp.** The royalties, on an if-used basis: 15 cents a set. Japanese manufacturers held off making a deal until it became apparent that the need for licenses wouldn't be eliminated by the legal fight between Hazeltine and the Zenith Corp.

The end is almost in sight, too, for Japan's IC patent problems. Five major producers have signed up for licenses from Texas Instruments. Still to be signed, though, is Nippon Electric. Since it holds the Japanese

Newsletter from Abroad

rights to Fairchild Semiconductor's planar-process patent, which is complementary to TI's basic IC patent, Nippon Electric wants a special deal with TI. The U.S. company plans to go into IC production in Japan through a joint venture with the Sony Corp. and **presumably will come to terms with Nippon Electric in the next month or two.**

Contacts point way to new transducer

Researchers at the Fuji Electric Co. have come up with an oscillating semiconductor transducer they think may turn out a winner. Its **output frequency varies with either applied voltage, light, or temperature.** The frequency ranges from several hundred hertz to several megahertz. But with an added external capacitor of about 100 microfarads, the value drops to well below 1 hertz.

Fuji calls the device a point-contact transducer. **It has two rectifying point contacts on a silicon chip having a high-resistivity n-type layer atop a low-resistivity p + layer.**

Relaxation oscillation starts when the voltage applied between the contacts rises above a threshold level—around 3 volts. But the oscillation stops when the voltage goes too high. Shining light onto the n-layer changes the values at which oscillations start and stop.

Touch phone lets caller see number

Italian semiconductor maker SGS-Fairchild has readied still another integrated-circuit device for the telephone market. This time it's a keyboard telephone set that **displays the number punched into it, something current touch phones can't do.** Earlier, the company developed a cut-out that prevents unauthorized long-distance calls.

In the latest SGS unit, the number punched into the keyboard is stored in a memory until the call is completed. Meanwhile, the number glows on a display of 16 cold-cathode tubes.

SGS expects to price its touch-phone unit between $100 and $130. This makes it a candidate for small switchboards, where it could catch wrong numbers in long-distance calls. **The prototype, built around 25 IC packages, can be adapted for electronic switching simply by changing one capacitor.**

U.S. may duck Paris Air Show

To the dismay of the aerospace industry, it appears that there'll be no U.S. Government participation in next year's Paris Air Show.

The Defense Department apparently intends to stick with its decision not to go, and other **Government agencies will probably follow suit.** This means that manufacturers will have to arrange their own exhibitions without the traditional help of the Commerce Department and without space in a U.S. pavilion. **The upshot: many small companies will be forced to skip the show.**

Bonn seeks F-104 warning system

West Germany's defense ministry has called on the Nortronics division of the Northrop Corp. to design an integrated status-reporting system for the Lockheed F-104G Starfighter, the Luftwaffe's standard fighter-bomber. The ministry says **it may install the gear in all of its more than 600 F-104G's after evaluation tests early next year.** The voice-based system would be similar to the one used in U.S. Air Force B-58 bombers for several years.

Electronics Abroad

Volume 41
Number 9

Japan

Three-shot gun

Yoke-less. With the Trinitron gun, Sony's tube needs no convergence yoke and panel. Flyback, shown resting on tube, does the job.

The Sony Corp. has decided to drop the Chromatron tube from the new 7-inch color tv set it will start shipping to the U.S. this June and use instead a tube right out of the laboratory. But Sony engineers insist that if they had followed the lead of other color-set makers and used a shadow-mask tube instead of working with the Chromatron, they would never have come up with their new baby—the Trinitron.

Despite production-line difficulties with a 19-inch Chromatron it used in a set made for the Japanese market, Sony originally planned to incorporate the tube in its 7-inch model because the Chromatron's brightness and convergence characteristics are superior to those of the conventional shadow-mask tube [Electronics, June 26, 1967, p. 208].

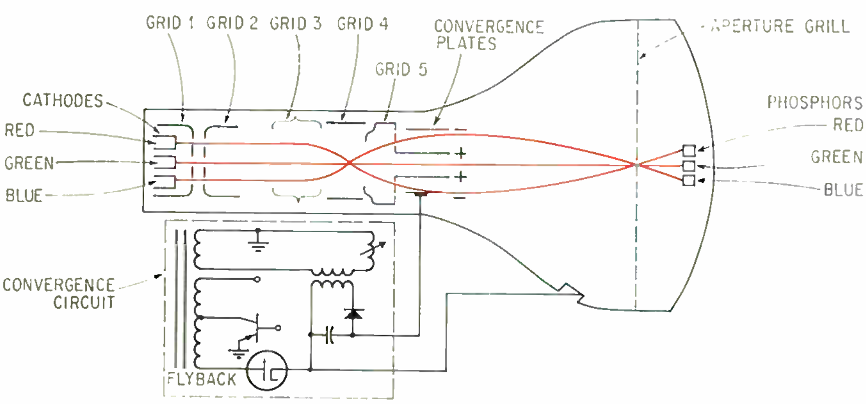
Tradeoffs. Among the production problems is the fact that the one-gun Chromatron requires hard-to-make color-switching grids with alternate wires insulated, a high-power switching input for the grids, and switching at the electronic gun's input. With this complicated arrangement, the one-gun model offered the advantage of automatic beam convergence.

To simplify the color-switching setup, Sony went to a three-gun version. But despite the inclusion of a dynamic convergence generator and yoke, plus 12 convergence adjustment controls, this Chromatron suffered from the same kind of misconvergence that plagues shadow-mask tubes.

So, combining the advantages of the first two models, Sony came up with the Chromagnetron, a one-gun tube that employs the simplified color-selection grid of the three-gun version. The problem here was that the Chromagnetron only works well in a line-sequential system and requires switching at about 3.58 megahertz. It uses two color-switching yokes—one to separate the beam so that it appears to originate at different sources, and the other to cause the beam to reconverge on the faceplate.

Trio. Instead of making one cathode do the work of three, Sony engineers decided to add two more, placing them where the other two beams in the Chromagnetron appear to come from. In this way, the Trinitron evolved.

The Trinitron gun doesn't need a convergence yoke. It has five grids and produces three separate beams from the three cathodes. The cathode assemblies are aligned behind three holes in the number one grid. Directly in front of this grid is another, also with three holes. Grids three, four, and five are tubular structures that surround the three beams. And at the muzzle of the gun is an electrostatic convergence arrangement consisting of four flat, vertical plates. The two inner and two outer plates are elec-



Color-full. The three beams are bent and shaped by five grids. Deflection plates, controlled by the flyback circuit, cause the beams to converge.

trically tied together, with the center pair being slightly positive—about 100 volts—with respect to the outer pair.

The three beams leave the gun in a single horizontal plane after the deflection plates have caused them to converge behind the center of the faceplate.

Sony points to several advantages this one-gun, three-cathode scheme offers. For one, the Trinitron uses only about a third the number of parts required by a three-gun arrangement. For another, electron density is far lower than in conventional tubes because the Trinitron grids' diameter is large and the beams are focused at the point where they cross—at the center of grid number four.

The neck of Sony's tube has a diameter of only 29 millimeters, but the company says the total beam current is 50% greater than that provided by the three guns of a shadow-mask tube, which has a 36-mm neck. Sony stresses that the 50% added current is not a maximum but rather an arbitrary limit at which the tube will maintain a better focus and brightness than the three-gun delta arrangement of the shadow-mask.

Well-shaped. The increased brightness results from the use of a slat-like structure called an aperture grill. This device, an array of vertical slots in front of vertical phosphor strips on the face of the tube, is formed into a cylindrical shape before the slats are etched. The faceplate is therefore also cylindrical. Because of this geometry, heating from wasted power merely causes the aperture grill frame to expand slightly in a vertical direction; there's no relative motion between the grill and the phosphor strips on the faceplate in a direction that would upset registration.

Sony notes that beam width is usually so narrow that only the color trio beneath one slot is excited at any given time. The shadow-mask tube's beam normally excites dots three holes away—vertically and horizontally—from its center, blurring the picture to a degree.

Big gainer

Until now, Japanese tv-set makers looking to design high-gain, integrated-circuit i-f sound amplifiers into their receivers have had to use U.S.-made IC's because domestic units produced only 50 decibels of voltage gain at 4.5 megahertz. The Nippon Electric Co. has moved to fill this gap, though, with a circuit having a gain of 72 db at that frequency.

The company has already started to distribute samples to prospective customers. In production quantities, the circuits will be available in either a silicone plastic dual in-line package or a 12-lead TO-5 can. The IC is expected to sell for between $1 and $1.10 in large quantities, compared with the $1.20 large-order price for a comparable RCA device.

Nippon Electric's circuit is basically similar in content to the one pioneered by RCA; it has three high-frequency differential-amplifier stages, a ratio discriminator, and a Darlington audio amplifier. But there is some difference in design.

Zener. The Japanese firm claims that its circuit is the first of its type to incorporate a zener diode in the regulated power supply. The zener, it says, makes for more consistent operation over a wide range of power-supply voltages—about 7 to 12 volts—and eliminates the need for the string of forward-biased diodes that perform the same function in the RCA design. The zener, which is diffused into the transistor emitter isolation area, has a voltage almost the same as the transistor emitter reverse breakdown level—about 6 volts.

The IC is designed for Japanese and American television sets, which have a carrier frequency of 4.5 Mhz, and European sets, which have a 5.5-Mhz carrier.

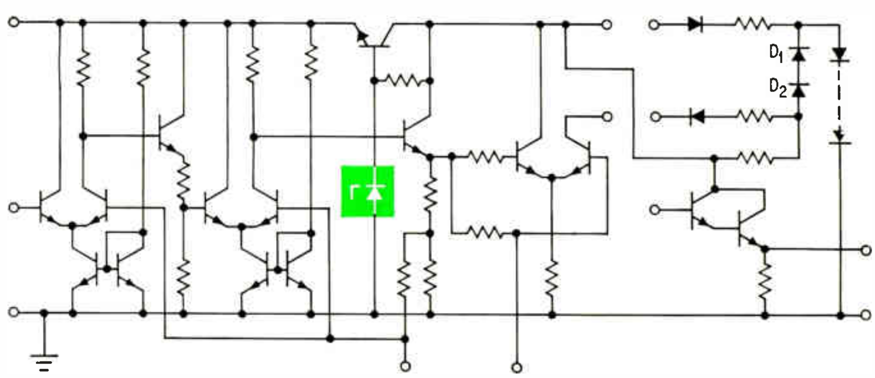
Nippon Electric says distortion of the ratio detector—mostly third harmonic—runs under 1%, against about 1.8% in the RCA device.

A current sink in the common-emitter lead of the differential-amplifier stages is used to improve limiting characteristics.

Bias push. Silicon diodes with threshold voltages of 0.6 to 0.7 volt are used in a ratio detector. At this level, a voltage input of more than 10 volts would be needed for undistorted detection. To improve the characteristics of low-signal inputs, the drop across diodes D_1 and D_2 is used to push a forward bias of about 16 microamperes through the ratio-detector diodes, which are both forward biased.

A portion of the ratio-detector bias is fed into the Darlington audio stage. No radio-frequency bypass capacitors are provided, but distributed capacitance of the resistors and the low impedance of the forward-biased diodes provides sufficient bypass action.

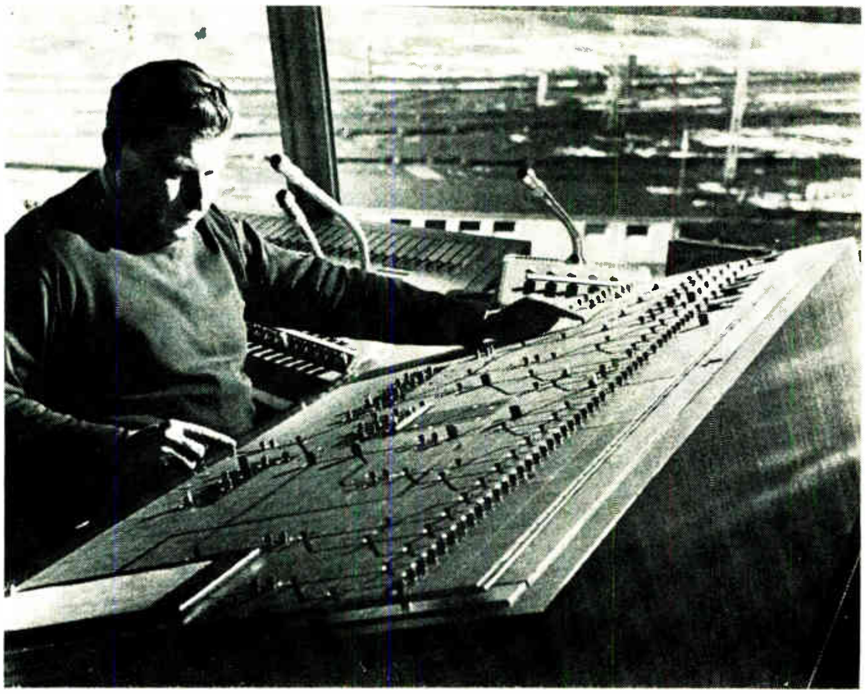
About 2 milliamperes can be tapped from the voltage regulator circuit for use in other circuits. However, one must be careful and not connect a large electrolytic capacitor to these terminals because the high inrush current could produce enough heat to evaporate the aluminum wiring in the IC.



Regulated. Zener diode, shown in color, provides regulated voltage for i-f circuit and also supplies 2 milliamps to external circuits.

West Germany

Training aid



Fast brake. Operator at control panel of automated railway yard monitors movement of freight cars while controlling switches and braking apparatus.

Germany's federal railroad system seems to be going all out for electronics when it comes to streamlining operations and traffic control. The past year saw the start of large-scale trials in computer-aided train routing, freight handling, and train breakup and makeup at several facilities including Seelze and Kassel-Bettenhausen in northern Germany [Electronics, Sept. 4, 1967, p. 206]. At Frankfurt's main freight terminal, work is in progress on re-equipping a train classification yard where track switches and car braking are electronically controlled.

The $4-million system, expected to be completed by mid-1969, will be capable of handling up to 5,000 cars a day on 51 makeup tracks. Already, 18 makeup tracks, complete with switching and braking gear, have been put under electronic control.

The yard will be controlled by Siemens AG digital equipment in the main control tower. The electronic gear, most of it already in place, costs about $350,000.

Train gang. The old facility required 15 control towers for yard operations, but the new one will have only two, and 24 people will do the work of 80.

At the terminal, information on individual freight cars—final destination, identification number, and other data—is radioed by a dispatcher to a nearby freight office. Each car is assigned a number that corresponds to the makeup and destination track into which it must be switched. The information is then coded and sent by teletypewriter to the main control tower.

At the tower, another teletypewriter prints out the incoming data and simultaneously produces a tape, which is put into a tape reader. The reader output programs the electronic control equipment.

The first step in making up new trains at the Frankfurt facility is determining a car's weight and speed as it comes from a ramp toward the automatic braking facility.

Car weight is determined by a bridge circuit arrangement in which a piece of track forms one branch of the circuit. As the car wheels move over that part of the track the branch resistance changes, unbalancing the bridge. The circuit output is then a measure of the car's weight. The amplified output is processed and evaluated in the control equipment, which then determines how hard the brakes are applied.

Car speed is measured by a radar set installed between the rails just ahead of the braking apparatus. Radar pulses reflected from the car's undercarriage are sent to the control equipment for processing and evaluation. The output acts to release the brakes when the car has been slowed to its proper roll-out speed.

On their way to the makeup tracks, cars pass over as many as five track switches. Equipment in the tower controls the position of the track switches in accordance with the program derived from the punched tape.

Magnetic rail contacts are used to count the number of car axles that pass over each track switch. If part of a car is still over the switch, the electronic control equipment is prevented from putting out a track-switching signal.

When the Frankfurt and Seelze facilities are connected, perhaps next year, the computer in the north will be linked by teletypewriter to one at Frankfurt.

Fair weather

The mood of this year's Hanover Industrial Fair, which opened April 27, leaves no doubt that West Germany's electronics industry is riding high once again. It contrasts sharply with the gloom that surrounded the 1967 fair, held at a time when the country's industry was going through one of its worst slumps in postwar history. The industry's sales last year fell an estimated 3% to 4% from the 1966 level.

"This year, though, it looks as if we'll see production expand at a rate of 7% or more," says an executive of a leading German components manufacturer. Pump-priming efforts by the Kiesinger government are paying off, with gains being registered across the board.

Last year, the government directed about half of the $625 million it added to the budget to the post office and the federal railroad system, the country's two biggest users of telecommunications gear.

Another boost to the electronics industry is promised by Bonn's efforts to shift its military hardware purchases away from foreign suppliers, a policy expressed recently by West Germany's defense minister, Gerhard Schroeder.

Renaissance. But by far the biggest gains this year reflect a revival in the consumer electronics market. "Confidence again prevails in the entertainment electronics industry," says Guenther Huecking, head of the radio and television section of the electrotechnical industry's trade association. Huecking predicts that 1.9 million black-and-white sets will be sold this year, against 1.56 million in 1967.

However, sharp production cutbacks during the 1967 slump have resulted in low inventories, and some producers are afraid they won't be able to meet the renewed demand for monochrome receivers.

Even with this demand for black-and-white sets, sales of color sets are expected to continue climbing. Huecking predicts that from 250,000 to 300,000 color receivers will be produced this year for both domestic and foreign markets. A big boost will come later this year when each of the country's two major networks expands color programming from the present four to five hours a week to between eight and 10. At the end of 1967 there were about 100,000 color sets in West German households.

IC gains. Although sales of integrated circuits to makers of consumer products are off to a healthy start, they account for less than 20% of the total West German IC market. However, marketing specialists at Hanover are forecasting a rise in over-all IC sales to about $20 million a year by 1975 from the present $1.5 million.

By far the biggest user of IC's in consumer products is Grundig Werke GmbH, whose share of West Germany's black-and-white tv market is around 20%—the largest single slice. Grundig says it uses more than 1,000 IC's a day.

The circuit it's talking about is the TAA 350 produced by Valvo GmbH, a subsidiary of Philips Gloeilampenfabrieken of the Netherlands. It's made up of four differential amplifiers and incorporates 21 transistors and 24 resistors on a 18-millimeter-square chip housed in a TO-74 can. The circuit, used in the sound i-f stage of the tv receivers, has an 80-decibel amplification and operates at 12 Mhz.

Great Britain

Down the tubes

Producers of precision metal tubing usually have to rely on the subjective judgment of a young lady with a microscope to determine the quality of steel tubing samples. She's the one who compares with graded charts the number, size, and coloring of microscopic nonmetallic particles, known as inclusions, and classifies the sample accordingly.

Now, however, researchers at Tube Investments Ltd., Birmingham, one of Europe's leading producers of precision tubing, have developed an instrument that automatically reads a polished metal surface.

Their machine, called an inclusion counter, classifies the nonmetallic particles and gives a digital readout of the number of each and the part of the total taken up by each type of inclusion. The operator need only set up the instrument to distinguish among sulphides, oxides, and holes in the surface of a given batch of samples.

Illuminated samples. Four prototypes of the counter have been built, and 12 preproduction units are being made under license by Hilger and Watts Ltd. of London.

A sample of polished metal tubing is passed over a scanning pinhole. The sample is illuminated through the pinhole at a constant level, producing an illuminated area one micron in diameter; smaller inclusions don't affect quality. The light reflected by the metal is focused onto a photomultiplier.

Bright pure metal returns nearly all the light and stimulates a strong signal from the photomultiplier; the grayish sulphides return less light and stimulate a weaker signal; and oxides, darker still, stimulate an even smaller response. The signals are turned into pulses inversely proportional to the amplitudes by adjustable discriminators, which then divide up the amplitude range into a bright metal part, a sulphide part, and an oxide part, with the oxide producing the widest pulse and the bright metal the narrowest.

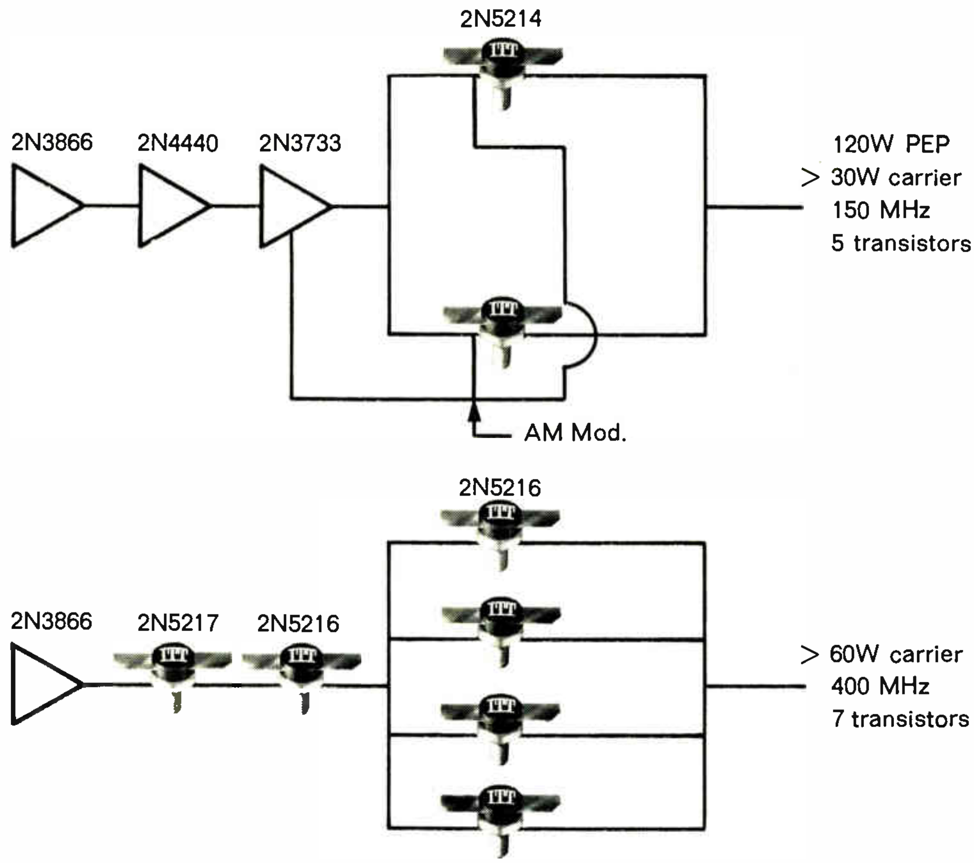
The three signal-level discriminators are conventional Schmitt trigger circuits fed via emitter-follower buffer stages from the sliders of potentiometers, which are used to set the minimum response levels. Logic gating is used to separate the discriminator outputs and in this way distinguish among metal, sulphides, and oxides. The logic gates then route the discriminator output to the appropriate counting mechanisms.

Slits vs. holes. The inclusion counter provides the operator with four simultaneous digital readouts, incrementing continuously during the duration of the scan: the total number of oxide inclusions, the proportion of oxide, the total number of sulphide inclusions, and the proportion of sulphide.

The fraction measurements are obtained by counting the pulses from a 45-kilohertz pulse generator during the duration of the discriminator outputs. Average inclusion size must be worked out manually.

To overcome this, the research laboratories at Tube Investments are now working toward substituting narrow slits for the pinholes. In this case, as the slit passes sideways across the inclusions, the photomultiplier's output is in proportion to the length of the inclusion relative to the length of the slit. By using a series of slits of different lengths, it will be possible to classify the inclusions by size.

Circle 149 on reader service card→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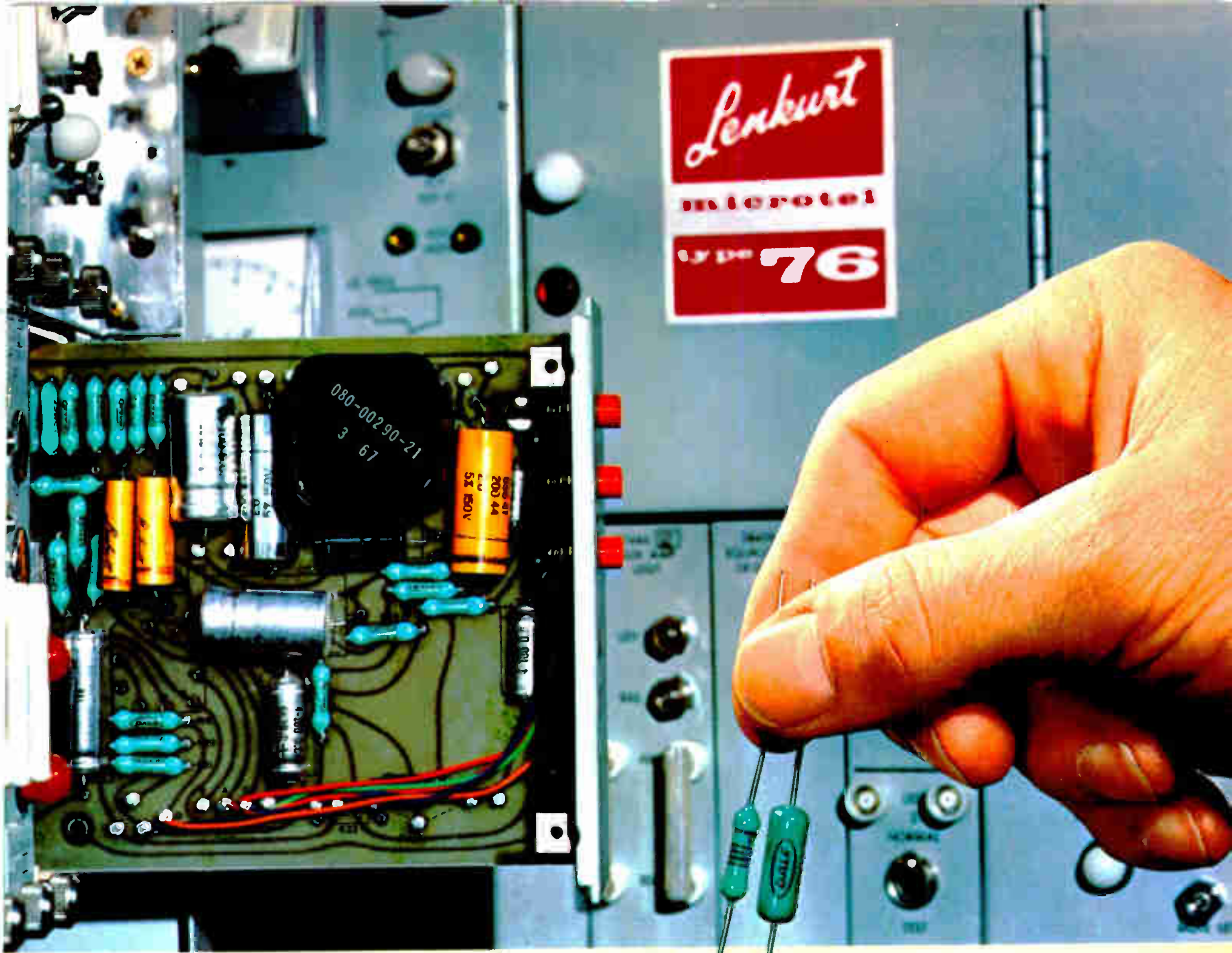

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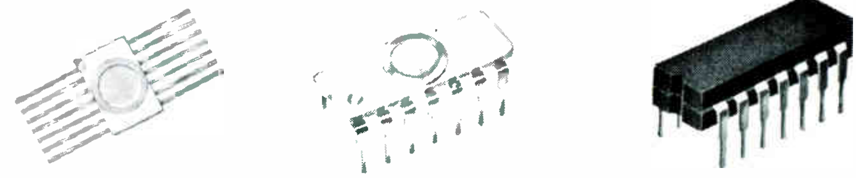

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