Electronics

Computer-aided design with symbols: page 92
Reducing distortion in FET amplifiers: page 99
Japanese technology in communications: page 133

December 12, 1966
75 cents
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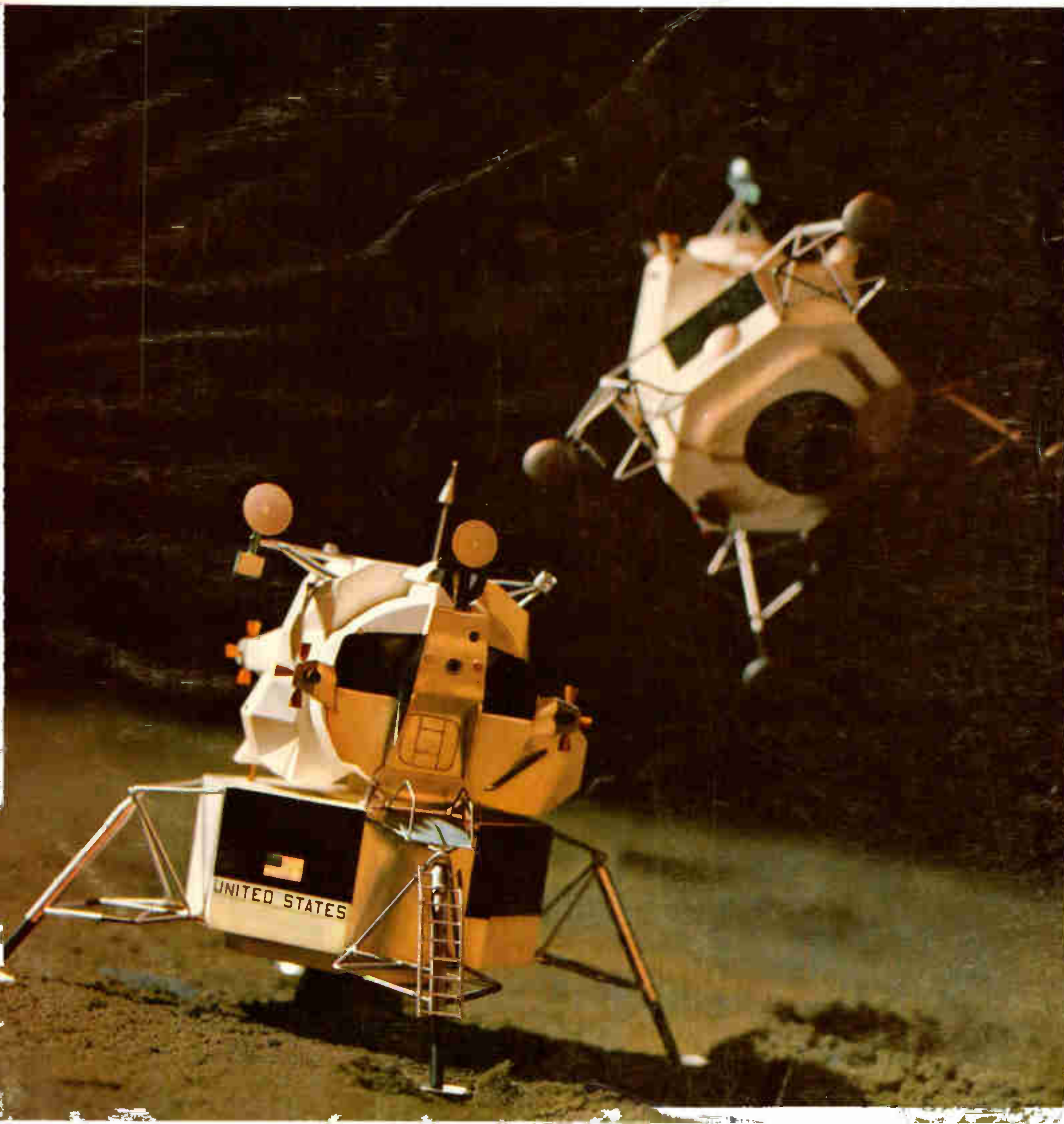
Below: Two views of Lunar Module in simulated moon landing, page 111



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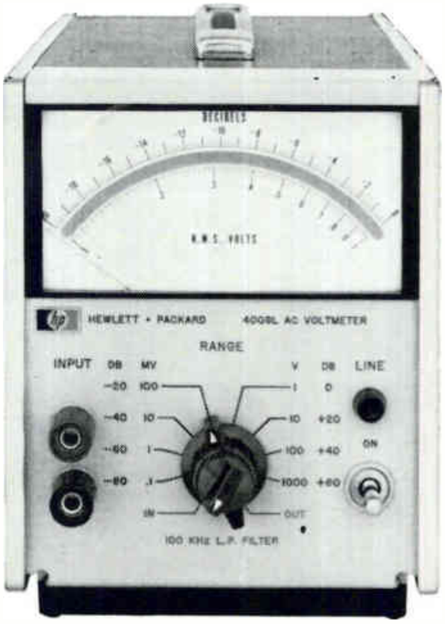

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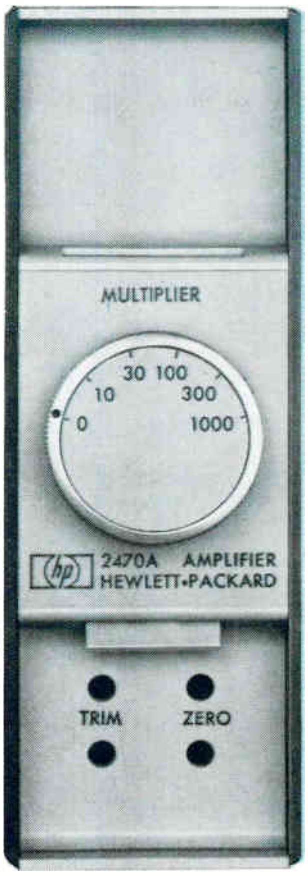

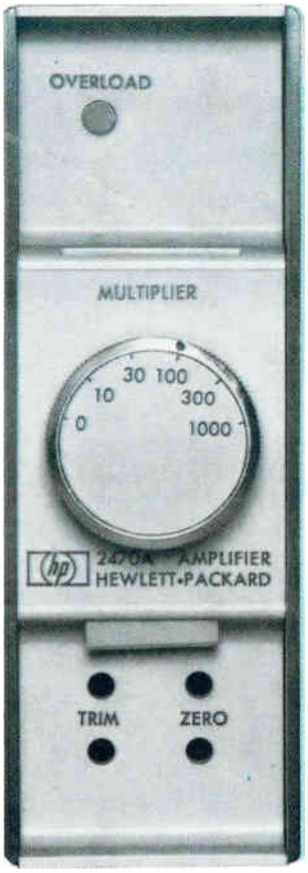

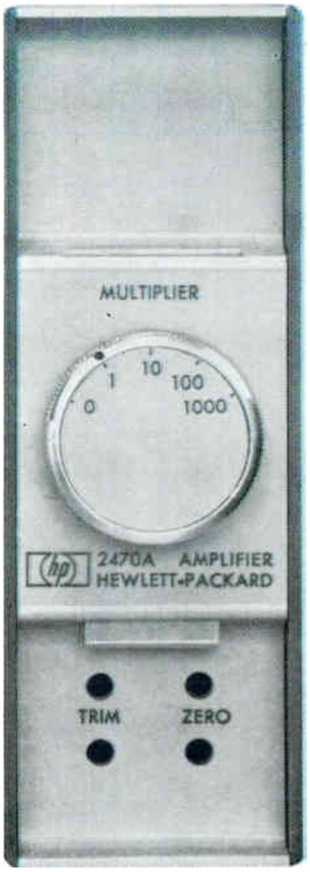

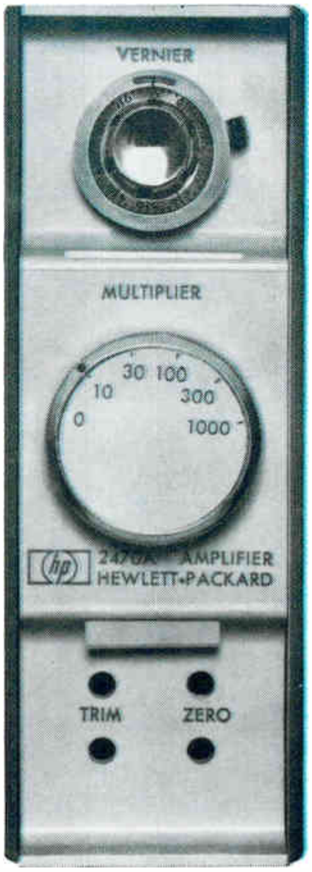

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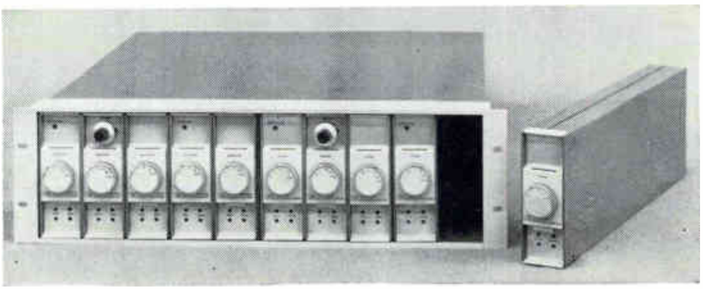

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Electronics

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Readers Comment

Questioning the laser gyro . . .

To the Editor:

The story "Laser gyro comes in quartz" [Sept. 19, p. 183] mentioned possible applications of strapped-down ring lasers for aircraft and missiles to sense ω. As in other approaches I have read about, the beat frequency f_b is explained by the change of wavelength λ due to Doppler effect in terms of $\lambda'=\lambda\ (1\pm v/c)$.

While this is correct for missiles, it certainly does not apply for aircraft where the observer rotates with the device and no Doppler effect will be noticed. Instead, while λ remains unchanged, the speed of light becomes $c'=c\pm\omega$ resulting in the same f_b as obtained in missiles. Both relations are complementary and should be used side by side when explaining f_b.

T. F. Heiting
Advanced Electronics
Seattle, Wash.

. . . In answer

To the Editor:

It is not entirely correct to say that the article explains the change in wavelength as being due to a Doppler effect. The article states only that as the gyro is rotated, the effective paths for the oppositely directed beams become different and as a result the frequencies differ.

These results are consistent with the general theory of relativity since the operation of the gyro takes place on a rotating frame, which is not an inertial frame. The theory predicts that light, whose velocity by definition is always equal to c, will take a longer time to traverse a closed contour on a rotating frame when traveling in the direction of rotation, than when traveling opposite to the direction of rotation. This lack of time synchronization results in an effective optical path difference for the two beams. A condition for laser oscillation is that an integral number of wavelengths, or the frequencies, differ for the two directions and this frequency difference is measured by an observer located on the

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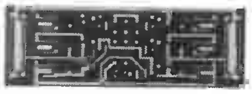

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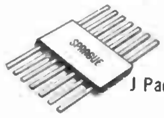

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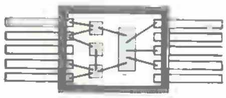

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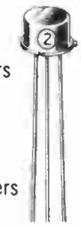

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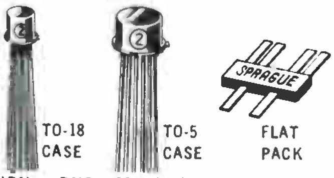

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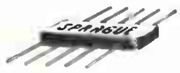

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rotating frame with the gyro.

Since the results are a first order effect, classical theory may be used to give the correct answer, to first order. In using classical theory one considers the speed of light to be different for both directions and the accepted result is obtained. However, it should be emphasized that this change in the speed of light is only an apparent change. What physically changes is the time for the light (whose speed is an invarient) to traverse a closed path on the rotating frame.

No matter which technique is used, applications in missiles and aircraft are identical, since the observer in both cases is on the rotating frame.

Possibly Heiting objects to the terminology, "Doppler effect" for the laser gyro, since there is no Doppler effect when a source and observer are on the same inertial frame. However this again illustrates the distinction between a rotating frame and an inertial frame. On a rotating frame the laser gyro effect can be considered a Doppler effect. The laser will oscillate with a corresponding change in wavelength due to the change in time interval for the light to traverse a closed path on the rotating frame.

Frederick Aronowitz
Principal Research Scientist
Honeywell, Inc.
Minneapolis, Minn.

Approval for the milliday . . .

To the Editor:

The milliday sounds great, and has fewer drawbacks than you indicate [Nov. 14, pp. 43-44]. The time-zone problem can be resolved by redividing the earth into 20 fifty-milliday or 25 forty-milliday time zones—take your pick. At the same time let's redivide the earth into 400 degrees (decents?). This will make one decent of latitude equal very nearly to 100 kilometers, and we can do away with the now very useful but then unnecessary nautical mile, 60 to a degree of latitude.

Many people would be satisfied to reset their clocks to 000.000 at New Year instead of to 001.000. This would make New Year's Day zero—an automatic holiday since numerically it wouldn't exist.

Whatever we do let's keep the second for scientific purposes. Imagine the argument on what to call the cycle per milliday!

David B. Hoisington
Professor, Electrical Engineering
U.S. Naval Postgraduate School
Monterey, Calif.

. . . ever since 1582

To the Editor:

The "Timely program" for measuring intervals in millidays worked out by Frank Cilino and his fellow engineers at Western Electric [Nov. 14, p. 43] has been in use by astronomers since 1582.

The current Julian Period began Jan. 1, 4713 B.C., and this year's Christmas, for example, is simply Julian Day 2,439,485. By the use of such a "counting" calendar no reference need be made to months or years, and a time specified is unambiguous to every astronomer, regardless of the factors of nationality or religion which often complicate calendar systems.

C.D. Geilker
Observatory assistant
Warner and Swasey Observatory
East Cleveland, Ohio.

People

The Semiconductor division of the International Telephone and Telegraph Corp. is aiming to reach the third spot in industry rankings by 1971. ITT, which now ranks itself seventh, will rely heavily on automation and has already committed $20 million to the task—$5.3 million earmarked for integrated circuit production alone.

In addition, ITT has hired two key men who want to automate the entire production process — including the mask-making. **Jack McVickers,** 34, who worked for the General Motors Corp. in the highly automated auto industry, takes over as manager of ITT's Semiconductor plant in West Palm Beach, Fla. McVickers, who is a member of the Tau Beta Pi society, gained valuable IC experience during his six years with the Molecular Electronics division of the Westinghouse Electric Corp. **James Nall,** 40, who designed a mask-making facility for the Fairchild Camera & Instrument Corp., becomes a special consultant to ITT.

Jack McVickers

James Nall

Under a licensing know-how agreement, the division got its integrated circuit program off the ground by copying Fairchild's diode transistor logic (DTL) line. ITT has been producing the DTL line for the past nine months and expects to have copies of Fairchild's transistor-transistor logic (TTL) devices on the market by February.

ITT makes its own masks from drawings supplied by Fairchild. Ultimately, ITT will be making more critical TTL circuits and its own proprietary designs as well. This is where Nall, who has a master's degree in both chemistry and engineering, comes in.

Nall is designing the equipment for the intricate mask-making process and attempting to advance the

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People

state of the art. He has the credentials; Nall founded and was the president of the Molectro Corp., known for its high-precision masks.

Nall, who spent nine years with the National Bureau of Standards doing photolithographic work, says present manufacturing processes usually are based on mechanization of laboratory methods—not the best approach to high-quantity production in Nall's view.

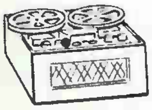
The next step is automation, which Nall defines as an open-loop system with no feedback. He wants to attain a new dimension in manufacturing—cybernation or advanced automation—a closed-loop system with real-time feedback to enhance yields and cut costs.

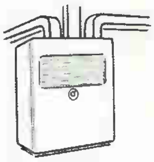
Common carrier. McVickers says that ITT is incorporating what he calls the common carrier system (a wafer moves through the entire process while remaining in the same holder) in the diffusion and photochemical processes. "At this time," he says, "I don't believe it would be economically justified to automate the entire wafer process." For example, he says a need to handle larger wafers could obsolete expensive equipment.

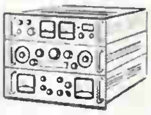
In assembly techniques, McVickers says ITT employs the most advanced die-mounting and wire-bonding machines in the industry. At present ITT produces TO-5 packages as well as ceramic dual inlines and flatpacks.

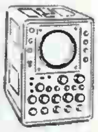
He notes that assembly techniques could be carried further but this depends on the package to be produced and its market potential. This, according to McVickers, hangs the semiconductor manufacturer squarely on the horns of a dilemma: if he commits an assembly and packaging process to advanced automation, he may not have the flexibility to make changes as new technologies, such as large-scale arrays, come in. McVickers points out that the arrival of LSI will drastically affect both packaging and the wafer assembly process.

Looking to the future, ITT is working on a new low-cost package that could be either epoxy or ceramic. Either, McVickers says, could use conventional or flip-chip technology.









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The G-V Air Flow Sensing Switch uses a new design concept and technique in monitoring the presence of air flow. The device utilizes a thermal principle which eliminates all moving parts, allows operation in any plane and eliminates maintenance and sensitive adjustments. It features a built-in time lag to disregard brief transient interruptions. It operates an alarm or automatic shut-down if the air flow drops below a safe level in electronic equipment, cooling packages, air conditioners, computers and wherever an air-flow cooling system is used. Military versions and mountings for industrial equipment are available.

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G-V

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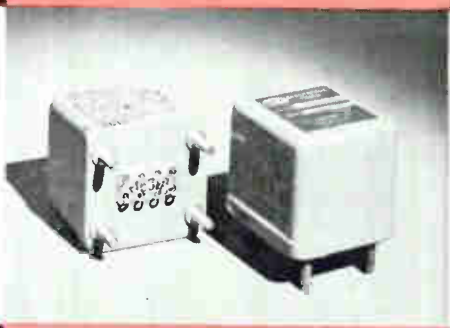
SOLID STATE TIME DELAY



Series 900-064 has been accepted as a standard for many military and aerospace applications where high quality, reliability and cost are requirements. **Features:** hermetically sealed; fixed or adjustable time delays 0.1 to 60 sec.; solid state or relay output; vibration to 2000 Hz; shock, 50g.

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G-V assistance is always available to help you design and produce a better product. G-V Regional Field Engineers in your area will assist you and your design group in new applications and proper selection of your controls. G-V Product Engineers will help you with special applications. When you require experience, products and services in electro-mechanical and solid-state controls . . . call your man from G-V.

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Meetings

Electrical and Electronic Measurement and Test Instrument Conference, IEEE; Talisman Motor Inn, Ottawa, Canada, **Jan. 9-11.**

Symposium on Reliability, American Society for Quality Control, IEEE; Sheraton-Park Hotel, Washington, **Jan. 10-12.**

Symposium on Computers and Communications, IEEE; Miramar Hotel, Santa Monica, Calif., **Jan. 19.**

American Society for Quality Control Meeting, American Society for Quality Control; California State Polytechnic College, Kellogg Campus, Pomona, Calif., **Jan. 21.**

Midwest Welding Conference, Illinois Institute of Technology Research Institute; Illinois Institute of Technology, Chicago, **Jan. 24-25.**

Ultrasonic Manufacturers Association Technical Symposium and Meeting, Ultrasonic Manufacturers Association; New York, **Jan. 25.**

Power Meeting, IEEE; Statler Hilton Hotel, New York, **Jan. 29-Feb. 3.**

Symposium on Nondestructive Testing of Welds, Illinois Institute of Technology Research Institute; Illinois Institute of Technology, Chicago, **Jan. 30-Feb. 2.**

American Society for Testing and Materials Meeting, American Society for Testing and Materials; Statler Hilton Hotel, Detroit, Mich., **Feb. 5-10.**

Winter Convention on Aerospace & Electronic Systems, IEEE; International Hotel, Los Angeles, **Feb. 7-9.***

Electronic Packaging Conference, Society of Automated Engineers; Roosevelt Hotel, New York, **Feb. 14-16.**

International Solid State Circuits Conference, IEEE; University of Pennsylvania, Sheraton Hotel, Philadelphia, **Feb. 15-17.**

Airborne Photo-Optical Instrumentation Seminar, Society of Photo-Optical Instrumentation Engineers; Ramada Inn, Cocoa Beach, Fla., **Feb. 20-21.**

National Air Meeting on Collision Avoidance, Institute of Navigation; Dayton, Ohio, **Feb. 23-24.**

Particle Accelerator Conference—Accelerator Engineering and Technology, IEEE; Shoreham Hotel, Washington, **March 1-3.**

International Symposium on Residual Gases in Electron Tubes and Sorption-/Desorption Phenomena in High Vacuum, Italian Society of Physics; Rome, **March 14-17.**

International Convention, IEEE; New York Hilton Hotel & Coliseum, **March 20-24.**

Symposium on Modern Optics, Polytechnic Institute of Brooklyn; Waldorf-Astoria Starlight Roof, New York, **March 22-24.**

Photovoltaic Specialists Conference, IEEE; Sheraton Cape Colony Inn, Cocoa Beach, Fla., **March 28-30.**

Technical Meeting and Equipment Exposition, Institute of Environmental Sciences; Washington, **April 10-12.**

International Conference on Electronics and Space, Electronic Industries Association of France; Paris, **April 10-15.**

Region III Meeting, IEEE, Heidelberg Hotel, Jackson, Miss., **April 17-19.**

American Society for Testing and Materials Symposium on Adhesion (Cold Welding) of Materials in Space Environments, American Society for Testing and Materials; Royal York Hotel, Toronto, Canada, **May 1-2.**

Call for papers

Symposium on Electromagnetic Compatibility, IEEE; Washington, July 18-20. **Jan 1** is deadline for submission of abstracts to Frank Mitchell Jr., Technical Program chairman, Jansky and Bailey Engineering Department, Atlantic Research Corp., Alexandria, Va. 22314.

International Symposium on Modern Optics, Polytechnic Institute of Brooklyn; Brooklyn, N.Y., March 22-24. **Jan. 15** is deadline for submission of abstracts to Symposium Committee, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, N.Y. 11201.

Intersociety Energy Conversion Engineering Conference, IEEE; Miami Beach, Fla., Aug. 13-17. **Jan. 15** is deadline for submission of abstracts to Manfred Altman, director, Institute for Direct Energy Conversion, University of Pennsylvania, Philadelphia, Pa.

* Meeting preview on page 16

THE Connector Thing

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

MICRODOT WELCOMES AMPHENOL

!!!

For over two years now, Microdot has had the subminiature, high density multi-pin connector market to itself. The sensational Microdot MARC 53 has been used on all the Gemini "Walks in Space" plus a multitude of military and NASA programs. Now, however, we've got competition...the brand new Amphenol Astro 348. Good to have you aboard.

IN HONOR OF THIS GREAT EVENT, MICRODOT IS HOLDING THREE

(count 'em, three)

CONTESTS

To be able to enter these contests, you've got to know a little something about the Microdot MARC 53. It's one of the real stars in the Microdot connector line...a high density (anywhere from 7 to 91 contacts in four shell sizes), subminiature, high-performance connector. The MARC 53 can save as much as 61% in weight and 54% in panel space. *Posilock*, a push-pull lock coupling, mates easily with high density inserts with no danger of damage. The dual locking action eliminates accidental disconnect, *Posiseal*, a multiple, environmental sealing system, *guarantees* an interfacial seal.

MARC 53 is approved to MIL C-38300A (USAF).

...AND ABOUT AMPHENOL.

We wish we could also tell you all about the high density (two insert arrangements of 55 and 85 contacts in two shell sizes), ™ subminiature, high performance, bayonet lock, bonded insulator Astro 348's but we're afraid that the Microdot officers, directors, stockholders, sales engineers and maintenance crew would hang us up by the thumbs. To find out more, write Amphenol.

CONTEST #1

Open only to employees of Amphenol, their families, friends, reps, distributors and advertising agencies.

WIN A REVELL SCALE MODEL KIT OF THE GEMINI SPACE CAPSULE

In twenty-five words or more, tell us why the Astro 348 is the best subminiature multipin on the market. Neatness does not count. TEN WINNERS...the prize is calculated to tantalize you because the Microdot MARC 53 is used on the Gemini program. So there.

CONTEST #2

Open only to employees, representatives and distributors of Microdot, their families, friends and advertising agencies.

WIN A REVELL SCALE MODEL KIT OF THE U.S.S. MIDWAY. In twenty-five words or more, tell us why the MARC 53 is the best subminiature multipin on the market. Neatness counts. *Ten Winners.*

CONTEST #3

Open to everybody except employees of Amphenol, Microdot, their families, friends and advertising agencies.

WIN A MODEL! SHE'S YOURS...

in perfect ⅛ scale, 8 x 10 glossy, perfect for your office wall, workshop or pool hall...inscribed "With Love and You Know What to__________ (your name here) from Marcia". All you have to do is write, in twenty-five words or more a description of your application for the MARC 53. You notice how fast we forget the competition when we get down to business. Remember...everybody who enters Contest #3 wins!

MICRODOT INC.

Microdot, Inc., 220 Pasadena Ave., So. Pasadena, Calif. 91030

- ☐ I want to enter Contest #1. My 25 words or more are attached. I am an employee of Amphenol.
- ☐ I want to enter Contest #2. Anybody who uses company postage for this one, gets docked.
- ☐ I want to enter Contest #3. My 25 words or more are attached. How does one go about getting Marcia in a slightly larger scale, say 1/1?
- ☐ I don't want to enter any contest. Just send specs on the MARC 53.

Name____________________

Title____________________

Company____________________

Address____________________

City____________________

State______________ Zip________

MARC 53, Posilock and Posiseal are trademarks of Microdot Inc. Astro 348 is not.

These contests are not valid in any locale where the local gendarmes take umbrage.

Meeting preview

Broader horizons

Electrical and electronics engineers must master new subjects—metallurgy, advanced chemistry and biology—to perform today's engineering tasks and those of the future. This need to broaden horizons will be the theme of the Winter Convention on Aerospace and Electronic Systems sponsored by the Institute of Electrical and Electronics Engineers. The meeting will be held in Los Angeles, Feb. 7 to 9.

Cybernetics, bionics and the man-machine interface will be discussed at the opening session which will be devoted to the brain and its analogy to electronic systems.

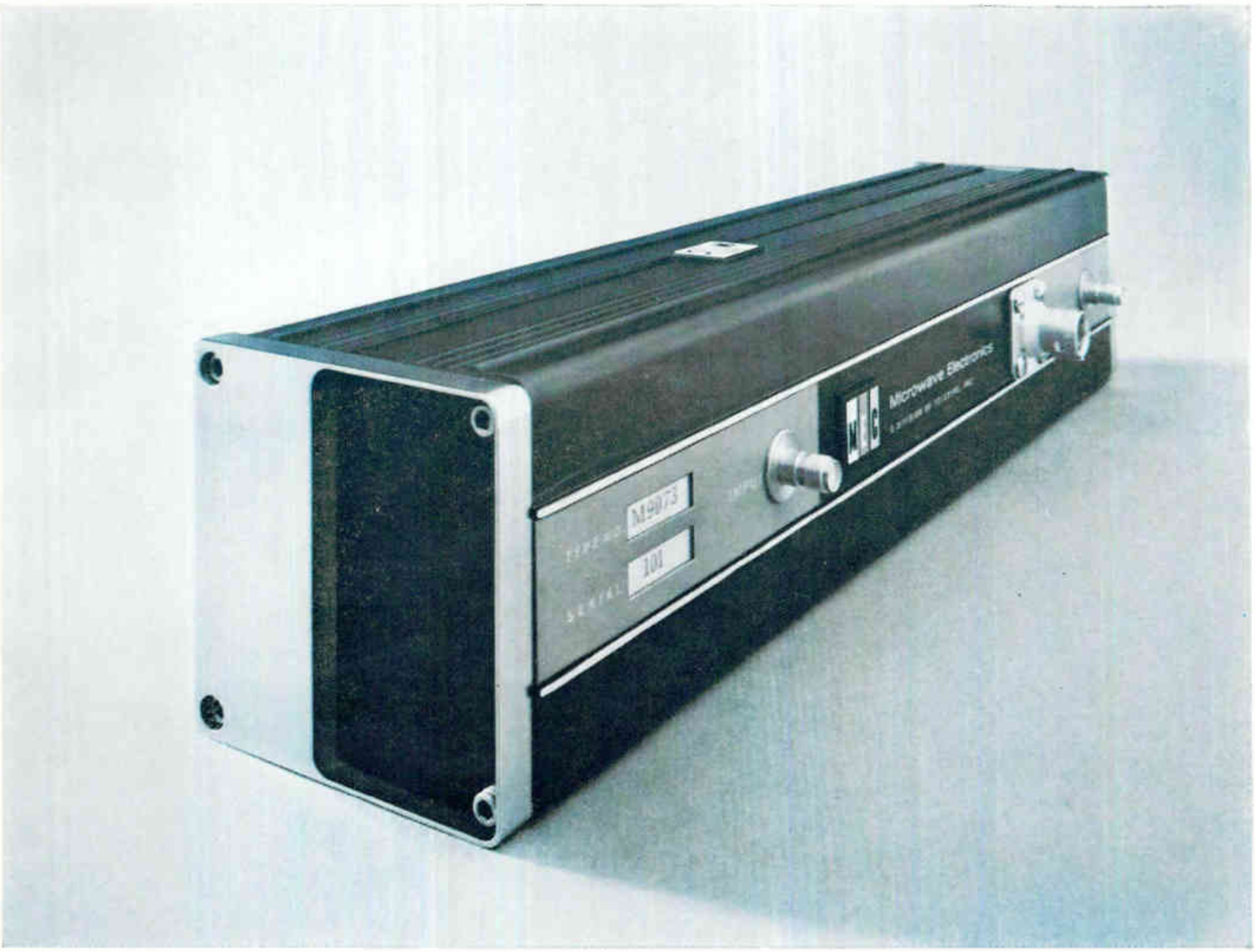
Participants will include John Eccles, co-holder of the 1963 Nobel prize in physiology; Dean Wooldridge, research associate at California Institute of Technology; George M. Austin, head of the neurosurgery division at the University of Oregon and Richard Bellman, professor of mathematics at the University of Southern California School of Medicine.

Parallels. To demonstrate the links between electronics and biology, George E. Forsen, a research engineer in the Applied Physics Laboratories of Stanford Research Institute, will describe the artificial "eye" he is building and the data processing equipment to extract visual information. His work is based on the study of the visual patterns of a cat—an investigation which might have application in unmanned reconnaissance systems.

John L. Stewart of Santa Rita Technology, Inc., will report on his work on the sound receptor of the inner ear in developing an electronic-mechanical parallel for use in sound identification and ultimately, voice recognition in automatic systems.

Other sessions will deal with interplanetary data transmission, meteorology, computer technology, information display systems, advanced communication techniques, mass transportation and information storage and retrieval. The Air Force will sponsor classified sessions on tactical communications, reconnaissance techniques.

It's later than you think!



Here's the second generation TWT amplifier.

Smaller and *lighter* than any other integrated TWT amplifier on the market! That's the difference – the BIG difference–between MEC's new low noise TWT amplifier and all first generation versions.

Let's be specific:

- ☐ MEC's rugged package weighs *less* than 4 pounds.
- ☐ It's only 11$^3/_8$ inches long and is 2$^3/_8$ inches square.
- ☐ It operates on *either* ac or dc.
- ☐ And, it meets MIL-E-5400 Class II requirements.

That's what makes MEC's TWT amplifier ideal for airborne and other applications where space and weight are at a premium.

The package combines MEC's proven miniature low noise TWT with an advanced power supply design. For precise, efficient, and stable performance, the all-silicon, solid-state supply features integrated circuitry and micrologic networks.

The unique primary input circuit allows you to operate from either 115 volt, 48 to 420 cycles ac, or 150 volt dc at efficiencies greater than 70%. That'll really simplify your flight line or service area testing!

Compare the specifications of integrated TWT amplifiers – then let's hear from you.

Model	Freq. (GHz)	Gain min (db)	N.F. max (db)	P sat min (dbm)
M9071	2 - 4	35	10	10
M9072	4 - 8	35	10	10
M9073	8-12.4	35	10	10
M9080	7-11	35	10	10

Please write for complete specifications.

Exceptional opportunities exist on our technical staff for qualified scientists and engineers. MEC is an equal opportunity employer.

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MEC

If weight is one of your problems, we've got a little something that'll

Like reducing pills, Unitrode diodes aren't made for everybody. If weight, space, and reliability are no problem to you, you may very well find cheaper components that will get by.

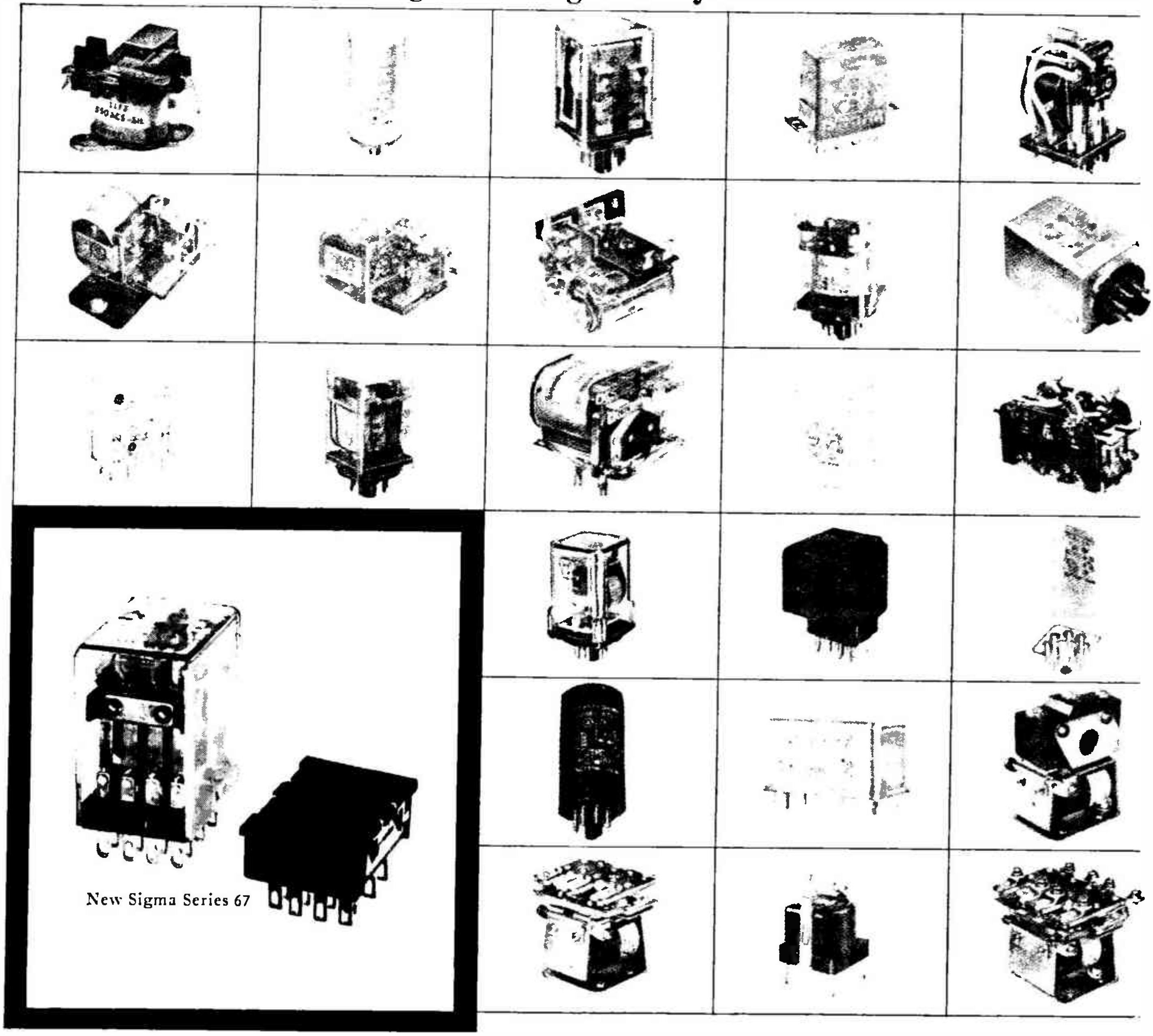
But we didn't develop Unitrode diodes for *every* application.

We developed them for applications that *need* high power and tremendous surge capacity. That would subject components to extra punishment. That would require components lasting virtually forever with no change in electrical parameters.

And when we say developed, we mean just that. *Developed.* From the ground up. With entirely new design. With entirely new methods of construction. The solid state bond that joins the silicon and the terminal pins is stronger than the silicon itself, so the silicon will break before the bond does. The entire unit is fused in hard glass at over 800°C. It's voidless, so all contaminants are excluded.

That's why you can hold a Unitrode diode in

From the expanding line of Sigma relays...



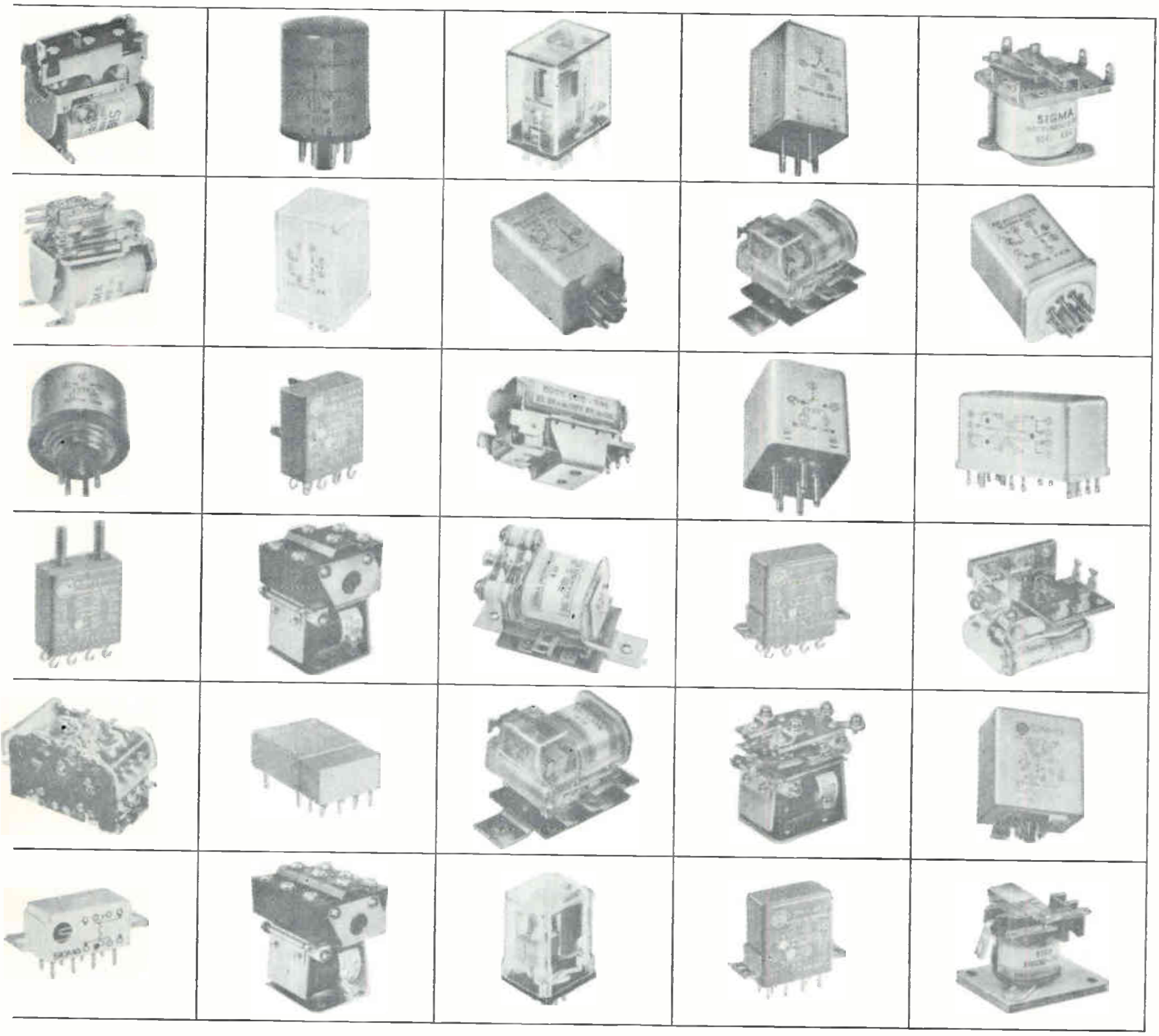
New Sigma Series 67

Miniature 4PDT relay switches
Try the new Series 67–or any

We'd like to give you a new Sigma Series 67—or any of our other standard relays. Tes and compare it against the brand you may now be using. It's the best way we know to prove what we say about Sigma relay performance.

Test the new Series 67, for example. This rugged AC-DC relay, only slightly larger than a cubic inch, brings new reliability and versatility to precision switching. Each of its four poles can switch a low-level to 3-ampere load 100,000 times minimum. The relay's in-line contact arrangement extends mechanical life to 100 million operations DC, and 50 million operations AC.

Completely versatile, the Series 67 is available for either direct solder-terminal installation or fast, easy, socket mounting with choice of solder or printed-circuit-terminal connections. The socket can be installed in seconds, with no need for screws or fasteners. It simply snaps into the face of the panel and four spring clips lock it.



3 amps 100,000 times minimum. Sigma relay–absolutely free.

Put Sigma relay performance to the test yourself, free of charge. Just send for the new Preferred Standard and Stock Relay Catalog of the expanding line of Sigma relays. Then select the relay you want to test and compare, and your Sigma representative will see that you get it. Offer limited to original equipment manufacturers having applications for relays.

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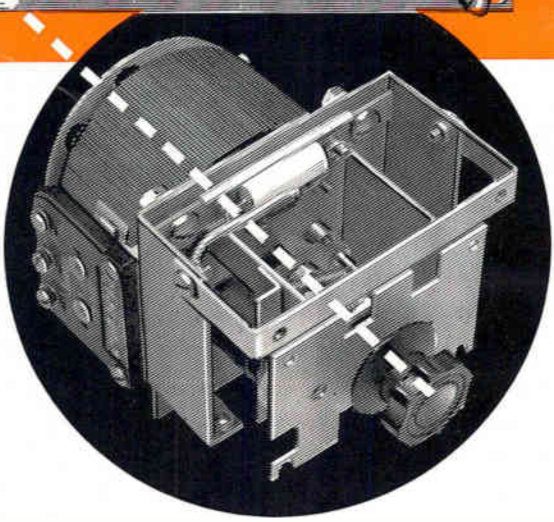
THE KEPCO VOLTAGE CONTROL

MAKES THE DIFFERENCE!



THE NEW KEPCO SM▪▪A GROUP

The familiar Kepco SM Power Supply is sporting a new suffix these days, "A." The new "A" version, in the Kepco tradition, designates a product improvement, introduced without price increase. Specifically, we've redesigned the voltage control assembly of the SM Power Supplies to accommodate a precision, 10-turn potentiometer control of the type used in most other Kepco Power Supplies.

This latest improvement continues a sequence of refinements that have marked the successful six-year history of reliable SM Series Power Supplies. Last year, for example Kepco's engineers gave the SM a better reference and jacked up the loop gain to tighten its regulation from 0.1% to 0.01% line, 0.05% load. Together with a 0.05% stability spec, less than a millivolt (rms) of ripple, and the new 10-turn control, the fifteen SM models are a pretty impressive group of supplies.

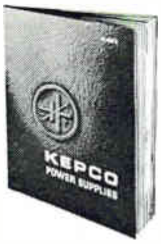
The SM design employs a mechanically coupled variable autotransformer and voltage control rheostat to limit dissipation, reduce overvoltage potential and control output. The new "A" models, with an efficient, low backlash gearing assembly, couples a full 3600° (10-turn) precision rheostat to the 320° variable autotransformer to improve resolution (to 0.05%).

The supplies employ Kepco's patented *Flux-O-Tran®* regulating transformer in an RFI-free (non-SCR) control circuit which includes a full feedback series transisitor regulator. Plug-in circuit cards and plug-in transistors simplify maintenance (even the power transistors are "plug-in"). Front *and* rear output terminals are provided, with remote error sensing connections at the rear. The table on the right lists the available models.

Applicable Patent Nos. furnished on request

REGULATION
0.01% LINE – 0.05% LOAD

MODEL	DC OUTPUT RANGE VOLTS	AMPS	DIMENSIONS H"	W"	D"	PRICE
SM 14–7AM	0–14	0–7	3½	19	13⅞	$405.00
SM 14–15AM	0–14	0–15	5¼	19	13⅞	525.00
SM 14–30AM	0–14	0–30	8¾	19	13⅞	725.00
SM 36–5AM	0–36	0–5	3½	19	13⅞	395.00
SM 36–10AM	0–36	0–10	5¼	19	13⅞	525.00
SM 36–15AM	0–36	0–15	8¾	19	13⅞	625.00
SM 75–2AM	0–75	0–2	3½	19	13⅞	425.00
SM 75–5AM	0–75	0–5	5¼	19	13⅞	525.00
SM 75–8AM	0–75	0–8	8¾	19	13⅞	625.00
SM 160–1AM	0–160	0–1	3½	19	13⅞	425.00
SM 160–2AM	0–160	0–2	5¼	19	13⅞	525.00
SM 160–4AM	0–160	0–4	8¾	19	13⅞	625.00
SM 325–0.5AM	0–165–325	0–0.5	3½	19	13⅞	440.00
SM 325–1AM	0–325	0–1	5¼	19	13⅞	555.00
SM 325–2AM	0–325	0–2	8¾	19	13⅞	675.00



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Editorial

Data management is the next step

Watching the burgeoning electronics technology, which advances and changes direction with lightning speed—in the past two years to integrated electronics; time-shared computers; high-frequency, high power semiconductors, and laser holography—a breathless observer might well ask, "What's next?"

Next, it is becoming increasingly clear, will be a subject that devotees are calling data management. It means assembling large volumes of data from all over the world, manipulating it automatically in a computer to distill an essence, and then displaying this end product to a military commander, government official or business executive who will then use it to make a decision.

At first breath, data management looks like little more than the next step in data processing systems. But a lot more is involved. Thousands of times as much raw data as is now encountered in data processing systems will be flowing in. The data will have to be received, processed and the end result displayed in real time. Many people will need access to the system at the same time to ask for information and receive it. And most importantly, the entire process has to be viewed, designed, installed and operated as an integrated system, not as separate pieces of hardware tied together with wires.

A prime data management system will use all of the technological developments of the past two years and a few that are still in laboratories. An essential requirement is the development of even bigger computer memories, up to billion-word capacities. And these memories have to possess very short access times and to cost even less than conventional-sized memories do today.

But probably the most significant change will take place internally in the central processor. Because it will have to manipulate so much more raw data and perform so many more kinds of operation, the computer organization and circuit design will be radically different. Conventional logic circuitry will not do because it would require far too many components, even far too many integrated circuits, to do all these operations. Instead, large scale integration—arrays of hundreds of circuits on a single silicon chip—will be used.

Since the operation of the computer has to be so complex, a lot more of the functions will be performed by hardware—the integrated arrays—than by software. Already, in third generation computers like IBM's system 360 and RCA's Spectra 70, which use integrated circuits, software costs have climbed so fast that they far outweigh the costs of hardware. The way software costs have been skyrocketing, according to one computer man, if the trend doesn't change, in a few years computer companies will be giving the machines away and selling just the software.

One of the most attractive attributes of the data management system is its scope, reaching to any part of the world. That will require some radical changes in communications equipment. Pulse code modulation is clearly the technique with the most promising future. Tremendous engineering strides have to be made to increase the capacity of pcm systems so they can handle this blizzard of data.

Peripheral equipment will be different too, allowing executives and officials who are not technically-oriented to carry on dialogues with the data management system. Three-dimensional displays, from holograms or cathode ray tv-like pictures, will be used along with conventional hard copy.

It is easy to visualize some pressing needs that the data management system will solve: automatic air traffic control, instant reservation and check-in systems for air travel, medical diagnosis, information retrieval, more efficient management of government, crime prevention and solution, traffic control and the scientific management of industry.

How far away is this data management system? Closer than most people believe. A Model-T version—though it is a wonderously sophisticated system by today's standards—is already operating in Cheyenne Mountain as the Combat Operations Center of the North American Air Defense Command. It sifts out a change in the status of air space over an area of 10½ million square miles through which more than 100,000 aircraft fly a day and 1,000 man-made objects orbit. Any change is reported and displayed instantly to the military commander.

In New York State, a plan is being prepared for a state-wide identification and intelligence system so that all the 2,600 agencies concerned with the administration of justice can share information. The scope of the system is immense: these agencies already store 60 million forms in their active files, and every year the state has three million violators of the law to arrest and prosecute.

Information technology has already had a spectacular growth. One estimate claims there are 35,000 electronic computers at work in the United States, and the number will double by 1970. The greatest impact of information technology is still ahead. More and more people are recognizing that the essential ingredient in business and government is information.

Tell us your precision switch problem . . .
Is it reliability?
Special characteristics?
Cost-to-quality ratio?
Delivery?

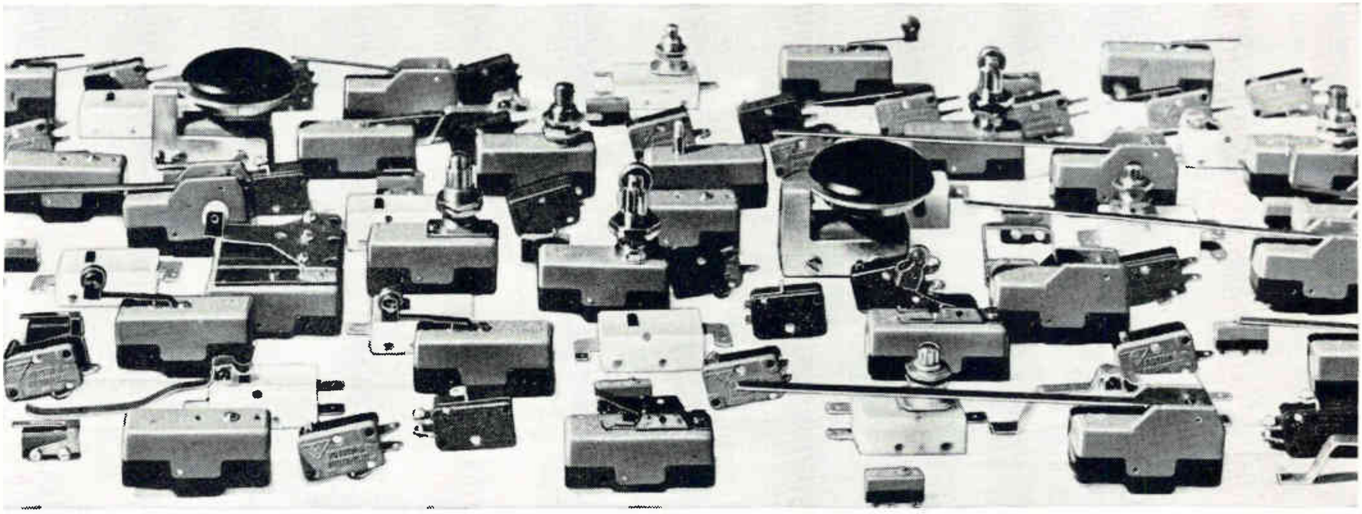
Potter & Brumfield's experience in producing top rated electromechanical relays (more than a third of a century) provides an exceptional background for the design and manufacture of precision switches.

RELIABILITY Vibration, acceleration, shock, humidity, electrical life and many other factors are tested as standard procedure. Certification of tests is supplied on request.

SPECIAL CHARACTERISTICS A well staffed engineering department is at your service for almost limitless modifications, including configuration of actuators, operating force, contact pressures, gaps, materials, terminations or performance characteristics. Any combination of these can be designed and produced to your exact specifications.

COST-TO-QUALITY RATIO A plant designed exclusively for switch production enables us to take advantage of all modern production techniques to provide top quality craftsmanship at competitive prices.

DELIVERY We can make next day shipment on most basic switches. Your local authorized P&B switch distributor has them on his shelf for immediate delivery at factory prices.



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Better check out this big new source for precision switches!

Write for your copy of P&B's Switch Catalog 1-A

Electronics Newsletter

December 12, 1966

Giant order for IC's?

Rumors persist that manufacturers of integrated circuits are being asked to bid on an order so large it would dwarf all existing IC contracts. Some industry observers claim that the General Electric Co. is circulating the request for bids, but spokesmen for the company deny it. The contract appears to be for a project so secret that even the IC producers won't admit its existence.

It's understood that the specifications call for circuits with a transistor-transistor logic that closely resembles the SUHL (Sylvania ultrahigh level logic). The SUHL circuit is produced by Sylvania Electric Products, Inc., a subsidiary of the General Telephone & Electronics Corp., and a competitive type is produced by Texas Instruments Incorporated. GE is said to be offering about 10 cents per logic gate for the multigate IC's. The going price for such IC's is about 25 cents per gate in large quantities and as low as 18 cents in extra-large quantities.

Although Sylvania and TI appear to have the inside track for the giant order, other producers aren't sitting on the sidelines. Motorola, Inc., and the Fairchild Camera & Instrument Corp. are understood to be applying for second-source contracts that may eventually be as large as the prime contract. Coincidentally, Sylvania is currently quadrupling its IC production facilities.

Apart from the obvious financial impact, other effects are likely if the order materializes. For example, it would undoubtedly place great economic pressure on all the IC producers to agree on common package pin positions. The byproduct of such standardization would be competition that's even keener than is currently evident.

IBM sets sights on holography

Researchers at the International Business Machines Corp. have developed what amounts to a simple hologram camera. Although the company won't disclose details of the design for several weeks—until patent safeguards are met—the project apparently ties in wih IBM's long-range plans to expand its activity in the display field. [For more on IBM's research into display products, see page 47.]

GE eyes auto market . . .

The General Electric Co. will soon enter the automobile equipment market. This week the giant producer of consumer and industrial products will show automobile producers an array of electronic items—from simple turn-indicator signals to complex laser ranging systems. GE plans to enter the lucrative auto market by developing ways to replace conventional electromechanical or mechanical equipment with solid state electronic components.

As yet GE has no finished products to sell. It plans to open an applications engineering office in Detroit and invite the Chrysler Corp. and the General Motors Corp. to consider—as one GE spokesman put it—the use of GE-conceived electronic designs as replacements for the conventional electromechanical designs. The Ford Motor Co. isn't expected to be a customer because Ford has its own electronics subsidiary.

GE's list of possible products includes: capacitive discharge ignition systems, windshield wiper controls, diagnostic equipment and warning control systems on highways. It also plans to show an electric-car control system that uses silicon controlled rectifiers.

Electronics Newsletter

. . . and H-P debates making an entry in calculator field

Another company that may enter a new field is the Hewlett-Packard Co., which is eying the office-equipment market with a desk calculator using integrated circuits. **The decision, according to informed sources, hinges on convincing some H-P officials that their sales organization can handle a commercial instrument.**

The desk calculator, it's reported, is still on the drawing board. Engineers are working on design, production and marketing plans for presentation to Hewlett-Packard's corporate officials.

IC's invade Scott hi-fi's

H.H. Scott, the hi-fi producer, introduced last week three f-m tuner-amplifier models containing integrated circuits. **This marks the introduction of IC's in the hi-fi field.**

Four identical IC's, manufactured by the Semiconductor division of the Fairchild Camera & Instrument Corp., are used in the amplifiers. Two stages act as intermediate-frequency amplifiers; the other two act as both i-f amplifiers and as limiters.

Scott says the IC models perform better than comparable models with discrete components but are priced the same—from $440 to $530. Scott reports that the IC tuner's capture ratio was lowered from 3 to 1.8 decibels and the stereo separation at 15 kilohertz was increased from 19 to 30 db. Interference noise (a-m rejection) was reduced to 52 db, down from 46 db. Additionally, there is some improvement in selectivity from 45 to 46 db, and in sensitivity from about 1.8 microvolts to about 1.6 μv. **The company is continuing use of field effect transistors in the front-end circuit.**

Collins will build ground terminal for Australia

The growth of the satellite communications ground terminal market is attracting an increasing number of companies. The Collins Radio Co. has won a contract, estimated at slightly more than $3 million, to build a ground station for Australia—the company's first order for such a station. The company has designed a 90-foot diameter antenna to be built on top of a five-floor tower. Collins will build most of the electronics at its Dallas, Texas, plant.

Chip functions in three modes

The General Instrument Corp. has delivered to a customer a complex integrated circuit that operates in three modes—as an analog-to-digital converter, as a digital-analog converter and as a multiplexer. Using metal oxide semiconductor technology, the device is built on one chip which has 470 transistors. The chip is bonded to a ceramic substrate which has 40 wire-bonded leads on 100-mil centers. It's tested before packaging. Packaged, it's 695 mils by 895 mils. **General Instrument will market the device in January.**

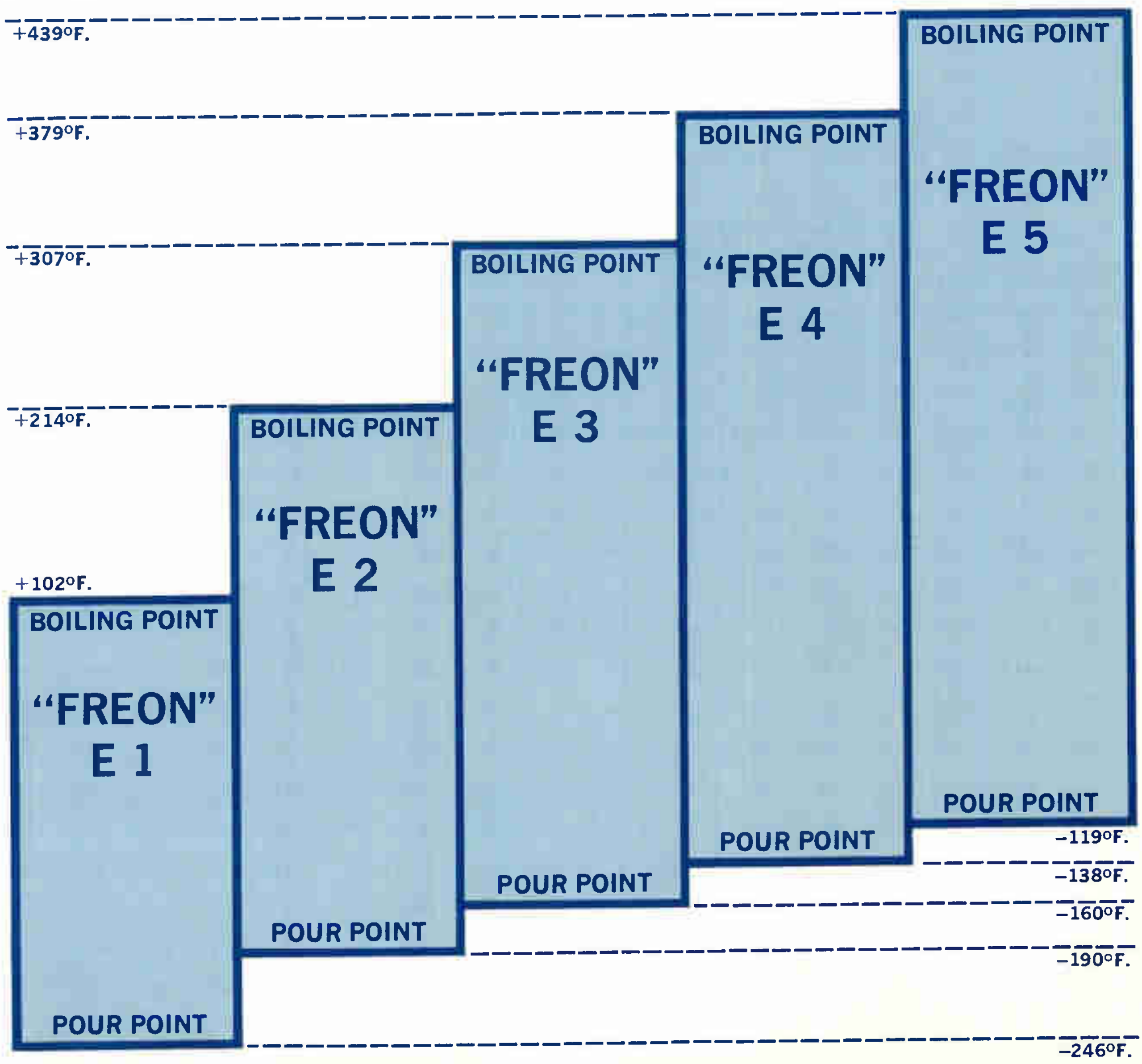
Addendum

The International Business Machines Corp. has submitted a technical proposal on the Air Force contract for 134 electronic data processing machines. The bidding on the $100-million order has been divided into two phases, technical and the pricing. [See earlier story on page 73.] . . . Walter Finke, a Honeywell, Inc., vice president, will take over as president of the Dictaphone Corp., a producer of dictating and recording equipment.

Circle 27 on reader service card→

FREON® E SERIES dielectric coolants let you specify— not speculate!

Du Pont's "FREON" E Series is a family of 5 homologous dielectric coolants setting totally new standards of performance and reliability. There's no guesswork necessary in choosing the right one for your equipment. With the "FREON" E Series, you can choose the exact coolant that best meets your needs, and permits the customer to operate the equipment exactly as specified for the task.



Here's why FREON® E SERIES coolants will increase your equipment performance and reliability:

1. Stable and compatible
"FREON" E Series fluorocarbon liquids are not affected at high temperatures (over 550°F!)—are inert with metals, plastics, elastomers.

2. Completely safe
No special safety precautions are necessary with "FREON" E Series coolants. They are nonflammable and relatively nontoxic. Use them anywhere!

3. Outstanding dielectric properties
These insulating fluids provide high dielectric strength in liquid and vapor—low losses—high resistivity.

4. Widest temperature ranges
The "FREON" E Series offers liquid limits from -246°F. up to +439°F. at zero psig. Each coolant has a specific, constant, and extremely wide liquid temperature range. You choose the one to meet your exact needs.

5. Unmatched purity and uniformity
Each coolant in the "FREON" E Series is a single, pure compound—not a mixture of several different fluids. Thus composition is always the same—lot to lot—day to day.

6. Precise boiling points and vapor pressures
There's no plus-or-minus factor on boiling points . . . and no "averaging." You're always sure of coolant characteristics—and operating temperatures.

If you're looking for new standards of performance in a dielectric coolant, find out more about the "FREON" E Series. Simply fill out and mail this card.

I would like to know more about "FREON" E Series coolants for use in:

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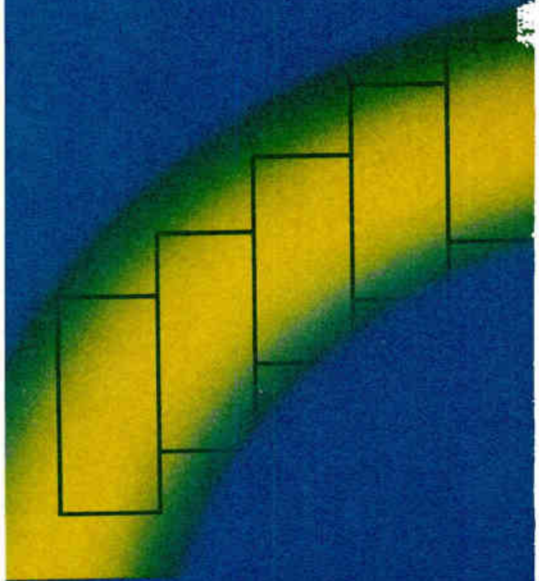
fluorocarbons offer new opportunities for creative design...

The unique thermal, electrical and chemical properties of "FREON" E Series fluorocarbons provide new opportunities for electronic and space-age engineering . . . in improving reliability by outstanding temperature control . . . in miniaturizing components or systems . . . in transmitting hydraulic pressure in systems operating under conditions of extreme temperature changes . . . in optical equipment . . . or you name it. Whatever new application you can think of, just jot it down on the reply card. We'll help you investigate the new use with necessary technical assistance.

In Europe, mail card to: Du Pont de Nemours International S.A., "Freon" & "Valclene" Products Department, 81, Route de l'Aire, CH 1211 Geneva, 24 Switzerland.



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...THROUGH CHEMISTRY

Like Popcorn.

The other day one of our engineers said, "We're turning out those Unibloc* plastic transistors like popcorn." And, boy did we jump all over him!

Sure, it's one way of saying we're making them by the millions (by the tens of millions as a matter of fact). And, we suppose it even reflects the fact that we produce them so fast right here in Phoenix that we can compete price-wise with devices made anywhere in the world.

But, that's not the point.

The trouble with likening them to "popcorn" is that it doesn't give you the true picture about the precision and quality that's built into each and every device we make.

As a matter of fact, we advertising guys are the ones who dubbed them "no compromise" transistors because you get the same premium performance with Unibloc devices that you've always associated with metal-can transistors.

That is the reason we were so upset.

So, on your next new design, grab a handful of popcorn and live it up.

*Trademark of Motorola Inc.

– *where the priceless ingredient is care!*

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ELECTRONIC INNOVATIONS IN ACTION

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smaller

smallest

G.E.'s new wet slug tantalum capacitor gives you the performance of the CL64 in only ½ the case size

Get the highest volt-microfarad product per unit weight and volume of any capacitor you can buy with General Electric's new 69F900 wet slug tantalum capacitor. How? General Electric reduced the case size of the military type (CL64) wet slugs by ½ (it's even smaller when compared to solids). Electrical characteristics and performance remain essentially the same. G.E.'s new 69F900 answers the need for a commerical wet slug capacitor with the high volumetric efficiency demanded by modern high density applications.

G.E.'s new addition to its complete line of tantalum wet slug capacitors has excellent high capacitance retention at low temperatures and can be stored to −65°C. Its wide operating range is −55°C to +85°C. And it meets the parameters of larger military wet slugs: vibration to 2000 Hz, 15g acceleration!

RATING	CASE SIZE	VOLUME
50V, 30µf		
solid (CS12)	.341 x .750	100%
wet slug (CL64)	.281 x .681	58%
69F900	**.145 x .600**	**15%**
15V, 80µf		
solid (CS12)	.341 x .750	100%
wet slug (CL64)	.281 x .681	58%
69F900	**.145 x .600**	**15%**
6V, 180µf		
solid (CS12)	.279 x .650	100%
wet slug (CL64)	.281 x .641	100%
69F900	**.145 x .600**	**25%**

The new sub-miniature 69F900 capacitor is fully insulated and has a low, stable leakage current. Voltage ratings are available from 6–60 volts; capacitance ranges from 3.3–450 microfarads.

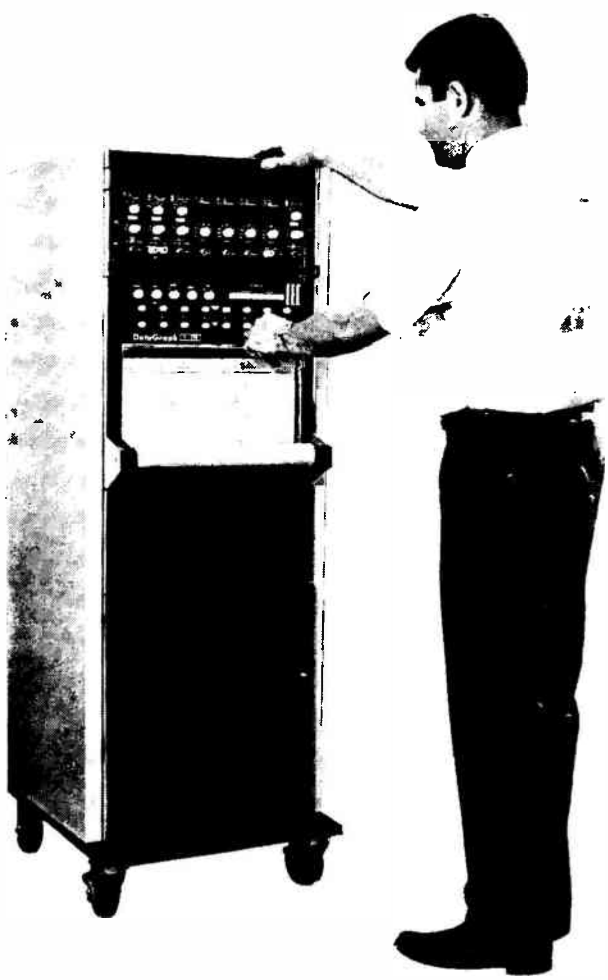
Choose from a complete line of G-E wet slug tantalum capacitors to fill your slim, trim circuit needs. Write for GEA-8369 for details about the 69F900 and the other capacitors in General Electric's complete wet slug tantalum line, or ask your G-E sales engineer. **Capacitor Department, Irmo, South Carolina.**

ELECTRONIC COMPONENTS DIVISION

GENERAL ELECTRIC

430-28A

Why has it taken 3 years for the leader in oscillography to introduce this thermal writing instrument?



Because we're exacting.

We refused to enter the field with "just another good recorder."

So we designed, tested and retested until we had perfected an instrument that was everything we wanted it to be. A thermal-writing recorder that would reflect the *highest* state-of-the-art in every important function and feature.

It's called the DG 5510. Its name may not inspire any hurrahs—but we believe its advantages will. Such as...

Modular Design—eight channels in a solid-state, self-contained unit with plug-in driver amplifiers and power supply capable of accepting a wide range of high-level signals.

Unmatched frequency response—dc to 115 Hz full scale, higher than any other thermal-writing recorder.

Electrical Signal Limiting to assure that the stylus motor and writing assembly cannot be damaged by transient or other high-level signals which may occur. Each analog channel is provided with this protection built into the driver amplifiers, adjustable to 115% of full-scale deflection.

Flexibility varying ac and dc signals, having a wide dynamic range, can be precisely conditioned by the proper choice of the Type 1-500 series preamplifiers available.

Solid-state driver amplifiers provide compensation and damping to the stylus motors throughout the entire operating limits to assure constant instrument accuracy.

A heated writing stylus traveling over a "knife edge" produces exceptionally sharp contrast rectilinear traces when used with CEC DataTrace™ thermal-sensitive paper.

Accessibility and ease of maintenance are additional advantages of the recorder assembly. It comes with 3-position rack slides and mounts into a standard 19" rack.

Widespread applications include the military, aerospace and industry in general.

Now you know why we waited for the DG 5510. And why the wait was worth it.

For all the facts about this advanced new thermal-writing recorder, call or write for CEC Bulletin 5510-X22.

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Data Instruments Division
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Cooking up a new product?

Add a dash of extra sales appeal
(and save a little money)
with Heinemann's good-looking
'instant color' circuit breaker.

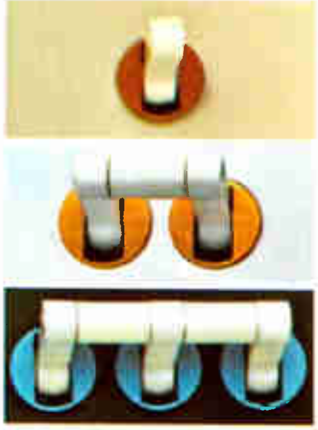
For years we've been making homely circuit breakers that work beautifully.

Our new Series JA breaker has changed things a bit. It's sort of handsome. For a circuit breaker.

The pictures opposite will show you how nicely a JA with a spot of color can dress up a panel.

The functional possibilities are intriguing, too. JA breakers in color are a very practical way to indicate a specific switching sequence. Keyed to matching pilot lights, they can neatly simplify equipment operation.

It takes just one second to color the JA in any of nine different hues. Slip a cap over the breaker's mounting boss and the job's done. (The caps cost a few pennies; the white handle comes at no extra charge when you buy the rest of the breaker.)



Price is another attractive feature. The JA runs about ten percent less than our Series AM12, which has long been the most popular OEM model on the market. Yet it has similar functional capabilities. It offers the same kind of precise overload response. And it can be had with all our usual options—custom current ratings, choice of time delays, special-function internal circuits.

Series JA breakers are available in one-, two-, and three-pole models, in any integral or fractional current rating from 0.100 to 20 amps. Standard maximum voltages are 250 vac, 60 or 400 cps; 50 vdc. Our Bulletin 3350 will give you full details. A copy is yours for the asking. Heinemann Electric Company, 2600 Brunswick Pike, Trenton, New Jersey 08602.

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devices

Today's best DVM value plus AC, Resistance, and low-level DC measurements!

Honeywell's New Autoject 620/623 package

We started with our outstanding 620 integrating DVM with Autoject – which provides greater than 60 db of normal mode rejection to noise of any frequency above 30 Hz in 250 msec!

Then we added the new companion 623 converter module with differential input to insure maintaining the 620's high CMR. Combined in a compact, fully portable cabinet for either bench use or rack mounting, the result is a highly versatile measuring instrument offering more performance per dollar than similar units.

The 620 DVM is accurate to ±.01%, gives you 4 readings per second, and has 4 full digits, plus a 5th for 20% overrange. Solid-state throughout, its isolated-guarded differential input (140 db of CMR) provides foolproof operation, with ground loops, offset, or error due to noise completely eliminated. The 620's *constant* high input impedance of greater than 1000 megohms eliminates errors due to source of loading.

Here are the highlights of the new 620/623 package:

- Low-level DC measurements to 1μv.
- 3 full ranges on DC: 10, 100, and 750 volts with overrange.
- 3 full-scale ranges with DC preamp for 10, 100, and 1000 mv with 20% overrange. Speed: 3 rdg/sec.
- 4 full ranges on AC: 1, 10, 100, and 530 volts RMS full-scale with 20% overrange.
- 5 full-scale Resistance ranges: 1, 10, 100K, 1 megohm, and 10 megohms with 20% overrange. Speed: 3 rdg/sec.
- All full-scale values presented as 5-digit display; i.e., 1-volt range = 1.0000.

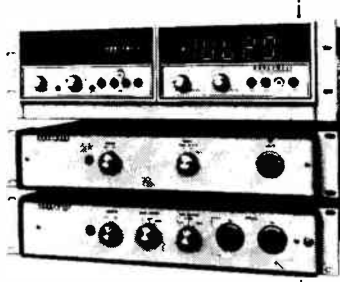
For automatic or systems use, the 620/623 provides these features:

- Automatic ranging on *all* functions, *all* ranges.
- Remote programming of all functions which include *automatic delays* to insure maximum accuracy on the first encoding.
- Electrical outputs for printer operation.

Buy the package or add on at any time. The 623 converter module utilizes plug-in circuit boards, one for each function desired (AC, Resistance, low-level DC). You can add measuring capability at any time, in any sequence, without field modifications. And, if you already own a 620 DVM, it's a simple matter to expand its capabilities through the addition of the 623 module!

For full specs and price information, mail coupon today!

Need extra measuring capability? Add the 625 milliohm and 626 phase converters for a complete measurement system.



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COMPONENT CAPSULES

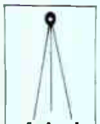
Improve Color TV life, reduce costs

Multifunction G-E compactrons do the job of 2 or more ordinary tubes . . . require less wiring and simplify your circuitry. Now G.E. offers 5 new types. G.E.'s new 6AG9 is the industry's first ultra-high transconductance video output pentode to incorporate other functional elements (in this case, a triode). The 6EF4 is an improved 40-watt, high voltage regulator that protects against destructive arcing.

New General Electric 6AG9, 25CG3, 6HS5, 6EF4 and 40KD6 compactrons

The 6HS5 is a new type of high voltage regulator of the pulse-shunting variety. The 40KD6 and the 25CG3 are series-string versions of the 6KD6 and 6CG3 respectively, designed for 270-volt large-picture sets. Circle **Number 90** for more details.

How tiny can a transistor get?



Actual size

0.07 x 0.07 x 0.085 inches is all G.E.'s new microtab transistors measure. Yet each delivers precisely the same performance as its larger, conventional-sized counterpart. They're perfect for hearing aids, miniature operational amplifiers and very small instruments . . . or for your hybrid circuits, and linear and analog circuits. Equivalents to 2N930, 2N2484 and 2N918 transistors are already available for less than $1.00 in quantities. Circle **Number 91** on the magazine inquiry card.

Designing small motors? Better check this new magnetic material.

Improved Cast Alnico 8

General Electric's new Improved Cast Alnico 8, the best material for small motor applications, is now available. Although this new material can be substituted directly for some existing designs at comparable costs, it is more economical and efficient to redesign the motor to utilize the improved properties available. Improved properties provide greater flux density, high coercive force, extreme temperature stability, and greater useful recoil energy. Circle **Number 92** for complete information.

What's new for peripheral computer equipment?

Instant response—inertial time constants low as 1 millisecond—is what you get with the new G-E Hyper-Servo* motor. And it accelerates faster than any other motor ever developed by General Electric. Hyper-Servo motors greatly increase the overall capacity of peripheral data processing equipment. They're available in 3.4-, 4.6-, and 4.8-inch diameters. Performances include torque-to-inertia ratios in excess of 350,000 rad/sec^2 and continuous torque ratings from 32 oz-in at 2700 rpm to 326 oz-in at 2800 rpm. A wide variety of models can provide the high performance drive motor for nearly every computer peripheral application. Circle magazine inquiry card **Number 93.**

*Trademark of the General Electric Company.

New high-response d-c motor

Switch to the lowest cost SCR

G-E C106 SCR's cost from 35 to 50¢ in volume. That's about half the price of other "low cost" SCR's. Yet you buy them at no sacrifice to performance or quality. New, planar C106's are reliable . . . give exceptional electrical uniformity and long term stability. They feature up to 200-v blocking capability, microamp triggering, and a configuration that's excellent for printed circuits, plug-in sockets, screw mounting, and point-to-point wiring. Circle **Number 94** on the magazine inquiry card.

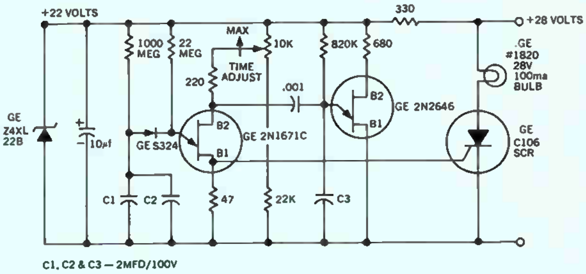
Actual size G-E C106 SCR

MORE ▶

COMPONENT CAPSULES

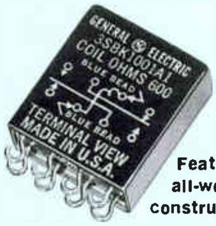
Tried this 45-minute timer circuit?

Check this circuit against others like it. See for yourself how it eliminates the need for many other components. The 2N2646 transistor applies a sampling pulse to base 2 of the 2N1671C and reduces required trigger current by 1,000:1 or more. Circle **Number 95** if you'd like a comprehensive paper on this and many other circuits like it.



Featuring the low-cost 2N2646 transistor and C106 SCR

Look! A 5-amp relay in a 2-amp package



Featuring all-welded construction

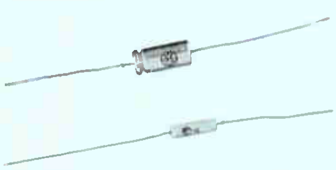
Weight: just 0.7 ounce maximum. Now, the proven magnetic motor design of G.E.'s 3SAF microminiature relay is combined with new, heavy-duty contacts and terminal leads. Result: 5-amp switching capability in a microminiature grid-space package. We call it the 3SBK. Electron-beam welding eliminates the need for solder flux, adding greater strength and delivering more trouble-free performance. Circle magazine inquiry card **Number 96.**

Up to 50 kv in this small ignitron

Use the ZG-7248 ignitron for high-energy-rate switching or crowbar service. You'll find that when adequate anode-to-cathode temperature differental is maintained, it is a reliable 50 kv device that will conduct up to 25,000 amps and a total charge of over 20 coulombs. Or you can take advantage of the auxiliary electrode that's provided for circuit control at very low currents. Maintain a current of just 10 amps between the auxiliary electrode and the cathode, and the tube will maintain its conducting state even for main anode currents of a few amps. Circle magazine inquiry card **Number 97.**

The ZG-7248

Introducing . . . new sub-miniature wet-slug capacitor



69F900 wet slug capacitor—50% smaller than the CL-64

Why struggle with larger-sized capacitors in your miniaturized circuits? Use G.E.'s new 69F900 subminiature tantalum wet-slug capacitor. Delivers performance and application characteristics virtually identical to those of standard military CL-64 units. Voltage ranges from 6 to 60 volts. Capacitance from 3.3 to 450 microfarads. And the 69F900 is especially suited for data processing, communication, and other industrial applications. Circle **Number 98** on the magazine inquiry card.

Tiny tubes for new telemetry frequencies

Actual size Y-1223 and Y-1226 ceramic planar tubes

Use the tubes specifically designed for the new 2200-2300 MC telemetry frequencies—G.E.'s Y-1266 and Y-1223 ceramic planar tubes. The Y-1266 packs excellent gain and efficiency, and 2-watt power capability into a tiny, 2-ounce package. The Y-1223's new high dissipation anode gives 10-watt power output at 2300 MC to provide higher power . . . improved RF characteristics, too. Couple the two tubes together for a small, reliable, low cost, two-tube circuit for space probes. Circle **Number 99** for more details.

WE MAY NOT OFFER EVERYTHING YOU WANT FROM ONE COMPONENTS SUPPLIER. BUT WE DO COME A LITTLE CLOSER THAN ANYONE ELSE.

285-15

GENERAL ELECTRIC

Circle 271 on reader service card

Now: A Fast Signal Averager

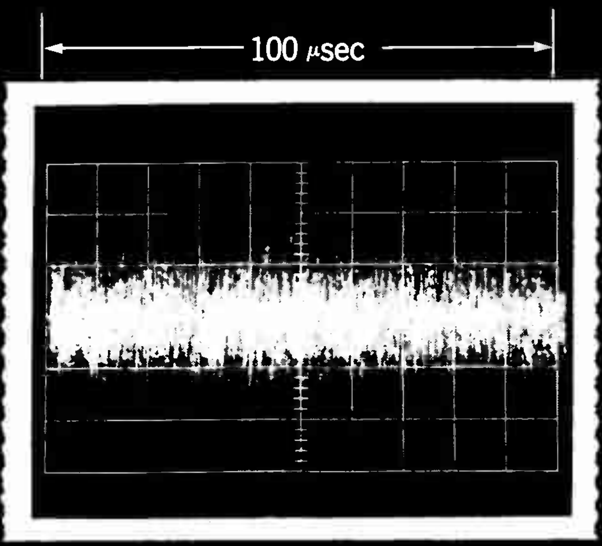


Photo #1—Input to Model TDH-9
SENSITIVITY: 5 V/cm
TIME: 10 μsec/cm
NOISE-TO-SIGNAL RATIO: 10:1

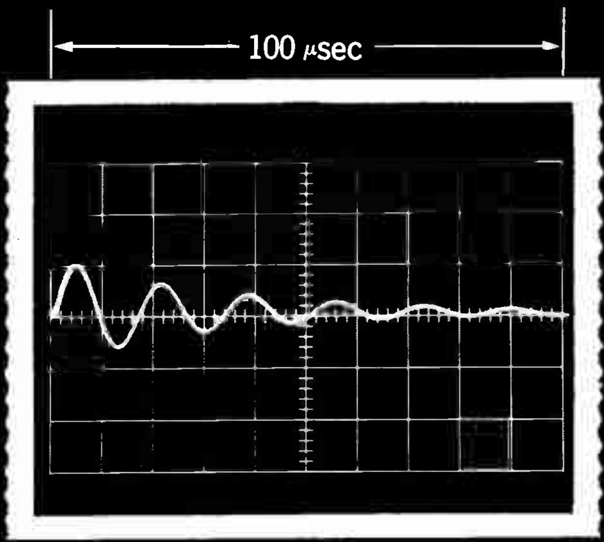


Photo #2—Output of Model TDH-9
SENSITIVITY: 5 V/cm
TIME: 10 μsec/cm
TDH-9 VOLTAGE GAIN: 10

PAR Model TDH-9 Waveform Eductor

Photo #1 is an actual oscillogram of a signal obscured by noise — a situation unfortunately prevalent in many research areas such as studies of biomedical evoked potentials, seismology, spectroscopy, fluorescent lifetime studies, and vibration analysis. Photo #2 shows the dramatic improvement in signal-to-noise ratio when the noisy signal was processed by the PAR Model TDH-9 Waveform Eductor.

This new instrument employs a highly efficient waveform-averaging technique, and at the same time offers the fastest sweep rates obtainable in signal processing equipment of the signal-averaging type. Sweep durations as short as 100 microseconds, with dwell times per channel of 1 microsecond, are obtainable. The high resolution capability of the Model TDH-9 allows observation of waveforms or transients which have heretofore been unresolvable by averaging instruments employing a greater number of channels.

Although the Model TDH-9 Waveform Eductor sells for only $4,200, we invite functional comparison with the higher-priced digital averagers. We believe you will be pleasantly surprised. For more information about the PAR Model TDH-9, ask for Bulletin No. T-126.

Have a noise problem?

PAR's technical staff, unusually knowledgeable in signal processing problems and techniques as a result of its experience in the development and application of Lock-In Amplifiers, welcomes your specific inquiries. Please call or write.

PRINCETON APPLIED RESEARCH CORP.
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Electronics Review

Volume 39
Number 25

Avionics

Quick as a wink

The old adage notwithstanding, the eye is quicker than the hand. But when researchers have tried to apply the eye's speed advantage to some control chores performed by hand, the results generally have never moved beyond the laboratory stage. Now, Honeywell, Inc.'s Radiation Center in Watertown, Mass., has unveiled a prototype system that it says is accurate to within 1° of arc.

The system, called an Oculometer, looks like a telescope. The user presses his eye against the eyepiece and tracks, for example, a satellite. Each time the satellite moves, the eyeball follows. The Oculometer translates each eyeball movement into guidance commands, in the x, y and z planes.

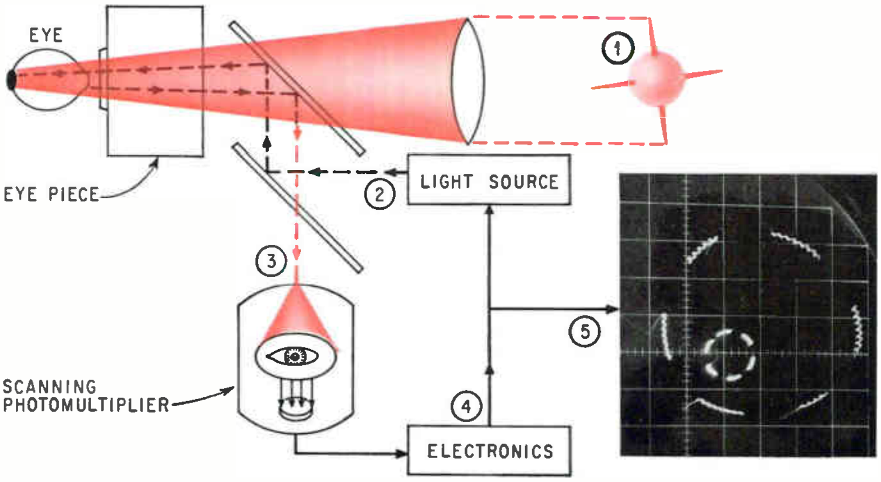
Eye on the target. The work, supported by the National Aeronautics and Space Administration, is now getting attention from the Army and Navy, which are weighing adapting the Honeywell system to gun, missile and vehicle controls. And Honeywell is negotiating a contract with NASA for further development of the system for control of some extra vehicular equipment for astronauts. This system. Honeywell says, will be accurate to within 0.25° of arc.

The Oculometer has other advantages, apart from speed. If, for example, an astronaut were steering his spacecraft toward an orbiting satellite with conventional hand controls, he would have to translate the steering operations—in the x, y and z planes—into four separate hand movements: up, down, left and right. With the Oculometer, the natural eye movements alone perform the steering operation.

Remote control. The actual target needn't be in direct view; it could be an image on a television screen. A gunner tracking an enemy craft on tv could aim his guns by following the moving target on the screen with his eyes.

To understand how the Oculometer works, consider the diagram shown below. An object (1) is spotted through the eyepiece. Simultaneously, a tiny spot of light (2), is aimed at the center of the viewer's eye. That light is reflected by the cornea—much the way a person standing eyeball to eyeball with another person is able to see his reflection in the other person's eyes—and the reflection is directed by mirrors to a scanning photomultiplier (3). The image appearing at the face of the photomultiplier is a virtual point image of the pupil. Any change in the position of the point can be translated as a movement of the eye—and a movement of the target.

The scanner views both the corneal reflection and the pupil-iris boundary of the eye. Then, the signals from the scanner are time-division multiplexed by a switch (4) into separate signals—pupil position and corneal-tracking—which are fed to the control mechanism, be it a steering wheel or a joy stick (5). Simultaneously the pupil-position signal is fed back to the light source (2) keeping the light aimed directly at the center of the pupil. In the diagram the output signal is presented as a line image projected on a cathode-ray tube.



Guiding a vehicle with the Honeywell Oculometer is as easy as keeping your eyes open.

Solid state

Bridges of gold

To the growing arsenal of isolation techniques [Electronics, Oct. 17, p. 125] developed to combat parasitics in integrated circuits, add another—air-oxide isolation. The technique was devised by James A. Cunningham, a scientist at Texas Instruments Incorporated's Semiconductor Research and Development Laboratory in Dallas.

When made by the new process, the devices look like a cross between circuits produced by Bell Telephone Laboratories' beam lead techniques and Fairchild Camera & Instrument Corp.'s mesa isolation techniques.

Building bridges. With the TI process, the device that's formed is a unique structure in which heavy gold interconnections form bridges between single crystal silicon islands floating on a sea of polycrystalline material

According to Cunningham, devices isolated in this fashion have been built in the laboratory and performed as well as silicon on sapphire or ceramic back-filled devices. However, TI is not presently producing IC's incorporating this or any other advanced isolation technique, so Cunningham feels it is still too early to tell which method will ultimately prevail on the basis of a performance-cost trade off.

The speed of the resultant circuit, notes Cunningham, is comparable to speeds of circuits made by other isolation techniques. In addition, the researcher says, the device dissipates heat better than those made by TI's ceramic process.

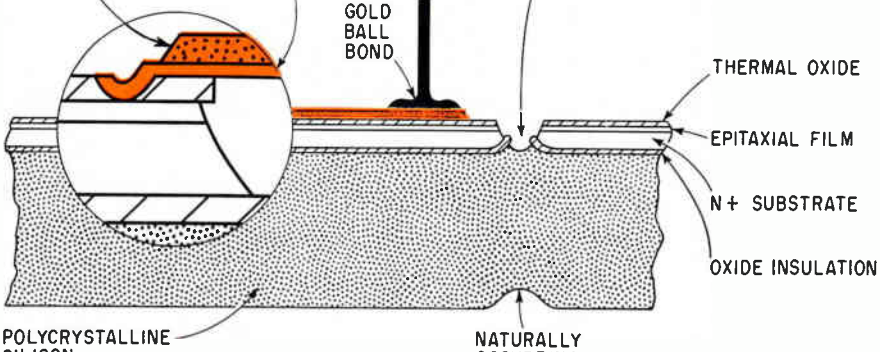
The isolation process begins with conventional wafers of n^+single crystal silicon. On one side of the wafer, a moat that is 1- to 2-mils deep, is etched in a pattern that corresponds to the final scribe and break operation for the wafer. Then an oxide, 1- to 2-microns thick, is formed on both sides of the wafer.

The next step is to deposit about 8 mils of polycrystalline silicon on the etched side of the wafer by epitaxial techniques. Then the starting material is etched until the polycrystalline material is exposed in the previously etched moat. This results in an n^+film of from 1- to 2-mils thick, over which an n-type epitaxial film is deposited. Thickness and resistivity of this layer depend on the specific device requirements.

At this point the wafer is reoxidized, and the necessary device diffusions are performed conventionally, except that deep-lying isolation diffusion used in p-n junction isolation is deleted.

Mask of gold. When the devices are formed and the last oxide layer removed, a layer of molybdenum, followed by a layer of gold, is deposited over the surface of the wafer, forming a bimetal film. Using standard photoresist methods, the gold is etched to form the desired contact and interconnection pattern, but the underlying molybdenum is left untouched. The interconnections are thickened to about 0.2 mil by electroplating gold through a photoresist pattern. The gold interconnections then serve as a mask for the subsequent etching of the molybdenum.

In the following step air isolation is achieved by etching down to the oxide through another photoresist pattern. Unlike other isolation methods, this is done from the front of the device. When exposed to the silicon etchant, the gold is not attacked, but the etchant removes the silicon underneath it, forming a gold bridge across the moat. At the same time, the scribing land extending into the polycrystalline material is exposed.



Electroplated bridges of gold interconnect are used to isolate devices in Texas Instruments' air-oxide technique.

Space electronics

Wanted: a multiprocessor

The greatest challenge facing the designers of space computers for the '70s is not so much to build a system that can juggle many complex problems, but to build one that could continue juggling, albeit in a limited fashion, if some of its circuits failed.

As one computer designer put it, "If it's got to fail, it has to occur gracefully."

During this "graceful" failure period, the astronauts could repair or replace burned-out parts, determine ways to reduce their reliance on the computer, or permit the computer itself to calculate ways to bypass the circuitry that failed.

Besides this, the post-Apollo space computer will have to perform navigational, scientific and other functions undreamed of five years ago.

Start from scratch. To assure this kind of performance, says Thomas E. Burke, assistant director of the computer research laboratory at the National Aeronautics and Space Administration's Electronics Research Center, "we can't just try to extend existing computers. We've got to take the systems approach and start from the bottom."

The Cambridge, Mass., center, focal point of NASA's long-range computer efforts, is laying the groundwork for such a system. The center is ready to move into large-scale simulation to evaluate various concepts, and plans are being made to develop experimental hardware that would be the test-bed for new memory systems and other hardware.

Some of this work, for manned flights, is already under way at North American Aviation, Inc.'s Autonetics division. And last month, the International Business Machines Corp.'s Federal Systems division won a contract to study multiprocessing techniques for unmanned flights; a team from IBM's Center for Exploratory Studies, Rockville, Md., will move to Cambridge next month for this project.

Also, the Instrumentation Laboratory at Massachusetts Institute of Technology is exploring for NASA the application of computer-aided design to the development of some of the next-generation hardware.

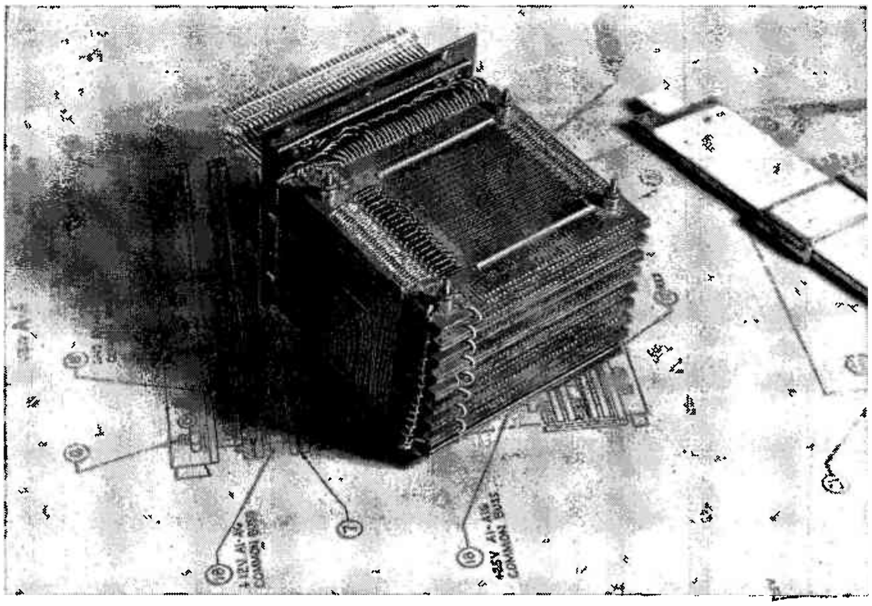
Right the first time. "If you want to use the technology of large-scale circuit integration, designs must be right the first time," Burke says. Further, he notes, the automated design technique would eliminate breadboarding of the system's logic.

The multiprocessor approach appears to be the dominant one in plans for spaceborne computers after the Apollo program. Alternatives include an array of independent computers for different tasks and distributed logic processors.

In the multiprocessor structure, as outlined by Ramon L. Alonso, a staff member at MIT's computer design center, each of a group of processing elements would have its own program and scratch-pad data memory. There would be no one supervisory element or processor; the combination would be truly collaborative.

A time-multiplexed bus would transfer information among the computer's units. Every unit having access to the bus would be able to receive all data appearing on it. Every unit would also be able to transmit data on the bus through a multiplexer circuit. And each multiplexer would "enable" the next in line as soon as it was through sending data. The next multiplexer could send its data or skip the enable on to the following one if it had nothing.

Remember. The data needed to start jobs would be stored in a common erasable memory. "This either must be infallible or else have graceful degradation properties," Alonso says. As the memory would have access to the bus, it could be interrogated by a message from a processor specifying its identity and stating that the contents of a certain memory address were desired. The memory would then place the message in a waiting stack; when its turn came, the message would trigger the start of a memory cycle, delivering both address and content to another waiting stack for transmission on the bus.



High-speed memory stack in RCA's variable instruction computer. The machine, developed for the military, is being proposed for use in space.

Based on experience with Apollo, Alonso says that within a few years a machine will have to handle a hundred programs at a time on a sampled basis, out of a total assembly of hundreds of programs in the complete multiprocessor system. Each program would periodically receive a sample update, requiring an average sample rate of about 50 per second per program. This means that 5,000 samples, or jobs, would be executed every second, an operation requiring a bit transfer rate of 14 megabits per second for common memory, input-output and messages.

Experience with the executive program structures of the Apollo guidance computer shows this to be the minimum bit rate that could serve the multiprocessor system. "But it's well within the reach of today's technology for memory and transmission systems," he says.

Building-block approach

Not everyone is convinced that the space computer of the '70s will have to be designed from scratch. Concepts that had their origin in reliability programs are now evolving toward the multiprocessor goal. At the Radio Corp. of America and NASA's Jet Propulsion Laboratory, for instance, computer researchers are convinced that approaches using existing designs as building blocks would effectively serve the space agency's needs.

An RCA computer that was built under military sponsorship is being proposed for the space job even though it wasn't developed specifically for such a function. This computer, developed by the concern's Aerospace Systems division in Burlington, Mass., and called VIC, for variable instruction computer, will fly early next year aboard a KC-135 plane out of Wright-Patterson Air Force Base, Ohio.

Detailed plan. VIC is designed for airborne command posts and airborne warning and control systems. This month, RCA will submit to the Air Force Electronic Systems Division a detailed proposal for the use of VIC in the 481-A program, the post-attack command-and-control system of the Strategic Air Command.

"But VIC will have applications in the Manned Orbiting Laboratory and other space projects," says E.H. Miller, manager of aerospace computer applications at RCA. The military has spent about $450,000 on the VIC project.

VIC uses integrated circuits, with each functional unit as nearly independent as possible. The main memory is expandable in 4,000 38-bit word modules to a total of 32,000 words; the variable instructions are stored in these redundant high-speed memory modules. Each module has its own independent address register, local control and power supply. Vic is an asynchronous machine and there is no central clock source, a feature critical to the operation of the separate functional units.

From the standpoint of reliability, the fundamental advantage of VIC lies in its instruction repertoire. A programer, for example, can find a great many ways to execute a particular macro-order, which may contain 12 to 15 micro-orders.

The program and variable words are combined to control the computer's step-by-step operation. The lists of the order register and variable register are decoded to generate specific data address and control operations. At least one, and sometimes four, variable words each containing three micro-orders, are required for each order.

Detect failure. With this flexibility, it's possible to program alternate ways to execute an order and circumvent the failure of some portion of every register and control path in the machine. A comprehensive set of diagnostics can detect failures in basic algorithms and then determine which secondary, or even tertiary, algorithms can be substituted.

Vic's 36-bit parallel arithmetic can be considered as three 12-bit sub-units. Even if two of these failed, it would still be possible to operate on the remaining sub-unit.

Another approach is being taken at the Jet Propulsion Laboratory, where an experimental computer called the STAR (self-testing and repairing) is being built.

The system organization of this machine is now being extended to include multiprocessing features according to Algirdas Avizienis, a member of the lab's staff.

'Self-repair.' JPL chose what it calls a selective-redundancy approach, using standby spares for replacement or "self-repair." The computer is required to survive space voyages of up to several years and then be able to control the approach of the unmanned spacecraft to a planet. The computer in the spacecraft would be employed for onboard processing of scientific data when guidance computation isn't in progress. At the end of the voyage, the surviving spares could be reconfigured to form a multiprocessor for scientific experiments and data transmission.

A replacement or self-repair system requires diagnosis of self-test. For the STAR, concurrent diagnosis was chosen, permitting a very brief rollback of the program each time a fault is found. This would be an important time-saver in approach and reentry guidance programs, which require real-time computing.

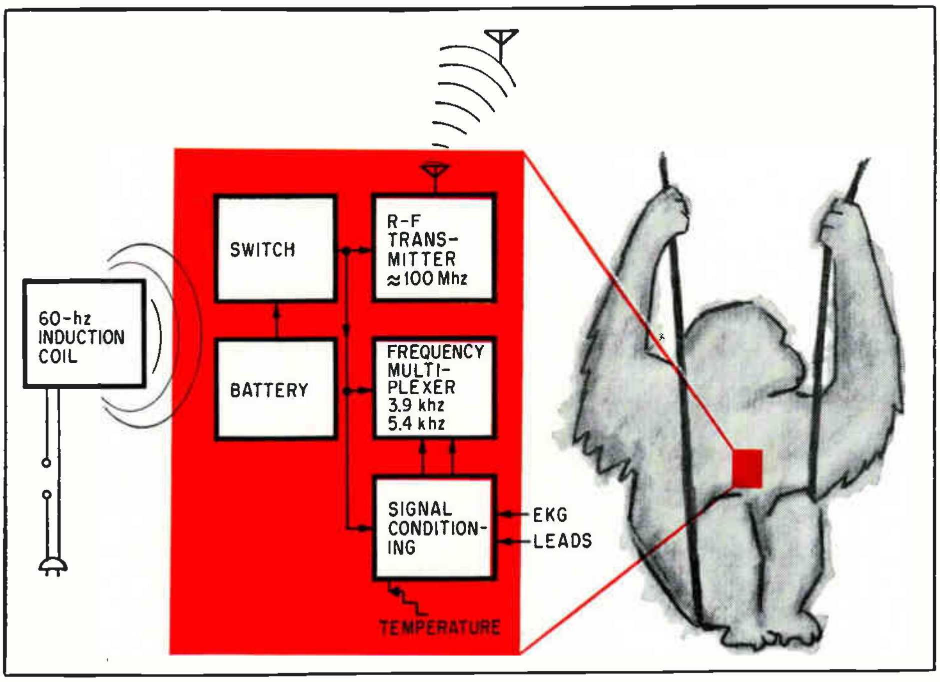
Medical electronics

The inside story

Researchers monitoring the physical reactions of chimpanzees in their natural habitat have consistently run into a problem. The electronics-crammed backpack and the electrical leads that protrude from the ape's body both irritate his skin and leave him a social outcast. And an angry chimp who has been mistreated by his jungle confreres is hardly a good subject for medical research.

Now, however, Electro-Optical Systems, Inc., Pasadena, Calif., is developing a special telemetry package for the Air Force that will do away with the backpacks and protruding wires for chimps under observation. The package—transmitter, antenna and batteries—will be implanted inside the chimp's body so researchers can monitor electrocardiogram and temperature data as the animal goes about its normal routine. Electro-Optical is a subsidiary of the Xerox Corp.

The idea is that the information obtained will make it easier to extrapolate data taken from chimps during space-environment tests and determine how a test would have affected an astronaut.



Swinging chimp can now enjoy life again. A special telemetry package, implanted within its body, does away with backpacks and protruding wires.

Versatile. Eventually, Electro-Optical plans to sell the device commercially for similar applications. For example, such a unit could possibly be used to monitor the operation of a pacemaker in a heart patient.

High-value resistors—up to one megohm—can be used because the pack is inside the chimp's body where the constant temperature overcomes thermal problems. The manager of the program for Electro-Optical, Robert Russell, says this allows for a relatively high-powered output signal that can travel as far as 1,200 feet—an order of magnitude improvement over previously developed devices transmitting from inside the body.

In addition, a full-scale receiver and a directional antenna can pick up the remote signal—something portable receivers are too weak to do. Only the path the signal travels limits transmission.

Canine check. A model is currently operating at Electro-Optical's research laboratory, and the company will deliver within a month a prototype for implantation in a dog to check out transmission. This encapsulated pack will measure 3¾ by 3 by ⅝ inches and weigh only two ounces. It will have a mercury cell battery putting out 500 milliamps for continuous use for 40 days and will transmit on one channel. The prototype will also contain a subcarrier oscillator working at 3.9 and 5.4 kilohertz, a biopotential signal conditioner, a bandpass amplifier to transform the oscillator's square wave into a sine wave for transmission and the signal transmitter.

The prototype package contains discrete components, but the company intends to put thick-film hybrid circuits in the final package.

Electro-Optical has a contract to deliver four units to the Air Force, excluding the prototype, with the first to be delivered around next April. These devices will transmit two multiplexed variables—temperature and electrocardiogram data or whatever else may be desired. Russell says transmission could be expanded to as many as four or five channels.

A saturated transistor switch rather than a magnetically latching relay will enable researchers to turn the device on or off remotely. "This saves weight and we feel it is more reliable," Russell points out.

End result. The final units will have a second subcarrier oscillator and bandpass amplifier for the second channel, a linear mixing amplifier for multiplexing and the circuitry for remote switching of the power.

The telemetry signals are transmitted in the f-m band at 88 to 108 megahertz.

Russell says the company first thought the package would need about 1,300 microamps. "But now," he comments, "it appears we will be able to get away with 530 microamps."

Depending on how the prototype works, the final design may be in the form of one or two packages. Russell observes that one advantage of having two packages would be that the battery could be implanted separately in an easily accessible place for simpler replacement.

Displays

IBM's new image

Increasingly, the International Business Machines Corp. is looking at the growing field of displays—generated by computers or by other equipment. One piece of gear that's being developed by IBM for this market is an electrostatic storage tube which is able to display bright, flicker-free, wall-size pictures. Additionally, the tube can store a picture for about a month without consuming energy or taking up computer time.

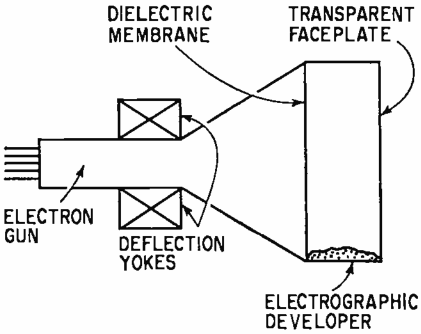
The tube was devised by Jan Engle, a researcher at IBM's Systems Development division in San Jose, Calif. With the basic work completed there, the project was moved to the division's Kingston, N.Y., facility for advanced development.

Dual chamber. Three basic parts make up the tube: a newly designed electron gun that boasts both high speed and high resolution, a dielectric membrane that can store a charge and an electrographic developer—a sand-like chemical with a net positive charge. The membrane divides the tube into two chambers, with the gun in one chamber and the developer in the other.

To produce a picture, the electron gun writes on the face of the dielectric membrane—much like an electron gun in a television picture tube writes on a phosphor coating. A latent image, written by the electron beam, is formed on the other side of the membrane; particles of the positively charged developer are attracted to the negative charges, which produce an image on the face of the membrane.

If the membrane is opaque, the image can be seen directly by reflected light; if it's transparent and the tube has a rear window, the image can be optically projected as a wall-size display. Both the direct-view and the rear-window tubes are currently under development.

Flexibility. Since the tube is sealed, it does not require vacuum equipment. And since there are no phosphors to be excited, it does not draw a high current. Further,



Display tube developed by the International Business Corp. is able to store information for a month without using current or computer time.

the optical-display system can be independently designed, permitting wide flexibility of application, ranging from high-density recording on film to the bright wall-size displays.

Tubes developed so far have a linear resolution of 2,000 television lines over a 3.4-inch diameter surface.

The principal disadvantage of the tube is the need for mechanically tipping it in order to dust the membrane with the developer. This takes less than one second, while erase time is a second and a half.

The first order of business at the Kingston labs is to solve the tipping problem.

Computers

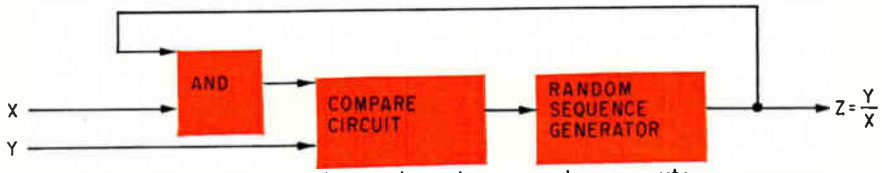
Dropping the guard

When a computer must work in an area cluttered with electromagnetic pollution, the traditional step is to protect its sensitive signals by shielding the entire machine with noise-absorbing screens. That approach is fine when the computer is being used in a factory, where space and weight are not at a premium. But in a missile or an airplane, where a few pounds and a few cubic inches count heavily, screening may be a bit of a problem. Now at the University of Illinois, a group of computer researchers has designed a series of analog computer circuits that depend on noise and therefore needn't be protected from it.

In the circuits, developed under the supervision of W.J. Poppelbaum, an electrical engineering professor, an analog quantity is represented by the average value of a sequence of randomly spaced pulses. The pulses are generated from white noise and a trigger level proportional to the analog signal.

Shaping the noise. The pulses are shaped and clipped so that all have the same duration and amplitude. Two or more such pulse trains applied to an ordinary diode AND gate, shown below, produce a random pulse sequence at the output; the average value of this sequence, after again shaping and clipping, is proportional to the product of the original analog quantity.

The quotient of two analog quantities can be obtained with a feedback network, shown below. In this network a random sequence generator produces a pulse train representing a quotient. An AND gate forms the product of the quotient and the divisor; the product is then compared with the dividend. If the two are unequal, the random sequence generator is automatically adjusted to make them equal.

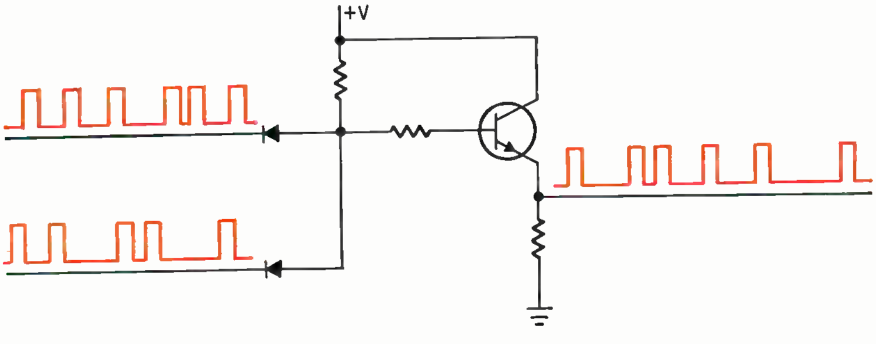


Ordinary AND gate, a comparator, and a pulse generator compute the quotient of two analog quantities.

The sum can be obtained just like the product, by using a diode OR gate, but a conventional adder network (a number of equal resistors with one common connection) is cheaper and works just as well. Likewise, the difference of two analog quantities is the sum of one and the logical inverse of the other; if the basic pulse train has positive-going pulses from a negative reference, the inverse would have the same voltage swing but negative-going pulses from a positive reference.

Problem-solving. With a sufficiently large number of units for performing the four basic arithmetic operations, theoretically almost any problem can be solved. The speed is limited only by the width and average frequency of the noise pulses; fractional nanosecond noise pulses can be obtained from a diode reverse-biased close to the avalanche point, providing a frequency response in the neighborhood of 500 megahertz.

The principal limitation to the circuits, as with any analog system, is in their precision. For example, a problem might be solved to a precision of 1% by taking the average value of 1,000 noise pulses; but 10 times the precision, or 0.1%, would require an average of perhaps 100 times the number of pulses. A very complex analog computer with a limited degree of precision can be designed at a fraction of the cost of ordinary analog machines that use operational amplifiers; but the circuits cannot economically approach the precision of digital computers.



Analog multiplication, using noise, can be performed with an AND gate.

AIAA meeting

Closer link

The dinosaur is extinct because it couldn't respond fast enough to attacks from the rear. The communications network between brain and tail was too lossy.

The Avco Corp.'s Electronics division in Cincinnati has developed a new approach to airborne high-frequency communication in order to prevent lossy communications aboard flying behemoths. The system will go into the C-5A, a heavy logistic transport aircraft being built for the Air Force by the Lockheed Aircraft Corp.

To avoid stringing a lossy coaxial cable 260 feet from the cock-

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pit electronics bay to the tailfin antenna, the h-f radio transceiver and antenna coupling equipment will be installed in the tail of the plane. Only wires carrying low-level control signals will traverse the distance from cockpit to tail.

The development was disclosed at the meeting of the American Institute of Aeronautics and Astronautics in Boston this month.

The new h-f system will also include binary tuning, controlled by integrated circuit logic. This will eliminate servomotors, precision gearing, sliding contacts and other mechanical techniques traditionally used to vary inductances and capacitances. The electronic tuning system is identical to one developed by Avco for the F-111 fighter-bomber now being built.

More power. Besides the drastic reduction in weight achieved by eliminating 260 feet of heavy coaxial cable, Avco designers say the radio-in-the-tail design will eliminate radio-frequency interference problems along the length of the fuselage and result in a higher level of radiated power.

"Putting the transmitter and receiver in the tail, with direct coupling to the antenna, effectively doubles the range of the communications system," according to applications engineer Bert Beitman.

The Avco system, called the AT-440, combines transmitter and antenna coupler in one piece of equipment called a couplifier. The plate of the power amplifier tube is matched to the antenna across a small length of coaxial cable, not more than two feet. Under present design plans for the C-5A, the shunt-type antenna will be part of the leading edge of the plane's vertical tailfin, and the radio equipment will be installed in the tail, just below the fin.

With the couplifier, says Beitman, receiver signal-to-noise performance can be improved up to 10 decibels, resulting from elimination of coaxial noise and impedance mismatch.

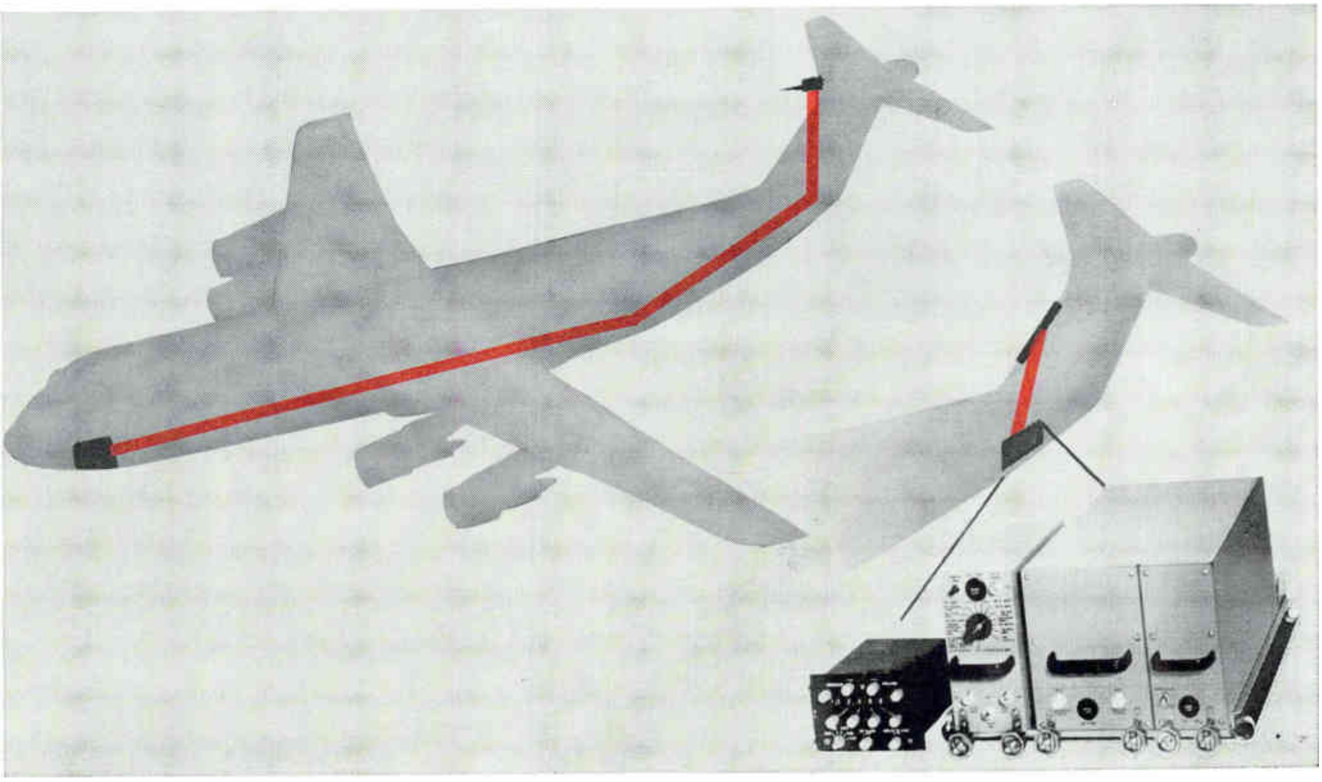
"You dump half of your power with the traditional cable and fittings, plus causing rfi problems," says Beitman.

Mismatch. There will still be a mismatch between antenna and cable, but the cable will be only two feet, and the standing wave losses will be drastically lower.

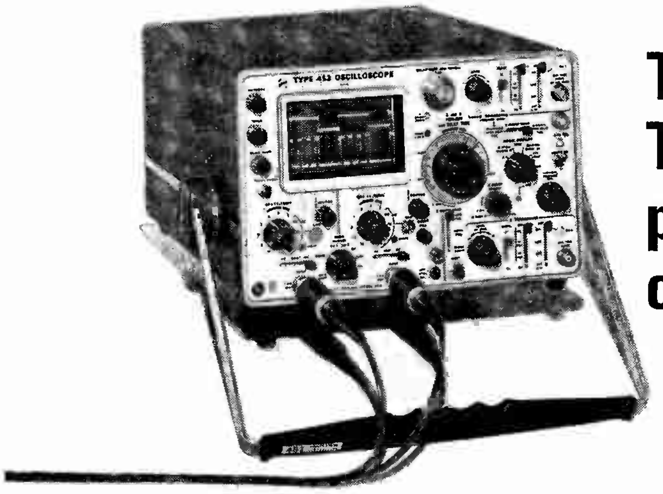
The binary tuning system in the AT-440 is part of the AN/ARC-123 radio which Avco has designed for the F-111. The F-111 and the C-5A represent the first applications of the technique to matching and tuning in communications systems.

The complete tuning time is 300 milliseconds. Under control of the computer logic, sensors in the couplifier probe r-f levels in 10-millisecond samplings, switching inductance coils on or off at each step to refine the tuning and match impedance loads. The coils are switched by relays which operate in a vacuum to heighten reliability and provide the required voltages in a small switch area. The relays never operate while transmitter power is on, a further protection for reliability purposes. Sampling is done for 10 seconds, then the r-f energy is removed while switching is accomplished. And the procedure is repeated until optimum match is obtained.

The AT-440 control box, the only part of the system up front, contains the solid state digital syn-

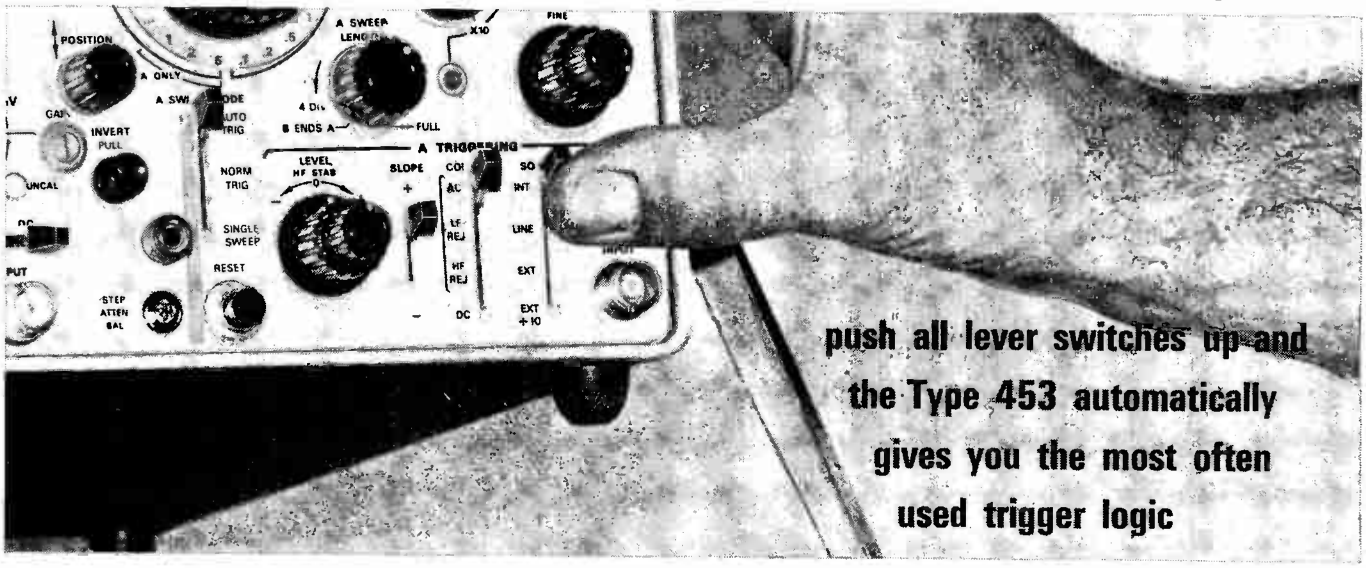


Radio-in-the-tail design shortens the transmission path between antenna and receiver. Design is for Lockheed's C-5A.



Tektronix Type 453 portable oscilloscope

takes the guesswork out of triggering



The Type 453 provides the following features when all lever switches are up: automatic triggering that allows discrete trigger level selection with the presence of a signal and provides a bright base line at all sweep speeds when no signal is present; + slope triggering; AC coupling that gives positive triggering regardless of vertical positioning; and internal triggering that makes full use of the vertical amplifier gain and the compact internal delay line. The Type 453 will trigger to well above 50 MHz and a green light gives a positive indication of a triggered sweep.

The Type 453 is a portable instrument with rugged environmental capabilities plus the built-in high performance normally found only in multiple plug-in instruments.

The vertical amplifier provides dual trace, DC to 50 MHz bandwidth with 7 ns risetime from 20 mV/div to 10 V/div. (DC to 40 MHz, 8.75 ns T_r at 5 mV/div.) The two included Type P6010 miniature 10X probes maintain system bandwidth and risetime performance at the probe tip—DC-50 MHz, 7 ns—with an increase in deflection factors of 10X. You can also make 5 mV/div X-Y and 1 mV/div single trace measurements.

You can operate the delayed sweep with ease. Lever control to the right and HORIZ DISPLAY switch to A INTEN DURING B gives delayed sweep operation. Setting the B TIME/DIV and the DELAY-TIME MULTIPLIER to meet your requirements and switching to DELAYED SWEEP allows ±1.5% delay measurements to be made.

The Type 453 is a continuation of the Tektronix commitment to quality workmanship. Its design and layout make it easy to maintain and calibrate. Transistors plug in and are easily removed for out-of-circuit testing. An accurate time (±0.5%) and amplitude (±1%) calibrator permits quick field calibration.

The front panel protection cover carries all the accessories with the complete manual carried in the rain/dust cover. The Type C-30 Camera and a viewing hood that fits in the rain cover also are available.

Type 453 (complete with probes and accessories) . . .	$2050.00
Type C-30 Camera	$ 350.00
Collapsible Viewing Hood	$ 7.50

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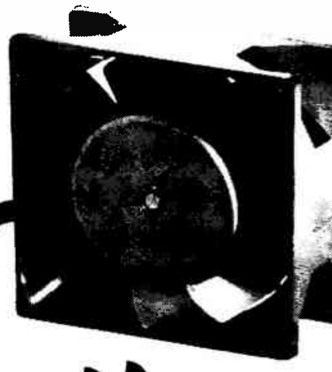

thesizer. Operating frequencies may be selected in 100 hertz increments from 2 to 29.999 megahertz. Other controls include those for audio volume, r-f gain, noise blanking, squelch disable and level, and system on-off. For high reliability design, the control box uses 85% integrated circuits.

Tuned to space

Ground-based radio telescopes, no matter how sensitive, can't detect celestial radio sources between 1 and 10 megahertz because the earth's atmosphere blocks these electromagnetic waves. At the AIAA meeting in Boston this month, the Avco Corp.'s Space Systems division proposed the orbiting of twin satellites some 6,000 miles out in space to hunt out these signals.

The twin-satellite plan stems from the need to keep the antenna system for such a project down to a workable size. With frequencies as low as 1 Mhz, the wavelengths that must be measured are 300 meters; to achieve a beamwidth resolution of about 1°, an antenna would have to be 12 miles wide.

Far apart. As an alternative, Avco's engineers propose the use of two satellites spaced six miles apart and acting as a single interferometer.

The antennas on each satellite would measure the relative phase and amplitude of the radio sources, and the combination of satellite relative motion and ground-data processing would be used to synthesize a large antenna aperture.

Avco selected a frequency range of 1 to 5 Mhz as one that could be used in such a space system to return information on discrete sources of radio energy, such as remnants of super novas, peculiar giant galaxies, and quasars. The company also settled for a resolution of 2° at 1 Mhz.

Each satellite would consist of a four-foot-diameter central body to house the electronic systems and a pair of 150-foot-long X-shaped antennas. Each antenna would be mounted on the end of a 37-foot boom extending from the satellite body.

Compromise. The trick would be to put the satellites into an orbit high enough to keep them away from the disturbing influences of the earth's atmosphere, but low enough to permit them to drift six miles apart in a reasonable time. At the 6,000 miles envisioned in the plan, Avco calculates the satellites would separate by 37.5 meters once each orbit of 5.8 hours. At this rate, they would reach the required interval of six miles in 64.3 days. During the separation process, measurements could be taken first at 5 Mhz and thereafter on down to 1 Mhz.

Once a certain portion of the sky had been studied, the satellites could be maneuvered to drift back together and the process could be repeated to study another portion. Francis W. French, an Avco engineer, estimates that the two satellites could cover 70% of the sky during their first 18 months in orbit.

Point the way. Proper attitude would be maintained by the antennas themselves acting as gravity gradient stabilization booms, keeping one of the antenna dipoles always pointing straight down. To maintain very accurate distances between the satellites, small cold-gas reaction jets would be fired at thrusts measured in thousandths of a pound. French estimates that 50 watts of continuous power would be adequate for each satellite and could be supplied by solar cells.

Addenda

Also at the AIAA meeting:

- Samuel C. Phillips, Apollo program director, said the software for the Apollo guidance and navigation computer may in the long run cost more than the hardware. More than 300 persons at the Massachusetts Institute of Technology are now programing computer subsystems for the various missions.
- The communications blackout during the Apollo reentry maneuver apparently doesn't worry the mission managers as much as it does NASA research groups. George E. Mueller, NASA associate administrator for manned space flight, said there are no plans to incorpo-

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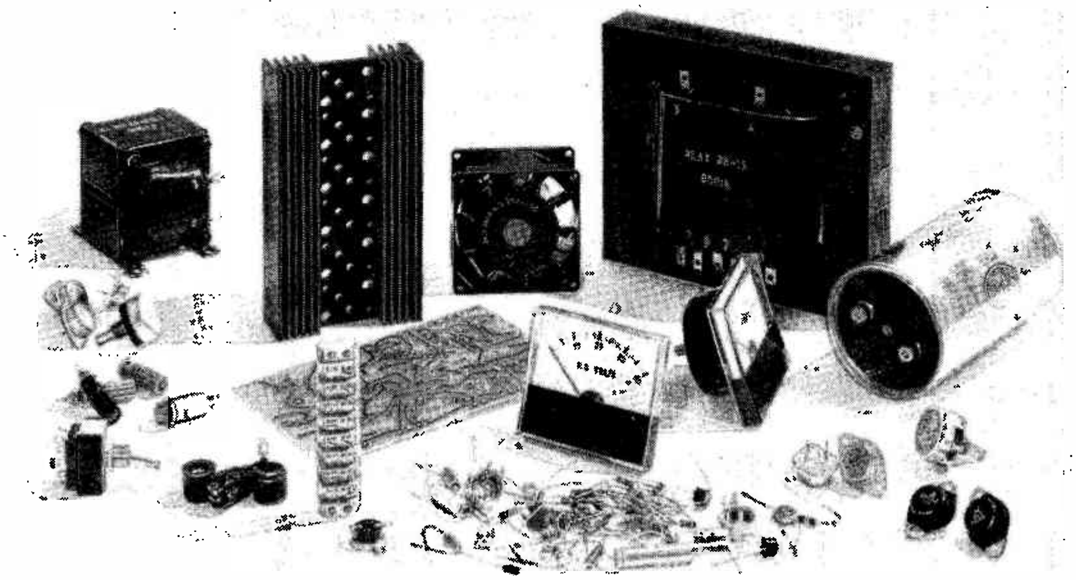

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rate a fluid injection system [Electronics, Nov. 14, p. 54] or any other technique to get signals through the plasma sheath that will envelop the vehicle. A fluid injection system would require structural changes in the spacecraft, and this undoubtedly is one reason why it isn't being considered at this late date.

▪ The space agency has decided to seek competitive proposals for flight models of an auxiliary memory system developed for the Apollo computer by the Raytheon Co. [Electronics, Oct. 31, p. 26]. The memory was first ordered by NASA in the belief that the standard Apollo guidance and control computer wouldn't be adequate for the moon trip; but NASA has decided to use the unit only in the follow-on Apollo Applications Program. The memory consists of 16,000 words stored on digital transistor logic (DTL) flatpacks and another 1.5 million words in the triple redundant mode stored in a tape unit. Each word consists of 15 bits plus a parity bit.

By using the memory unit in the simplex mode, as many as 4.5 million words can be stored, the company said.

▪ The electronics for the nation's first satellite-borne X-ray astronomy experiment will be redesigned as a result of schedule changes in the Apollo program. Now planned sometime after the summer instead of February, the flight will be the first in which a manned vehicle has been used for a complex scientific experiment.

"Its success or failure can be a guidepost for the Apollo Applications Program," says John R. Waters, project scientist.

A change in the Apollo vehicle will improve detection instrumentation. In the original spacecraft, a shield guarded against the effects of radioactivity in the fuel gauge system. The new vehicle will jettison the shield to make room for larger and more sensitive X-ray gear. The astronaut will search for an X-ray source and when he finds it, he'll maneuver the spacecraft into the best position and hold it there.

Consumer electronics

One for all

The Westinghouse Electric Corp. early next year will market a phonograph in which one integrated circuit replaces all electronic components. Containing the equivalent of 39 transistors, diodes and resistors, the Westinghouse-made IC itself will also go on sale early in 1967.

The Westinghouse phonograph, to be priced at about $50, is a one-watt battery-powered model. Because of the mechanical drive system, it's about the same size as a previous model, which contained 18 discrete components.

"Engineers have combined voltage and power amplification with this chip to unite for the first time all the requirements for an electronic consumer product," says a Westinghouse spokesman.

Trends. Other companies use IC's in consumer products, but the items also contain discrete components. The General Electric Co. has developed a portable radio the size of a cigarette pack, with an IC that includes all the active components and some resistors but with the remaining passive components attached to a printed-circuit board [Electronics, July 11, p. 40]. Two models of the radio will be available late this month and the prices ($39.95 and $29.95) compare favorably with comparable discrete-component radios.

GE has put IC's in the audio amplifiers of three other consumer products—a phonograph, a portable television set and an eight-track cartridge tape player for home use.

Industrial electronics

Stop gap

Engineers at the Texas Transportation Institute say they have found a way to sharply reduce the auto-traffic accordion effect—the bunch-

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	P_T	BV_{CBO}	V_{CEO} (SUS)	BV_{EBO}	h_{FE}		V_{BE} (sat)	V_{CE} (sat)	I_{CBO}	f_T
	Watts 25°C Case	Volts	Volts	Volts			Volts	Volts	μA	MHz
		I_C = 1mA	I_C = 0.2A	I_E = 1mA	I_C = 40A	I_C = 60A	I_C = 40A	I_B = 6A	V_{CB} = 100V	
	Max.	Min.	Min.	Min.	Min.	Min.	Max.	Max.	Max.	Typ.
SDT8951	350	200	200	8	10-40	5	2.0	2.0	10	20
SDT8952	350	225	225	8	10-40	5	2.0	2.0	10	20
SDT8953	350	250	250	8	10-40	5	2.0	2.0	10	20
SDT8954	350	275	275	8	10-40	5	2.0	2.0	10	20
SDT8955	350	300	300	8	10-40	5	2.0	2.0	10	20

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ing up of cars on high-speed highways. So satisfied are they with the solution—a computer-controlled traffic-light system at entrance ramps—that plans are under way to extend the system to cover a six-mile stretch of the Gulf Freeway in Houston.

A prototype designed and installed by the Taft Broadcasting Co. of Houston has been in operation at a freeway access ramp during the morning traffic rush for the past 14 months. Studies show that traffic speed during the test period increased 30% and traffic volume rose 10% while the number of accidents fell 50%.

Flashing lights. The system works this way: overhead sensors detect gaps in freeway traffic, send a signal to a control center and a computer controls the ramp traffic signal. If there is room the light flashes green; if traffic is too heavy, the light remains red until the sensors again detect a gap in the traffic flow. The presence or absence of cars on the access ramp is detected by sensors beneath the pavement.

Avionics

Toward a standard

The Airline Electronic Engineering Committee, whose job it is to set international avionics standards for all commercial planes, early this month settled on standards for a second-generation weather radar and for inertial navigation systems.

Equipment produced under these criteria will be built into such planes as the Boeing Co.'s giant 747 subsonic transport, the Anglo-French Concorde supersonic transport and the United States version of the SST. In fact, it was the rapid progress toward the design of the Concorde and the 747 that spurred the committee to speed its rulings on the standards.

Things to come. The committee is made up of engineers representing both U.S. and foreign carriers and is sponsored by Aeronautical Radio, Inc., (Arinc), which is jointly owned by the airlines. Working with avionics and aircraft producers, the panel sets the Arinc equipment standards, which cover not only such factors as outside configuration, interwiring, input-output and connections, but often the operational specifications for electronic hardware.

Although the Arinc committee's aim is to achieve standardization of avionic gear—especially to make equipment interchangeable — airlines aren't committed to installing only equipment that fits the committee's standard. Realistically, the problem of redesigning an aircraft installation to accommodate a special piece of gear would be prohibitively expensive for an airline.

Approval of the weather radar specification caps nearly two years of work by the committee, according to William T. Carnes, Arinc avionics engineering manager and chairman of the group. Frank C. White, manager of communications-data processing for the Air Transport Association and head of the panel's radar subcommittee, says the panel " later will probably come out with a more sophisticated version of the radar for follow-on SST's. Later SST's may require a two-frequency weather radar, some officials believe.

Controversy. The standard gear was originally slated to be X-band only, but late in the game some airlines wanted it expanded to include the next generation of C-band. The frequency controversy continues.

The Arinc specification doesn't presage a big step in technology. To avoid what the airlines considered to be the high cost and complexity inherent in more advanced systems, such techniques as electrically steerable antennas weren't considered. The group did consider specifying complete interchangeability of units but decided against this because of the restrictions such a move would place on designers.

The radar standard sets forth a new way to calculate performance, White notes—a "performance index." This index relates the radar equation "to the real world—how far you'll see a storm," he explains. An airline will specify the range it wants and the builder will know

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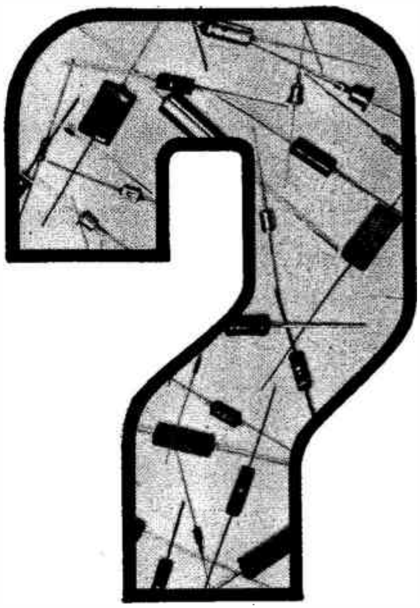

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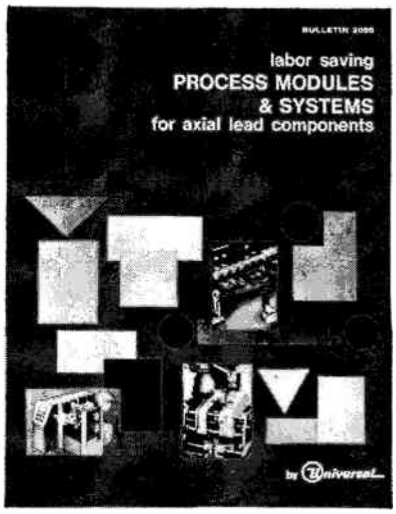
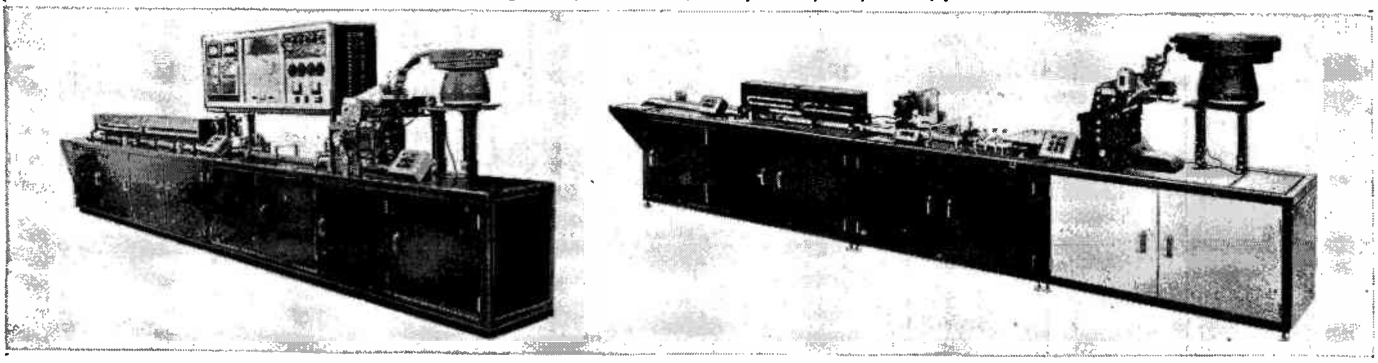


Typical process systems including bowl feed, lead straightener, line loader, multiple test, sort, orient, print and cure.



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Universal INSTRUMENTS CORPORATION / E. FREDERICK ST., BINGHAMTON, N. Y. 13902 / 607-772-1710 what he has to do. Up until now, radar performance has been a "gambler's choice and a salesman's gambit," White says.

The index may also be applicable to the aircraft equipment needed for satellite communication, the official says.

Display. Although a bright display—a direct-view storage tube—is more expensive, less reliable and has less gray-scale capability than conventional tubes, it is specified for the radar to insure adequate visibility of the display in all cockpit light conditions. The antenna is restricted to a 30-inch diameter because of the tapered noses of jetliners.

The inertial navigation system characteristic doesn't include all the detailed specifications normally given in an Arinc document, but it does define the basic installation and interchangeability standards urgently needed by airlines and manufacturers. The entire specification was approved, Carnes says, subject to the working out of digital data standards at a meeting of the inertial navigation subcommittee in Washington on Dec. 15.

Basic system. From the beginning—despite a request by some hardware builders for a specification covering a large central digital process system to integrate the platform with other aircraft systems—airline interest has concentrated on a basic navigator that would include only the computation gear necessary for a "minimum system." The platform will supply to the computer only aircraft position and velocity data needed to compute vertical navigation and steering command signals. If more complex signals are needed, another computer could be selected without changing the basic inertial system.

Although most carriers indicated a preference for a single unit design, the committee decided to accept some restrictions and limitations in order to achieve both current "standard installation" and provide for future design trends. Specified is a navigation unit containing sensors and associated stabilization platform, plus control and computation circuitry to operate the platform and signal processing. The computer and associated circuitry can be packaged in a separate case as an option.

Connector. The standard significantly reduces the necessary interwiring by prescribing circuit multiplexing and direct "Y" connections to the platform and the optional electronics unit.

The airlines say it is absolutely imperative that the inertial system's digital signal be standardized wherever an interface between another system currently exists or will in the future. Two basic types of digital transmission have been proposed: two three-circuit serial data transmission systems and a two-circuit system to transmit incremental data by bipolar d-c signal on one three-wire circuit and the clock signal on the other circuit.

Electronics notes

- **Hard copy.** The Xerox Corp., which specializes in the office-copying field, now has branched out to produce peripheral computer gear. Its product, naturally, has the Xerox electrostatic machine as its building block and produces hard copy of graphics generated by a computer. The product, called a Xerox Computer Adapter, ties in with the company's Long Distance Xerography (LDX) system to transmit computer graphics to any remote location via telephone lines.
- **New failure mode.** Investigators at the Sudbury reliability analysis laboratory of the Raytheon Co.'s Space and Information Systems division have found that catastrophic lead bond failures can be induced under pulse conditions in small signal transistors. Such failures occurred when high forward current pulses were applied at a low repetition rate to the emitter base junction of wedge bonded transistors. The Raytheon experimenters postulate that the failures resulted from thermal expansion of the wire in a section close to the bonded area. This portion, particularly in aluminum - to - aluminum wedge bonded transistors, is work-hard-

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MC301/MC351	5-Input OR/NOR Gate	7.5	7.5	37
MC302/MC352A	R-S Flip-Flop w/Buffered Outputs	10.5**	11.5†	43
- /MC352	R-S Flip-Flop	10.5**	11.5†	40
MC303/MC353	Half-Adder	7.0	8.0	63
MC304/MC354	Bias Driver	—	—	18
MC305/MC355	Gate Expander	5.0	4.0	—
MC306/MC356	3-Input OR/NOR Gate	7.5	7.0	37
MC307/MC357	3-Input OR/NOR Gate	7.5	7.0	15
MC308/MC358A	AC-Coupled J-K Flip-Flop w/Buffered Outputs	8 **	10 †	87
- /MC358	AC-Coupled J-K Flip-Flop	8 **	10 †	50
MC309/MC359	Dual 2-Input NOR Gate	6.5	8.0	54
MC310/MC360	Dual 2-Input NOR Gate	6.5	8.0	54
MC311/MC361	Dual 2-Input NOR Gate	6.5	8.0	41
MC312A/MC362A	Dual 3-Input NOR Gate w/Buffered Outputs	7.5	7.0	70
MC312/MC362	Dual 3-Input NOR Gate	7.5	7.0	54
MC313F/MC363F	Quad 2-Input NOR Gate	6.5	8.0	125
MC314/MC364	AC-Coupled J-K Flip-Flop	12 **	13 †	118
MC315/MC365	Line Driver	14	12	270
MC316/MC366	Lamp Driver	—	—	135
MC317/MC367	Level Translator — MECL to Saturated Logic	30 **	25 †	63
MC318/MC368	Level Translator — Saturated Logic to MECL	17	16.5	105
- /MC369F	Dual 4-Input Clock Driver/High-Speed Gate	3	3	250
- /MC369G	Dual 2-Input Clock Driver/High Speed Gate	3	3	250

†† MC300 Series −55 to +125°C ** t_{d+}
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ened and inflexible. The researchers suggest that the effect may be minimized using low-resistivity lead wires with a low coefficient of work-hardening. Lead movement under current pulses was also noted in gold bonded devices.

▪ **Frequency split.** The Federal Communications Commission has ordered land mobile stations operating in the 450- to 470-megahertz band to reduce channel spacing from 50 to 25 kilohertz [Electronics, Oct. 17, p. 40]. The order will increase the number of authorized channels to about 600 and temporarily relieve frequency congestion in metropolitan areas. Although existing stations have until Nov. 1, 1971, to change over, stations licensed after Nov. 1, 1966, must comply by June 1. 1967. The order means land mobile stations will either have to modify their transmitters or buy new ones. It costs from $70 to $100 to convert a transmitter.

▪ **Emergency radio.** The Air Force is flight testing three developmental models of emergency radios small enough for pilots to carry in their vest pockets. Designated the AN/URC-64, the radio will weigh 1 pound and operate on four channels in the ultrahigh frequency band. One channel will be the international distress frequency. Although the final design won't be approved until the device is tested, the initial models use thick-film, hybrid integrated circuits. The Magnavox Co.'s Research Laboratories at Torrance, Calif., is developing the radio under a $334,000 contract from the Air Force Systems Command. The flight tests are being made at Wright-Patterson Air Force Base, Ohio.

▪ **Lay-offs.** The General Electric Co.'s computer plant in Phoenix, Ariz., will lay off 450 employees over the next few weeks. The company explained the move would bring employment levels in line with contracts.

▪ **Acquisition.** The Perkin-Elmer Corp. will buy the Aerospace Systems division of Scientific Data Systems, Inc. The division develops electro-optical equipment for space and defense programs.

▪ **Price cut.** The Admiral Corp.

has lowered the so-called fair trade minimum prices on 18 color television sets to meet competition in the New York metropolitan area. The company says the reductions apply only to the New York area, which is the only place where Admiral products are fair traded. The General Electric Co., Magnavox Co., Zenith Radio Corp. and the National Union Electric Corp. say they are not considering any price changes. National makes Emerson and DuMont sets. The Radio Corp. of America, which increased prices on some sets in September, also reported that no price changes were planned.

▪ **Chemicals from coal.** Add another application for the laser. Researchers at the Interior Department's Bureau of Mines report that lasers have been used to break down coal into its chemical components. The results also indicate that the technique—firing the beams at coal for split-second intervals—may eventually be successful in producing some chemicals for less than it would cost using conventional methods. Bureau scientists, focusing 2- to 10-joules of laser energy at the coal, generated temperatures of more than 1,000°C. The gases liberated in the process were cooled rapidly to prevent a secondary chemical reaction.

Analysis showed that the products formed contained up to 25% acetylene and lesser amounts of diacetylene vinyl-acetylene, hydrogen cyanide, ethylene and ethane. The reaction occurs in milliseconds, whereas conventional techniques for producing the chemicals, using carbonization methods, may take hours.

▪ **Electronics, too.** Johnson & Johnson, one of the largest suppliers of medical products, is entering the medical electronics field as a distributor. The company has signed an agreement with United Aircraft Corp.'s Vector division to act as the exclusive distributor of United's electrocardiogram electrode.

The EKG electrodes, called Telectrodes, are disposable sensors that are applied to a patient's body with adhesive.

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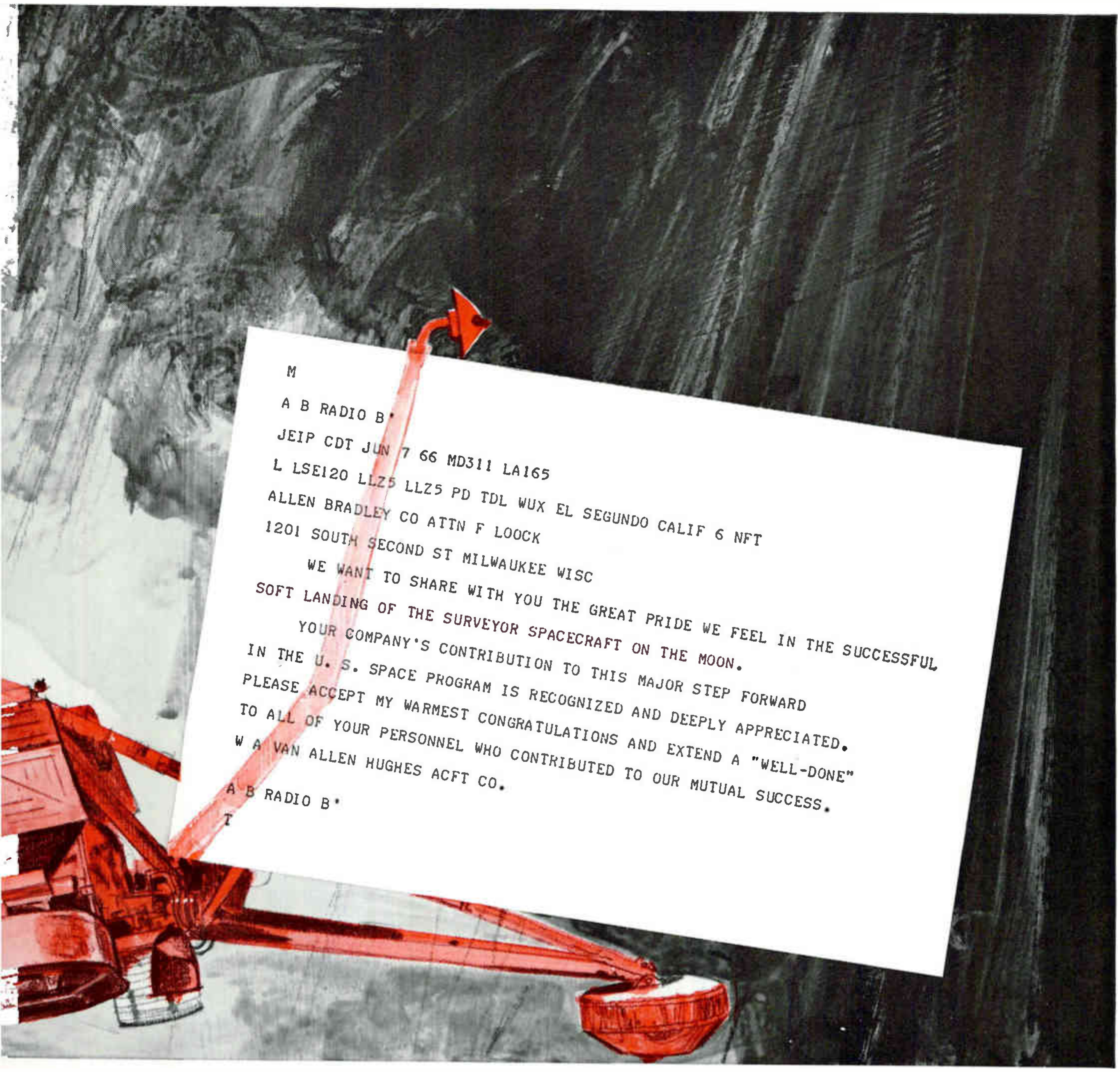

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Slew rate	3.2	30	3.2	V/μs
Voltage gain	2,700	2,700	50,000	
Offset voltage	2.0	2.0	2.0	mV
Offset current	80	400	80	nA
Thermal drift	±5 ±1	±5 ±5	±5 ±1	μV/°C nA/°C
Undistorted output swing	21	21	9 (11.6)†	V_{P-P}
Power dissipation	90	160	90	mW
Common mode rejection	100	100	100	dB
Power supply rejection	100	100	100	dB
Input bias current	0.4	1.0	0.4	μA

*Standard temperature range: −55°C to +125°C. V⁺ = +25V; V⁻ = −15V.
†V⁺ = +20V; V⁻ = −20V.

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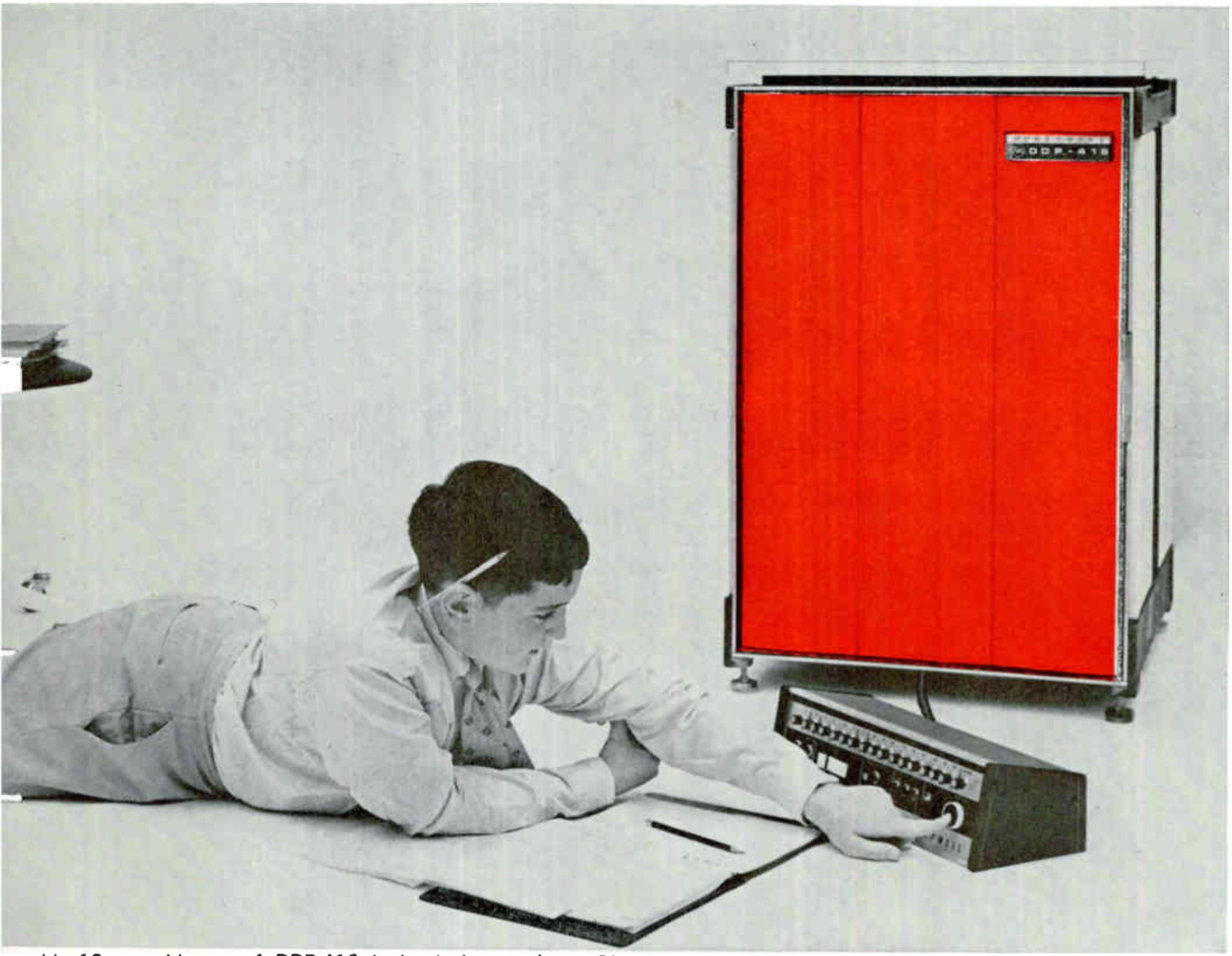

onald, 12-year-old son of DDP-416 logic design engineer Bill Woods, writing software demonstration program for new ·COMP computer.

ubtract, Logical AND, Exclusive OR, crement Memory and Skip, Jump, ump-Skip. And two-cycle I/O com- ıands that select device, test status, nd transfer data without I/O hold-off. iority interrupt and power-failure pro- ction are standard.

ODULAR CONSTRUCTION . . . system ower supply, central processor and a ,096 word memory (expandable to 6,384 words) are mounted in a single 4" x 24" x 38" cabinet. Tilt out con- ruction gives you easy front access to th modules and interwiring. The con- l console is moveable and the entire omputer may be mounted in a stan- ard 19" rack.

XPANSION CAPABILITY . . . memory rity, memory lockout, real-time clock nd multiplexed channel for multi-sta- on time-shared I/O capability are all asy to add as plug-in options.

nd if your problem is too big for the DP-416, or if you think you'll grow out it too fast, you may want the more owerful μ-COMP DDP-516 for $25,000.

IMPLIFIED SOFTWARE . . . it may take bright 12-year-old to work with the DP-416, but you'll find it a snap to rogram. The package of 50 programs is written in a simple format to give the real-time systems builder extended flexibility. You get mathematical and I/O subroutines, complete diagnostics, DESECTORIZING that lets you ignore memory addressing restrictions, a de- bug program, plus participation in our active users' group.

Best of all, if you decide to get the more powerful DDP-516 in the future, you can continue to use your DDP-416 programs because of direct compati- bility.

DELIVERY . . . both hardware and soft- ware, second quarter of 1967.

IMMEDIATE DELIVERY RESERVATION
FILL OUT AND RETURN COUPON NOW

☐ Please reserve a DDP-416 and confirm approximate delivery date. Send more information by return mail. Hold this delivery date for me for 15-days so I can make a final decision and get my P.O. to you.

☐ Don't reserve a DDP-416 for me yet. I need more facts. Send me your DDP-416 summary brochure.

☐ I think I need a more powerful computer. Send me your DDP-516 summary brochure.

Name____________ Title____________

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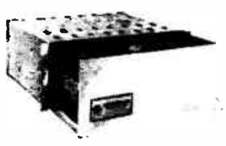
Please attach this coupon to your letter- head — we'll take it from there.
Honeywell, Computer Control Division
Customer Services
Old Connecticut Path
Framingham, Mass. 01701

Honeywell

3C COMPUTER CONTROL DIVISION

Now you can throw out less versatile storage techniques. A Ferroxcube core memory costs as little as $1,190.



We haven't been a leading core memory manufacturer all these years for nothing. We learned how to mass produce core memories and thereby sell them to you at prices competitive with less reliable, less versatile storage techniques.

Aside from price (we'll get back to that in a moment), consider the advantages of core memory systems. Speed. Random access. Non-dissipative. And they're non-volatile. We could go on and on. We won't because you've probably always wanted to design your system around core storage anyway. Only the cost stopped you.

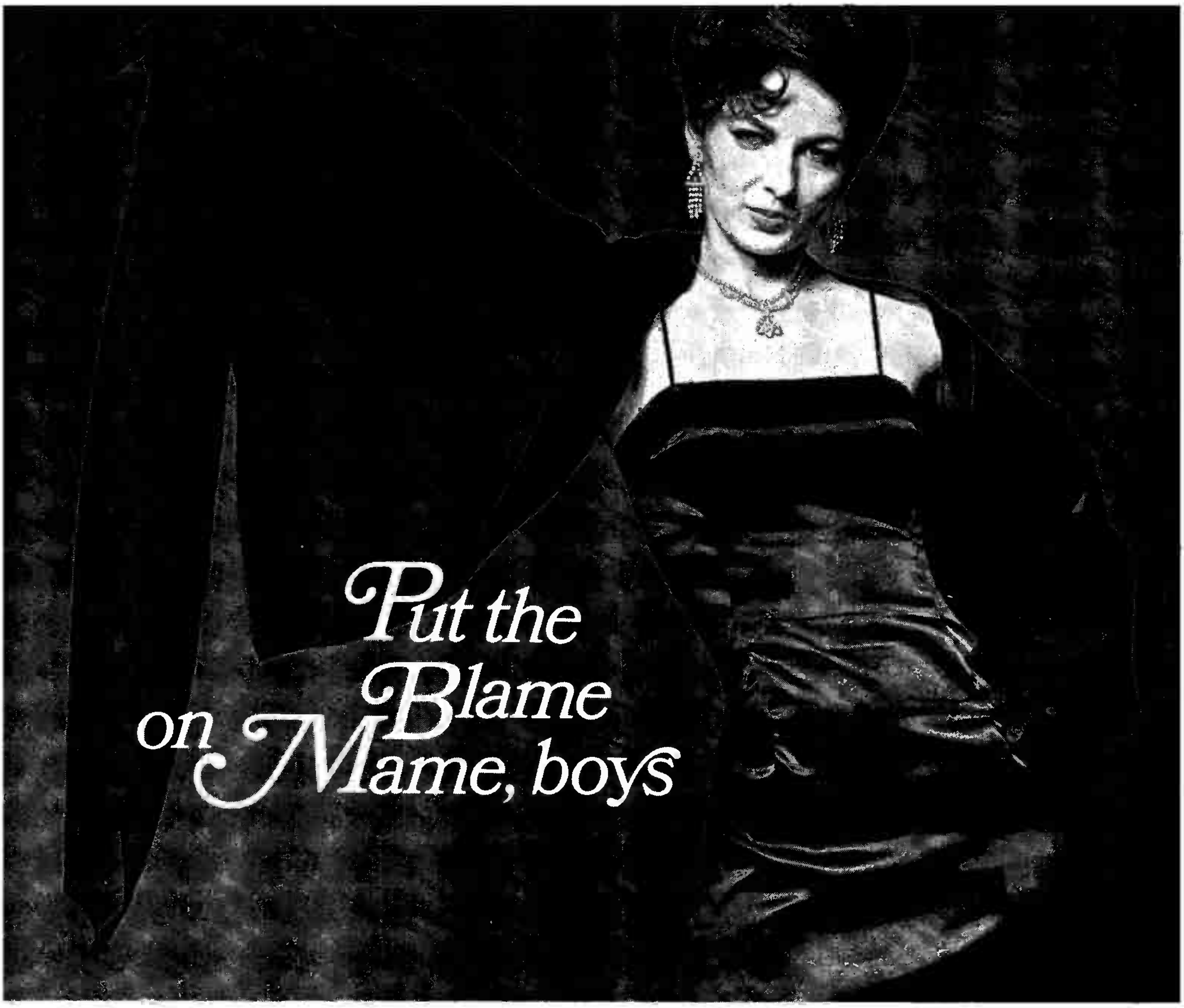
Now you can buy a Ferroxcube 128 x 8 core memory system complete with stack electronics, data register and timing for a paltry $1,190. That's our FX-12. Its capacity ranges up to 512 x 8. The FX-14 picks up there and goes on to 4,096 x 32. Prices are comparably low. Moreover, the FX-14 is available with almost any choice of interfacing elements. Buy only what you need to interface with what you already have.

In brief, Ferroxcube core memories make both functional and economic sense. Write or call for Bulletin M661.

Ferroxcube

FERROXCUBE CORPORATION OF AMERICA
Saugerties, New York 914-246-2811

Boston 617-899-3110 · Chicago 312-261-7880 · Dallas 214-255-0441 · Los Angeles 213-837-1484 · Minneapolis 612-333-4381 · New York Area 201 267-5888 · Phoenix 602-265-1792 · Philadelphia 215-927-6262 · Washington, D.C. 703-893-4900

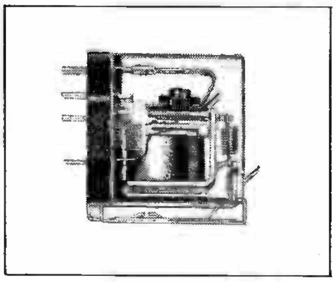


Donna Dinkler is a final inspector on one of our series 1220 relay production lines. The little picture below shows her doing her job. We only called her "Mame" up above because—well, we had trouble trying to rhyme Donna Dinkler.

Anyway, you'll look a long time before you find an inspector that's fussier than Donna. A 1220 doesn't measure up in *every way* and ZAP! Into the reject pile.

Now this kind of painstaking inspection doesn't speed up the production of 1220's one single bit. But it's the only way to assure that the 1220's you get are no less than perfect.

Multiply Donna by the other inspectors on the series 1220 lines and their fussiness and you see why we occasionally have sales running ahead of delivery. *So many engineers have found these versatile, enclosed 10 amp. DPDT or*



3PDT relays to be so reliable and long lived that we're hard pressed at times to keep up with the demand. The 1220 is a U/L listed relay with terminals that can be used as solder lug, AMP Faston 110 series quick connect or socket plug-in that comes complete with mounting bracket.

So, if you need 1220's in quantities up to 399, see *your Guardian distributor*. If you need larger quantities order direct from factory production. If you want more information, send for bulletin B2.

GUARDIAN ELECTRIC®

1550 W. Carroll Avenue, Chicago, Ill. 60607
Guardian Electric Manufacturing Company,

Circle 69 on reader service card

TYPE 209 **WIDEBAND PRIMARY PHASE STANDARD**

FEATURES:

Accuracy 0.015°, resolution 10 micro-degrees (10^{-5}).

Self-calibration, self-checking by means of fundamental bridge balancing, without the use of an external standard.

Directly traceable to National Bureau of Standards.

USES

- As a primary wide-band phase standard in any standard laboratories.
- For accurate measurement of phase shift of an unknown network.
- For calibration of phase meters, complex ratio bridges and phase sensitive equipment.
- As a precision phase meter, measures phase shift between two voltages.

SPECIFICATIONS:

FREQUENCY — Continuous coverage from 50 cps to 10 kc with rated accuracy.

PHASE RANGE — Can be set for any phase angle from 0° to 360° with 7-digit resolution.

ACCURACY — ±0.015° for 50 cps to 1 kc; ±0.02° from 1 kc to 2 kc; ±0.03° from 2 kc up to 3 kc; ±0.04° from 3 kc up to 5 kc; ± 0.07° up to 10 kc.

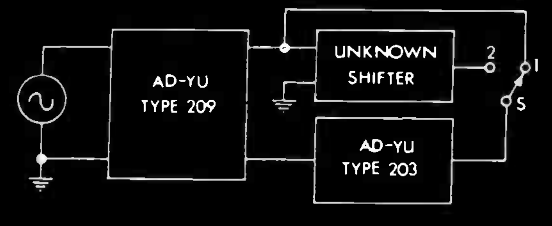
RESOLUTION — 0.00001 degree (10 micro-degrees).

MAXIMUM INPUT — 70 volts rms above 200 cps; 0.35 x signal frequency below 200 cps.

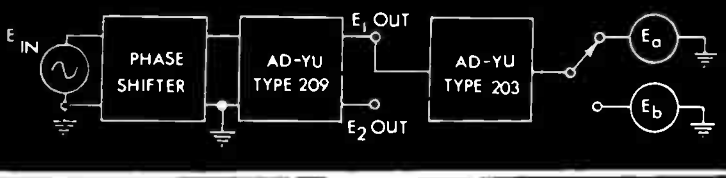
REQUIREMENT FOR INPUT SIGNAL: Percentage of Frequency Stability — Less than 0.14 x maximum tolerance of phase error in degree. Waveform Distortion — Less than 0.2% desirable; Source Impedance — 600 ohms or less.

MAXIMUM OUTPUT SIGNALS — 50 volts above 200 cps; decreases to 0.25 x signal frequency below 200 cps.

Measure phase shift of unknown network with accuracy better than 0.02



Measure phase between two signals, E_a and E_b with AD-YU Type 203 as null detector. Phase angle between E_a and E_b is read directly on the 7-digit dial of Type 209.



ADYU ELECTRONICS INC.

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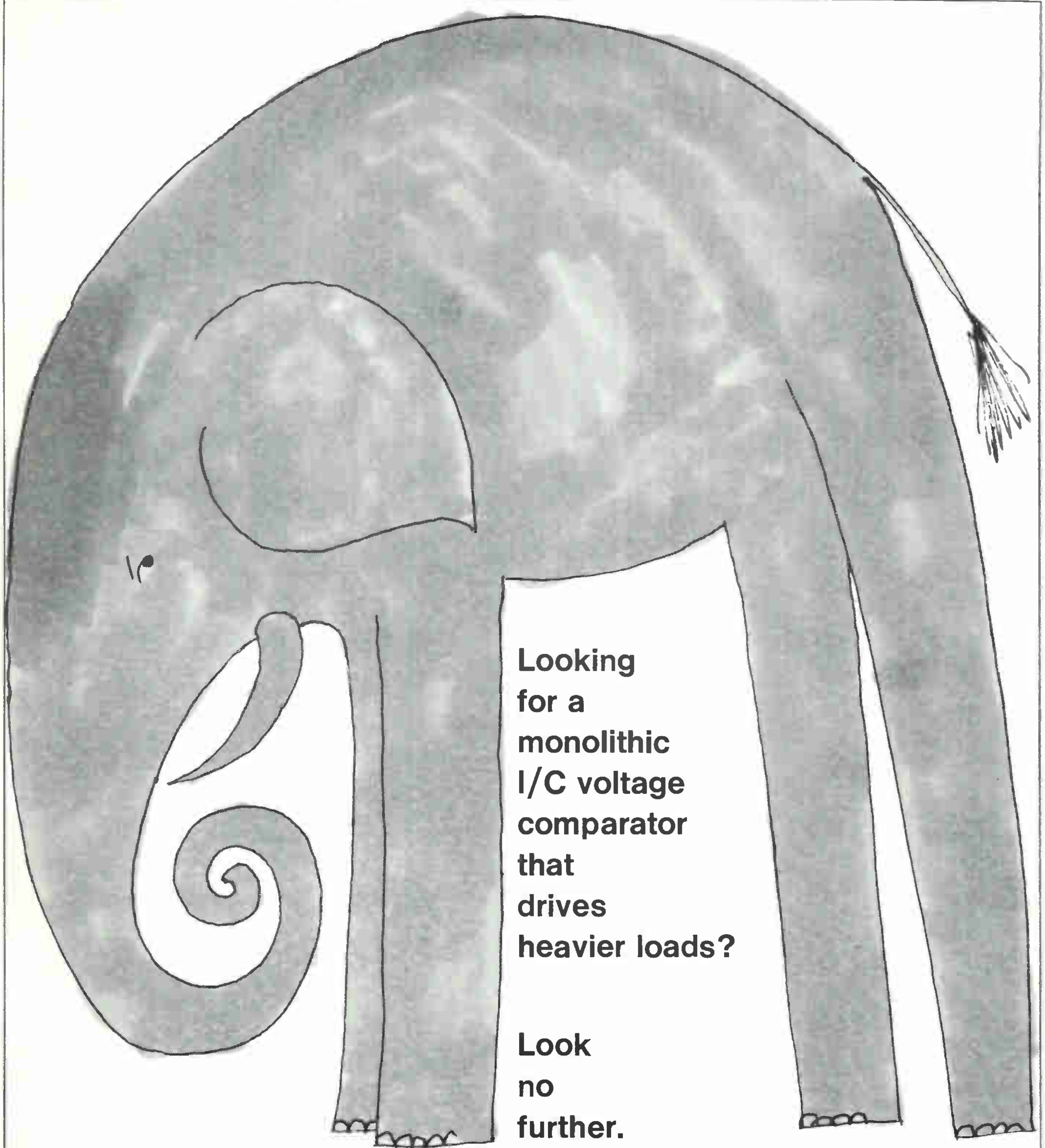
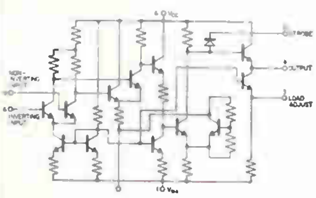
WORLD FAMOUS IN PHASE AND TIME MEASUREMENT.



Looking for a monolithic I/C voltage comparator that drives heavier loads?

Look no further.

Signetics SE518* provides much more than an unusual load-driving capability. It interfaces directly with all popular logic circuits—DTL, TTL, RTL, or any of several types of CML. For application ease and flexibility, the SE518 operates from standard logic power supplies, and provides a strobe control. No other I/C voltage comparator offers all these advantages in one package. We'd be happy to show you how to use it as a Schmitt Trigger, a Sense Amplifier, a Line Receiver, a Window Detector, or in dozens of other applications. Send for our application notes and data sheet today. Write Signetics, 811 E. Arques Ave., Sunnyvale, California.



*Just one of the Signetics product family that is also available from Sprague Electric Co. under a technology interchange agreement.

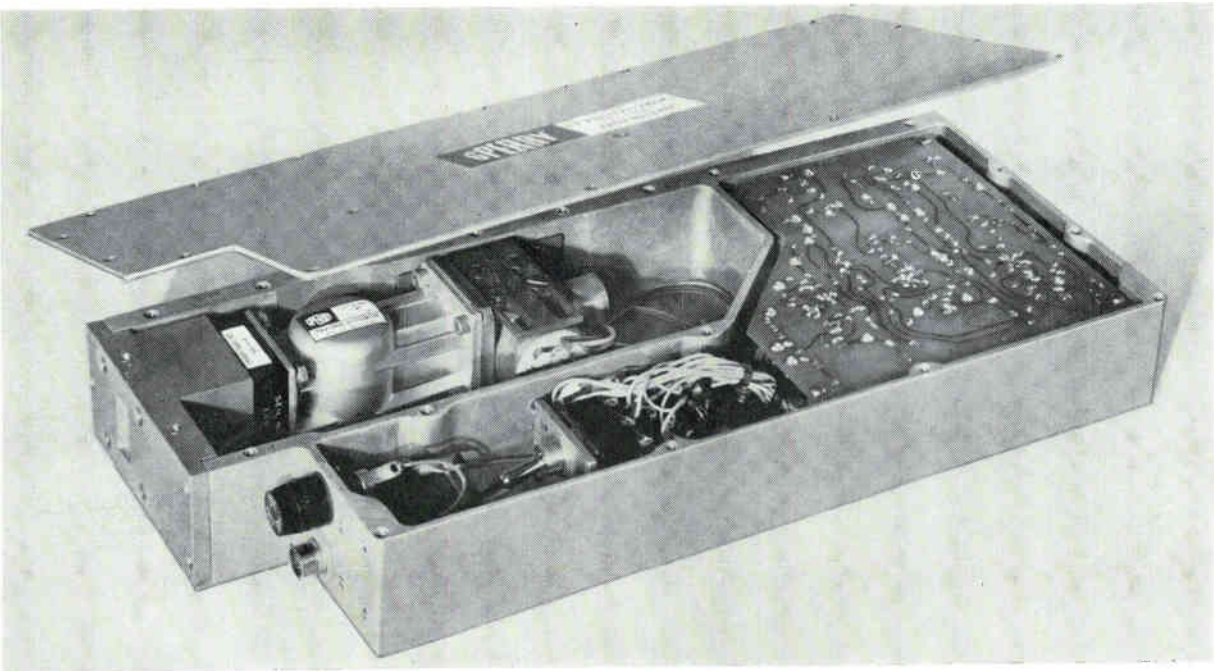
SIGNETICS INTEGRATED CIRCUITS

A SUBSIDIARY OF CORNING GLASS WORKS

Circle 71 on reader service card

E PLURIBUS UNUM

Unitized approach to microwave source solves multiple system problems



Microwave system designers are discovering a remarkable new work-saving technique — a way to get a lot of answers by asking just one question. They are asking Sperry to supply a microwave oscillator, its solid-state power supply, and associated stalo cavities and isolators (as required), in a single, fully-integrated package.

System designers simply specify a single voltage input and the microwave output characteristics they desire. Sperry does the rest.

Sperry accomplishes this by starting with a fixed reflector voltage reflex klystron. They add "instant" temperature compensation and hook up a solid-state power supply that has been specially designed to match the characteristics of the tube. Next the required stalos and isolators are added, and the entire microwave source is packaged as a unit.

With the proper mix of solid-state and tube techniques, Sperry is able to produce desirable secondary characteristics—such as outstanding frequency stability, low FM noise level and precise RFI control — that are beyond the reach of either technology alone.

Learn how Sperry's unitized approach to microwave sources can simplify your design problem. For your free copy of a new technical paper on the subject, contact your Cain & Co. man or write Sperry, Gainesville, Florida.

Don't fight the interface problems inherent in microwave source design — let Sperry solve them for you. Put the Sperry "Storehouse of Knowledge" to work on your system. It will give you predictable source performance at predictable cost, while freeing you to concentrate on other aspects of the system design.

SPERRY

DIVISION OF SPERRY RAND CORPORATION

SPERRY ELECTRONIC TUBE DIVISION, Gainesville, Fla.

National Representatives: Cain & Co., Los Angeles, 783-4700; Boston, 665-8600; Arlington Heights, 253-3578; Dallas, 369-2897; Dayton, 228-2433; Eastchester, 337-3445; Philadelphia, 828-3861; San Francisco, 948-6533; Syracuse, 437-2933; Washington, 296-8265; South Amboy, 727-1900; Huntsville, 859-3410; Orlando, 422-3460; Montreal, 844-0089.

Washington Newsletter

December 12, 1966

Navy faces battle over FDL program

Despite powerful opposition from merchant ship operators and shipyard builders, the Navy expects to win its battle for the billion-dollar Fast Deployment Logistics ships program when Congress convenes in January. **Instead of the highly automated floating warehouses that would form the FDL fleet, its opponents want 100 ships subsidized by the Navy that could be used in peacetime or adapted to military use when needed.**

Builders of conventional shipyards are backing the merchant ship lobby because they've been shut out of bidding for the construction of the country's first fully automated shipyard. Only aerospace firms with shipbuilding operations have the systems design and engineering capability needed. In the running for the automated shipyard contract are the Lockheed Shipbuilding and Construction Co., a subsidiary of the Lockheed Aircraft Corp.; Litton Industries, Inc. and the General Dynamics Corp.

NASA cancels advanced Surveyor

The National Aeronautics and Space Administration has decided not to build the second model of the Surveyor spacecraft. **It had planned to buy three of the heavier, more complex lunar soft landers from the Hughes Aircraft Co. at a total cost of $150 million.** However, the advanced versions have been looking less desirable in recent months because they couldn't have been launched early enough to provide lunar surface information for the Apollo program—their primary mission requirement.

Comsat proceeds with Intelsat 2

Comsat will launch its second Intelsat 2 satellite on Jan. 11 now that it knows for sure why the first satellite failed to go into proper orbit over the Pacific Ocean. Ground tests confirm that the apogee engine was exposed to colder temperatures than it was designed for [Electronics, Nov. 14, p. 74] so it shut off prematurely.

For the January launch, also over the Pacific, Hughes Aircraft Co., the builder, will insulate the motor. **If Comsat succeeds in achieving a synchronous orbit, a third Intelsat 2 satellite will be launched over the Atlantic Ocean three weeks later to give Comsat a worldwide network.**

Meanwhile, the Communications Satellite Corp. will make money from the first Intelsat 2 (called Lani Bird) even with its nonsynchronous elliptical orbit. Eight-hour a day commercial service began on Dec. 2 between Hawaii and San Francisco. More than 40 of its 240 circuits have been leased, 10 by the Defense Department, so Comsat should earn from $75,000 to $100,000 a month with Lani Bird.

Air Force demand for fixed prices irks computer firms

Computer companies are bristling at a demand by the Air Force that they quote firm prices over a 2½ year period on 134 electronic data processing systems. Some companies, including the International Business Machines Corp., may decline to submit bids.

The Air Force won't guarantee that it will use or accept the systems and the companies consider this a one-sided deal. An added source of irritation to many of the 15 computer makers invited to bid on the giant order is that the Air Force waited until Nov. 25, only five days before the original deadline for bids, to spring its suprise request. The deadline for the pricing portion of the proposal has been extended one month to Dec. 30.

The systems are being sought for the second phase of the Air Force's Base Level Automation Standardization program. Despite the rumblings from the computer makers, the Air Force says it is studying the feasibility and desirability of continuing to seek firm prices on future data-processing-systems orders.

Avionics systems being weighed for new VTOL

Two integrated avionics systems are likely candidates for the supersonic fighter bomber with vertical takeoff and landing capability under joint United States-German development. They are the Mark-2 system now being developed by North American Aviation, Inc. and the Integrated Light Attack Avionics System (Ilaas) developed by the Sperry Rand Corp.

The Republic Aviation division of Fairchild Hiller Corp. and the German combine of Entwicklungspring-Sud are to conduct a prototype definition on the VTOL. Early in 1968, a decision on whether or not to produce prototypes for testing will be made.

NASA announces space lab launch for 1968

The National Aeronautics and Space Administration isn't letting the refusal of the White House to provide funds stop it from putting up a manned orbiting space station. The agency has announced plans for a 1968 launch of a station using hardware left over from the Apollo moon program.

NASA will orbit equipment for the station over a period of several months. First, it will use the top stage of a Saturn rocket as a workshop for astronauts [Electronics, Nov. 14, p. 73]. After they've conducted experiments, the astronauts will be returned to earth and the workshop will remain in orbit. A few months later, a telescope will be put up in an unmanned craft. Finally, a manned Apollo ship will be launched. The three systems will be docked together for up to two months of experiments before the astronauts return to earth.

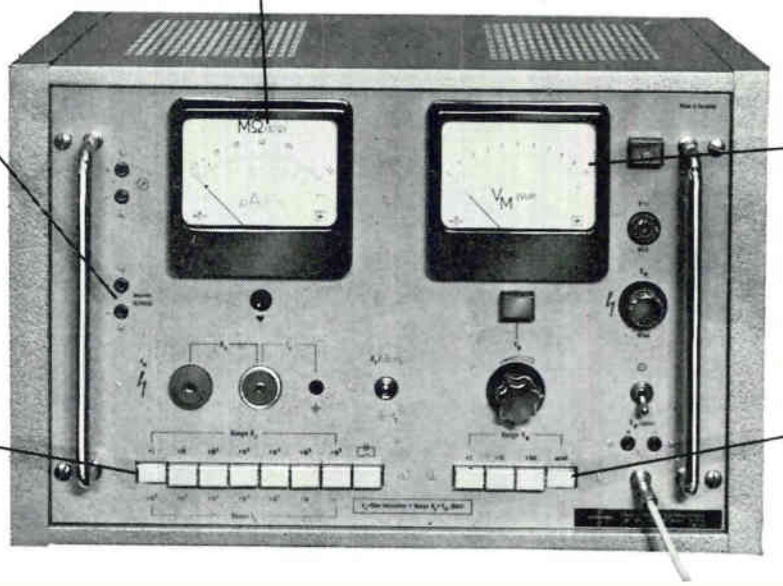
The station would put NASA ahead of the Air Force, which plans to launch its manned orbiting laboratory in 1969. The Air Force program, with the strong support of the Pentagon and the Administration, seems likely to survive any attempt to cut back its funds.

Addenda

Seven airlines will participate in very-high-frequency communication experiments [Electronics, Nov. 14, p. 73] during their regular Pacific flights via the space agency's Applications Technology Satellite. Equipment for the tests beginning in mid-December came from the Bendix Corp; the Collins Radio Co; and Dorne and Margolin, Inc. . . . The Federal Communications Commission has ordered the international communications carriers, the broadcasting networks and the Communications Satellite Corp., to settle their differences and decide what the charges will be for future satellite services by Jan. 16, or face a formal investigation. . . . Negotiations between the Hughes Aircraft Co., and the Air Force on the contract to build a demonstration tactical communications satellite have run more than 15 days, making it appear stronger than ever that Hughes has won [Electronics, Nov. 28, p. 52]. The first satellite of two the Air Force is ordering is scheduled for delivery 16 months after the contract is signed.

NEW!

IMMEDIATE DELIVERY
FROM STOCK
$1,380



TYPE TO7a

TERA-OHMMETER®

FOR INSULATION MEASUREMENTS

FEATURES

- Resistance Range: 100kΩ to 10,000TΩ ($10^5\Omega$ to $10^{16}\Omega$)
- Current Range: 0.1 pA to 10 μA
- Test Voltage: 0 to 1000 V dc
- High Speed: less than 4 sec. for measurement
- High Accuracy: ±3% of f.s.d
- All Silicon Solid State Design

APPLICATIONS

- Measure Insulation Resistance and Leakage Current of
  - *Components, including: Capacitors, Transformers, Switches, Cables, Wires, Pots, etc.*
  - *Semiconductors*
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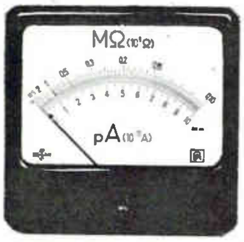
- Determine Volume and Surface Resistivity
- Measure Voltage Coefficients
- Measure Purity of Liquids



RESISTANCE/CURRENT
Measuring Scale

Type TO7a Tera-Ohmmeter® offers highly accurate resistance measurements. Analyze the many factors affecting insulation resistance: humidity, temperature, impurities, voltage coefficient, surface conditions, etc. The Tera-Ohmmeter finds unlimited application in both R&D and production use. It is unique in offering an extremely wide resistance and current measurement range, at accurate test voltages from 1 V to 1000V, high measuring speed, recorder output, high stability and provision for charge and discharge of test item. Accessories available include: comparison resistors, sample holders, and shielded cables.

Get The Extra Capability,
Greater Reliability, and
Longer Useful Life Of . . .

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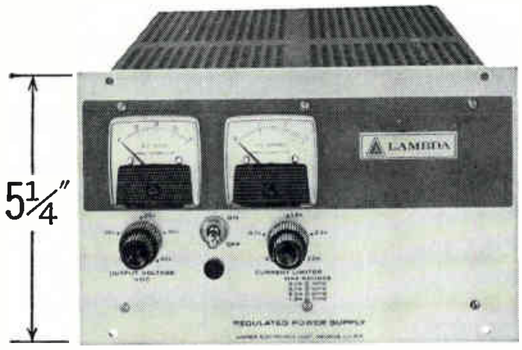
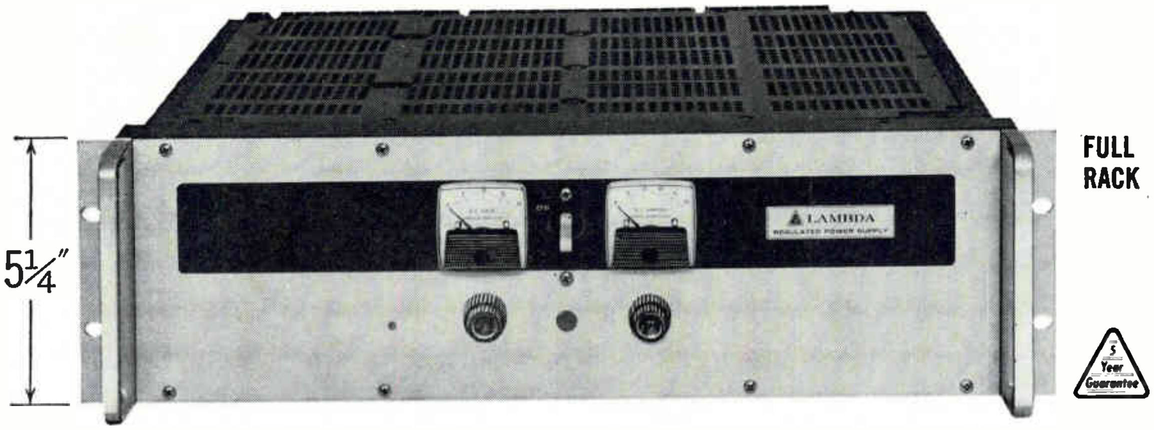
NEW

Lambda high current LK Series power supplies

0-20, 0-36, 0-60 VDC • up to 35 amps • 5¼" height • starting at $330.



HALF RACK



FULL RACK

Features

- **All Silicon**
- **Convection cooled**
- **Remotely programable**
- **Meet Mil-Environment specs**
  Vibration, MIL-T-4807A
  Shock: MIL-E-4970A
- Proc. 1 & 2
  Humidity: MIL-STD-810
- Meth. 507
  Temp. Shock: MIL-E-5272C
- (ASG) Proc. 1
  Altitude: MIL-E-4970A
- (ASG) Proc. 1
  Marking: MIL-STD-130
  Quality: MIL-Q-9858
- **Remote Sensing**
- **Series/Parallel Operation**
- **Regulation**—.015% or 1 MV (Line or Load)
- **Ripple**—500 uV RMS.
- **Temp. Coef.** .015%/°C
- **Transformer**—designed to MIL-T-27 Grade 6
- **Completely Protected**—Short Circuit Proof—Continuously Adjustable Automatic Current Limiting
- **Constant I./Constant V.** by automatic crossover
- **No Voltage Spikes or Overshoot** on "turn on, turn off" or power failure
- **Wide Input Voltage and Frequency Range**—105-132 VAC, 47-63 cps

Rack or Bench use—rubber feet included for bench use.

3 full-rack models — Size 5¼" x 19" x 16½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 40°C	50°C	60°C	71°C	Price[2]
LK 350	0-20VDC	0-35A	0-31A	0-26A	0-20A	$675
LK 351	0-36VDC	0-25A	0-23A	0-20A	0-15A	640
LK 352	0-60VDC	0-15A	0-14A	0-12.5A	0-10A	650

6 half-rack models — Size 5³⁄₁₆" x 8⅜" x 16½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1] 40°C	50°C	60°C	71°C	Price[2]
LK 340	0-20VDC	0- 8.0A	0- 7.0A	0- 6.1A	0-4.9A	$330
LK 341	0-20VDC	0-13.5A	0-11.0A	0-10.0A	0-7.7A	385
LK 342	0-36VDC	0- 5.2A	0- 5.0A	0- 4.5A	0-3.7A	335
LK 343	0-36VDC	0- 9.0A	0- 8.5A	0- 7.6A	0-6.1A	395
LK 344	0-60VDC	0- 4.0A	0- 3.5A	0- 3.0A	0-2.5A	340
LK 345	0-60VDC	0- 6.0A	0- 5.2A	0- 4.5A	0-4.0A	395

[1] Current rating applies over entire voltage range.
[2] Prices are for non-metered models. For metered models add suffix (FM) to model number and add $30.00 to price.
[3] Overvoltage Protection: Add suffix (OV) to model number and add $70.00 to the price for half-rack models; $90.00 for full-rack models.

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515 BROAD HOLLOW ROAD • MELVILLE, L. I., NEW YORK • 516 MYRTLE 4-4200
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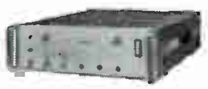
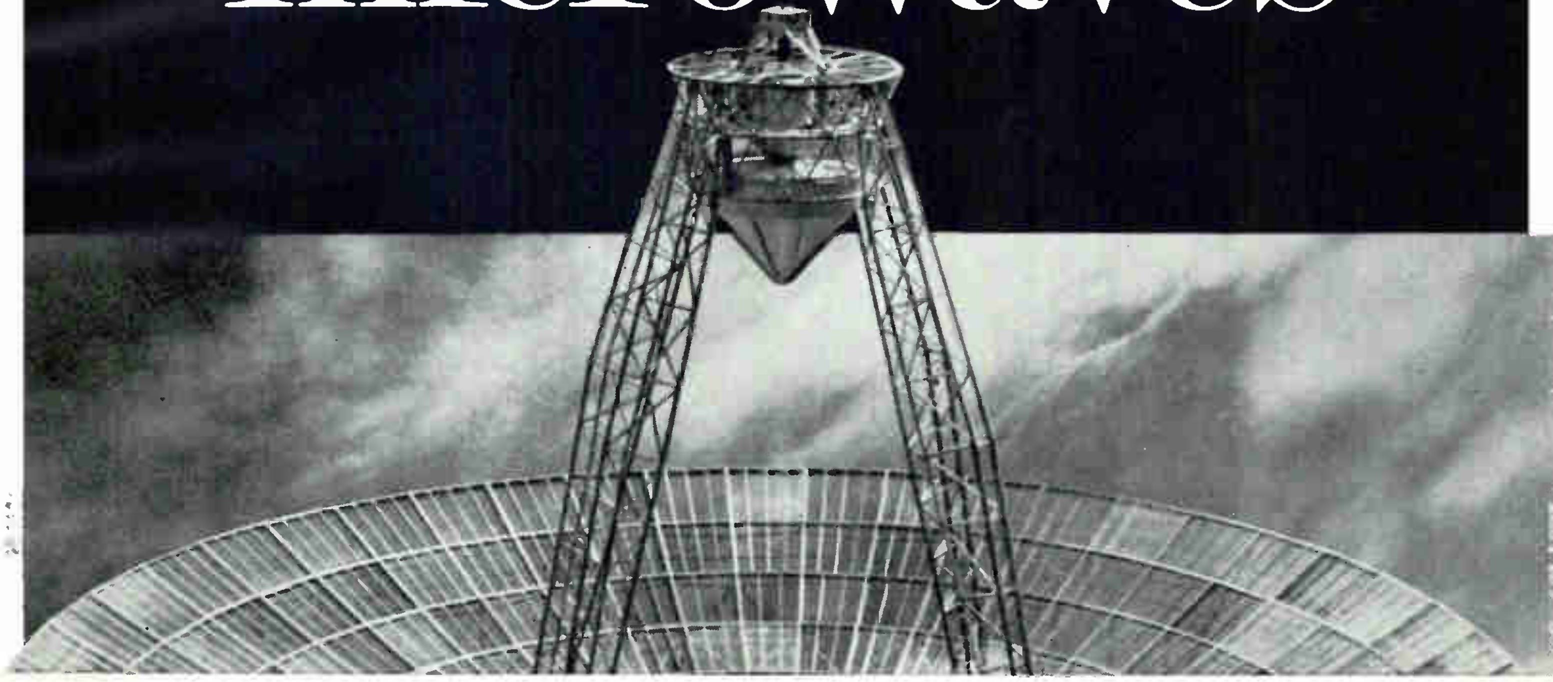
LA-173



servo is microwaves



Want to generate a signal in the Ka band, test electronic gear on an aircraft, or check out the guidance system of a missile? Servo designs and manufactures instruments for these applications. And many others.

Our engineers are expert in producing microwave pulse-swept systems, microwave signal generators, microwave amplifiers and high voltage power supplies. Take the unit pictured above, for example. It's the first 20-watt TWT amplifier available...and industry's most compact, too. Servo's amplifiers have many unusual features, and are supplied in models for operation from 1 to 18 GHz in octave bandwidths.

Our Servodynamics Division also supplies special synchro-to-digital and digital-to-synchro conversion equipment and servo analyzers, digitally programmable function generators, and phase meters.

Other Servo divisions design systems and products which serve safety through science: the Railroad Products Division, the Infrared & Electro-Optics Division, and the Communications & Navigation Division.

servo corporation of america

servo

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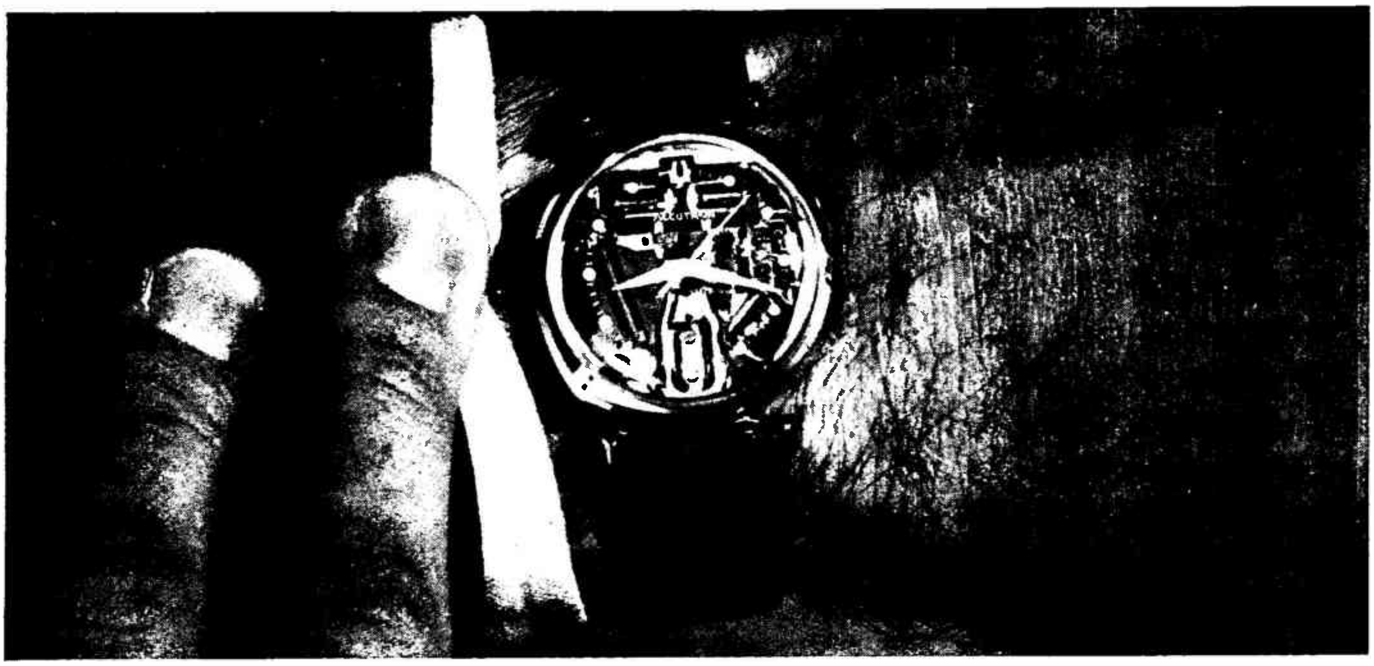
hicksville, l.i., new york 11802
516 938-9700

Circle 77 on reader service card

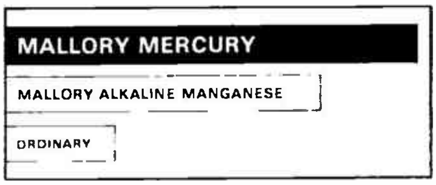


Bulova needed a battery smaller than a button to power its Accutron*timepiece for 15 months.

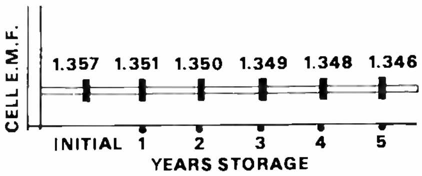
Mallory made it.

What can we do for you?

The Mallory people pride themselves on solving specialized problems. What they did for Bulova, they can do for you. Mallory's skilled engineers lead the way in miniaturized power sources for every power need. From hearing aids to Bulova electronic clocks for Gemini spacecraft, Mallory has solved the problem of packaging long-lasting power in button-size batteries. Quality manufacturers are willing to spend more to bring their customers the best batteries in the business. They come to Mallory.



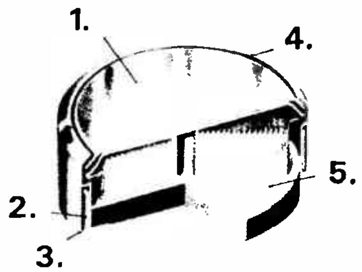
High Energy. The secret of Mallory batteries long-lasting life is high energy. More energy per ounce squeezed into each battery reduces battery changing to a minimum. Mallory high-energy battery systems offer the longest life—more maximum hours of service than any other battery commercially available. Mallory Mercury batteries for electronic circuits have about 4 times more energy per unit volume than ordinary zinc carbon batteries. Mallory heavy-duty Alkaline batteries have about 3 times more energy than conventional zinc carbon batteries. All this adds up to peak power at a lower cost per hour usage.



Higher Stability. Mallory high-energy Mercury batteries have the unique property of staying exactly at the same operating range throughout long life. Their output is so exact, they are used as laboratory voltage standards. This stability is most useful and often essential in powering products which remain idle for months but must operate perfectly when the occasion arises. This also means that Mallory battery systems have exceptional shelf stability. In fact, Mallory has had cells in storage for 12 years and more which still maintain useful capacity.

The reason for this higher stability is that the Mallory Mercury system is inherently inactive when not being discharged; and is, in effect, hermetically sealed, preventing evaporation of the electrolyte.

Of course, Mallory high-energy batteries cost more, but they're worth more because of the superior performance they give your product.



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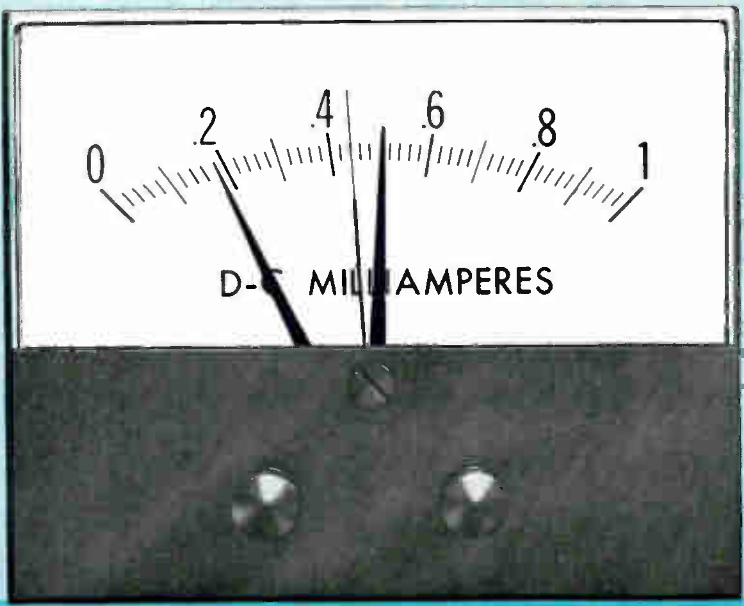
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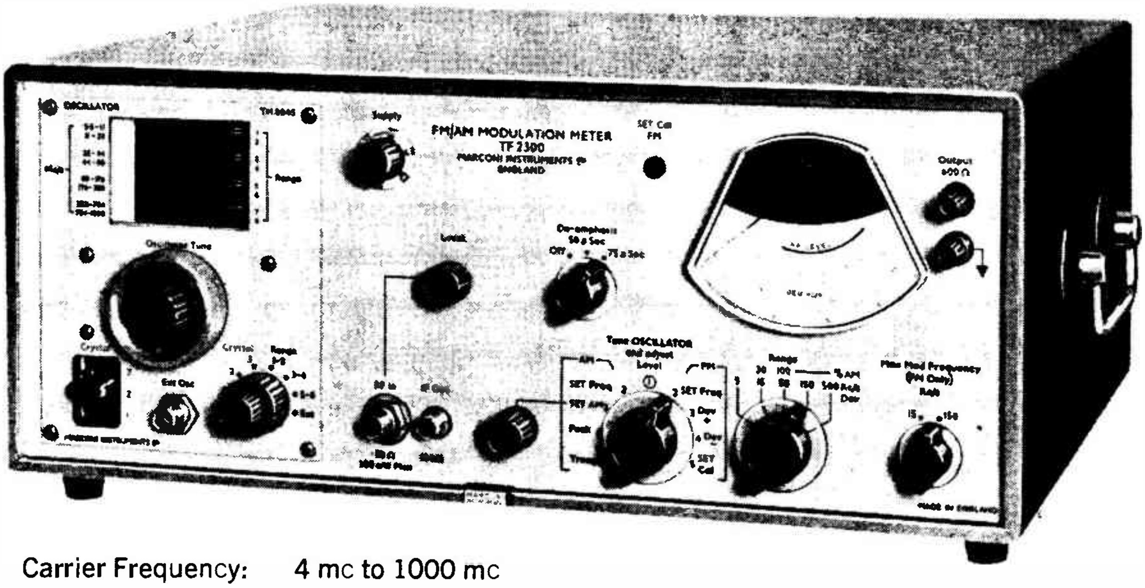
MODEL 2300



Carrier Frequency: 4 mc to 1000 mc

Sensitivity: 20 mV to 250 mc
50 mV to 500 mc
100 mV to 1000 mc

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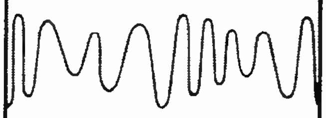
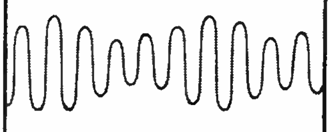
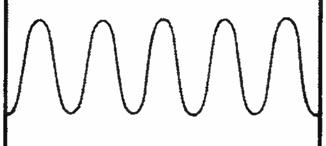
FM MEASUREMENT
Peak deviation in five ranges of 5, 15, 50, 150 and 500 kc. Modulating frequencies 30 cps to 150 kc. Suitable for AM or FM broadcast (mono or stereo) TV Sound, telemetry and communications.



AM REJECTION.
Less than ±1 kc additional deviation error with 80% amplitude modulation superimposed at 1 kc using a 15 kc audio bandwidth.



AM MEASUREMENT
for carriers to 500 Mc. Two ranges of 30% and 100% (usable to 95%). Peaks or troughs switch selected. Modulating frequencies 30 cps to 15 kc.



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Low distortion, low noise demodulated signal derived from FM or AM carrier. Switchable de-emphasis 50 μsec and 75 μsec. Level OdB into 600Ω feeds distortion or wave analyser.

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NEW family of medium-power silicon NPN transistors packs BIG performance at mass production prices

Here's A Typical Value: RCA 40458

h_{FE} .... 50 min. at 300 mA

V_{CEO} (sus) .... 40 V min. at 100 mA

V_{CE} (sat) .... 0.3 V max. at 300 mA

f_T .... 150 MHz min.

I_C 1A

Dissipation: 2 W at 75°C Case Temp.

only 47¢*

Hermetically sealed in a metal case

now examine the entire family of value-packed industrial types

RCA 2N3241A Silicon Epitaxial Planar Transistor Family Characteristics

	2N3241A	2N3242A	2N4074	40397	40398	40399	40400	40458	
BV_{CEO}	25	40	40	25	25	18	18	40	max. volts
h_{FE} 10V, 10mA	100-200	125-300	75-300	165-600	75-300	165-600	75-300	100-300 (50 min. @ 300mA)	
f_T typ.	175	175	80	80	80	80	80	150 min.	MHz
V_{CE} (SAT)	0.25 at 200mA I_C	0.3 at 300mA I_C	0.3 at 300mA I_C	0.25 at 200mA I_C	0.25 at 200mA I_C	0.2 at 100mA I_C	0.2 at 100mA I_C	0.3 at 300mA I_C	max. volts
Turn-on I_C = 150mA	75	75	—	—	—	—	—	75	max. nanoseconds
Dissipation** at 25°C Ambient	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	max. watts
I_C	Limited by P_T	Limited by P_T	0.3	0.2	0.2	0.2	0.2	1.0	max. amperes
Price*	$0.44	$0.50	$0.44	$0.40	$0.36	$0.33	$0.30	$0.47	

*In quantities of 1,000 and up. **All types available with integral heat radiator for 1 watt dissipation at T_A = 25°C. Add 4¢ per unit for these versions.

The new RCA 2N3241A family of NPN epitaxial planar transistors, designed for amplifier and switching service in audio and video frequency ranges, is as versatile as it is reliable. Applications include • relay drivers • video amplifiers • high current audio drivers • saturated switches • TV deflection drivers • medium power audio output amplifiers. All devices offer exceptionally low leakage, low saturation voltages, and high minimum beta. Check the chart for specifications...*and note the low prices!*

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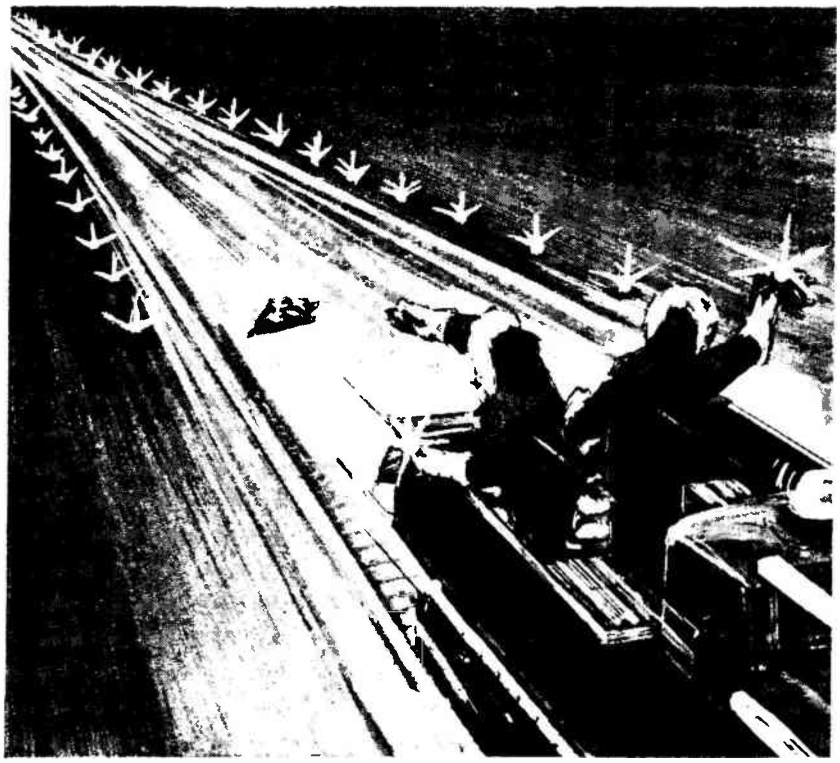

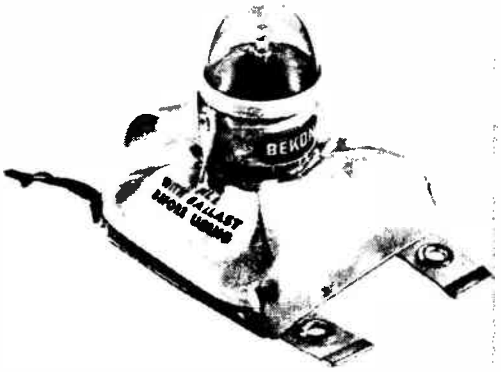

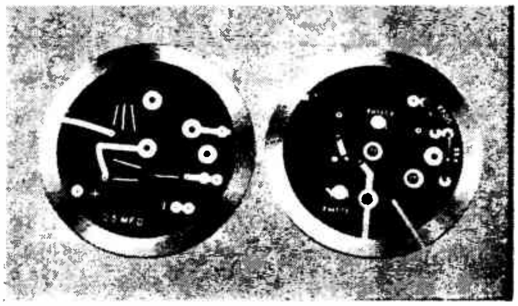

Power failure puts an airfield out of business—or rather it used to. Today, airfields throughout the world depend on Bekon* lights for such emergencies. These rugged little life-savers, thrown quickly from moving trucks, to serve as emergency runway markers, keep working in any climate, under any weather condition. The Bekon Light nerve center is a printed circuit, made of a FORMICA® brand copper clad laminate. If the dependability of the p. c. in your product is also important, write Dept. ID-7 for data on FORMICA® brand copper clad laminates. Look for the FORMICA® brand, your assurance of quality.

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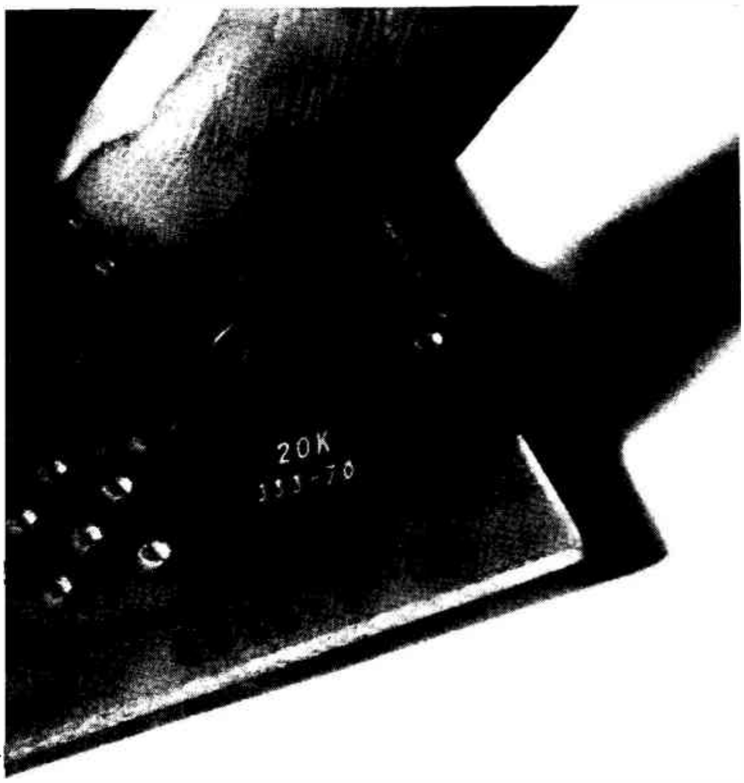
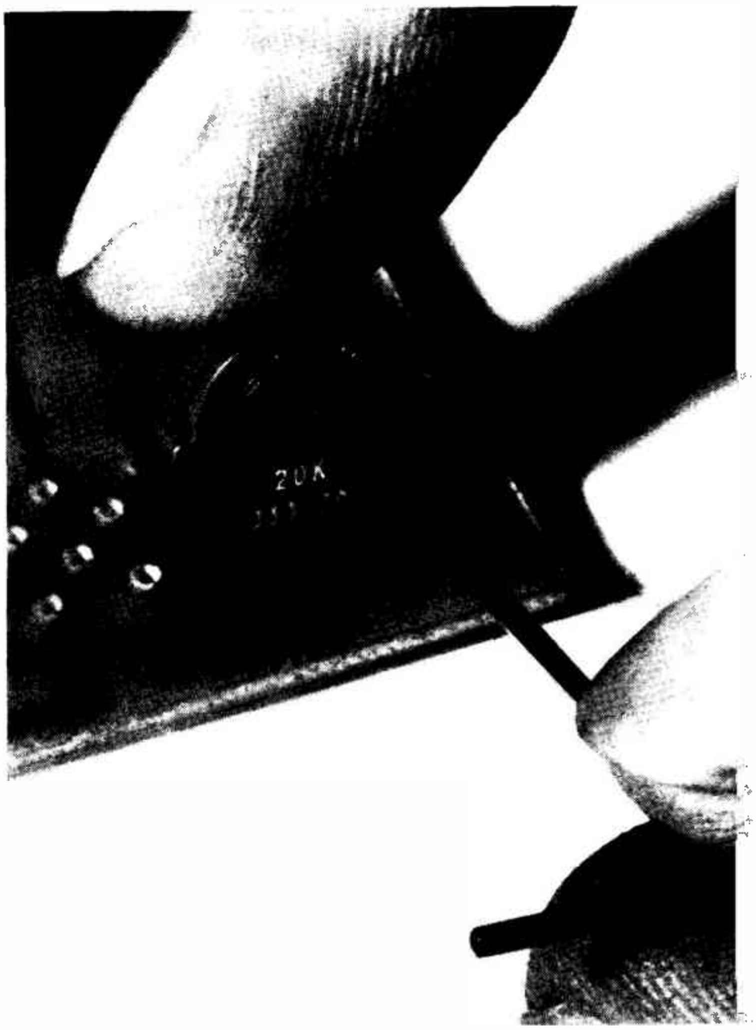
6589

It's a bargain, no matter how you trim it





with the flick of a finger... or the turn of a key.

You can trim the Daystrom Model 333 pot with your thumb on the convenient knurled knob. Or, use a hex-key on the Allenhead vernier for finer (4:1) settings.

But dual adjust is just one of the design features that make this low-cost commercial trimmer a bargain. Others are Weston's exclusive wire-in-the-groove construction which locks linearity in and contact noise out—even under shock and vibration . . . a slip clutch stop that protects the wiper at the end of rotation . . . Suregard™ terminations for long-life reliability.

You'll recognize these features as the same used in Weston's rugged MIL-type Squaretrim® pots.

In addition, compact 333 series pots take up less than 1/10 square inch on your PC boards. They're designed for edge mounting, with provision for dip soldering, so they're ideal for automated production techniques. And they'll handle 0.25 watt comfortably—in still air.

The price is a trim $1.25 in lots of 500. Standard values range from 50Ω to 50K. For complete details or evaluation samples, contact your Weston distributor or call:

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V_{CEO} (SUS) 30 TO 250 VOLTS

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ELECTRICAL CHARACTERISTICS
(T_C=25°C, unless otherwise noted)

CHARACTERISTIC	TEST CONDITIONS	2N1015 SERIES MIN.	2N1015 SERIES MAX.	2N1016 SERIES MIN.	2N1016 SERIES MAX.	UNITS
Breakdown Voltage, Collector to Emitter, BV_{CEO} (sus)	*I_C=100mA, I_B=0	30 A-60 B-100 C-150 D-200 E-250		30 A-60 B-100 C-150 D-200 E-250		Volts Volts Volts Volts Volts Volts
Collector Cutoff Current, I_{CEX}	V_{CE}=rated voltage V_{BE}=1.5V, T_C=150°C		20		20	mA
Emitter Cutoff Current I_{EBO}	V_{EB}=25V, I_C=0, T_C=150°C		20		20	mA
D.C. Forward Current Gain, h_{FE}	*I_C=2 Amps, V_{CE}=4V	10				
	*I_C=5 Amps, V_{CE}=4V			10		
Saturation Resistance, r_{CE} (sat)	*I_C=2 Amps, I_B=300mA	0.3 Typical	0.75			Ohms
	*I_C=5 Amps, I_B=750mA			0.2 Typical	0.5	Ohms
Base to Emitter Voltage, V_{BE}	*I_C=2 Amps V_{CE}=4V	1.5 Typical	2.5			Volts
	*I_C=5 Amps, V_{CE}=4V			1.7 Typical	3.5	Volts

*Pulse Cond. 300 μ sec., 2% duty cycle.

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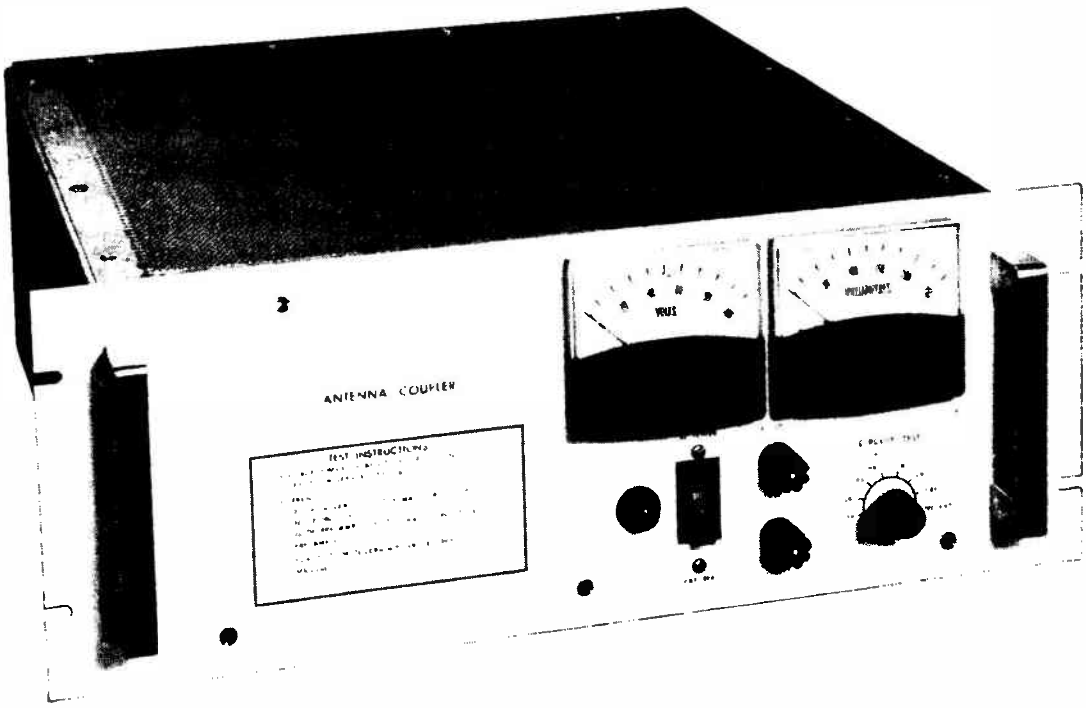

only from Conductron-MRC

MODEL	C 325-24	Outputs	24
Bandwidth	2 MHz—30 MHz	VSWR	< 1.25:1
Gain	2 dB ± 1 dB	Impedance—In	50 ohms
Noise Figure	7.5 dB: 20 MHz—30 MHz, 6.5 dB: 10 MHz—20 MHz, 6 dB: 2 MHz—10 MHz	Impedance—Out	50 ohms
		Power Required	115 V ± 10%, 50—60 cps or 48 V ± 3V, DC
Intermodulation Distortion	− 56.5 dB, 2nd order − 60 dB, 3rd order	Dimensions	19" wide x 20" deep x 7" high
		Mounting	Standard 19" rack
Phase Tracking	2 degrees ± 1 degree	Connectors	BNC
Amplitude Tracking	1 dB	MTTR	< 30 min.
Isolation, Back to Front	> 52 dB	MTBF	> 30,000 hours
Isolation, Output to Output	> 40 dB	Fault Isolation	Internal
Gain Reduction (Overload)	< 2.5 dB for .8 volt signal	MIL Qualified To	MIL-E-4158C, MIL-Q-9858A
Inputs	1		

If 24 for 1 sounds like good odds for your antenna coupling requirements, check the specifications above, then write Conductron—MRC Division, 2311 Green Rd., Box 614, Ann Arbor, Michigan 48107. Ask for Bulletin 11C.

CONDUCTRON - M R C Division

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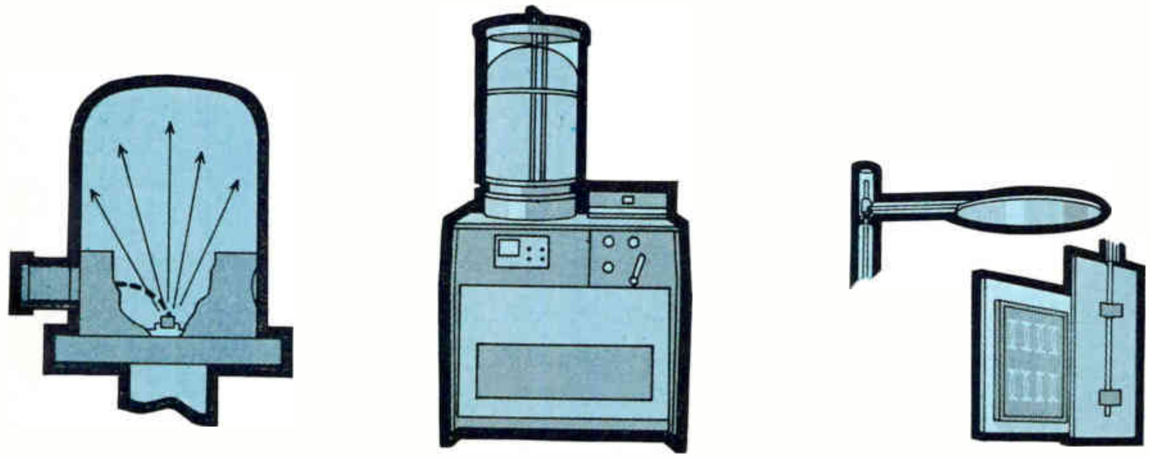
Which vacuum deposition method is best for you?



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CVC can demonstrate the advantages of each.

Resistance heating, electron beam evaporation, advanced low-energy sputtering—each has its distinct advantages for thin-film applications. CVC has the techniques and the Application Laboratory to help you select the right method. CVC has the equipment to help you do the job.

GUARANTEED PERFORMANCE CV-18 TYPE VACUUM COATERS come completely equipped for resistance heating. Pumpdown to 8×10^{-7} torr in 9 minutes (with standard CV-18) is guaranteed for your laboratory or production line. These vacuum chamber systems are the basis of any vacuum coating operation — electron beam evaporation and sputtering, as well as resistance heating.

ELECTRON BEAM GUN EVAPORATORS with the new CVC deflection system give you high purity films of many metals, insulating materials and ceramics too difficult to handle by resistance heating. The new deflection system permits external mounting of the gun on a baseplate feedthrough ring. The beam enters the chamber and is deflected down to the evaporant. The advantages of this system are many: easy mounting, greater flexibility in substrate location, longer filament life, greater control over evaporation location, and more working room within the chamber.

PlasmaVac® LOW-ENERGY SPUTTERING with RF SPUTTERING CAPABILITY. The most versatile thin-film deposition tool ever developed! Will deposit almost any material (including metals, alloys, semi-conductors, and insulators) on almost any surface. Gives precision control of deposition rate and film thickness. Adapts easily to laboratory or production line set-ups. Because it increases quality and yields, PlasmaVac is a valuable new tool in the fields of electronics, ceramics, optics, and metallurgy. With PlasmaVac, you have an almost limitless capability for thin-film deposition.

Please write us with details on what you'd like to do in the thin film field. We'll be glad to make recommendations. Dept. J.

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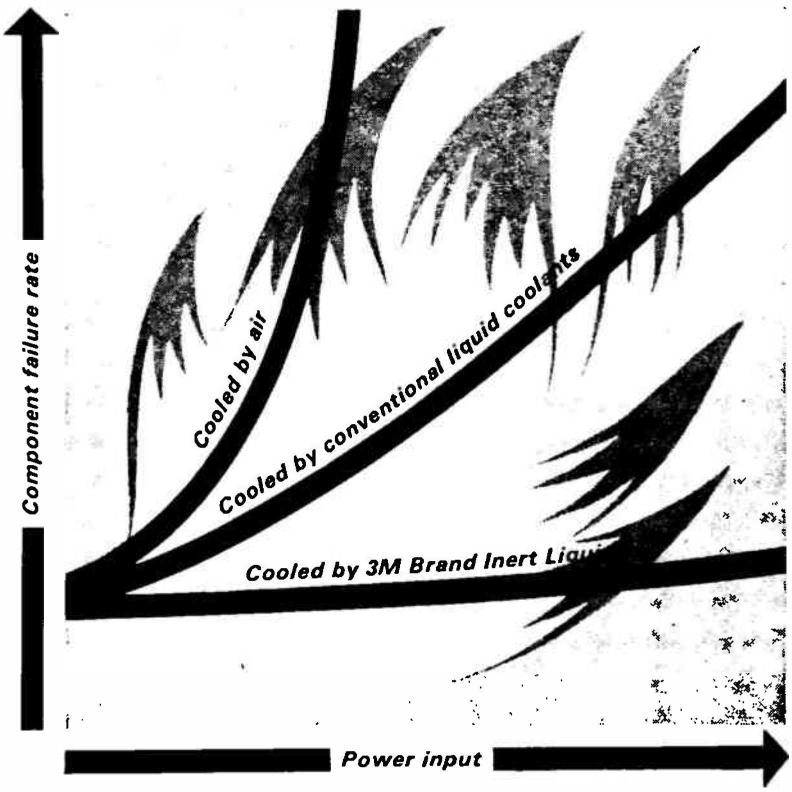
3M Brand Inert Fluorochemical Liquids cut component failure rates drastically by removing heat faster.



PRACTICALLY EVERYTHING we can say about 3M Fluorochemical Inert Liquids adds up to one thing for the designer and engineer: INCREASED RELIABILITY. Why? Because component failure rates increase sharply as component temperatures increase. Efficient heat removal lowers the temperature and increases reliability.

3M Inert Liquids are far more efficient at removing heat than air or other conventional dielectric coolants. Results: LOWER COMPONENT TEMPERATURES, LOWER FAILURE RATES, HIGHER RELIABILITY.

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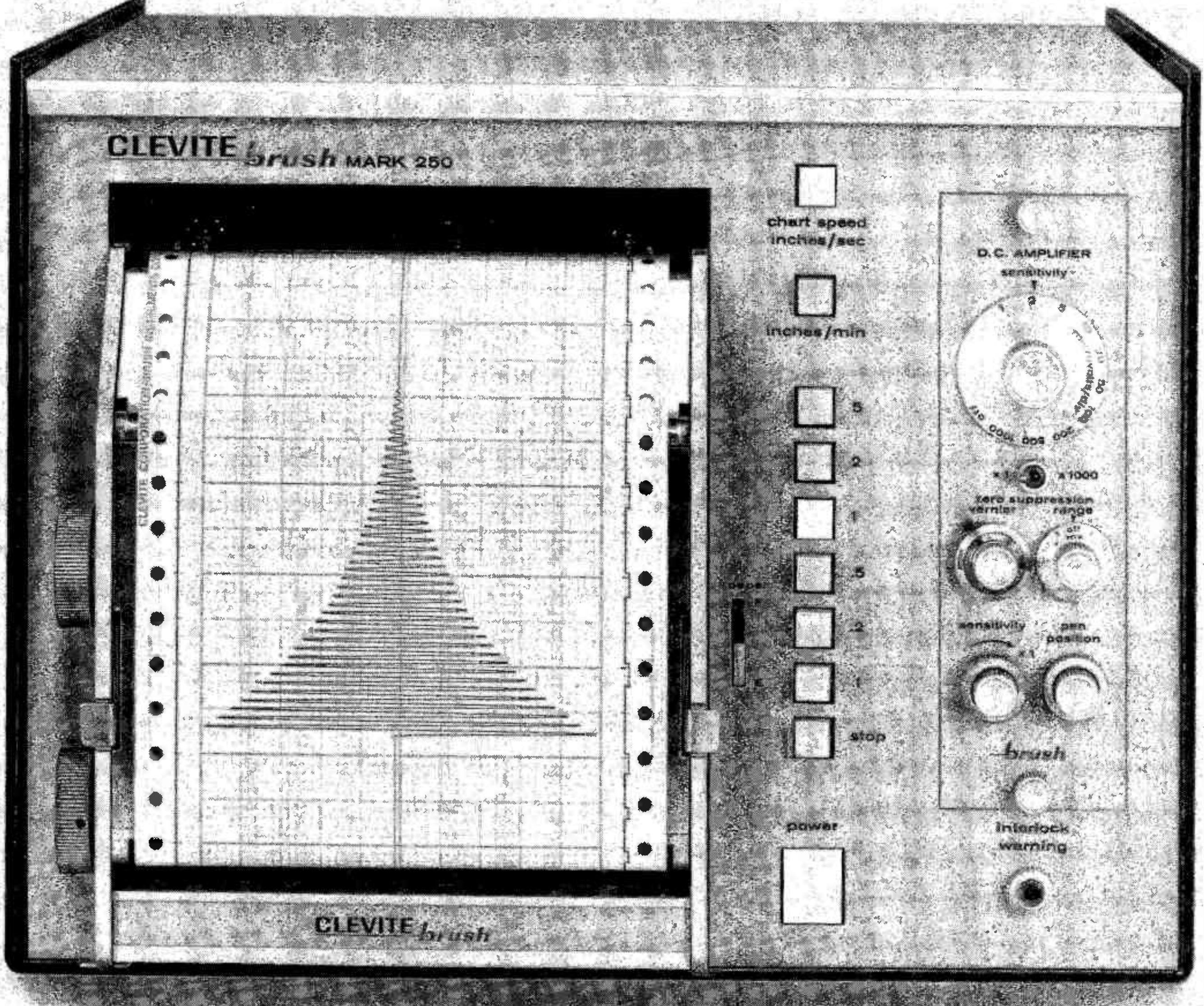
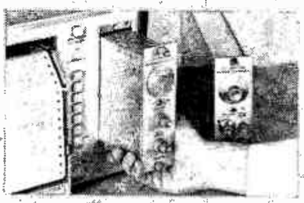
Shown with 1 μv preamplifier RD 4215-70; event markers optional.



Meet the fastest, most accurate strip chart recorder on record: The new Brush Mark 250. When you read about all the features you'll know why we call it the first recorder for the perfectionists of the world!

1 Unmatched frequency response. Flat to 10 cycles on full 4½" span! Useful response to 100 cycles. Nobody has a strip chart recorder in the same league.

2 Wide selection of signal conditioners. Choose from 21 interchangeable preamps. Use one today; plug in a different one when your recording requirements change.



3 Crisp, clean rectilinear writing. Patented, pressurized inking system puts smudge-proof trace *into* the paper not just on it.

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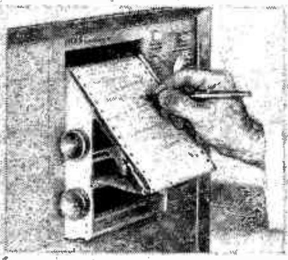
5 Multiple chart speeds. Pushbutton choice of twelve . . . from 5 inches/second to 1/10 of an inch/minute (up to 8 days of continuous recording).



6 Portable or Rack mounting. And either way you get the exclusive new dual position writing table.

7 Removable chart paper magazine. Great for desk top record reviews. Man-sized manual winding knobs let you roll chart forward *and* back. Chart reloading is a cinch.

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The Brush Mark 250 First recorder for perfectionists

think faster think Burroughs memory systems

IN MEMORY SYSTEMS THE FASTEST BIT MAKES THE DIFFERENCE . . . AND BURROUGHS MAKES ITS OWN BITS (BOTH CORE AND THIN FILM).

The new Burroughs line of core Memory Systems is fast . . . as fast as 0.6 μsec. full cycle time. You can also have a "not-so-fast" model at lower cost if you don't need the speed.

Now, Burroughs 14 years of experience is available to provide you with the Memory System you need for your data handling equipment.

- System cycle times of 0.6 and 1.0 μsec.
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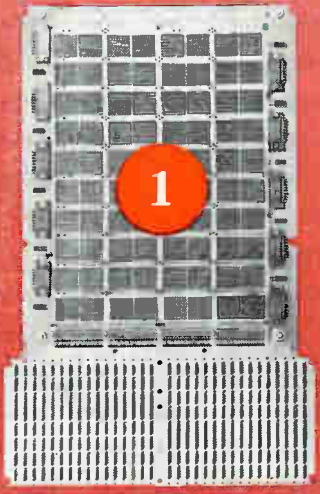
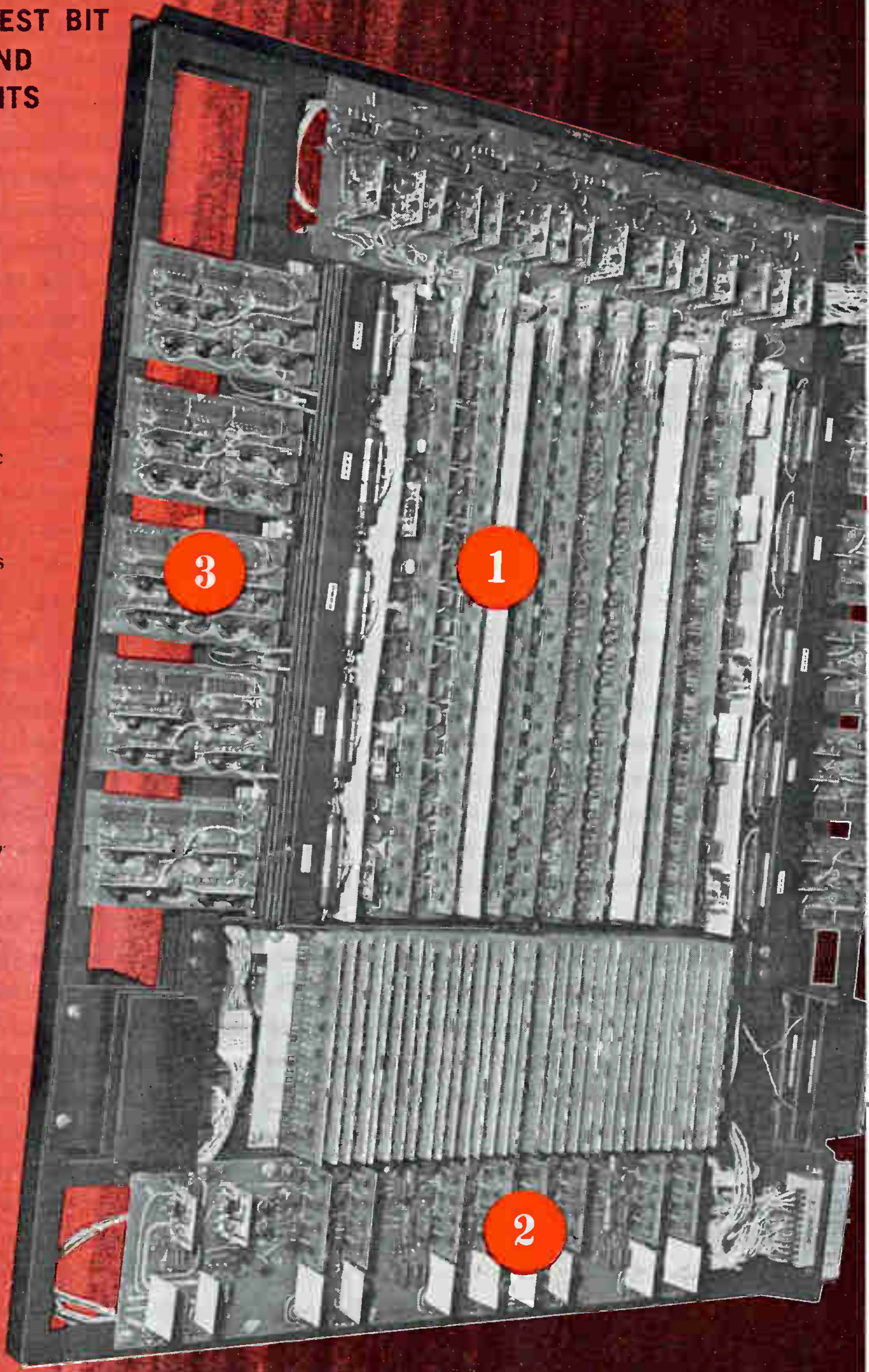
- Associated memory control module includes timing circuits, address register and decode logic.

FEATURES:

1. 20 mil, 2-1/2D ferrite core memory—manufactured by Burroughs.
2. Driver Circuits and sense amplifiers use Burroughs hybrid microcircuits.
3. Monolithic integrated circuits used for all logic and registers.

If you would like your system to think faster write or call for further information on Burroughs memory systems.





Burroughs Corporation / ELECTRONIC COMPONENTS DIVISION

Technical Articles

Computer-aided design, part 3; symbol analysis: **page 92**

Manipulating letter symbols in a computer is easier than performing calculations with actual component values when a circuit is being analyzed because the numbers can hide relationships among components. With symbols, the engineer can visualize such relationships and obtain a deeper feeling for how the circuit works.

Knowing the cause helps to cure distortion in FET amplifiers: **page 99**

To engineers, the field effect transistor offers the advantages of high gain and low noise in an amplifier. But, because the FET is a relatively new device, many engineers still do not understand how distortion affects its performance. Here are some rules for operating an FET amplifier at maximum effectiveness.

Apollo: the goal is in sight: **page 111**

Now that the Gemini program has been completed, space technologists are in the full glare of publicity on the next step, putting men on the moon. The Apollo mission will give space electronic equipment the toughest test to date. This overview of the electronics for Apollo describes the mission and how it affects the major electronics systems. Future articles will dissect the Apollo electronic equipment. For the cover, Richard Saunders made a double exposure of a model of the lunar module as it was landing and after it had settled on a simulated moon surface built at the Grumman Aircraft Corp.

Communication technology in Japan: **page 133**

Of all aspects of technology, the Japanese are probably doing more original development work in communications than in any other. One reason is the explosive growth of telephony inside Japan. Another is Japanese determination to supply equipment to fill the vacuum in communications that exists in Asia and in Africa. The Japanese want to be competitive with hardware and techniques everywhere in the world.

- Japan stays with pcm to meet mushrooming growth in telephony
- Bit-by-bit, Japan speeds its data communications

Coming December 26

- **Second annual European market report**
- **Integrated circuits in action: reliability tests**
- **Using the state variable in circuit analysis**

←Circle 273 on reader service card

Computer-aided design: part 3 Analyzing circuits with symbols

Manipulating symbols instead of numbers offers many advantages, especially in determining the sensitivity of circuit performance to parameter changes and component tolerances

By Richard Carpenter and William Happ
Electronic Research Center, National Aeronautics and Space Administration, Cambridge, Mass.

Manipulating letter symbols in a computer is an easier way to analyze a circuit than performing the calculations with actual component values. If the numerical values of the components are inserted at the start of a computer-aided design, the numbers hide the relationships among components. Also the designer can lose sight of how the component variables affect the circuit's operation.

By substituting symbols for the component values, the relationships between circuit parameters are easier to visualize and the designer gains insight into the circuit's operation. In addition, the formula of letters can be manipulated faster by the computer than the actual numbers. And since the numerical component values are not substituted until the last step in the process, the technique avoids the inaccuracies of cummulative rounding out of numbers that are entered into the program at an early stage [see "Advantages of symbolic analysis," p. 93].

Symbolic analysis establishes the desired relationships among components from a topological study of the network; that is by graphing the circuit. To do this the network is divided into branches by a graphic procedure and all of the variables associated with each branch are coded for a computer. In contrast, numerical analysis requires a matrix of numbers derived from the circuit node voltages.

Because of its advantages, the symbolic technique is a good candidate for performing both sensitivity and tolerance analysis—two major design problems that require computing partial derivatives. The symbolic approach can obtain the partial derivatives in terms of letters and thus avoids tedious numerical calculation.

Sensitivity analysis determines how aware a network is to changes in element values. Tolerance analysis measures the total circuit change caused by various combinations of element value deviations. The components, of course, change in value because of temperature variations and normal deviations from a mean manufacturing value.

Finding partial derivatives

Most engineers are experienced in deriving circuit responses from transfer functions. The transfer function, the ratio of an output to an input function, is usually expressed in letters related to the complex frequency variable, s. Both the sensitivity and tolerance analyses are evaluated from a transfer function; thus, the engineer works with terms

The authors

Richard Carpenter is studying toward a doctorate with a thesis topic in the area of computer-aided circuit design. His experience with NASA includes circuit design on the Nimbus meteorological satellite and applied research in computer-aided design of standard reliable circuits for space missions.

William W. Happ received a doctorate in theoretical physics from Boston University in 1949. He taught in Canada for nine years and has worked for several electronics and aerospace firms since returning to the United States in 1952. He is now chief of the design criteria branch at NASA's electronics facility.

that are familiar to him. Both analyses are further aided by indicators that are called tagging parameters. These indicators, when programed into a computer, isolate certain terms in a transfer function with a 1 when they appear and with a 0 when they don't. Here is a simplified illustration of the tagging procedure:

Suppose P is represented by an equation for a variable in a given circuit. It is desired to have the computer tag the letter "a" whenever it appears in the equation. So the tag 1 is assigned to the letter a and the tag 0 is associated with all other letters. The computer results are tabulated as follows

$$P = abc + bcd + acd + abd$$

Tag	Equation terms
1	abc
0	bcd
1	acd
1	abd

By removing a from all terms tagged and summing these terms, the partial derivative of P with respect to a is obtained.

$$\frac{\partial P}{\partial a} = bc + cd + bd$$

Sensitivity analysis

Sensitivity analysis allows the engineer to observe the effects of changes in circuit functions caused by changes in element values. These observations are based on the output expressions for the circuit that result from the symbolic technique. One definition of sensitivity is given by

$$S = \frac{\partial (L_n P)}{\partial (L_n Q)}$$

where S = sensitivity,
P = the transfer function
Q = a circuit parameter
L_n = the natural logarithm

Sensitivity is a dimensionless quantity that represents a percentage change in the transfer function of the circuit or system. It corresponds to a percentage change in a parameter of the system. For example, if P represents a circuit's voltage gain and Q represents the beta of a transistor in the circuit, then S represents the percentage of change in the voltage gain due to the change in beta.

Previously, the manual calculation of sensitivity required the engineer to derive the equation that contained the parameter and then either to take a derivative of the equation and evaluate the derivative, or to solve the equation for the value of the transfer function each time the value of a component changed.

The following equation calculates sensitivity with the symbolic method:

$$S = -\frac{H(\bar{Q})}{H(\bar{P})} \quad (1)$$

where H $(\bar{Q})$ is that part of the topology equation devoid of the parameter Q, and H $(\bar{P})$ is that part without P.

An alternate for equation 1 is the following expression for the sensitivity:

$$S = -\frac{H(\bar{Q}, \bar{P})}{H(\bar{P})} + \frac{H(\bar{Q}, P')}{H(P')} \quad (2)$$

where

$H(\bar{Q}, \bar{P})$ = that part of the topology equation that is simultaneously devoid of both P and Q;

$H(\bar{Q}, P')$ = that part that contains P devoid of Q;

$H(P')$ = that part that contains P;

$H(\bar{P})$ = that part devoid of P.

Since all of these terms can be obtained easily by tagging the appropriate parts of H, the solution is obtained easily by computer analysis.

Evaluating sensitivity by tagging is part of a subroutine of a computer program developed at the National Aeronautics and Space Administration's Electronics Research Center.

Advantages of symbolic analysis

- The symbolic technique highlights those parameters that are most critical in a desired function.
- All circuit functions are presented in terms of the complex frequency variable, s. (Small s should not be confused with capital S, which means sensitivity.)
- Partial derivatives can be computed as symbolic functions, thus avoiding tedious numerical calculations.
- The technique is inherently faster than the numerical technique because no numbers are calculated until the last step.
- Since no numbers are required, no numerical round-off error occurs due to matrix inversion.
- The technique is easily adapted to a small or medium size computer or time-sharing console.
- Only one coded description of the circuit is need for listing in the computer.

Sample sensitivity problem

The program produces the system response of a circuit from a coded signal flow graph that is obtained with an equivalent schematic of the circuit. Once the representation is formed, each of the N elements (or components) in the schematic of the circuit is numbered consecutively. The computer program uses a nine-digit code for specifying each component of the circuit. A tenth entry is given for the numerical value associated with the element.

Since each element is dependent on a voltage or current that produces a voltage or current, the problem is in two parts: one part contains the voltage generators and the other part contains the current generators. These two are then interrelated via the network's immittances.

Finding impedance sensitivity

To illustrate how the program computes sensitivity analysis consider this problem: find the sensitivity of the input impedance to changes in the two inductors, L_2 and L_4 for the circuit at the right.

Step 1. An imaginary element is required by the program to relate the current I and the terminal voltage V. This imaginary element is drawn across the driving-point terminals and labeled 1. Then each of the remaining elements and nodes is numbered consecutively as shown in the colored diagram. The node numbers appear in circles, the element numbers are not circled.

Step 2. Code each element in the circuit as either a voltage generator, shown by double arrows, or a current generator, shown by a single arrow and a horizontal bar. To do this, a current source is drawn as a voltage generator controlled by current, I, and a voltage source is drawn as a current generator controlled by voltage, V. For the imaginary element a current generator is needed because it represents a voltage source. The direction of the arrows specifies the direction assumed for positive current flow.

Element L_2 is arbitrarily chosen as a voltage generator. Therefore, the engineer must draw element C_3 as a current source. Two voltage sources are not allowed in parallel because this would violate Kirchhoff's voltage law. Current sources in parallel are permitted.

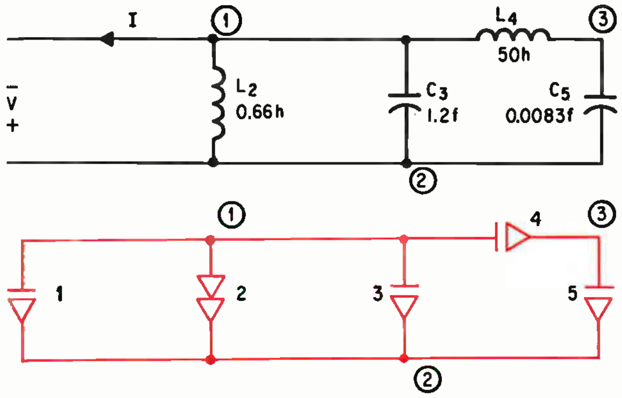
Also, element L_4 is a current generator and C_5 is a voltage generator. This is required since no two current generators may be connected in series because this would violate Kirchhoff's current law.

Step 3. Form table 1 from the coded schematic diagram, with the tagging procedure detailed below. The nine columns, A through K, represent the inputs needed for the computer program. Column E, shown with the numerals in color, should be determined first. It lists the number that corresponds to the element.

Columns A and B are obtained from the direction of current flow between any two nodes connected to an element, with A the starting point (circled numerals in the schematic) and B the terminating point. Thus, for element 1 a value of 1 is entered in column A because the current flows from node 1. In column B a 2 is entered because the current from node 1 terminates at node 2. The same entries are recorded for elements 2 and 3. Since the current in element 4 flows from node 1 to 3, a 1 is entered in column A and a 3 in column B. Finally for element 5, a 3 is entered in column A and a 2 in column B.

Column C indicates the controlling variables, 0 for voltage, 1 for current. Column G represents the generator function and is coded in the same binary manner as for column C. For example, element 1 is a voltage-controlled current generator. Hence, it is coded 0 in column C and 1 in column G. Likewise, element 2 is a current-controlled voltage generator. It is coded with a 1 in column C and a 0 in column G. Note that column C entries are always the reverse of the entries in column G for passive elements, and the same for active elements.

Column D indicates the variable that performs the controlling function. In all passive elements



Analysis of the sensitivity of the circuit above, a passive one-port network, to changes in the component values, is made with a coded circuit, in color. The elements are numbered consecutively and the node numbers are circled. Element 1 is an imaginary element needed to relate the terminal voltage, V, with the input current, I. Single arrows with a bar above are current sources and double arrows represent voltage sources.

the entry for column D will be the same as in column E since a passive element cannot create current or voltage. This is true for elements 2 through 5 in this example. However, the current in element 1 is controlled by the voltage generated by element 2; hence, a 2 is entered in column D.

Column F specifies frequency dependence in terms of the complex variable s, 0 for no frequency dependence, 1 for frequency dependence of s^1, 2 for s^2, etc. For most networks the power of s will not be greater than s^2. For example, element 2 is a current-controlled voltage generator (an impedance); hence, its frequency dependance is s^1. Therefore, a 1 is entered in column F.

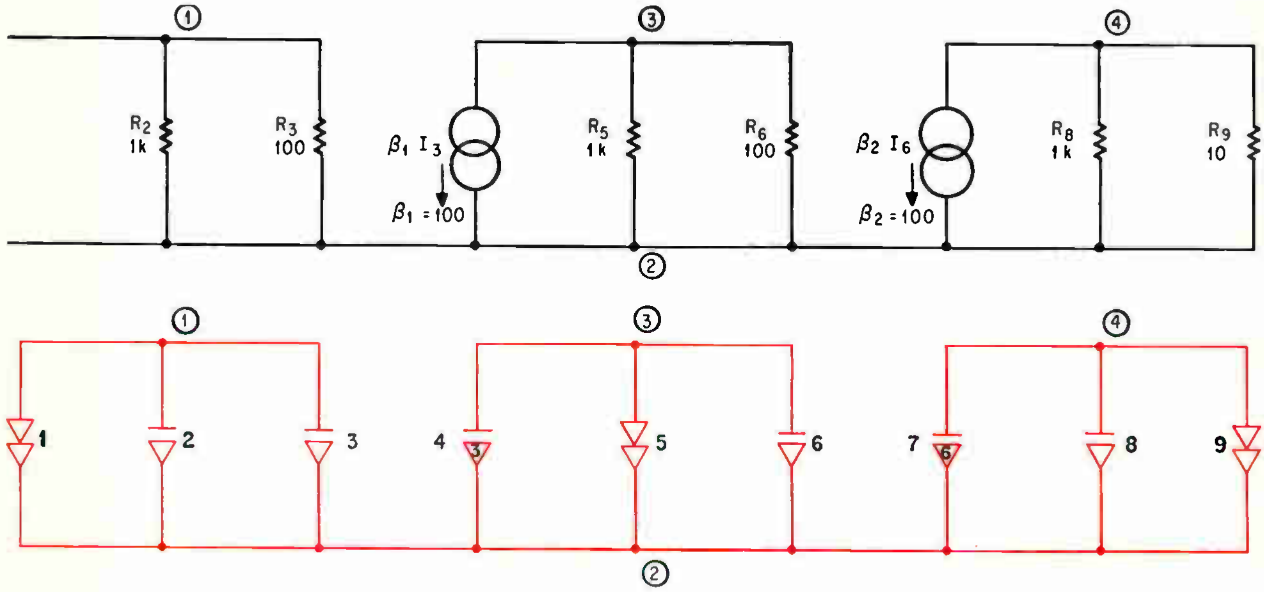
Column H indicates the presence of the imaginary element by a 1 for the element and a 0 for all other elements.

Column K indicates the elements for which the sensitivity is desired, coding a 1 for those elements and a 0 for all others.

The column at the far right of table 1 corresponds to the component values in a numerical form suitable for input to the computer. The imaginary element is listed as a 1 and is indicated by .100E + 1. This term .100E + 1 for the imaginary element, 1, means that it has a value of .100 times 10 with an exponent +1, or $.100 \times 10^{+1}$. Element 2 is an inductance of .666 henry and is considered here as an impedance. Hence, its coded entry .666 E + 0 and is read as $.66 \times 10^0$ henry. Element 4 is an inductance of 50 henrys and is considered here as

Table 1: Computer inputs, first example

A	B	C	D	E	F	G	H	K	Numerical Value
1	2	0	2	1	0	1	1	0	.100E+1
1	2	1	2	2	1	0	0	1	.666E+0
1	2	0	3	3	1	1	0	0	.120E+1
1	3	0	4	4	−1	1	0	1	.200E−1
3	2	1	5	5	−1	0	0	0	.120E+3



Equivalent of a transistor circuit contains both passive and active elements. Coded model, in color, is used to analyze the circuit's sensitivity to the voltage gain due to changes in the load resistor, input impedance and current gain of the transistors. The double circles represent transistor current sources. The numbers 3 and 6 inside the arrows indicate that elements 4 and 7 are dependent on currents 3 and 6 respectively.

an admittance. Hence, its numerical entry is 1/50 or .200 E-1, read a .200 × 10−1, and so on.

Step 4. The computer performs the necessary calculations with the NASA program and prints out the information listed in table 2.

Step 5. Determine the sensitivities of the input impedance due to changes in L_2 and L_4. To do this relate the data in table 2 to the terms in equations 1 and 2. The sensitivity can be computed both symbolically and numerically. For example, the sensitivity of the input impedance caused by L_2 is determined from

$$S = -\frac{H(\bar{Q})}{H(\bar{P})} = -\frac{H(\bar{L}_2)}{H(\bar{P})}$$

$$= -\frac{1+1/(L_4 C_5 s^2)}{1+1/L_4 C_5 s^2+L_2/L_4+L_2 C_3/L_4 C_5}$$

$$= -\frac{(1+2.4s^{-2})}{2.4 s^{-2}+2.9+.8s^2}$$

And, for changes caused by L_4, the sensitivity is found to be,

$$S = -\frac{H(\bar{Q}, \bar{P})}{H(\bar{P})} + \frac{H(\bar{Q}, P')}{H(P')}$$

$$= -\frac{H(\bar{L}_4, \bar{P})}{H(\bar{P})} + \frac{H(\bar{L}_4, P')}{H(P')}$$

$$= -\frac{(1+L_2 C_3 s^2)}{1+L_2/L_4+L_2 C_3/L_4 C_5+1/L_4 C_5 s^2} + \frac{L_2 s}{L_2 s+L_2/(L_4 C_5 s)}$$

$$= -\frac{(1+.8s^2)}{2.4s^{-2}+2.9+.8s^2} + \frac{.66s}{.66s+1.6s^{-1}}$$

A study of the sensitivities will show that system sensitivity is fairly constant over part of the frequency spectrum. At zero frequency or d-c, L_2 has a direct 1-to-1 relationship to the impedance but L_4 has no affect because it is in series with an infinite impedance. At very high frequencies the value of L_2 has almost no effect because it is an open circuit and L_4 has a 1-to-1 effect on the impedance.

Analyzing an active circuit

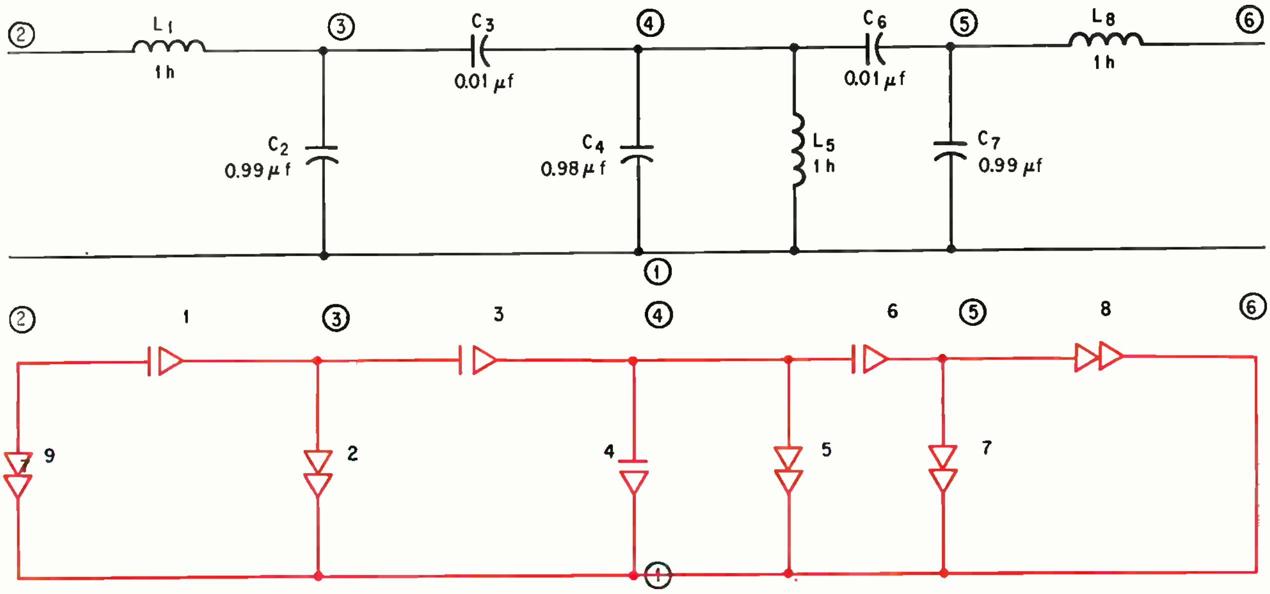
As a second example of the technique, determine the sensitivity of the voltage gain for the circuit shown above due to changes in the load resistor R_9, the input impedance R_2 and in the betas, β (transistor current gain) of the two transistors.

Step 1. Draw the schematic of the circuit following the method of the previous problem. Remember to add an imaginary element at the input terminals and label it 1. For this problem element 1 was arbitrarily chosen as a voltage generator.

Step 2. Number all nodes and all elements con-

Table 2: Computer outputs, first example

Tags	Symbolic value	Numerical value
$H(P')$	$\frac{L_2}{(L_4C_5s)} + L_2s$	$.66s + 1.6s^{-1}$
$H(\bar{P})$	$\frac{1}{(L_4C_5s^2)}+1+\frac{L_2}{L_4}+\frac{L_2C_3}{L_4C_5} + L_2C_3s^2$	$2.4s^{-2}+2.9+.8s^2$
$H(\bar{L}_4\bar{P})$	$1 + L_2C_3s^2$	$1 + .8s^2$
$H(\bar{L}_4P')$	L_2s	$.66s$
$H(\bar{L}_2)$	$1 + \frac{1}{(L_4C_5s^2)}$	$1 + 2.4s^{-2}$



Bandpass filter network and its coded form, in color, serve to analyze a circuit's sensitivity to the voltage transfer function caused by changes in L_5. Element 9 is dependent on the current through element 7.

secutively as in the diagram on page 95.

Step 3. Enter the coded inputs in table 3, as in the first example. Hence, elements 2 and 3 are coded as admittances and have no frequency dependence. Element 4 is coded as a current generator dependent on the current in element 3. This is actually the β_1 of the circuit. Element 5 is a current-controlled voltage generator (impedance) and is not frequency dependent. Element 6 is a voltage-controlled current generator and is not frequency dependent. Element 7 is also a current generator controlled by the β_2 of the circuit, and depends upon the current through element 6. Element 8 is a voltage-controlled current generator and is not frequency dependent. Element 9 is a current-controlled voltage source and is not frequency dependent.

Step 4. Obtain table 4 from the NASA computer program.

Step 5. Form the sensitivity relationships defined in equations 1 and 2. Hence, the sensitivity of the voltage gain due to β_1 is,

$$S = \frac{1 + R_5 G_6 + G_8 R_9 + R_5 G_6 G_8 R_9}{1 + R_5 G_6 + G_8 R_9 + R_5 G_6 G_8 R_9}$$

$$= \frac{.111 \text{ E} + 1}{.111 \text{ E} + 1} = 1$$

For this example the sensitivity due to β_2 is the same as that due to β_1; thus, the voltage gain is directly affected by either β.

The sensitivity of the voltage gain due to R_9 is determined from,

$$S = -\frac{.110 \text{ E} + 2}{.111 \text{ E} + 2} = -.99$$

The output load directly affects the voltage gain of the circuit; in the example there is almost a 1-to-1 relationship.

By checking the sensitivity of the voltage gain to the input impedance, R_2 (element number 2), the engineer will find that R_2 has extremely little effect on the gain of this transistor circuit. The numerical value of the sensitivity is computed from equation 2 and the appropriate values from table 4.

$$S = -\frac{.110 \text{ E} + 2}{.111 \text{ E} + 2} + \frac{-.100 \text{ E} + 5}{-.100 \text{ E} + 5} = 10^{-2}$$

Table 3: Input data, second example

A	B	C	D	E	F	G	H	Numerical Value
1	2	0	9	1	0	0	1	.100E+1
1	2	0	2	2	0	1	0	.100E−2
1	2	0	3	3	0	1	0	.100E−1
3	2	1	3	4	0	1	0	.100E+2
3	2	1	5	5	0	0	0	.100E+4
3	2	0	6	6	0	1	0	.100E−1
4	2	1	6	7	0	1	0	.100E+2
4	2	0	8	8	0	1	0	.100E−2
4	2	1	9	9	0	0	0	.100E+2

Table 4. Output data, second example

Tags	Symbolic value	Numerical value
$H(P')$	$-\beta_1\beta_2 G_3 R_5 G_6 R_9$	−.100E+5
$H(\bar{P})$	$1+R_5G_6+G_8R_9+R_5G_6G_8R_9$	.111E+2
$H(\bar{\beta}_1)$	$1+R_5G_6+G_8R_9+R_5G_6G_8R_9$	.111E+2
$H(\bar{R}_9)$	$1+R_5G_6$	.110E+2
$H(\bar{R}_2, \bar{P})$	$1+R_5G_6$	.110E+2
$H(\bar{R}_2, \bar{P})$	$-\beta_1\beta_2 G_3 R_5 G_6 R_9$	−.100E+5

Analyzing a bandpass filter

Determine the sensitivity of the voltage transfer function caused by changes in L_5 for the bandpass filter network that is shown on page 96.

The solution is found with the same procedure outlined in the earlier examples. [Table 5] represents the coded inputs obtained from the coded schematic. Element 9 is added to the circuit to close the system.

Element 1 is coded as a voltage-controlled current source (admittance) and has a frequency dependence of −1. Element 2 is coded as a current-controlled voltage source and has a frequency dependence of −1.

Elements 3, 4 and 6 are all coded as voltage-controlled current sources (admittances) and, since they are all capacitors, their frequency dependence is +1. Elements 5, 7 and 8 are coded as current-controlled voltage sources (admittances).

Elements 5 and 8 have a frequency dependence of +1; element 7 has a frequency dependence of −1, element 9 has no frequency dependence and is coded as 0.

Table 6 shows the data necessary for the determining of the sensitivity of the network due to L_5. The sensitivity is computed from equation 2 and is

$$S = \frac{.201E + 7s^{-2} + 3.96}{.201E + 7s^{-3} + 3.98 + .199E + 7s^2}$$

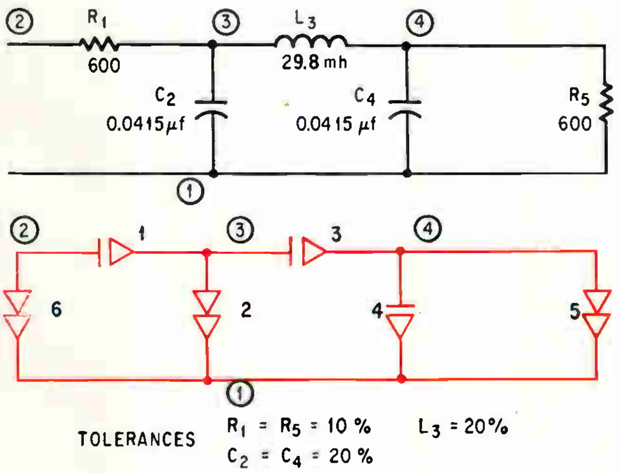
Thus, at high frequencies the sensitivity to L_5 is practically zero.

Changing theoretical to practical

To sketch a preliminary model of a circuit, a designer can assume that perfect components, with exact values, are available. However, actual components fluctuate in tolerance; the current gain of transistors for example, can vary from 10% to 300%. The designer therefore needs a technique for determining how changes in component values around the nominal value can affect total circuit performance. The technique: tolerance analysis.

The computer program for tolerance analysis is based on the following equation:

$$Y = f(P_1, P_2, P_3, \ldots, P_n)$$



Effect of component tolerances (shown in percent) on the sensitivity of the network's input impedance is computed from a tolerance analysis.

Table 5: Inputs, third example

A	B	C	D	E	F	G	H	Numerical Value
2	3	0	1	1	−1	1	0	.100E+1
3	1	1	2	2	−1	0	0	.101E+7
3	4	0	3	3	1	1	0	.100E−7
4	1	0	4	4	1	1	0	.980E−6
4	1	1	5	5	1	0	0	.100E+1
4	5	0	6	6	1	1	0	.100E+7
5	1	1	7	7	−1	0	0	.101E+7
5	6	1	8	8	1	0	0	.100E+1
2	1	0	5	9	0	0	1	.100E+1

Table 6: Outputs, third example

Tags	Symbolic value	Numerical value
H(P')	$\frac{C_3}{C_2} + \frac{C_3L_5}{(L_1C_2)}$	.980
$H(\bar{P})$	$\frac{1}{(L_1C_2s^2)} + \frac{C_6}{(L_1C_2C_7s^2)} + \frac{(C_3L_5+C_4L_5+L_5C_6)}{(L_1C_2)} + \frac{C_3C_6}{(C_2C_7)} + \frac{C_3L_5C_6}{L_1C_2C_7} + \frac{C_4L_5C_6}{L_1C_2C_7} + 1.00 + \left(C_3L_5+C_4L_5+L_5C_6 + \frac{C_3C_4L_5}{C_2} + \frac{C_3C_4L_5}{C_2} + \frac{C_6C_3L_5}{C_2} + \frac{C_6C_3L_5}{C_7} + \frac{C_3C_4L_5C_6}{(C_2C_7)}\right) s^2$	$.201E+7\ s^{-2}+3.98$ $+.199E+7\ s^2$
$H(\bar{L}_5)$	$\frac{1}{(L_1C_2s^2)} + \frac{C_3}{C_2} + \frac{C_6}{C_7} \frac{C_6}{(C_7L_1C_2s^2)} + \frac{C_3C_6}{(C_2C_7)} + 1.00$	$.201E+7\ s^{-2}+3.96$

where Y is a function of the independent variables $P_1, P_2, P_3 \ldots, P_n$ (Y in this case does not mean admittance). For small changes in each of the independent variables the statistical tolerance T_Y of Y is defined as:

$$T_Y = \left[\left(\frac{\partial Y}{\partial P_1}\Delta P_1\right)^2 + \ldots + \left(\frac{\partial Y}{\partial P_2}\Delta P_2\right)\right]^{1/2}$$

If the dependent variable Y represents a circuit function such as input impedance, voltage gain or transfer impedance and if the independent variables represent the circuit components, then the statistical tolerance of Y represents a measure of the deviation of Y from its mean or nominal value because of deviations of the components from their respective means or nominal values.

To evaluate statistical tolerance the engineer must perform a differentiation of performance criterion with respect to each of the elements in the circuit. The number of elements in a typical circuit can make this evaluation prohibitive and time-consuming if it is done manually. Although computer programs have been written in the past that incorporate numerical schemes to calculate all the partial derivatives for determining the statistical tolerance, the answers obtained were not accurate because the nature of a digital computer prevents these integration schemes from being exact.

Table 7: Tolerance analysis inputs

A	B	C	D	E	F	G	H	K	Numerical Value
2	3	0	1	1	0	1	0	0	.167E−2
3	1	1	2	2	−1	0	0	0	.241E+8
3	4	0	3	3	−1	1	0	0	.360E+2
4	1	0	4	4	1	1	0	0	.415E−7
4	1	1	5	5	0	0	0	0	.600E+3
2	1	0	5	6	0	0	1	0	.100E+1

Table 8: Sensitivity magnitudes

	R_A	C_A	L_A	C_B	R_B
a_0	.754E+8	.000E+0	.000E+0	.000E+0	.754E+8
a_1	.376E+4	.188E+4	.350E+4	.188E+4	.350E+4
a_2	.869E−1	.869E−1	.174E+0	.871E−1	.869E−1
a_3	.217E−5	.217E−5	.217E−5	.217E−5	.000E+0
b_0	.151E+9	.151E+9	.151E+9	.151E+9	.151E+9
b_1	.726E+4	.726E+4	.726E+4	.726E+4	.726E+4
b_2	.174E+0	.174E+0	.174E+0	.174E+0	.174E+0
b_3	.217E−5	.217E−5	.217E−5	.217E−5	.217E−5
$\|S\|$					
$\omega_0 = 0$	.499E+0	.000	.000	.000	.499E+0
$\omega_1 = 30k$	.340E+0	.491E+0	.102E+1	.492E+0	.660E+0
$\omega_2 = 40k$	.326E+0	.772E+0	.140E+1	.773E+0	.777E+0
$\omega_3 = 50k$	.551E+0	.939E+0	.149E+1	.940E+0	.755E+0
$\omega_4 = \infty$	.100E+1	.100E+1	.100E+1	.100E+1	.000
$\frac{\Delta P}{P}$	.1	.2	.2	.2	.1
$\omega_0 = 0$	.499E−1	.000	.000	.000	.499E−1
$\omega_1 = 20k$	.340E−1	.982E−1	.205E+0	.984E−1	.660E−1
$\omega_2 = 30k$	.326E−1	.154E+0	.281E+0	.154E+0	.777E−1
$\omega_3 = 50k$	.551E−1	.187E+0	.298E+0	.188E+0	.755E+0
$\omega_\infty = \infty$	.100E+0	.200E+0	.200E+0	.200E+0	.000

Table 9: Weighted element importance

	R_A	C_A	L_A	C_B	R_B
$\omega_0 = 0$	A	O	O	O	A
$\omega_1 = 30k$	B	B	A	B	B
$\omega_2 = 40k$	B	B	A	B	B
$\omega_3 = 50k$	B	B	A	B	B
$\omega_\infty = \infty$	A	A	A	A	O

A — major contributor to tolerance
B — minor contributor to tolerance
C — insignificant contributor to tolerance
O — no contribution to tolerance

Table 10.: Percent tolerance outputs

Frequency	% tolerance
$\omega_0 = 0$	7.06
$\omega_1 = 30k$	36.6
$\omega_2 = 40k$	41
$\omega_3 = 50k$	36
$\omega_\infty = \infty$	36

Understanding the program

Another method, based on flowgraph techniques, eliminates the need to evaluate any partial derivatives explicitly and also reduces calculations.

A flowgraph is defined in this application as a topological network in which each element is identified by two variables, such as current and voltage. A functional relation specifies the direction of dependance betwen the variables and a symbol or number denotes its junction.

A circuit analysis program based on this dichotomy of networks has been developed at the space agency. It analyzes and evaluates the flowgraph of any active or passive electrical network that contains 30 to 100 elements. The result is a relationship of T_Y/Y, the fractional change in Y due to the fractional changes in each component value $\Delta P_i/P_i$.

Select a frequency variation

If a circuit contains energy storage elements, then the sensitivity of the circuit will be a complex function of frequency. To handle these elements the sensitivity is evaluated at distinct frequencies and the magnitudes obtained are used to calculate the circuit's tolerance. This procedure provides the designer with data about the adequacy of the circuit model at different frequencies. Consequently, the model can be adjusted until it produces the desired frequency response.

An example of tolerance analysis is illustrated in the following problem: Determine the variance of the input impedance at different frequencies for the passive network on page 97. Component values are given with their tolerance in percent.

The coded electrical equivalent circuit is formed as previously outlined and each component is chosen as either a current-controlled voltage source (impedance), Z or a voltage-controlled current source (admittance), Y. From the coded circuit the input matrix of [table 7] is constructed with each row containing the input data that completely describes one element of the circuit.

A sensitivity analysis is first performed on each element of the circuit. As before, the result is a ratio of two polynominals in s. The coefficients of these two functions appear in the a_0 to a_3 and b_0 to b_3 rows in [table 8], which is the computer output. The next entries in table 8 are the magnitude of the sensitivities of each element evaluated at several frequencies (ω). Following this is a row, $\Delta P/P$, containing a fractional change in each element. The last set of rows in table 8 is simply the product of the sensitivity of each element and its fractional tolerance. With this data the engineer finds, T_{ZI}/Z_I.

The larger the magnitude of the sensitivity the more important the element is in the calculation of T_Y. [Table 9] indicates importance of elements.

[Table 10] lists T_{ZI}/Z_I in percent. The evaluation is performed at several frequencies to give the designer an indication of the range over which the model will work satisfactorily.

Knowing the cause helps to cure distortion in FET amplifiers

Circuit designers can steer clear of distortion trouble by following rules that are based on the interrelation of FET characteristics and the factors that cause distortion

By James S. Sherwin

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In an amplifier, the field effect transistor offers advantages of high gain and low noise but many designers, unfamiliar with the relatively new device, are unable to cope with the effects of harmonic distortion. By knowing the types of distortion and their causes it is possible to establish rules for operating an FET amplifier at maximum effectiveness.

Harmonic distortion in an FET amplifier is determined by many elements in the circuit—bias, operating voltage, load impedance, signal level, device characteristics and variations in input impedance. It is a function of the extent to which the device transfer curve departs from a straight line. Assuming neither load current cut-off nor saturation and neglecting the effect of supply voltage the transfer curve for an FET and other amplifying devices are closely approximated by the following: [1,2,3,4]

FET

$$I_D = K\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

$$g_m = \frac{2K}{V_P}\left[1 - \frac{V_{GS}}{V_P}\right] \qquad (1)$$

TRIODE

$$I_P = K_1\left[V_G + \frac{V_P}{\mu}\right]^{3/2} \qquad g_m = \frac{3}{2} K_1\left[V_G + \frac{V_P}{\mu}\right]^{1/2}$$

PENTODE

$$I_P = K_2\left[V_G + \frac{V_{G2}}{\mu_{G2}}\right]^{3/2} \qquad g_m = \frac{3}{2} K_2\left[V_G + \frac{V_{G2}}{\mu_{G2}}\right]^{1/2}$$

BIPOLAR TRANSISTOR

$$I_C = K_3\left[e^{\lambda V_{BE}} - 1\right] \qquad g_m = K_3 \lambda e^{\lambda V_{BE}}$$

Definitions of the terms in the FET relations and others used below are in the table on page 101.

In determining the degee of distortion, the transfer curve may be expressed as a power series in which each term represents a fundamental and distortion component. For example, the small signal transfer function for a triode tube evaluated at a given set of d-c conditions may be written:[5]

$$i_p = g_m e_{sig} + \frac{1}{2!}\frac{\partial g_m}{\partial V_G} e^2_{sig} + \cdots \frac{1}{3!}\frac{\partial^2 g_m}{\partial V_G^2} e^3_{sig} + \cdots \frac{1}{n!}\frac{\partial^{n-1} g_m}{\partial V_G^{n-1}} e^n_{sig} \qquad (2)$$

Each term, except the first, includes a partial derivative of the transconductance term g_m. The first term represents the desired fundamental. Because the input signal voltage, e_{sig}, is a sinusoidal function [(and $\sin^2 wt = ½(1-\cos 2wt)$)], the second term represents a constant plus a second harmonic. The third term contains first and third harmonics. [For brevity, these terms have not been multiplied out in equation 2.]

The author

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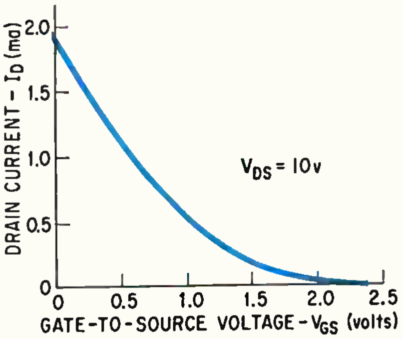
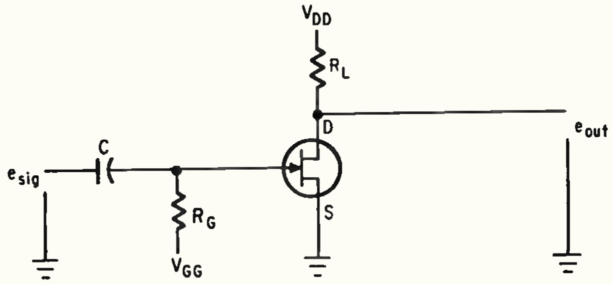
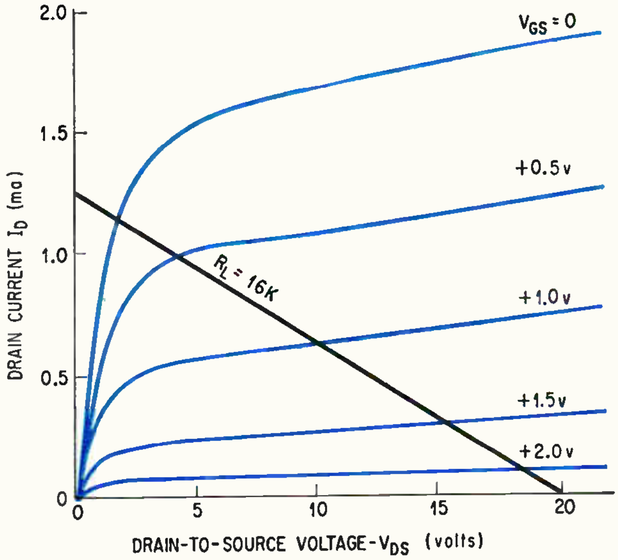


D-c transfer curve normally plotted for an FET at a constant drain-to-source voltage may not tell entire distortion story. Curve does not show effect of V_{DS} varying with input signal nor of the common-source output conductance varying with drain current.



Single-stage FET amplifier circuit is used to determine the effect on distortion of various device and circuit parameters.



Forward transconductance, g_{fs}, a function of the output characteristics, increases as V_{GS} goes to zero and operating point moves up and to the left along load line. This causes second harmonic distortion. However, as drain current, I_D, decreases, so does common-source output conductance, g_{oss}, also a function of the characteristics, introducing more distortion.

The first harmonic component of the third term adds to the fundamental causing a loss in proportionality between input and output. The third harmonic component causes cross-modulation and intermodulation distortion when two or more signals are present at the input.

Because the second term of the series is proportional to curvature in the transfer characteristic, second harmonic distortion may be minimized by operating on the most linear portion of the transfer curve. The third term is proportional to rate-of-change of curvature. Therefore, the third harmonic and cross-modulation may also be minimized by operating in the most linear portion.

With field effect transistors, the transfer curve is shaped so that the second and higher order derivatives of transconductance, g_m, are zero. Only a second harmonic is present. Cross modulation products are extremely low. In the case of vacuum tubes, fourth and higher order terms are negligible. However, the series does not converge so rapidly for the transistor. Hence, fourth and higher order harmonic distortion may be significant and cross modulation is more serious in a transistor than in a vacuum tube.

Although FET's promise to generate only second harmonic distortion, the operating point must be carefully controlled for minimum distortion. Calculations made from an idealized or even a measured transfer curve may not tell the entire story. For example, a d-c transfer curve (top, left) normally plotted at a constant drain voltage V_{DS}, does not take into account the effect of v_{DS} varying with the input signal or of the common source output conductance g_{oss} varying with drain current, i_D.

The single-stage amplifier circuit (center, left) may be used to determine the effect on distortion of variations in e_{sig}, V_{GS}, R_L and FET characteristics V_P, g_{oss}, and g_{fs}. It will be shown that, for low distortion, it is desirable to operate with a small input signal near zero bias. Both R_L and V_{DD} should be high and V_{DS} should be sufficiently above the knee of the output-characteristic curves of the FET but no more than necessary. Also the region near drain-to-gate breakdown should be avoided to prevent the flow of gate current on signal peaks. And, certain field effect transistor geometries are preferred over others.

Transfer curve and conductances

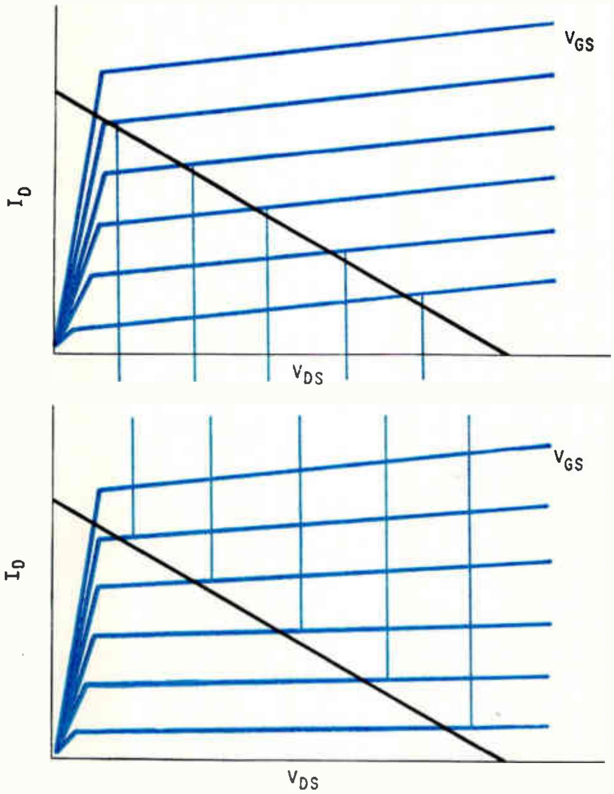
The transfer curve alone, at top, left, will not yield a completely correct picture of the harmonic distortion introduced by the FET amplifier. As the input signal varies, so do the two conductances, g_{fs} and g_{oss}, which affect the gain of the stage.

Follow the instantaneous operating point up and left along the load line drawn on the FET output characteristics curves at the left.

Transconductance g_{fs} (which is the ratio of the change in output current, I_D, to the change in input voltage, V_{GS}, for a constant output voltage, V_{DS}) increases as V_{GS} approaches zero. This variation in g_{fs} is reflected in the curvature of the transfer curve for the FET. The curvature causes second harmonic distortion.

What is not so apparent is that nonlinearities also exist because g_{oss}, the ratio of the change in output current I_D to the change in output voltage, V_{DS}, for a constant bias voltage, V_{GS}, also varies with the instantaneous operating output current—g_{oss} increases as V_{GS} approaches zero, and as I_D increases.

These two effects become more visible by refer-



Idealized FET output characteristics are drawn to show (top) constant g_{fs}, constant g_{oss} and (bottom) constant g_{fs} and nonconstant g_{oss}. Transconductance g_{fs} is constant because for a given value of V_{DS} distances between V_{GS} curves are constant. Transconductance g_{oss} varies when slopes of V_{GS} curves vary.

ring to the stylized sets of constant g_{fs} output characteristics shown above. Both sets of curves exhibit a constant g_{fs}, that is, for a given value of V_{DS} the distances between the curves for constant V_{GS} are the same.

However, the top set has constant g_{oss}—the slopes of the constant V_{GS} curves are identical—while the bottom set has a varying g_{oss}—as I_D increases, the slopes of the constant V_{GS} also increase and g_{oss} increases. In effect, the bottom set of curves indicates an increase in gain as the operating point moves down and right along the load line.

Definition of terms

E_a	peak signal amplitude
e_o	output signal voltage
e_{sig}	input signal voltage
g_{fs}	common-source forward transfer conductance
g_m	mutual conductance (in FET's, g_{fs} is identically equal)
g_{oss}	common-source output conductance (input shorted)
i_D	instantaneous drain current
I_D	drain current
I_{DSS}	drain saturation current
V_{DD}	drain supply voltage
V_{DS}	drain-to-source voltage
V_{DS}	instantaneous drain-to-source voltage
V_{GG}	gate supply voltage
V_{GS}	gate-to-source voltage
V_P	gate-source pinch-off voltage

From the gain equation for the FET:

$$\frac{e_o}{e_{sig}} = \frac{g_{fs}}{G_L + g_{oss}} \quad (3)$$

it is apparent that the effect of a change in g_{oss} is less for large G_L, reciprocal of load resistance. As V_{GS} increases, the decrease in g_{fs} is partially offset by a corresponding decrease in g_{oss}. In effect, the degree of distortion produced by a nonlinear transfer curve is diminished. At a certain operating point the two distortion sources will most nearly cancel to produce a point of minimum distortion.

Expanding the power series transfer function of equation 1 for the a-c terms for the FET gives the expression:

$$i_d = \frac{2I_{DSS}}{V_P^2}(V_P - V_{GS}) E_a \sin \omega t - \frac{I_{DSS}}{V_P^2} E_a^2 \left(\frac{\cos 2\omega t}{2}\right). \quad (4)$$

where E_a is the peak signal amplitude

Taking the ratio of the amplitudes of the second harmonic and the fundamental, the expression for percent second harmonic distortion is:

$$\%\text{ second harmonic distortion} = \frac{25\,E_a}{(V_P - V_{GS})} \quad (5)$$

This expression is valid for small-signal distortion due only to curvature of the transfer characteristic. Required conditions are that the drain voltage saturation region is avoided and that drain current flows during all portions of the cycle.

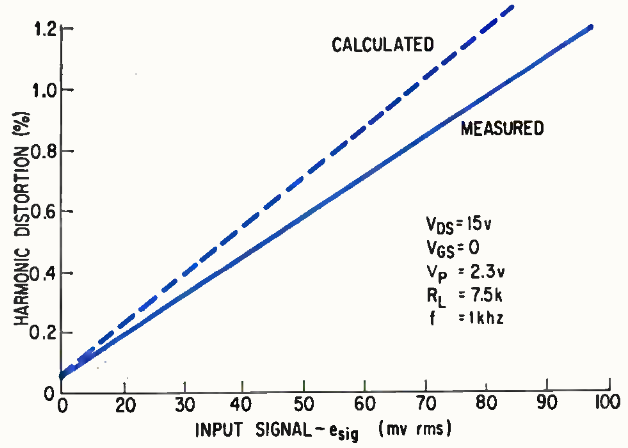
Gate bias and signal level

According to equation 5, small-signal distortion is directly proportional to the input signal level. However, the distortion also depends upon the difference between the pinch-off voltage and the voltage on the gate.

The plot of total harmonic distortion vs input signal in the figure top, page 102 bears this out. This curve was plotted from data taken at zero gate bias. However, the distortion level is unaffected by the slight forward gate biasing on negative signal peaks because the transition of the gate diode of the FET from reverse bias to forward bias is gradual.

Input circuit distortion is not measureable until the rms input signal level exceeds 100 millivolts. This is apparent in the figure bottom, page 102 which plots input distortion vs input signal for gate-circuit time constants, RC, of 10 milliseconds to 1 second. The reason the distortion increases with the input signal is that the gate draws current from the signal source on input peaks; distortion is reduced by adding the equivalent of grid-leak bias.

In this manner, the d-c current drawn through the gate-return resistor, shown in the amplifier circuit on page 100, develops a gate bias approximately equal to the peak forward signal voltage. So long as the input capacitor remains charged, the gate ceases to draw current on signal peaks.



Harmonic distortion is directly proportional to input signal level. Calculated curve is plotted from equation 5.

Thus, distortion becomes a function of frequency. Reducing the frequency to 100 hertz will have the same effect as reducing the time constant by a factor of 10.

This means that for low distortion when the gate conducts on signal peaks, RC must be about 1,000 times the period of the lowest frequency to be handled. If the generator impedance is quite low, say a few hundred ohms, the input distortion will be reduced considerably. However, because this is not a normal operating condition, the gate should be operated at a bias level that insures signal peaks will not forward-bias the gate by more than 100 to 200 millivolts.

Equation 5 indicates also that distortion increases as V_{GS} approaches V_P; for $V_{GS} = 0$, distortion is inversely proportional to V_P. Distortion vs V_{GS} is plotted in the figure on page 103 for two values of input signal for a device with $V_P = 2.3$ volts. The figure below it plots distortion against V_P for $V_{GS} = 0$. The calculated and measured values agree closely in both plots. However, as $(V_P - V_{GS})$ approaches zero, the measured distortion significantly exceeds the calculated value, possibly because the signal level may no longer be considered as small signal or the true transfer curve departs from the mathematically ideal parabola of equation 1.

Drain voltage

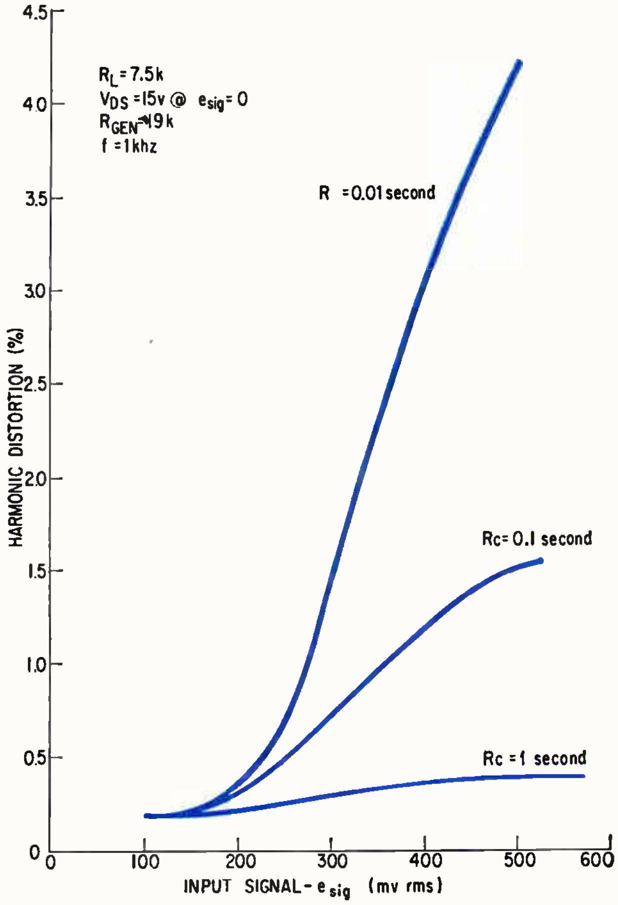
The effects of V_{DS} and g_{oss} on distortion are illustrated in curves on page 104. The V_{DS} effect is in reality a g_{oss} effect as may be seen from the g_{oss} vs V_{DS} curves. Distortion due to g_{oss} becomes large at low V_{DS} due to the very high value of g_{oss}, while the distortion at high V_{DS} is due principally to the variation in g_{fs}. As V_{DS} is decreased, the g_{oss}-induced distortion increases and counteracts the g_{fs}-induced distortion. At a specific and fairly low V_{DS} the two distortions nearly cancel to produce a minimum in the distortion curve.

Unfortunately, operation at the point of minimum distortion is not particularly recommended. Its location is uncertain and, as can be seen from the figure on page 104, very near a region of excessive distortion.

Operation below the point of minimum distortion at low V_{DS} results in a significant increase in nonlinear distortion due to drain saturation. This is reflected in the rapidly increasing g_{oss}. This effect is also visible on the FET output characteristic on page 101 as the operating point moves up and to the left along the load line approaching the knee of the output curves.

The effect may be further described by the saturation of the transfer curve that can be plotted for the condition of insufficient V_{DS}.

Operating a FET with the drain voltage at or near breakdown has been reported as one method for improving bias stability.[6] The idea, apparently, was that with the FET biased to the point where drain-gate breakdown occurs, any FET plugged into the socket will find a stable operating point at breakdown even though V_{GS} may vary somewhat from one unit to another. As signal is applied, voltage peaks at the gate drive the device further into breakdown. Zener breakdown current then flows from the drain to the gate developing a gate-leak bias in much the same manner as already described on page 101.



Input circuit distortion is negligible until the input signal reaches 100 mv. The larger the input circuit time constant, the lower the distortion.

The result is effective in stabilizing the operating point; however input circuit distortion becomes significant with normal generator resistances, a fact overlooked by the author. In fact, distortion of up to 44% was measured with an FET operating from a 20-kilohm/100-millivolt source under the other conditions reported in reference 6.

Long, short and medium gates

The physical geometry of the FET also has an effect on distortion, as shown by the three curves in the figures on page 104. Three devices of approximately equal pinch-off voltage generate significantly different distortion levels. These distortion levels are due to different gate lengths, which affect the value of g_{oss} and the rapidity with which the device output characteristics shift from triode to pentode type as V_{DS} increases. The three photos on page 105 show the output characteristics of the three devices. That the values of g_{oss} differ is apparent from the slopes of the characteristics.

The 2N3578 is a very long gate FET, top photo, and has the lowest value of g_{oss}. The transition from the triode- to pentode-like characteristic is also quite rapid. Distortion is high because g_{oss} is low and the g_{oss}-induced distortion only slightly reduces that induced by g_{fs}.

On the other hand, excessive distortion at drain saturation decreases rapidly as V_{DS} increases because of the rapid shift from the triode to pentode character. Where drain supply voltage is limited, the long gate device is perhaps preferred over other types because the operating point may be closer to the knee of the output curves.

The 2N3376 is a short-gate device, middle photo, with rather high g_{oss} and a poorly defined transition region from triode to pentode character. The high g_{oss} causes a fairly low distortion as long as adequate drain voltage is available. A short-gate device is probably the best choice where minimum distortion is required and the supply voltage is not severely limited.

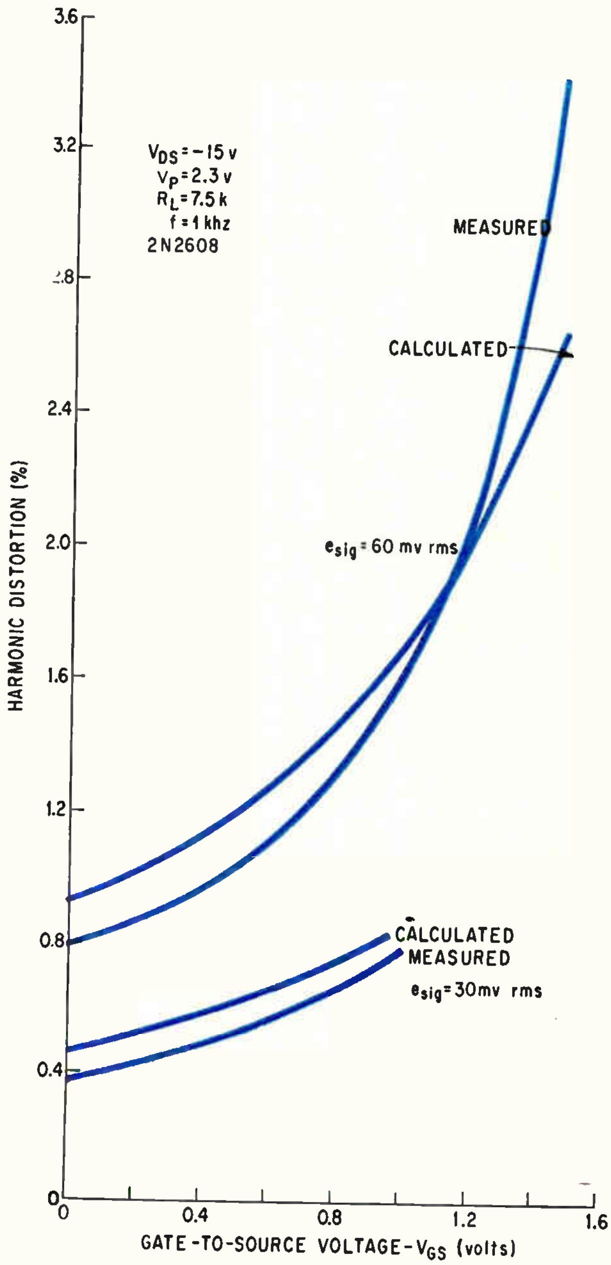
The 2N2608, bottom photo, is a medium gate-length device. It is a compromise between the low distortion and low saturation voltage characteristics of the long and short gate devices.

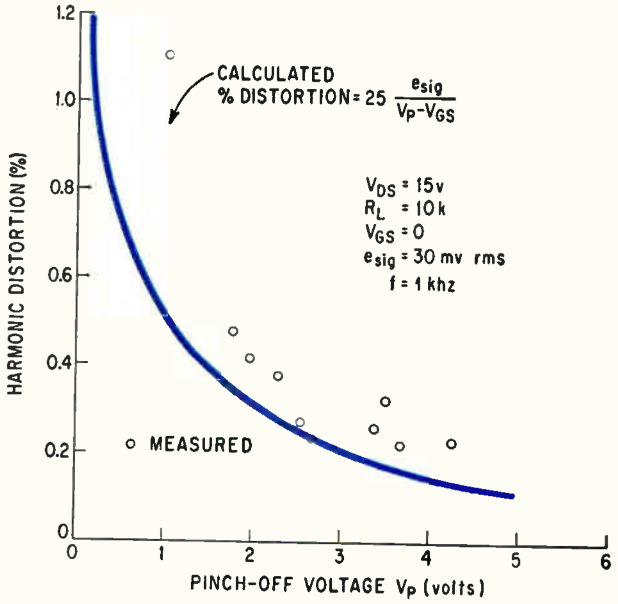
Load resistance

Load resistance also affects distortion level. The effect is, again, a function of g_{oss}. Distortion decreases with increasing R_L. Distortion is less with devices having short gates because g_{oss} is greater than it is for FETS with much longer gates. The reason for the improvement with increasing R_L is that the g_{oss}-induced distortion has a greater opportunity to counteract g_{fs} distortion as the load line becomes more nearly horizontal.

Consider, for example, that g_{oss} effects are zero when $R_L = 0$ and the load line is vertical. Conversely g_{fs} effects are near zero when $R_L = \infty$ and the load line is horizontal. At some point with high R_L, a distortion minimum will occur beyond which g_{oss} distortion is greater than g_{fs} distortion.

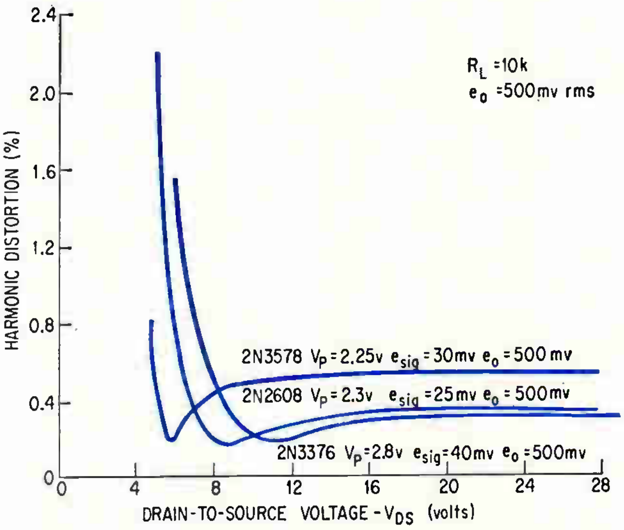
A particularly effective way of operating with



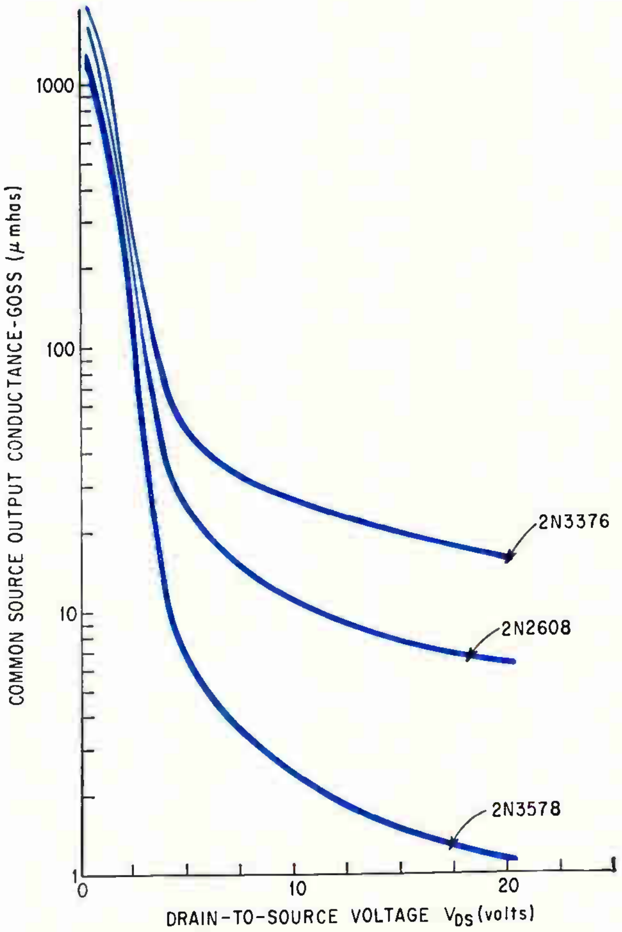


Distortion increases as the gate-to-source voltage, V_{GS} approaches the pinch-off voltage, V_P.

high R_L for low distortion and high gain is shown in the circuit next page. A second FET is used here as the load resistor. The load line is one of the constant V_{GS}-output curves of Q_2 superimposed upon the output characteristics of Q_1. The load FET should have I_{DSS} greater than that of the amplifier



Drain-to-source voltage, V_{DS}, must remain well above the pinch-off voltage for the FET or the distortion increases sharply.



Output transconductance g_{oss} goes up for three types of FET's with varying gate lengths as drain-to-source voltage, V_{DS}, goes down.

field effect transistor used in the circuit.

Load resistor R_1 is adjusted for an operating point A, at $V_{DS} \approx V_{DD}/2$. It is important to use devices with high g_{oss}, otherwise V_{DS} will be unstable because of device heating and the consequent decrease in I_D. The operating point then shifts from $V_{DS} \approx V_{DD}/2$. Low I_{DSS} is also desirable to maintain low power dissipation and, hence, good temperature stability.

Rules for low distortion

To attain the lowest possible distortion with an FET amplifier close attention must be given to d-c operating point, bias level, load resistance and, of course, the FET characteristics. The rules to follow, listed in descending order of importance, are:

1. Maintain V_{DS} high enough so that peak output signal swing will not reduce V_{DS} below two to four times V_P. Distortion increases sharply for drain-to-source voltages approaching the pinch-off voltage.
2. Maintain V_{GS} at such a point that peak input signal swing will not forward-bias the FET gate junction by more than 200 mv.
3. Do not operate near drain-gate breakdown voltage unless the signal source impedance is low.
4. Maintain a minimum V_{GS} consistent with other circuit requirements. More properly, maximize (V_P — V_{GS}.) Distortion increases with bias voltage.
5. Minimize input signal level.
6. Use a high value of load impedance. Distortion decreases with R_L.
7. Maintain V_{DS} at the lowest value consistent with rules 1 and 3.

Note that rules 4 and 6 indicate operation at the highest practical gain commensurate with power supply and frequency response limitations.

Distortion redefined

A particularly practical viewpoint is to consider distortion as a percentage of output voltage rather than of signal voltage as represented by equation 5. The combined effects of FET parameters V_P, I_{DSS}, g_{fs} and stage gain may then be determined. It is also reasonable to assume that prime interest lies in the output distortion level regardless of what input signal level is required.

Consider the stage gain expressed in equation 3 simplified to

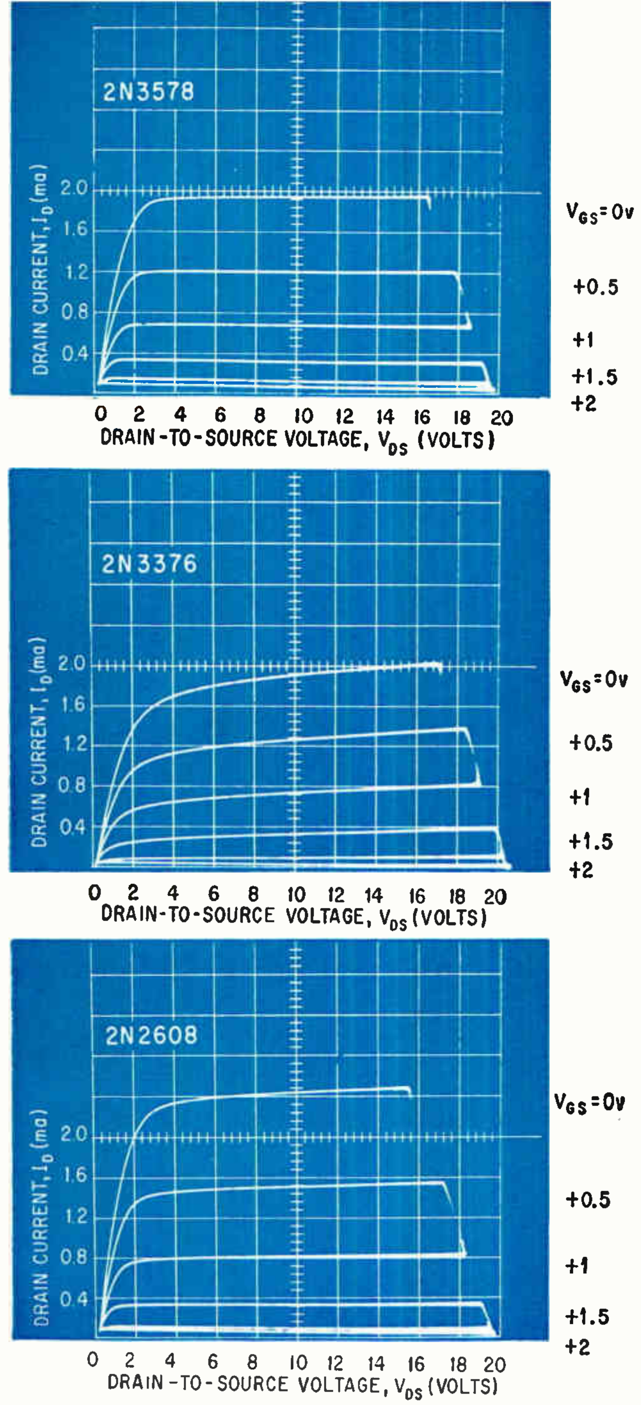
$$\frac{e_o}{e_{sig}} = g_{fs} R_L \qquad (6)$$

Combine this with equation 5 to obtain distortion in terms of peak value of rms output voltage.

$$\% \text{ Distortion} = \frac{25 e_o}{g_{fs} R_L (V_P - V_{GS})} \qquad (7)$$

If R_L is related to supply voltage and FET characteristics as follows:

$$R_L = \frac{V_{DD} - 2V_P}{2I_D} \qquad (8)$$



Different gate lengths of the FET's affect the distortion levels because they also affect the value of common-source output conductance, g_{oss}, or the slope of the curves. Very long gate 2N3578 has lowest slope and lowest g_{oss} (top). Short gate 2N3376 has rather high g_{oss} (middle). Median gate 2N2608 is compromise between the other two FET's (bottom).

for maximum output signal swing, then the FET characteristic equations

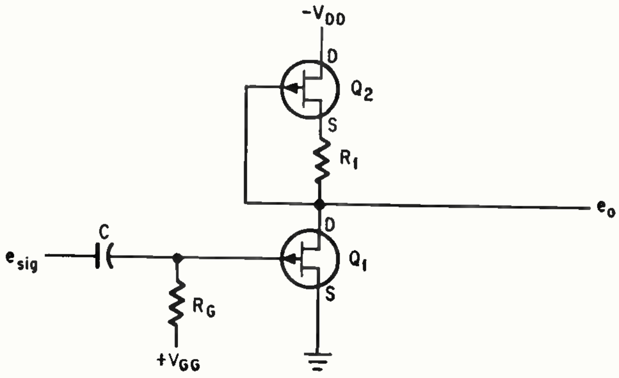
$$I_D = \frac{I_{DSS}}{V_P^2}(V_P - V_{GS})^2 \tag{9}$$

$$g_{fs} = \frac{2I_{DSS}}{V_P^2}(V_P - V_{GS}) \tag{10}$$

may be used with equations 7 and 8 to find output distortion (again, at peak out voltage).

$$\% \text{ Distortion} = \frac{25\, e_o}{V_{DD} - 2V_P} \tag{11}$$

From equation 11, it is apparent that FET amplifier distortion for a given output voltage is independent of I_{DSS} and g_{fs}. Rules 4 and 5 become of little importance for the case where e_{sig} is small and R_L may be increased without regard to bandwidth or other design considerations.[7] High V_{DD} and low V_P allow high R_L, high gain, and thus low e_{sig} to produce a given e_o. Distortion is minimized not only because of the low signal required, but also because of the advantages of high R_L already discussed (but not expressed in equation 11).



FET used as load resistor is effective way of operating for low distortion and high gain. Load line is a constant V_{GS} characteristic curve for Q_1 superimposed on the ouput characteristics of Q_2.

Transistor selection

The FET to be selected for lowest distortion will depend upon the available input signal, supply voltage, and required bandwidth. For large input signal and large bandwidth, a high V_P is desired unless source degeneration is applied. For small input signal or low V_{DD}, a low V_P unit is desired. The choice will depend upon the specific conditions of application. In any case, an FET exhibiting high g_{oss} is desired. This characteristic may be evaluated by referring to the output characteristic curves for any particular FET. Output characteristic curves with large slope mean high g_{oss}.

No attempt has been made to play off one characteristic against another. For example, a low V_P unit from any one given geometry will exhibit a slightly higher g_{fs} at a given drain current than will the high V_P unit of the same family. This means that the device may be operated at low I_D for higher gain ($g_{fs}R_L$) than is attainable with high V_P units.

The author believes that few, if any, of these trade offs can significantly improve the distortion level.

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6. W.A. Rhinefelder, "FET's Outperform Bipolars, Pentodes in Linear Voltage Amplifiers," Electronic Design, December 20, 1965, p. 24.
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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.

Warning lights monitor d-c supply voltage

by Robert L. Nuckolls III

Electronic Designs Development, Wichita, Kan.

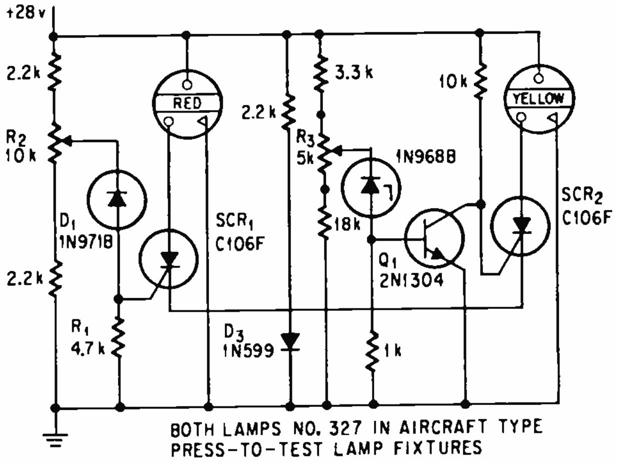
Overvoltages in an aircraft's d-c supply can ruin expensive radio equipment. A pilot confronted by a myriad of dials may not notice supply voltage changes on a voltmeter dial in time to take corrective action. The circuit at the right, replaces the voltmeter with warning lights that display overvoltage or undervoltage conditions. Installed in an automobile, the circuit warns of voltage regulator malfunctions so that repairs can be made before the battery is destroyed.

When the 28-volt supply voltage rises to 32 volts, it back biases zener diode D_1 into conduction; current flows through R_1 and D_1, triggering SCR_1 and turning on the red overvoltage warning lamp. Although the cathode of SCR_1 is clamped at 0.6 volt by diode D_3, the voltage at the anode of zener D_1 is 1.1 volts; the 0.5-volt difference is enough to turn on the SCR which requires only 0.2 volt for triggering. Once turned on, the SCR continues to conduct and the lamp remains lit. It can be extinguished by pressing the lamp's press-to-test mounting fixture. This opens the circuit.

To control the yellow undervoltage warning lamp, zener diode D_2 is chosen so that it is back biased into conduction as long as the supply voltage stays above 24 volts. The current through D_2 holds transistor Q_1 in saturation by making the base of Q_1 positive with respect to its grounded emitter. With Q_1 in saturation, the gate of SCR_2 is held 0.2 volt above ground by the voltage drop across Q_1. Since the cathode of SCR_2 is fixed at 0.6 volts by diode D_3, the reverse bias from gate to cathode on SCR_2 is 0.4 volt, maintaining SCR_2 and the lamp in a normally off condition.

When the supply voltage drops below 24 volts, zener diode D_2 cuts off; this drops the base voltage on transistor Q_1 to ground and shuts it off. With Q_1 an open circuit, the gate of SCR_2 is switched to the supply voltage and SCR_2 conducts, turning on the yellow lamp.

Potentiometers R_2 and R_3 provide some adjustment of the critical supply voltage levels which trigger the warning lamps. The voltages handled by the circuit are typical for a 28-volt battery/alternator d-c supply in an aircraft; however, the circuit can monitor voltages as large as 600 volts with appropriate lamps and semiconductor devices. This circuit was designed for cockpit installation and is not temperature compensated, but it will operate satisfactorily over a range of 50° to 90°F.



An increase in supply voltage to 32 volts brings zener diode D_1 into conduction firing SCR_1 and turning on the red overvoltage warning lamp.

Tunnel diodes lock output of servocircuit

By John C. McKechnie

Martin Co., Orlando, Fla

An often-ignored property of tunnel diodes, the reverse current-voltage curve, can be the basis for a family of circuits that delivers a nearly constant output when the input voltage is between two specified levels. This form of response, provided by an offset hysteresis transfer function, is particularly useful in servosystems.

Features of the offset hysteresis transfer function [the top curve in the diagram at the right] are:

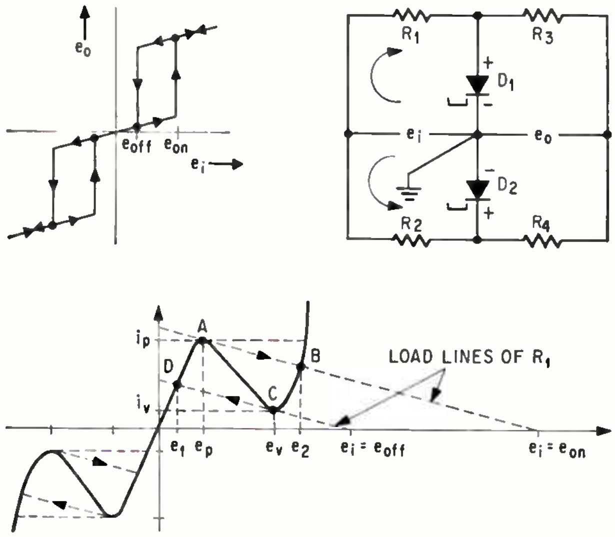
- Output is delayed until the input signal, e_1, reaches a minimum level, e_{on}.
- There are only two response states, full on (plus or minus) and off.
- Once the function is on, an overshoot voltage in the opposite direction—to e_{off}—is necessary to turn it off.
- An increase in the input signal will not change the output when the function is on.

Among the circuit types that can exploit these actions are analog computing elements, absolute value threshold detectors, bang-bang elements of nonlinear servosystems and servofeedback loop elements. A circuit built with radiation-hard tunnel diodes has been developed at the Martin Co. to produce a dead band and gated response in the feedback of a missile servosystem.

The basic form of the circuit is shown and the reverse current-voltage characteristic of the tunnel diodes is displayed in the lower section of the diagram. The forward current-voltage characteristic is similar to that of a conventional diode; that is, it presents essentially zero impedance.

The circuit consists of two loops, each containing a tunnel diode, a current-limiting resistor, an output resistor and a ground reference. The upper loop (e_i,R_1,R_3,e_o) provides the hysteresis characteristic when the input voltage, e_i, is positive. When the input is negative, the loops work in reverse.

As e_i rises until it equals e_{on}, the reverse current in the upper loop through D_1 increases to a value i_p, at point A on the characteristic curve. At this point, D_1 switches to its higher voltage state, e_2, as determined by the intersection of the curve and the load line of the current-limiting resistor, R_1, at point B. Since the curve's slope is quite steep at point B, any further increase in e_i is mostly absorbed across R_1 and the output voltage, e_o, remains nearly constant.



Offset hysteresis transfer function, shown at top, is achieved in the circuit by exploiting the reverse current-voltage characteristic of tunnel diode, seen in bottom curve.

Then, as e_i decreases to a value that equals e_{off}, the reverse current through D_1 also decreases. When the current falls to i_v, at point C of the curve, D_1 switches to its lower voltage state. This state, e_1, is determined by the intersection at point D of D_1's characteristic curve and the load line of R_1. It is apparent from the curve that e_{off} is less than e_{on}, accomplishing the desired hysteresis characteristic.

Meanwhile, D_2 in the lower loop is virtually a short circuit. As the positive e_i gradually increases from zero, a forward current flows through D_2 and R_2. As long as e_i is positive, forward conduction is maintained and essentially all of E_i in the lower loop is dropped across R_2.

The switching point of the output with respect to the input voltage level depends upon the values selected for R_1 and R_2. The output voltage in the on state is varied with output resistors R_3 and R_4, which combine with the output load resistance to make a voltage divider.

Agc circuit possesses 60-decibel gain

By William H. Ellis Jr.

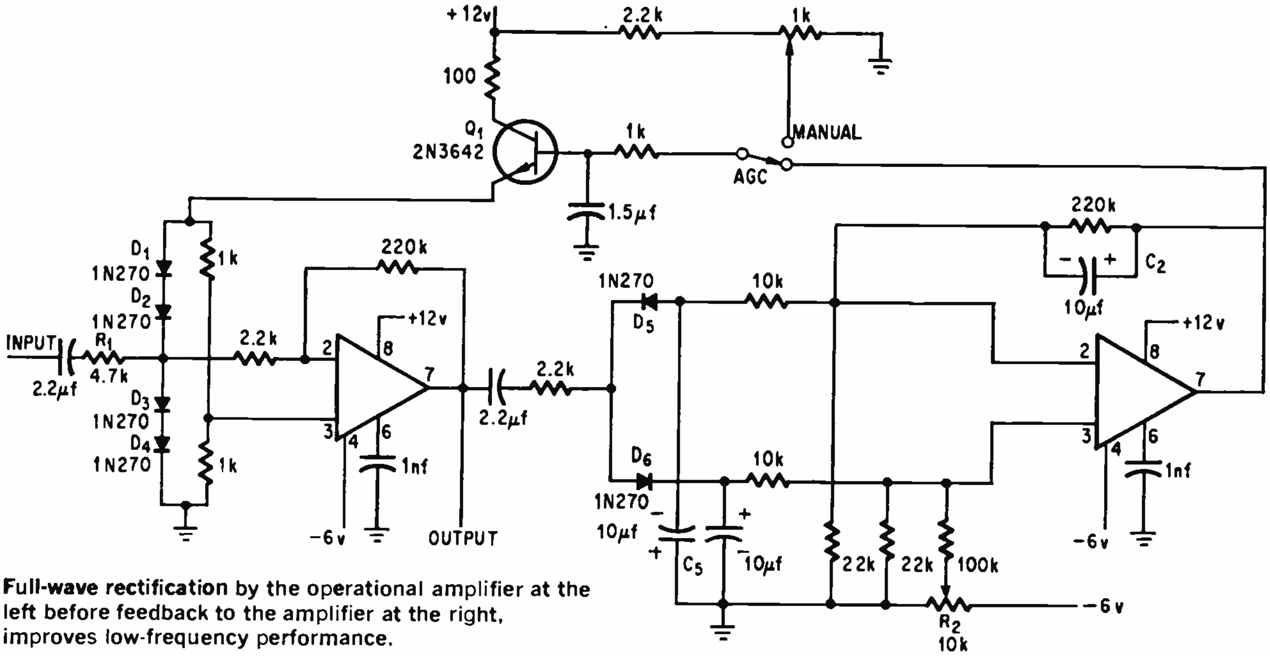
Page Communications Engineers, Inc., Washington, D.C.

Integrated circuits, diodes and a single transistor form an automatic gain control circuit that provides an output change of less than 6 decibels for an input change of greater than 60 db. Frequencies can range from 20 hertz to over 10 khz [See Electronics, p. 81, Nov. 28, 1966 for an alternate circuit.]

Resistor R_1 and diodes D_1, D_2, D_3 and D_4 form a voltage divider in the circuit [at top p. 108]. Current through the diodes establishes the voltage division ratio because it changes the effective resistance of the diodes. The signal at the voltage divider is amplified by the integrated circuit at the left of the diagram on the next page, an operational amplifier with a gain of 100. The output of this amplifier is rectified by D_5 and D_6.

Effective full-wave rectification—which improves the low frequency performance of the circuit—is achieved without a transformer by the second operational amplifier. The control signal at the output of the second amplifier is buffered by the emitter follower, Q_1, that drives the input diodes.

For manual control the feedback loop is broken



Full-wave rectification by the operational amplifier at the left before feedback to the amplifier at the right, improves low-frequency performance.

and a potentiometer inserted to control current flow through the diode voltage divider. Adjusting R_2 varies agc delay. Capacitor C_1 controls agc delay.

The circuit exhibits good d-c stability at a temperature of 70°C.

Variable voltage division requires several volts of input signal for maximum agc range under maximum signal conditions. Consequently, one or more stages of linear amplification may be required ahead of the agc circuit.

Adding transistors makes voltage shifter adjustable

By James E. Walters

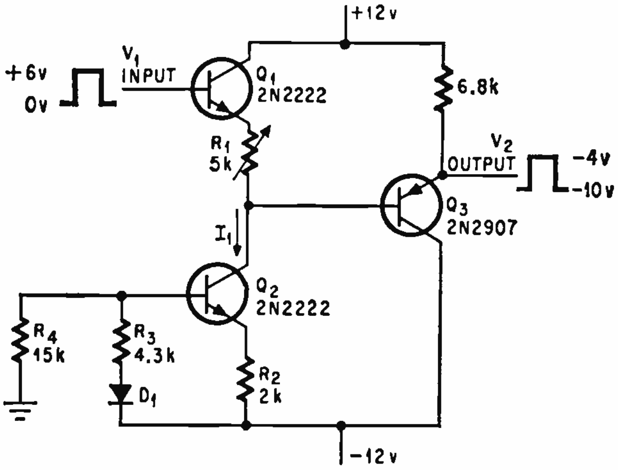
Light Military Electronics Division,
General Electric Co., Utica, N.Y.

Single-transistor circuits for shifting voltage levels have been the rule in digital systems that require two or more driving voltages. In contrast, the circuit at the right is more complex but offers several advantages over the usual logic-level shifter: it has high input impedance, has good thermal stability and provides accurate control and adjustment of the output level.

These advantages are frequently desirable in interfacing, where the amount of shift must be adjustable, or the amount of shift must be more precise than that of the zener shifter. The circuit, as shown, is capable of shifting signals over approximately an 18-volt range.

As the input voltage V_1 goes from Q_1 through Q_3 its level is shifted downward by the voltage drop across potentiometer R_1. Transistor Q_2 is a constant-current source that preserves the preset voltage drop across R_1, regardless of input. If the shift desired is a fixed one, the potentiometer can be replaced by a fixed resistor.

Output transistor, Q_3 is an emitter follower, which buffers the effect of the load on the amount of shift. Resistor R_1 clamps the base of Q_3, a fixed voltage drop below V_1. The level shift is due only to changes made to variable resistor, R_1.



Potentiometer R_1 combines with constant current generator Q_2 to form an adjustable zener diode.

Because Q_1 and Q_3 are complementary npn and pnp transistors, the voltage drop across their base-emitter junctions cancel out and these thermal drifts nullify each other. Diode D_1 compensates for the —1.8 millivolt per °C drift of Q_2 base to emitter drop.

Selection of component values for different amounts of voltage drop can be made from the following current-voltage relationships:

$$I_1 = \frac{(V_{cc} - 0.6)}{(R_3 + R_4)} \cdot \frac{\alpha R_3}{R_2}$$

$$V_c \approx V_1 - I_1 R_1 \text{ for } I_1 > i_{b3} \text{ and } V_{be1} = V_{be2}$$

Bipolar pulse generator tests fast flip-flops

By Otakar A. Horna

Research Institute for Mathematical Machines, Prague, Czechoslovakia

Fast flip-flop circuits are easily tested with a bipolar pulse generator whose pulse repetition frequency goes up to 50 megahertz. The high prf is achieved with a gallium-arsenide tunnel diode that functions as a relaxation oscillator.

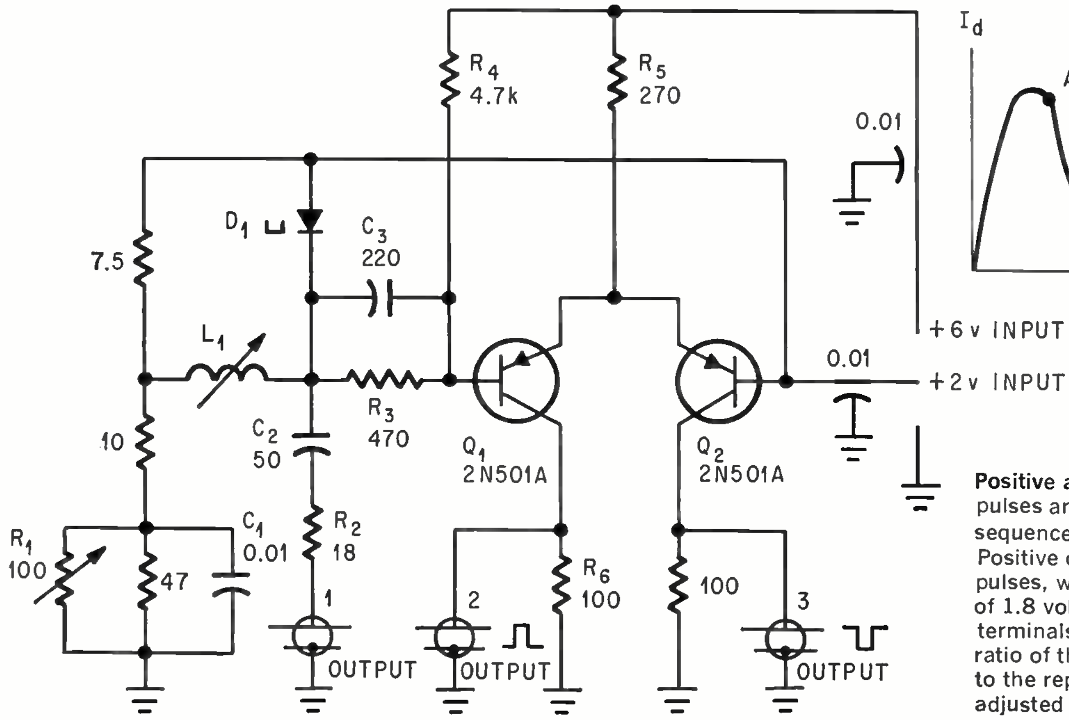
The pulse driver shown below is formed by the tunnel diode, D_1, a developmental type, with a peak current of 10 milliamperes, that is similar to the RCA 40062. The frequency of oscillation is changed by varying inductance L_1. When L_1 is 0.5 microhenry, the prf is 25 Mhz. When L_1 is increased, the frequency goes up.

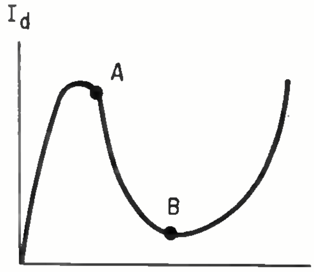
The ratio of the pulse width to the repetition period can be adjusted continuously by varying resistor R_1. This essentially shifts the operating point of the tunnel diode from point A on the I_d versus V_d curve where the ratio is 1 to 7, to point B, where the ratio is 1 to 1. In addition, this adjustment changes the prf slightly.

The bases of transistor Q_1 and Q_2 act as a current switch. The bases are connected between the tunnel diode, D_1, and the d-c level shifting network $R_3R_4C_3$. Thus, Q_1 and Q_2 are driven from a source with a very low internal resistance and do not saturate. Hence, the rise and fall times are less than 5 nanoseconds, and the delay between both pulses is less than 0.5 nsec.

Isolating network, R_2C_2, receives the 1-volt pulse signal from D_1 and applies it directly to output terminal 1 where a signal for time-base synchronization can be taken for an oscilloscope. A positive pulse can be taken for terminal 2 and a negative pulse for terminal 3.

With the given values of resistors R_5 and R_6 and a supply voltage of 2 volts the amplitude of the output pulse is 1.8 volts and the output impedance is 100 ohms. This impedance terminates a 100-ohm coaxial cable. The terminals are miniature coaxial connectors. Terminals 2 and 3 are short-circuit proof.



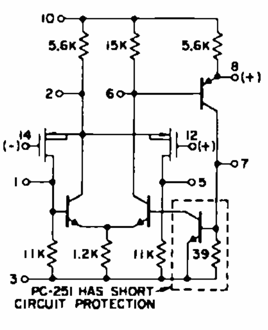


Positive and negative pulses are obtained in sequence at terminal 1. Positive or negative pulses, with a magnitude of 1.8 volts, appear at terminals 2 and 3. The ratio of the pulse width to the repetition period is adjusted by varying R_1.

New MOS hybrid microcircuits

An industry first. General Instrument, the leading producer of both hybrid and MOS ICs, has combined both technologies to create the most advanced line of hybrid ICs yet produced. The PC-250 is the result of this marriage of high performance MOS transistors and high performance bi-polar transistors used in conjunction with GI's proven hybrid assembly techniques.

The PC-250 is an ultra-high input impedance amplifier which can be used not only as a general purpose amplifier, but is designed for use wherever electrometer type high input impedance circuits are required—as in infrared detectors, high impedance transducers and crystal cartridges—thereby eliminating the need for the much larger, more complex, less reliable electrometer tube. The PC-250 and the PC-251 (the short-circuit-proof version of the PC-250) are immediately available in hermetically sealed ceramic-metal flatpacks from your authorized General Instrument Distributor. Write for full information.



CIRCUIT DIAGRAM:

- The high impedance MOSFETS matched in a differential pair form the front end of the amplifier—resulting in an electrometer type performance input circuit.
- No external frequency stabilization is required in most normal closed loop amplifier configurations.
- This circuit is indicative of the many types possible with this new combined technology.

FEATURES:

Input resistance .... 10^{14} typical
Voltage Gain... 50dB, 44dB min.
Input Leakage Current .. .3 pA

GENERAL INSTRUMENT

GENERAL INSTRUMENT CORPORATION • 600 WEST JOHN STREET, HICKSVILLE, L. I., NEW YORK

Apollo: the goal is in sight

The lunar landing mission will provide the stiffest challenge to date for electronics equipment. Ultrareliability is the aim of the engineers and test performances thus far have been outstanding

By John Rhea
Electronics Washington Bureau

Now that the Gemini project has been completed, the engineers working on space technology have turned their attention to the next step in space exploration: Apollo, landing men on the moon. The exacting requirements of this mission will pose the toughest test yet for electronics equipment. In preflight tests so far the electronic gear has performed spectacularly. A sliding of the launch date of the first vehicle, from December 1966 to March 1967 and then April 1967, is due to mechanical difficulties not electronic.

Apollo electronics hardware is the best yet, says George Mueller, the former professor, Bell Telephone Laboratories scientist and TRW, Inc. executive who runs the entire manned space program. There are exceptions, he adds, but "we can solve a finite number of problems."

Maj. Gen. Samuel Phillips, Mueller's top aide, agrees that Apollo is over the hump on technical problems. "We are almost complacent about the lunar landing," says Phillips, who was loaned to the space agency after ramrodding the Air Force's Minuteman missile program to success ahead of schedule.

In 1961, when President John F. Kennedy announced the national goal of sending men to the moon during this decade, the challenge was not to invent radical new electronics equipment as much as using existing technology to develop an ultrareliable system that would ensure the safety of the astronauts.

The National Aeronautics and Space Administration has used this philosophy in its own planning and has applied it to industry, insisting that electronic devices be limited to the 1962-63 technology. As a result, for example, integrated circuits were limited to only a few applications where it was essential to save weight without sacrificing reliability, most notably in the spacecraft's guidance computer.

Reliability was achieved through a combination of redundancy in circuits and systems, careful screening of all parts and torturous qualifications testing. Apollo is unlike previous space efforts in that the bulk of the testing is being done before anything flies. Although an astronaut has yet to make an Apollo flight, more than half of the $22.7 billion to be invested in the manned flight program has already been spent. "The cardinal rule is that we do everything that can be done to develop reliable systems through ground testing," says Phillips, comparing Apollo to early missile programs in which the bugs were ironed out in test flights—many of them spectacularly unsuccessful.

In the mission, an Apollo capsule containing three men will be launched from Cape Kennedy into an orbit around the moon. While the Apollo vehicle circles, two explorers will climb into the lunar module for the trip from capsule to moon. After exploring the surface, they'll fly the module to the Apollo vehicle for the return trip to earth. The trickiest part is the rendezvous between the capsule and the lunar module for the return.

The three basic elements in the Apollo system are the spacecraft (the Apollo capsule and the lunar module), launch vehicle and ground support equipment. All depend heavily upon electronics technology. Electronic systems will guide the spacecraft throughout its journey, maintain communications and record volumes of data. The Instrument Unit serves as the "brains" of the Saturn launch vehicle while it is being boosted out of the earth's atmosphere. On the ground, simulators are preparing the astronauts for their complex tasks. Checkout equipment at spacecraft manufacturers' plants and NASA centers verify that all hardware is ready for the mission. Finally, a global tracking network and control center will monitor every aspect of the flight.

Two to make ready

There are really two sets of launch vehicles and spacecraft, and consequently, two categories of electronic equipment. The early flight tests, such as the upcoming manned flight, use the so-called Block 1 Apollo spacecraft and the uprated Saturn 1 launch vehicle, a two-stage rocket that develops 1.6 million pounds of thrust in its booster stage.

The "lunar capable configuration," NASA jargon for spacecraft-launch vehicle combination able to take men to the moon and back, will use the three-stage Saturn 5 launch vehicle, which has a 7.5-million-pound thrust booster. Instead of one spacecraft, there are two in this configuration: a more advanced Block 2 Apollo consisting of Command and Service Modules and a two-man spacecraft known as the Lunar Module [formerly the Lunar Excursion Module].

These differences stem from the original plan to use two Saturn 5's to assemble a lunar landing spacecraft in orbit around the earth and fly directly to the moon and directly back. Then, in early 1962, NASA studies showed that it would be safer to fly from an earth orbit to an orbit around the moon and send a landing module to the moon. The Apollo, still orbiting the moon, is to rendezvous with the returning Lunar Module and come back to earth. This approach required only one Saturn 5 launch vehicle, another point in its favor.

While NASA began developing the lunar landing spacecraft and the more advanced Apollo spacecraft needed for the new mission, work continued on the original Apollo for use in earth orbital test flights. Officials reasoned that if they held up these early flights while waiting for the Block 2 version they would lose too much time in an already tight schedule.

I. Freeze it if you can

The major problems facing Apollo now are more structural than electronic. Saturn 5's second stage, the S-2, has generally been considered the "pacing item," or single element that is delaying the program. The stage's propellant tank walls have cracked at joints in pre-firing tests, thus delaying flight qualification. Every day lost in test-firing the stage at NASA's Mississippi test facility delays the first Saturn 5 flight by a day. Other delays have been caused by problems with the spacecraft environmental control system used to cool equipment and the rupture of a fuel tank in the Service Module during a recent test at the North American Aviation, Inc. plant in Downey, Calif.

Weight has been bothersome throughout the program, but NASA officials believe they have it under control. The problem centers in the Lunar Module since it was the last major element of the Apollo-Saturn system to be placed under contract and hence is going through the early development problems that have been met and solved in the Command and Service Modules. The Lunar Module is a separate spacecraft—the first ever designed to operate entirely outside the earth's atmosphere.

This weight problem translates into more stringent design requirements for the electronics in the module—and an unanticipated entry for integrated circuits as a means of slimming the module. The Aerospace Systems division of the Radio Corp. of America, Grumman Aircraft Engineering Corp's electronics subcontractor on the lunar module, has consequently used integrated circuits in such subsystems as the descent engine control assembly and the rendezvous radar range tracker. This approach would not have been possible had the design of the Lunar Module been frozen as early as the Command and Service Modules.

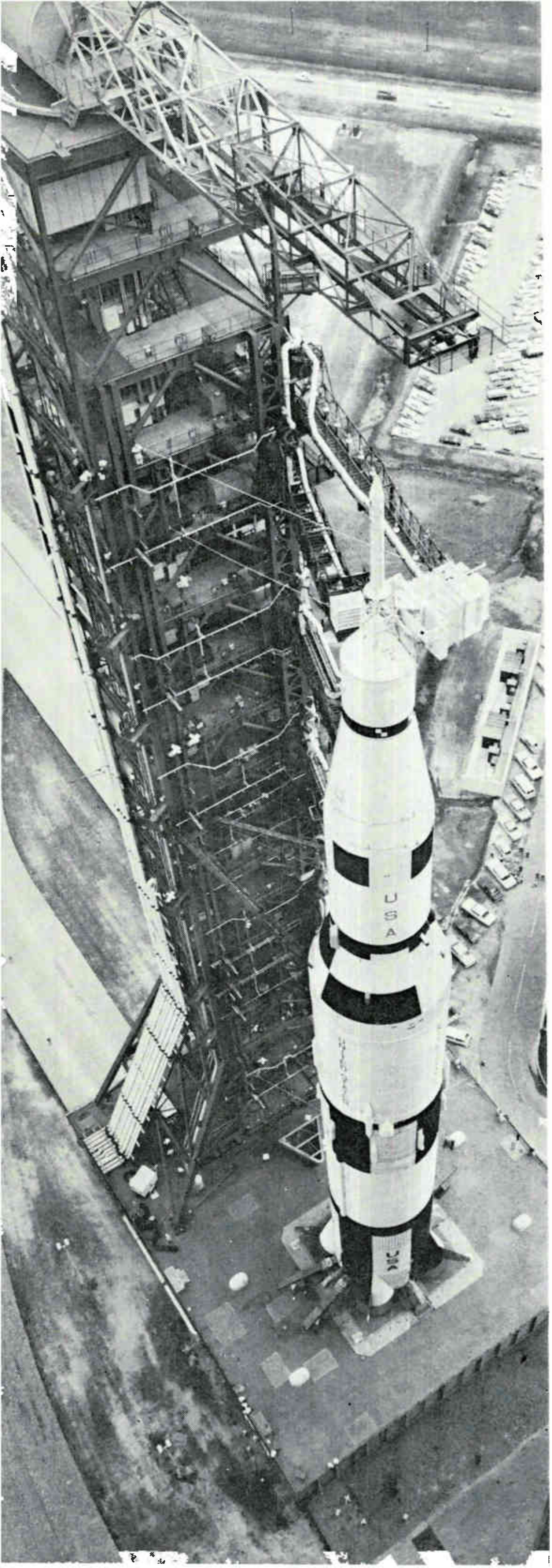
Late start for IC's

One problem that was solved conclusively in 1966 was whether the moon's surface had sufficient bearing strength to support the Landing Module. This conclusion, based on the successful Surveyor I landing June 2, was particularly important since the landing structure and radar system had already been designed on the assumption that the astronauts could safely guide the lunar module to a suitable landing site with the aid of landing radar. Many landing systems had been considered—monopulse terrain avoidance radar, laser range finders and systems for tracking a transponder previously placed on the moon—but a multibeam, doppler radar altimeter was chosen.

RCA explains that this approach was taken because it permits day or night landings, does not depend on prelocated landing aids, allows unmanned landings and supplies data directly to displays to permit the crew to land entirely under manual control. Also, since the radar equipment is on the lunar module's descent stage, it can be left on the moon when the Lunar Module returns to the Command Module. It's weight does not penalize the performance of the ascent stage. RCA also is subcontractor to Grumman for the rendezvous radar that will be used to guide the Lunar Module's linkup with the Command Module.

The attitude and translation control assembly (ATCA) and the descent engine control assembly (DECA) on the lunar module are also being built by RCA. The DECA controls engine gimbals to the correct pitch and roll trim positions in response to trim error signals from the ATCA and position commands from the computer. It also provides throttle control signals and actuates the start solenoid of the descent engine, both in response to commands from the astronaut control panel and from the guidance system. It performs the logic functions necessary to determine the proper firing combination of attitude jets and provides modulated trains of pulses to the 16 jet-solenoid drivers.

Between 25% and 35% of the functions per-



formed by ATCA and DECA are done by integrated circuitry, both digital and analog. The digital IC's are principally gates and flip-flops. The analog units are used principally in operational amplifiers and preamplifier circuitry. Digital and analog IC's are also used in the rendezvous radar, notably in the three-tone range tracker which measures the phase angle between the transmitted tones and those received back from the Command Module transponder.

The project leaders at RCA say they used IC's wherever it was possible to replace discrete components with qualified, proven IC's. In some cases, IC's were not available at the required frequencies and in other instances it would have been necessary to change the basic design in order to incorporate integrated circuitry.

Digital IC's presented no particular problem as far as approval is concerned, but, at the time that the RCA project engineers wanted to use analog integrated circuitry, the analog IC's offered by vendors did not have the required life-time tests behind them. Grumman insisted that 500 of the μA702's, made by the Fairchild Camera & Instrument Corp., undergo 2,000-hour tests. This was done at Fairchild under a special contract.

Lasers squeezed out

Weight and the desire to freeze designs also decided the 18-month competition between radar and optics in 1965-66. The Hughes Aircraft Co. was studying an optical rendezvous system with the idea of comparing it with radar for operational capability, simplicity, size, weight and power drain [Electronics, Jan. 24, 1966 p 123]. NASA decided in 1966 to go with the radar technique. Radar enthusiasts generally concede that if the competition were to take place in a few years—when the right kind of laser will probably be available—coherent optical techniques could win the battle.

One of the few areas in which NASA is pushing the state of the art is the fuel cells used to power the spacecraft's electrical and electronic equipment. A major reason for selecting cells powered by liquid hydrogen and liquid oxygen was that they could produce water for the astronauts as a byproduct and thus reduce the weight of water to be carried on the spacecraft. However, the fuel cells developed by the Pratt & Whitney Division of United Aircraft Corp. fell behind schedule early in the program and bothered the North American Aviation, Inc. and NASA project managers to the point where they seriously considered developing a backup power system.

One company, Hoffman Electronics Corp., sub-

The Saturn-Apollo assembly and its 39-story service structure at the Merritt Island launch facility. This dizzying view was photographed from the 52-story building where the Apollo system is assembled. The slim tower atop the spacecraft is the launch escape rocket.

mitted an unsolicited proposal to build a backup system consisting of solar cells mounted on panels extending from the side of the spacecraft. For various reasons—including Pratt & Whitney's ability to solve some of its critical problems in the fuel cells and a lack of money to develop a backup —NASA decided to gamble on the fuel cells. The wisdom of this decision still has to be proven in the flight tests.

II. The seven phases of Apollo

Program chief Mueller divides the Apollo program into seven major phases. Only the first has been completed—three unmanned Saturn 1 launches this year to verify that the spacecraft and launch vehicle work in space as well as they did in test facilities on earth. Attention was focused on such potentially troublesome items as the heat shield, guidance system and on-board propulsion systems. NASA was satisfied that all systems were safe enough for the astronauts—manrated in spacetalk.

On the next Apollo-Saturn flight, astronauts Virgil (Gus) Grissom, Edward White 2d, and Roger Chaffee will usher in the second phase—long, manned missions. The first manned Apollo flight may last up to 14 days, or twice the time it will take to go to the moon and back. The Gemini flights have made space agency engineers confident that man and equipment can function that long in space.

The first manned flight is designated 204. A second two-week mission, flight 205, was canceled last month in a schedule shuffle. The realignment was made in an attempt to circumvent the problems in the Service Module's fuel tanks and in the environmental control system.

The third phase begins with flight 206 later next year, an unmanned test flight of the Lunar Module. If the results are negative, the flight will be repeated until the module is manrated. If the module qualifies in one flight, a dual rendezvous mission will be performed next fall with flights 205 and 208. A three-man crew in an Apollo spacecraft would rendezvous with an unmanned Lunar Module.

The Apollo timetable allows three attempts to master rendezvous, but there are compelling reasons why NASA wants to do it with only one mission: the Dec. 31, 1969 deadline and the limited number of launch vehicles available—12 Saturn 1's and 15 Saturn 5's. If rendezvous can be mastered in one mission, four launch vehicles and two Apollo spacecraft would become available for earth orbital scientific experiments of the Apollo Applications Program [see "Science on the moon," p. 122]. This program is considered the essential bridge between the moon trip and the more advanced space missions expected to follow, but NASA ground rules forbid them from interfering with the mainline Apollo program.

The first four phases all use the smaller Saturn 1 vehicle. The first Saturn 5 flight, designated 501, is planned for early next year. This fifth phase is flight qualification of Saturn 5 and proof that it is compatible with the Block II Apollo spacecraft.

The millions add up to billions

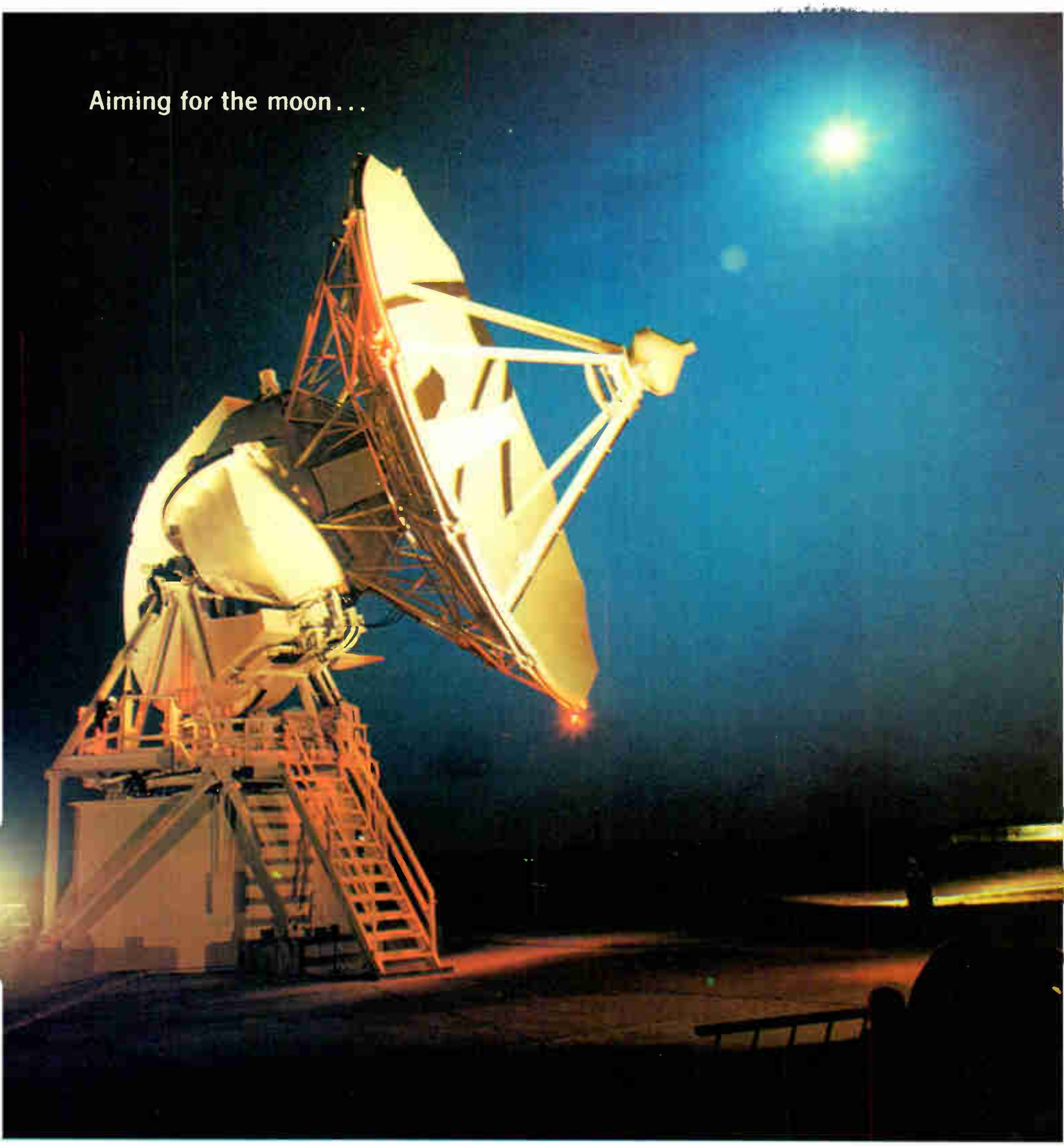
One measure of how deeply electronics is involved in Apollo is the amount of money the program has meant to the industry since the lunar landing goal was established in 1961. The price tag for putting a man on the moon is estimated at $22.7 billion, including the earlier Mercury and Gemini programs and the construction of facilities. Using the standard yardstick that 50 cents out of every space dollar is spent with the electronics industry, this represents a market of more than $11 billion over the scheduled eight-year life of the program.

Although most of this money is channeled through the airframe companies making the Apollo spacecraft and Saturn launch vehicles, several electronics firms are major contractors in their own right. Chief among these is the General Electric Co., which established a special department at Daytona Beach, Fla., to perform over-all integration, checkout and reliability of the entire Saturn-Apollo system. GE received $411 million for this work through the end of the last Federal fiscal year, which ended June 30, and stood fifth among National Aeronautics and Space Administration contractors for that year.

Ranking behind GE last year was the AC Electronics division of the General Motors Corp. in Milwaukee, which is the prime contractor for the guidance and navigation system to be used in Apollo. This program has meant $230 million for the AC division. The Raytheon Co. is building the guidance computer for the AC division at Lexington, Mass. A related system, the stabilization and control equipment, is built by Honeywell, Inc., Minneapolis, under a $114 million subcontract to North American Aviation, Inc., which was given $2.2 billion to build Apollo spacecraft. Subcontractors received more than $847 million of that money and most of them are in the electronics industry.

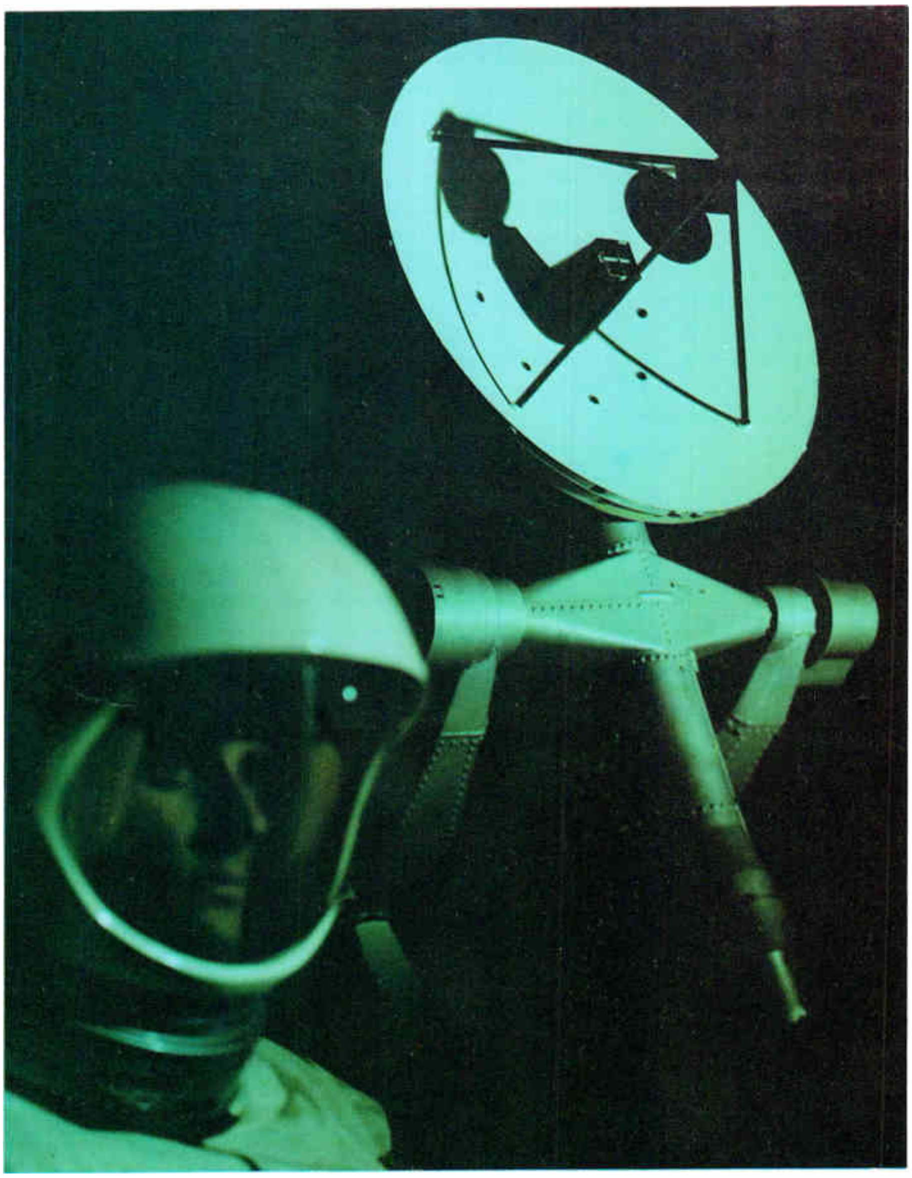
International Business Machines Corp., seventh largest NASA contractor in fiscal 1966, has received $93 million for the instrument units used to control the Saturn launch vehicles. The firm is assembling the units at its new plant in Huntsville, Ala. IBM also provides a variety of the instrument unit's digital computers, data adapters and associated hardware and has received $37 million for those jobs.

Other major Apollo electronics contractors include Radio Corp. of America, partner to the Grumman Aircraft Engineering Corp. on Apollo's Lunar Module; Bendix Corp., which runs the Manned Space Flight Network used to track Gemini and Apollo; and Collins Radio Co., subcontractor to North American for Apollo communications and data subsystems. All have received more than $100 million in space contracts.

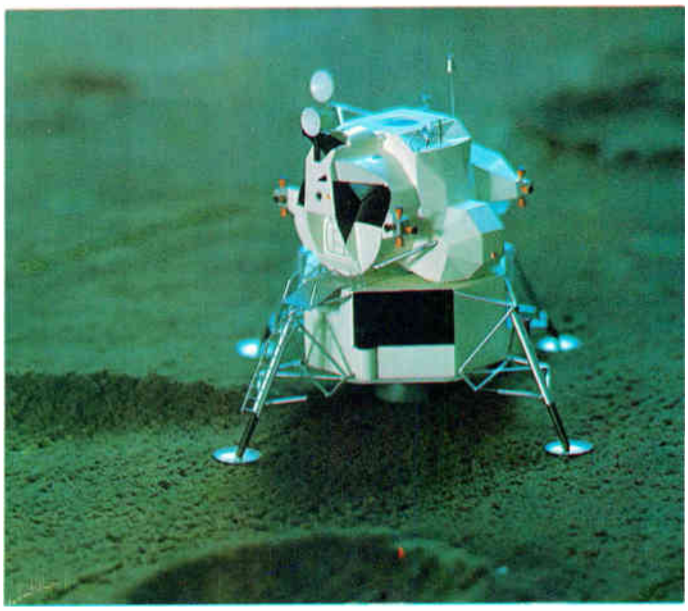


Pointing symbolically at the moon, a 30-foot antenna for the unified S-band system is readied by Collins Radio for a tracking station near Corpus Christi, Texas. Tracking signals, voice communications and digital data transmission from ground stations to the Apollo spacecraft will all be beamed over a single carrier by this antenna and others like it in the ground tracking network.

...with complex assemblies...



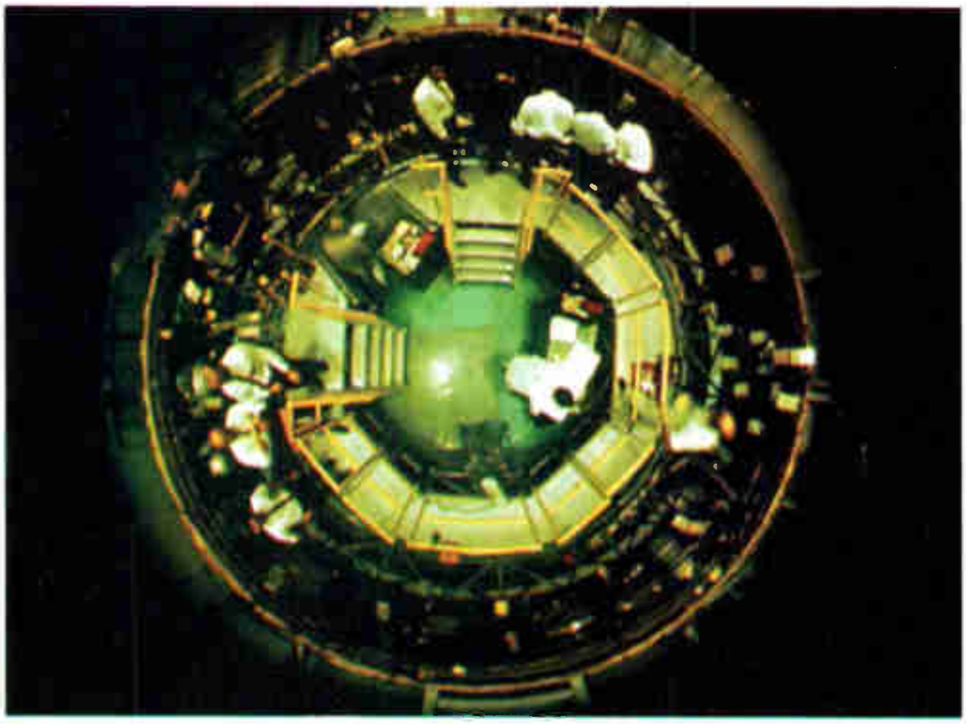
A closeup of the antenna built by the Radio Corp. of America. The microwave circuitry is mounted on the rear of the antenna. Intermediate frequency signals are carried to supporting equipment inside the module by flexible coaxial cable.



Scale model of the Lunar Module sits on a mockup of the moon at Grumman Aircraft Engineering Corp. The small parabolic antenna above the ladder is part of the rendezvous radar system that will guide the Lunar Module to the Command Service Module.

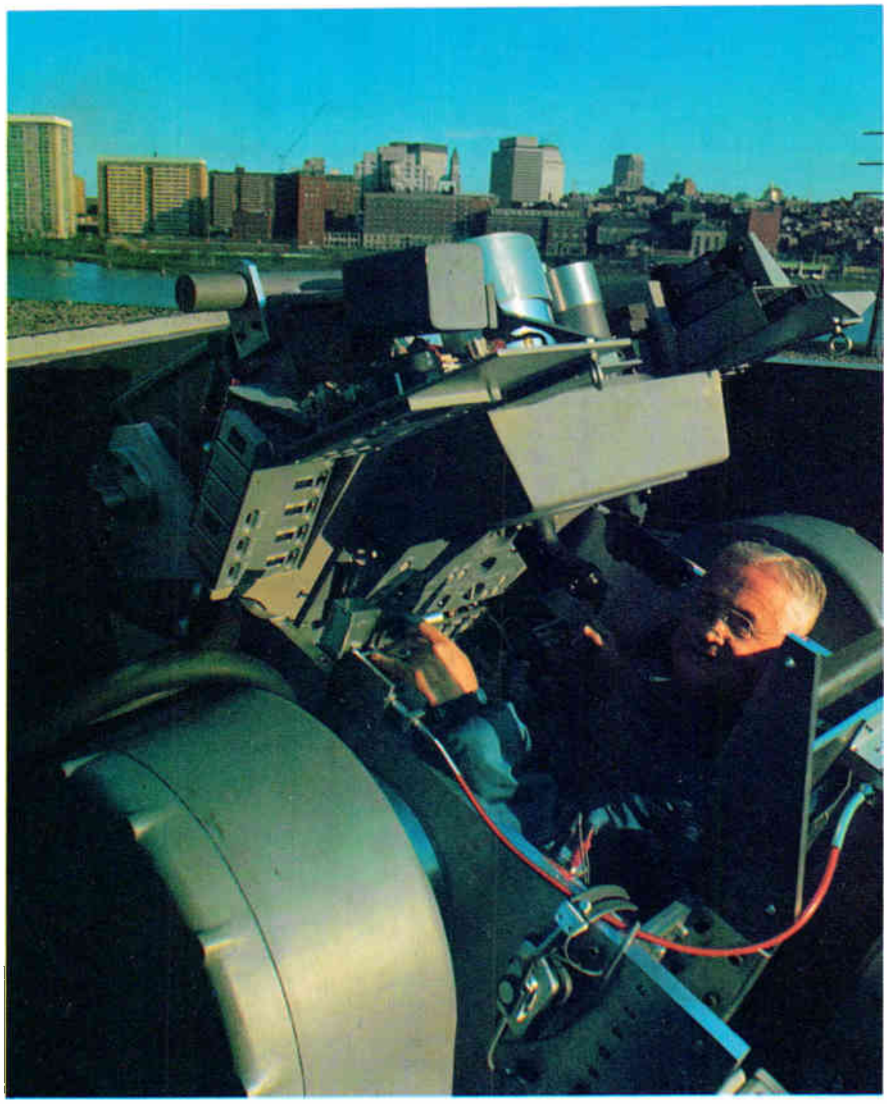
Apollo spacecraft is prepared for altitude chamber tests. The cone-shaped section is the Command Module, in which the astronauts will live and work during the round trip to the moon. Under it is the cylindrical Service Module, which will be jettisoned after it propels the command section home.

On a producton line in a special plant in Huntsville, Ala., IBM turns out the ring-shaped instrumentation units that control the vehicle during takeoff.

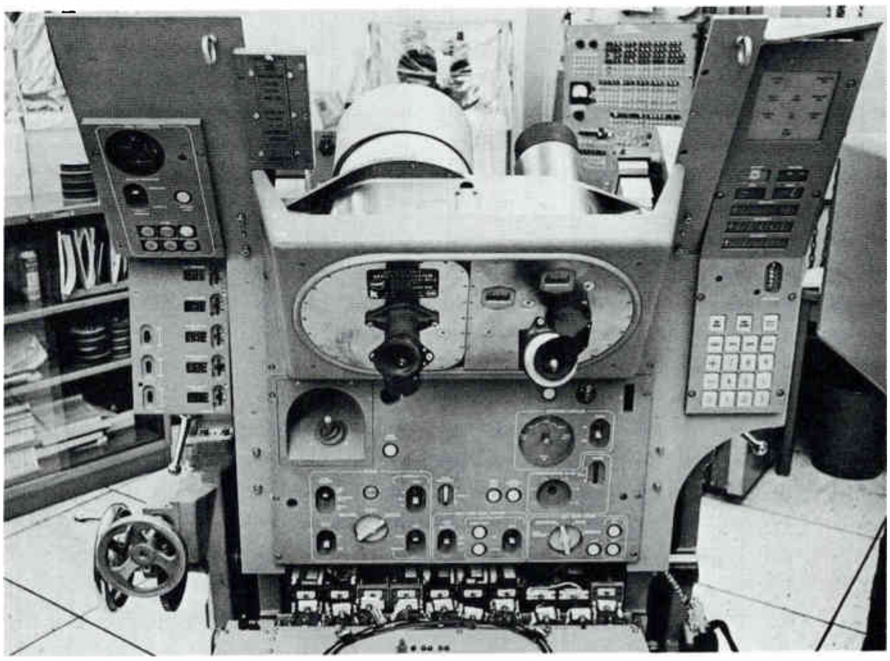


Brains of the Saturn launch vehicle and the underpinning of the spacecraft during takeoff, is this big Instrument Unit. This bird's-eye view of the 22-foot diameter ring shows the booster guidance and control subsystems being installed.

...and failure-free guidance



The Apollo guidance and navigation system being "flown" by C. Stark Draper, inertial guidance pioneer and founder-director of the Massachusetts Institute of Technology's Instrumentation Laboratory. The system is identical to an Apollo spacecraft installation except for its structural support. Tests are run regularly from the roof of an MIT laboratory building by institute engineers and sometimes by astronauts, using the edge of the moon as a landmark and measuring the angle between the moon and known navigational stars.



An astronaut's-eye view of the guidance and navigation system in the lower bay of the command module. The left eyepiece is a sextant and the right one a scanning telescope. Immediately below are navigation optics controls, spacecraft attitude controls and servoassembly. At the bottom is the guidance and navigation computer. The focal point of the entire system is the computer display at the upper right, called DSKY, for display and keyboard.

Mueller's conservative timetable calls for as many as five unmanned flights. However, many people in the space program hope to qualify the Apollo-Saturn 5 combination after two shots. If so, flight 503 will be manned.

Plans are to man a Saturn 5 flight in 1968, but it could occur late in 1967. In this, the sixth phase, the astronauts will run through a dress rehearsal of every step of the lunar journey except time spent on the moon. There is a chance, a very slim one, that they would go take a look at the moon. Finally, phase seven will be the culmination of nearly a decade of work: the landing on the moon.

Nine steps to the moon

The lunar mission will consist of nine steps, or decision points, separated by mission "plateaus." At each point the ground controllers and astronauts will assess the spacecraft's condition before deciding to go on to the next plateau. If the spacecraft is not ready they may take an alternate step, such as returning to earth, or tolerate a short delay until the spacecraft is ready. This approach is known as open-ended mission planning.

The first step, prelaunch preparations, is conducted in the sprawling Launch Complex 39 at Merritt Island just north of Cape Kennedy proper. The entire system is checked out in the world's most voluminous structure, the 52-story vehicle assembly building. Then, the entire vehicle, or stack in spacetalk, is rolled to the launch pad along with its Mobile Service Structure. This 39-story structure stays with the vehicle until the final countdown for the moon flight.

Other ground-based electronics equipment checks out the spacecraft and launch vehicles prior to flight. High-speed digital computers generate simulated conditions and measure the response of the vehicles. The automatic checkout system at the North American plant, for example, can monitor more than 25,600 samples per second. Similar equipment is installed at other prime contractor facilities and at the NASA centers in Houston, Huntsville and Cape Kennedy.

Two mission simulators produced by General Precision's Link Group and located at Houston and Cape Kennedy, and five system trainers produced by North American's Los Angeles division, familiarize astronauts with operating procedures. The two Apollo mission simulators are used by the astronauts to practice their flights and are programed with all possible emergencies the crew might face on the actual mission.

Before the astronauts proceed to the moon on a real flight, they must again check out all systems at a way station in space, a parking orbit around the earth. If all systems are go, the next plateau is translunar coast. During this step, the astronauts jettison a launch escape rocket atop the command module and dock the Command Module nose-to-nose with the Lunar Module. The Command and Service Modules are turned around by small reaction-control rockets.

During the three-day coast to the moon, course corrections are made two or three times under control of the guidance system. Proper temperature is maintained by a technique known as barbecuing. The spacecraft slowly rotates like meat on a spit so that one side does not face the sun too long.

On the moon

Near the moon, one astronaut checks the equipment in the Lunar Module. If everything is in order, the fourth plateau, lunar orbit, begins. After three orbits, 80 miles high, two astronauts get into the Lunar Module, detach it from the Command Module and coast down to 50,000 feet above the moon. Ten minutes later, after a manually controlled engine has braked the descent, the module lands.

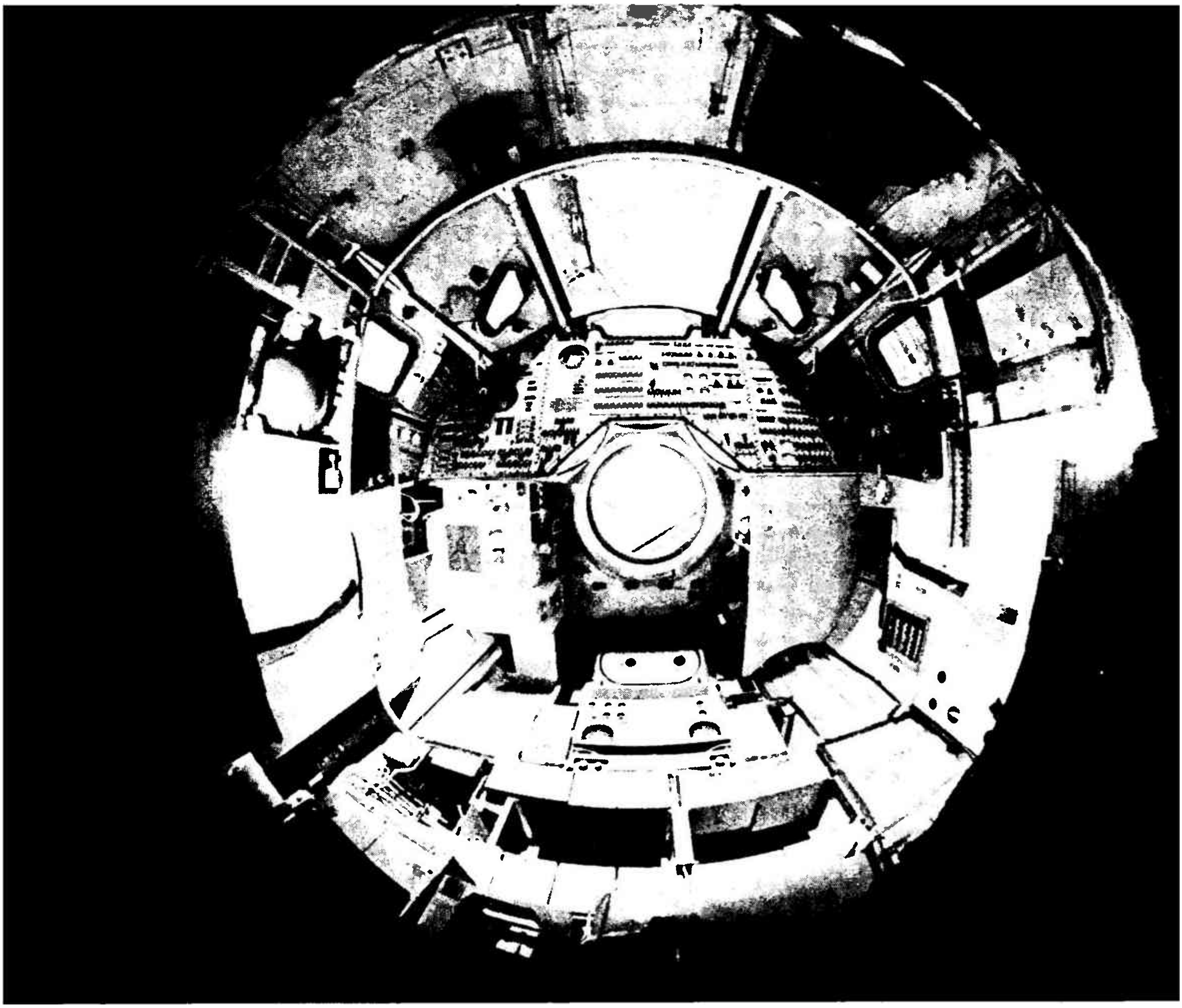
The lunar surface stay, the sixth plateau, will last 18 hours and 22 minutes. After about two hours spent in checking the spacecraft for damage and preparing it for the return trip, the two men will put on their space suits and walk down the ladder to the moon's surface. They'll explore the moon for three hours, collect samples of rocks, photograph the barren landscape—including live television beamed back to earth—and set up experimental equipment that will send data to earth after they leave [See "Science on the moon," p. 122]. Then, after six hours of sleep and a meal in the Lunar Module, and another three hours of exploration, the astronauts will check out Lunar Module systems again and take off.

When the two spacecraft have rendezvoused and docked, the Lunar Module crew returns to the mother ship, bringing along their lunar samples. The Lunar Module is then jettisoned and the Service Module's propulsion engine is ignited to send the spacecraft home. Shortly before it reaches the earth's atmosphere, the Service Module is also jettisoned and only the Command Module returns to earth.

Reentry blackout

Earth reentry is regarded as the most critical phase of the entire trip. When reentry begins 400,000 feet over the western Pacific, the spacecraft will appear like a glowing fireball in the sky as it enters the atmosphere at 25,000 mph, faster than any other spacecraft. At 24,000 feet, parachutes will begin slowing the spacecraft to 25 feet per second at splashdown. The astronauts will then be recovered in much the same manner used in the Mercury and Gemini programs.

An unsolved electronics problem is the communications blackout period caused when an Apollo spacecraft returning from the moon penetrates the earth's atmosphere at 25,000 mph and heats the surrounding gases into a plasma that prevents communications for as much as ten minutes. Losing contact with the tracking network during this critical phase of the mission is expected to hamper recovery operations. A possible solution is in sight with the development of techniques to inject water



All the controls in the spacecraft are displayed in this 360-degree view of the Command Module's interior.

into the plasma and thus cool it sufficiently to permit limited communications. Questions still to be answered are whether the technique can be perfected in time for the moon mission and whether total spacecraft weight can be held to a level that will permit carrying extra water.

III. Flight electronics systems

The electronic equipment that controls the Saturn launch vehicles has its antecedents in early missile programs. The inertial guidance platform can be traced from the earlier Pershing, Jupiter and Redstone programs. The telemetry system evolved from a design first used in Redstone.

To meet manned flight needs, NASA's Marshall Space Flight Center designed—and asked International Business Machines Corp. to build—a separate stage of the Saturn vehicle called the Instrument Unit. The unit, shown on page 116, is nearly 22 feet in diameter and three feet high. It fits between the S-4B propulsive stage and the spacecraft. Besides carrying the launch vehicle electronics, this unit structurally supports the nearly 50 tons of spacecraft above it. The system performed successfully in 10 unmanned flights of a smaller version of the Saturn 1.

The Instrument Unit goes into operation about five seconds before liftoff, when the inertial guidance platform and the general-purpose launch vehicle digital computer are released from ground control. The guidance platform, previously aligned to the desired launch angle, measures the vehicle's acceleration and attitude as the vehicle ascends. The digital computer integrates these measurements with the time since launch to determine vehicle position relative to starting point and destination. It then computes attitude correction signals.

At first the vehicle is buffeted by the thick atmosphere and the guidance system's principal job is to keep the vehicle's nose up. After the booster stage has done its job and is jettisoned, the guidance system tries to find the best path to achieve the mission.

During the boost phase, guidance is accomplished by a series of repetitive computations known as iterative, or closed-loop, guidance. About once every two seconds the guidance computer determines vehicle position and vehicle conditions required at the end of power flight such as velocity and attitude. Based on the most recent solution to the guidance problem, the digital computer generates attitude correction signals 25 times a second.

These signals, rate gyro outputs and control accelerometer outputs go to the analog flight-control computer, which issues control commands. These commands swivel the rocket engines to keep the vehicle pointed in the right direction.

To ensure reliability, all critical circuits of the digital computer and data adapter that links the analog and digital equipment are triplicated. The outputs of the three identical circuits are compared, or voted upon. The majority rules so that a random failure is ignored. Also, the computer memory is duplexed so that if an error is generated in one part of the memory, the output is obtained from the other memory. Correct information is then read back into both memories to correct the error.

Spacecraft guidance

The spacecraft guidance evolved from work done by the Massachusetts Institute of Technology for the Navy's Polaris submarine program. This system combines what man can do best, pattern recognition in sighting stars and landmarks, with what machines can do best, tedious and repetitive computation and high-speed switching. It has three subsystems: inertial guidance, optical equipment and digital computer.

Heart of the inertial system is the Inertial Measurement Unit (IMU), a spherical structure that establishes a stable onboard frame of reference for measuring spacecraft acceleration. The IMU consists of three gyroscopes and three accelerometers mounted on a stabilized structure that, in turn, is suspended inside three concentric spherical gimbals connected to each other by drive motors and angle resolvers. Gyro signals drive gimbal motors to hold the inner member in a fixed spatial orientation despite spacecraft movements. The gyro design is the MIT 25 IRIG (for 2.5-inch-diameter inertial reference integrating gyroscope) and the accelerometer is the MIT 16 PIPA (for 1.6-inch-diameter pulsed integrating pendulous accelerometer). Inertial unit data flows to the guidance computer, which generates steering signals for the small thrustors mounted around the craft. Position information is also transmitted directly to the computer from ground-based tracking stations. The ground commands were originally planned as a backup to the spacecraft systems, but were applied as the primary mode of guidance because of the greater accuracies possible with the ground equipment.

Apollo earth orbital experiments

In-flight exerciser. (M) A bungee cord is held between the feet and stretched to measure an astronaut's reactions to physical exertion in flight. (Gemini)

In-flight phonocardiogram. (M) Piezoelectric transducers are attached to an astronaut's chest to record the sound of his heart beats for comparison with electrocardiogram data. (Gemini)

Bone demineralization. (M) Pre- and post-flight X-rays are taken of the heel bone to find occurrence and degree of bone demineralization. (Gemini)

Human otolith function. (M) A 16 mm. sequence camera is used to determine the degree of counter-rolling of astronauts' eyes, or movement in the opposite direction from that of the spacecraft.

Cardiovascular reflex conditioning. (M) This involves one of the astronaut's donning a pair of space leotards that apply a small pressure to the lower part of his body. The purpose is to prevent blood pooling at the lower extremities.

Cytogentic blood studies. (M) A count of the astronauts' red and white blood cells are taken before and after flight to assess the effects of space flight.

Synoptic Terrain photography. (S) A 70-mm. Hasselblad camera is used to photograph features on earth. (Gemini)

Synoptic weather photography. (S) The same camera is used for weather observation. (Gemini)

Dim light photography. (S) The camera is used again with more sensitive film to study dimly lit phenomena such as zodiacal light and the upper atmosphere air glow.

Daylight sodium cloud photography. (S) It involves using the Hasselblad camera to photograph sodium vapor clouds emitted from French sounding rockets launched from an Algerian launch site. The photographs are expected to add to the basic information on upper atmosphere patterns.

In-flight nephelometer. (T) This experiment is intended to measure the size and number of dust particles in the spacecraft cabin by shining a beam of light at a right angle from a photomultiplier.

Experiments designated (M) are medical, (S) are scientific and (T) technological. (Gemini) indicates that the experiment was previously conducted in Gemini flights.

The optical equipment permits the astronauts to realign the inertial unit orientation as needed by referring to the stars and to landmarks on the earth and moon. The two main units are a wide-angle scanning telescope for landmarks and a 28-power magnification space sextant to measure angles between two sighting points such as stars.

Single-circuit computer

The application of integrated circuitry in the guidance computer, built by the Raytheon Co., has permitted a reduction in weight along with an increase in memory capacity. It has also brought problems. In the original Block 1 guidance computer, encapsulated transistors were used in the processor; in the more advanced Block 2 design for the moon flight, these components were replaced by Texas Instruments Incorporated, and Fairchild Camera & Instrument Corp. flatpack IC's developed for the Minuteman missile program. This required a change in internal wiring from the ribbon type to multilayer boards and gave NASA some anxious moments.

The Apollo computer relies completely on one standardized integrated circuit to perform all logic functions. The only logic element in the computer —and in the digital portions of the coupling and display unit (CDU)—is a three-input NOR gate. The MIT design group specified a planar integrated circuit, sponsored a tightly-supervised competition among vendors and—more than two years ago—imposed rigid quality-control procedures to eliminate failure modes.

The designers settled on standardized dual-gate circuits in a single flatpack. Says Eldon Hall, head of the Apollo computer group: "The standardization approach to reliability is the conservative approach. But it is hard to sell to engineers. They prefer exotic circuits and variety."

There was an element of hedging in the MIT decision, made when IC's were still in their infancy. "Integrated circuit users were then being led to believe that reliable circuits would be available in great diversity, just by using different masks," says Albert L. Hopkins Jr., of the MIT computer design group. "The people here decided on a single type circuit which they were sure could be delivered by vendors. It's a good thing they did. A gated flip-flop, for example, would have been a good circuit as far as the logic design is concerned, but we never would have gotten delivery of high-reliability circuits in time."

The high level of confidence in these circuits played a key role in the MIT and NASA decisions on the over-all design of the guidance and navigation system. Originally, the plan was to use a single modular computer plus trays of spare modules. Because of the housekeeping problem this would impose on the astronauts, and because moisture-proofing requirements ruled out in-flight maintenance, it was decided instead to install two redundant computers, thus using up the space and weight gained in going to an IC logic element.

Paul Schrock, who is in charge of guidance testing at NASA headquarters, says that the packaging and connection problems have been overcome and estimates that the entire Block 2 system can be flight-qualified by next February.

The Block 1 version, to be used in the first manned Apollo flight, has been qualified. That system was rated as accurate to within one mile on the last unmanned flight on Aug. 25. The spacecraft on that flight missed its landing point by 198 miles. "The miss was caused by a very mundane thing," says Owen E. Maynard, chief of mission operations at the Manned Spacecraft Center. The aerodynamic characteristics, based on wind tunnel tests were not known precisely. "We went through our data after the flight and there is no uncertainty about this anymore," Maynard reports. Had updated data been fed into the computer by the tracking station in Australia as planned or had a man been aboard, NASA officials believe that the landing would have been right on target.

Basic word length for both computers in all parallel operations is 15 bits with an added bit for parity check and with subroutines for double precision operations. Memory cycle is 11.7 microseconds and single addition time is 23.4 microseconds. Core ropes are used for fixed memory and the erasable memory consists of ferrite core planes. The erasable memory in the Block 2 configuration is of 2,048 words, twice as large as Block 1. The Block 2 unit also has a 36,864-word fixed memory capacity, 50% more than Block 1. The Block 2 computer at 65 pounds is also 15 pounds lighter than the Block 1 machines.

Navigation changes

The arrangement of the guidance and navigation subsystem in the over-all control system also differs from Block 1 and Block 2. In the earlier version, the guidance and navigation system is connected

Science on the moon

On the Apollo lunar landing mission, the two astronauts to walk on the surface will scoop up some 50 pounds of samples, package them in a vacuum container and return them to earth. These samples will include two 1-foot-long core samples taken by driving small tubes into soft spots on the lunar surface.

The main experiment is known as the Alsep (for Apollo lunar surface experiment package) and will be carried on each of the three flights currently planned to land on the moon's surface. Alsep is being developed by Bendix Corp.'s Systems division, Ann Arbor, Mich., and consists of a 170-pound package of seven experiments, geological sampling equipment and power and data transmission subsystems.

The experiments are a seismometer to measure lunar tremors; a magnetometer to search for magnetic fields, a plasma spectrometer to measure the solar wind; a suprathermal ion detector/cold cathode gauge experiment to measure the moon's ionosphere, if any; a heat flow experiment consisting of a probe that extends two feet into the lunar surface; a charged-particle lunar environment experiment and a small device to fire projectiles on the surface so that astronauts can record seismic shock tremors. The Alsep is left on the moon after the astronauts leave and uses a nuclear power source to transmit data directly to earth for another six months to a year. Bendix has a $20.9 million contract to produce four Alseps.

Apollo applications program

More advanced studies are being planned for the Apollo Applications Program (AAP) that the space agency hopes will be the successor to the manned lunar landing. The National Aeronautics and Space Administration has $41 million in available funds during the current fiscal year to study various scientific missions, but as yet has not approved any flight hardware. If next year's total NASA budget can be kept at this year's $5 billion level despite the pressures of Vietnam, there should be several hundred million dollars available for AAP experiments.

Initial AAP missions could actually fly before the manned lunar landing. However, this is based on the preparatory steps being accomplished in fewer flights than planned.

The two leading candidates for AAP missions are probably the Apollo Telescope Mount (ATM) and the S-4B workshop, both in the study phase at NASA's Marshall Space Flight Center, Huntsville, Ala. ATM is a telescope similar to those used on the unmanned Orbiting Astronomical Observatories and would be carried into orbit on an unmanned Lunar Module. The astronauts would come up later in the Apollo spacecraft to set up the experiment, make studies of the sun from space and return with the film. The telescope might even continue to operate unmanned until astronauts in another spacecraft can come up later and retrieve the film.

Workshop in space

The S-4B workshop idea involves using the third stage of the Saturn 5 launch vehicle for experiments once it has completed its primary job: putting the Apollo spacecraft into orbit. The McDonnell Corp., St. Louis, recently won a $9 million contract to produce an airlock necessary for the astronauts to enter the empty rocket stage. Once the stage was pressurized and furnished with oxygen, food and water, the astronauts could take off their spacesuits and conduct biological and other experiments requiring zero gravity.

A variety of other experiments have been proposed for Apollo applications, including attaching a cable between the S-4B and the Apollo spacecraft and rotating the two to produce artificial gravity; orbiting a big piece of reflecting material that could be inflated in space to create a 2,000-foot-diameter mirror that would reflect sunlight and illuminate areas at night—such as Vietnam battle areas; erecting large antennas for radio astronomy; and carrying high resolution cameras operating in spectra ranging from infrared to ultraviolet to measure natural resources on earth.

Lunar exploration

Extended lunar exploration may also be part of AAP. This program was once considered the likely successor to the Apollo moon landing, but has received a much lower priority during the last two years. The Boeing Co. and Bendix have NASA contracts to study lunar jeeps capable of making short trips across the moon's surface. Other studies have looked into the possibility of establishing a semi-permanent scientific base on the moon similar to those in Antarctica.

Probably the two most important questions to be answered by the Apollo and AAP experiments are whether man can function normally for long periods in space and whether he can conduct investigations sufficiently better than automated equipment to justify the extra expense of sending him along on scientific missions.

Results of the Mercury and Gemini programs have shown that man can survive two weeks in space and that a properly trained astronaut can respond to unexpected situations as no space robot could do. But until much more is known about man's capabilities in space, top Government officials inside and out of NASA are reluctant to commit themselves to the next giant step in space: the major goal of sending a manned expedition to Mars.

in series with the stabilization and control system, which is linked directly with the spacecraft's two rocket systems: the small group of attitude control rockets around the spacecraft, known as the correction control system, and the main propulsion unit in the service module, known as the service propulsion system. In this configuration the guidance and navigation system cannot act as a backup to the stabilization control system.

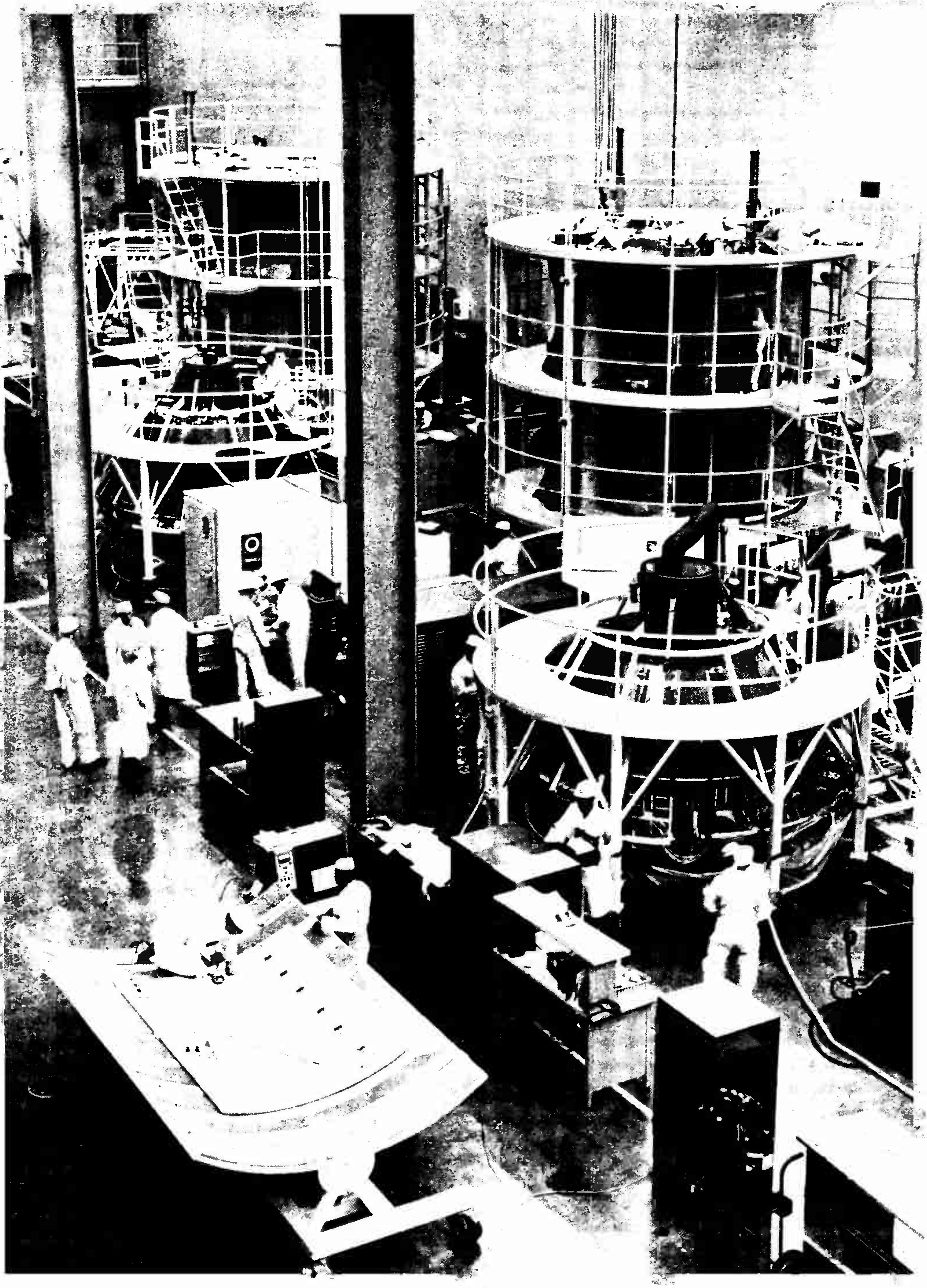
In the Block 2 configuration, the guidance, navigation and control system and the stabilization control system are connected in parallel and each has direct links to the two rocket systems. Either control system can work alone if the other fails.

The Lunar Module also uses the Block 2 system, but with a few differences. An abort guidance system is added in case the astronauts have to scramble back to the Apollo orbiting the moon before they land. This system is connected to the stabilization control system and is made by TRW Systems under subcontract to Grumman. TRW also makes the computer designed specifically for this system and uses a strapped down inertial platform provided by United Aircraft Corp.

Another difference in the Lunar Module guidance system is that Grumman furnishes its own stabilization system using electronic components from RCA and a rate gyro package from General Precision's Kearfott division. The stabilization control system in the Apollo spacecraft is built for North American by Honeywell, Inc.

Astronauts communicate with the computer in a coded numerical language via a 12-digit character display and a 16-button keyboard designated DSKY, which stands for display and keyboard. There have been problems in the DSKY resulting from the use of mechanical relays, according to Schrock, but these units are considered adequate for the current missions. Development is under way at Raytheon on solid state relays, which will replace the mechanical units later in the program.

Two other subunits complete the guidance and navigation system. They are the power servoassembly and the coupling and display unit. (CDU). The servo accepts power from the spacecraft main power supply, converts it into the required currents and frequencies for different parts of the guidance system and also serves as an amplifier for servo-



mechanism signals. The coupling and display unit is the interface between the inertial unit and optical measuring systems and the computer. The Block 1 electro-mechanical coupling unit will be replaced by an all-electronic unit in Block 2.

Abort guidance system

If the primary guidance system is not functioning properly, the abort guidance system (AGS) goes into action. The AGS is a strapped-down system, a type that does not require the sensors and drive for the platform of a fully stabilized inertial navigation system. To account for the differences between a stabilized platform and the strapped-down instrumentation requires a complex computer program. So, TRW Systems developed a large-scale, high-speed all-IC computer.

"If we had to use commercially available computers for the job—and there are some that could do the job—we would have had to add another spaceship just to carry the computer," reports Nathaniel Trembath, AGS program manager at TRW.

As in Block 1, TRW avoided pressing the state-of-the-art in the Block 2 design. As an example, most analog circuits are discrete instead of linear IC. TRW tried to use vendor standard designs that had been upgraded for Apollo—but was rarely able to use anything directly off the shelf.

Some failures occurred in Block 1 because of humidity corrosion. The designers decided to repackage as a solution. In the process, they changed a basic philosophy regarding system protection. In Block 1, the concept was to provide a capability for repairs in flight. This meant sliding tray-type chassis and plug-in modules. To provide better environment protection in Block 2, they decided to bolt everything in so it couldn't be removed. This meant that redundancy of circuitry had to be provided since it couldn't be repaired by replacement. Some redesign was necessary and some realignment of existing circuits so that some could take over for others in case of failure.

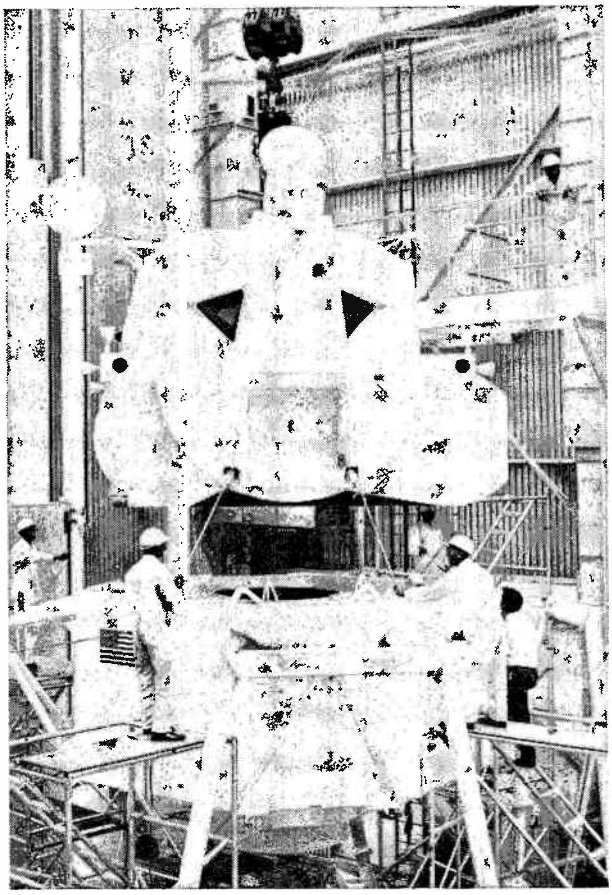
Instead of using an egg-crate concept [where all the component trays are tightly packed against one another], TRW is using separate bolt-down boxes with enough clearance to make connections by hand, while allowing visibility of the work being done. The new bolt-down boxes themselves are sealed. In Block 1, the trays weren't sealed, they depended upon the sealing of the individual modules for protection. Now they are multi-sealed; that is, the modules are still sealed and the box containing the modules is also sealed. The vendors were given a choice of a gasket seal or a hermetic seal—most chose the gasket seal for its obvious repairability.

In the Service Module, they were able to increase the packaging density somewhat in redesign, but not enough to compensate to the increased cost in weight and volume of the added box seal. The net result is a slight increase in weight and increase in volume. In the Command Module, the situation is even more disadvantageous with regard to weight and volume.

One major and immediate advantage of the change (in addition to better environment protection) is the loosening of mechanical tolerances for the hardware. This doesn't mean too much in terms of fabrication costs although it does save some money), but it means a great deal in terms of schedule which is already in trouble. It avoids the problems of having to rework already-built modules to make them mate when they reach the assembly stage, or of holding up critical construction waiting for a module to make sure it is going to fit.

IV. Unified S-band communications

The Apollo telecommunications system is a combination of equipment on the ground, in the Apollo spacecraft and the Lunar Module. Here, too, there is an evolution from the early Block 1 tracking network that grew out of the Mercury and Gemini programs to the Block 2 network for the Apollo moon landing. The most significant modification is the



Sections of the Lunar Module are being mated during checkout procedures underway at the Kennedy Space Center. The bottom section which will serve as a launch platform when the moon explorers are ready to head back to the Apollo mothership, will remain on the moon.

Subsystems are installed in the Command Module and checked out in this huge cleanroom, at North American Aviation Inc.'s Space and Information Systems division in Downey, Calif.

The Apollo-Saturn Command Module is mated to the Saturn Lunar Module Adapter in the skyscraper building constructed at the Kennedy Space Center. They will fly in the Apollo-Saturn 202 mission to verify performance of the uprated Saturn engine.

replacement of the vhf, uhf and C-band stations by what NASA calls its unified S-band system.

In the unified S-band approach, all voice and data are modulated onto the same r-f carrier used for tracking. This equipment, operating in the 2,100-2,300 megahertz band, is produced by Motorola, Inc. The unified S-band approach is based on the coherent doppler and pseudo-random range system developed by Jet Propulsion Laboratory for its deep space unmanned missions. This method was adapted for manned flight use since it reduces spacecraft equipment requirements.

Voice and digital data are modulated onto subcarriers and then combined with the ranging data for the uplink, the transmission to the spacecraft. The composite information phase-modulates the transmitted carrier frequency. The transmitted and received carrier frequencies are coherently related to allow measurements of the carrier doppler frequency by the ground stations for precise determination of spacecraft velocity.

In the transponder the subcarriers are extracted from the radio-frequency carrier and detected to produce the voice and command information. The ranging signals, modulated directly onto the carrier, are detected by a wideband phase detector and translated to a video signal. The voice and telemetry data to be transmitted from the spacecraft are modulated onto subcarriers, combined with the video ranging signals and used to modulate the downlink carrier.

The unified S-band network, which is currently being phased into operation, consists of 85-foot antennas at Canberra, Australia, Goldstone, Calif., and Madrid, Spain; single and dual 30-foot antennas at the old Mercury and Gemini stations; three ships with 30-foot transportable antennas to track the spacecraft during orbital insertion and injection into the lunar trajectory; and two ships in the reentry area with 12-foot antennas.

NASA has completed qualification testing of all the Block 1 communications equipment, according to James Allman, who is in charge of communications and instrumentation equipment testing at NASA headquarters, and is currently trying to verify that spacecraft and ground equipment will be compatible in the Block 2 configuration. He hopes to complete these tests this year so that everything will be ready for the first Block 2 mission involving the dual launch and rendezvous between Apollo and Lunar Module in mission 205/208. These compatibility tests are being made at Houston using spacecraft equipment and a simulated ground station.

One piece of equipment currently under test is the lunar television camera built by Westinghouse Electric Corp. The preproduction model of this camera, which will be carried by astronauts to the moon's surface for live tv, was delivered last summer for integration tests at NASA's Marshall Center and North American's Apollo plant at Downey, Calif. Eighty percent of the camera's components are IC's, thus making it one of the few examples of state-of-the-art hardware in Apollo. A similar camera, built by RCA for the Block 1 flights, will provide the first live tv from a U.S. spacecraft on the initial manned Apollo flight.

As the time for the first manned Apollo flight draws near, a portion of the scientific community still doubts the merits of a trip to the moon at the price it is costing. In rebuttal, defenders of the project are pointing to some accomplishments in electronics that help justify the costs: like the perfection of ultrareliable components and circuits, and accelerated development of S-band communications. In addition, work on Apollo has clearly catapulted U.S. advanced technology far ahead of that in European countries.

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ANALOG MONOLOGUE

On Means for Modelling, Measuring, Manipulating, & Much Else

BUILDING BETTER BREADBOARDS

Since the days of crystal sets, the term "breadboards" has been used for the structures on which temporary or experimental electronic circuits were assembled . . . probably because the earliest experimenters, working in attics, cellars, or garages, *did* in fact raid the kitchen, for oatmeal boxes, glass jars, and — to serve as a convenient wooden "chassis" — even the household breadboard.

Although the wooden plank has long since been replaced by various mechanical schemes — some of them impressively elaborate and complex — the homely name has survived . . . along with the need to plan a layout, assemble the hardware, cut and solder wires, and (again a classic phrase) the need to "debug" the resultant lashup.

During the past twenty years, breadboards — wooden, metallic, or plastic — have cost us and our customers an unbelievable amount of wasted time and effort. Operational amplifier circuits are, when correctly built, among the most reliable, stable, and "forgiving" devices in all of electronics; but they are easily encouraged to misbehave by "haywiring," "strays," and other parasitic temptations. Now we have Built a Better Breadboard . . . and we invite you to beat a path to our door.

Because they do not retain any of the limitations and defects of older schemes, we feel that this new generation of circuit-assembly aids deserve a new generic name. We call them, therefore, *not* breadboards, but OPERATIONAL MANIFOLDS. Two designs are now available, as shown in figures 1 and 2. Both offer the same four features: *Speed, Convenience, Flexibility, and Logical Organization.* In essence they consist of compact bench-mounting structures of unique design — containing a well-regulated dual power supply, four or five pluggable (and therefore interchangeable) operational amplifiers, and a completely wired jack-panel. The spatial organization and marking of the panel greatly simplify rapid interconnection of the amplifiers, which is accomplished by means of pluggable components and jumper leads. Provision is also made for the addition of plug-in networks, such as linear and nonlinear Philbrick Transconductors. The wire-routing, shielding, grounding, dynamic-stabilization, and guarding problems normally associated with low-level, wide-band, high-gain circuits have been almost entirely eliminated in these manifolds, almost as effectively as in our single-amplifier Q3-style Universal Operational Modules in fact... at much lower cost per circuit, too.

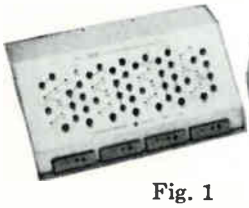

Fig. 1

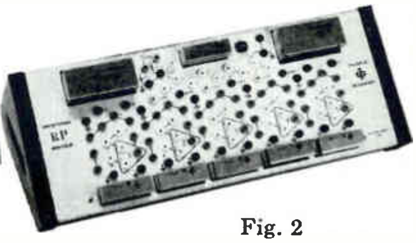

Fig. 2

It takes but a few weeks of active use to recover the modest cost of either the MP (4 amplifiers, plus power supply, $390) or the RP (5 amplifiers, plus power supply, $495.), and you will probably notice certain extra-economic bonuses: superior circuit performance, sunnier dispositions, and greater freedom of invention, to name three. In time, you may find yourself using manifolds for semi-permanent circuits that must be built to otherwise-impossible schedules. They *are* neat enough, they compete very favorably with one-shot "custom" chassis-punching and wiring, and RP is easily rack-mountable.

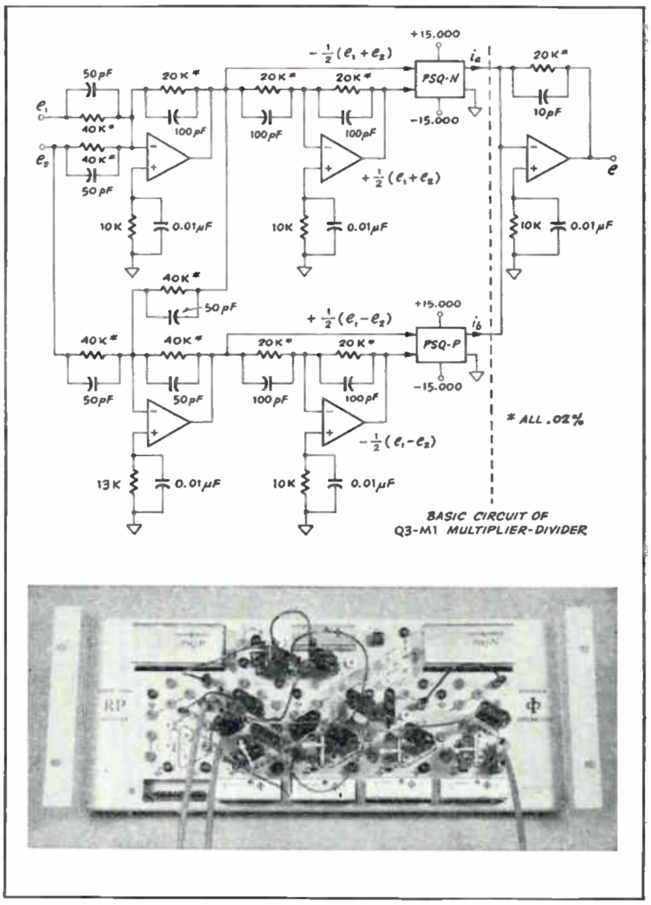

Fig. 3

As for speed and convenience, we should be content to rest our case on the schematic and photograph of Figure 3. This 5-amplifier multiplier was "constructed" in just 27 minutes, starting with the schematic. To make the test perfectly fair, we ran it in the laboratory of a customer, only 15 minutes after he first saw the RP, and with no rehearsals. We didn't help him, except to run through the instructions once, and hand him one of our standard kits of plug-in components and jumper-leads . . . informally known, by the way, as our "Bag of Worms."

Would you like to try our Better Breadboard? Call your local Philbrick field engineer (or the factory) and ask for a free demonstration. If you like, we'll leave one with you for a few days, Worm-Bag and all — but we think it only fair to tell you that you probably will not be able to resist keeping it. Even the fellow with the "non-electronic brain" can understand it. The easy-to-follow instruction book guarantees that. If you'd prefer to start off more slowly, write for free literature package MBA3. Philbrick Researches, Inc., 22D Allied Drive at Route 128, Dedham, Massachusetts 02026. Phone (617) 329-1600.

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The Klixon® 2ST detector is a sensor-switch combination designed to protect air-cooled electronic and electrical equipment against overheating due to the decrease of air flow and/or increase of incoming temperature. It is used in conjunction with Texas Instruments 4 MC Magnetic Circuit breaker to give warning of a dangerous condition or to cut off power.

The 2ST not only eliminates the need for vane switches and thermostats, but offers many advantages over these devices at little or no extra cost.

The 2ST functions perfectly in any position. It's rugged... can withstand the ordinary knocks of installation and maintenance. The sensor reacts to the cooling capacity of the air... it is not affected by the individual parameters of velocity and/or temperature. The sensing element is a thermal analog of the equipment being protected. Its thermal characteristics can be matched to thermal limitations and requirements of the equipment. Other successful applications of the Klixon 2ST cooling effect detector include computer high-speed printers and card-reader-punch units, copying machines and projectors.

Texas Instruments and other manufacturers get together daily to solve problems. Perhaps we have the answers to help you, too. Get more information. Circle reader card 488.

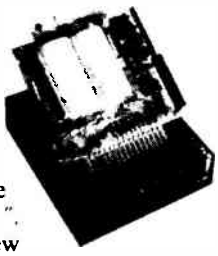
Texas Instruments makes it happen in industry.

Electric utilities going solid state for power control and protection.

Electric power. It must be generated ...controlled. There must be protection against blackouts... against damage to company and consumer equipment.

One unique electronic protective device is Esco Manufacturing Company's CM-78 inverse timer and control. It is made to sense overcurrent conditions in power lines and generate a command signal to trip circuit breakers before damage can be done.

The CM-78 is a custom-designed, solid-state electronic assembly made for Esco by Texas Instruments. All its semiconductor components are produced by TI . . . SCR's, silicon transistors, silicon rectifiers, and silicon diodes. Precision resistors and solid tantalum capacitors from TI are also employed. The circuits are solidly encapsulated in epoxy in a module only 5" x 4" x 1⅛".



The advanced new electronic module offers a multiplicity of advantages over the electromechanical devices now in general use, yet it costs no more. It's faster, more reliable, and many times smaller.

Esco came to Texas Instruments because they found that TI offers the broadest, most complete line of semiconductors in the industry and because TI can provide these products in preassembled, pretested electronic assemblies. This eliminated the need for large capital investments in new production facilities and extensive electronic engineering capability. Considering solid-state electronics? Send for a free packet of detailed information by circling reader service card no. 489.

TI semiconductors help brokers read market quotations easier

Texas Instruments semiconductors will soon be in brokers' offices all over the country as part of a new stock quotation display made by Trans-Lux Corporation.

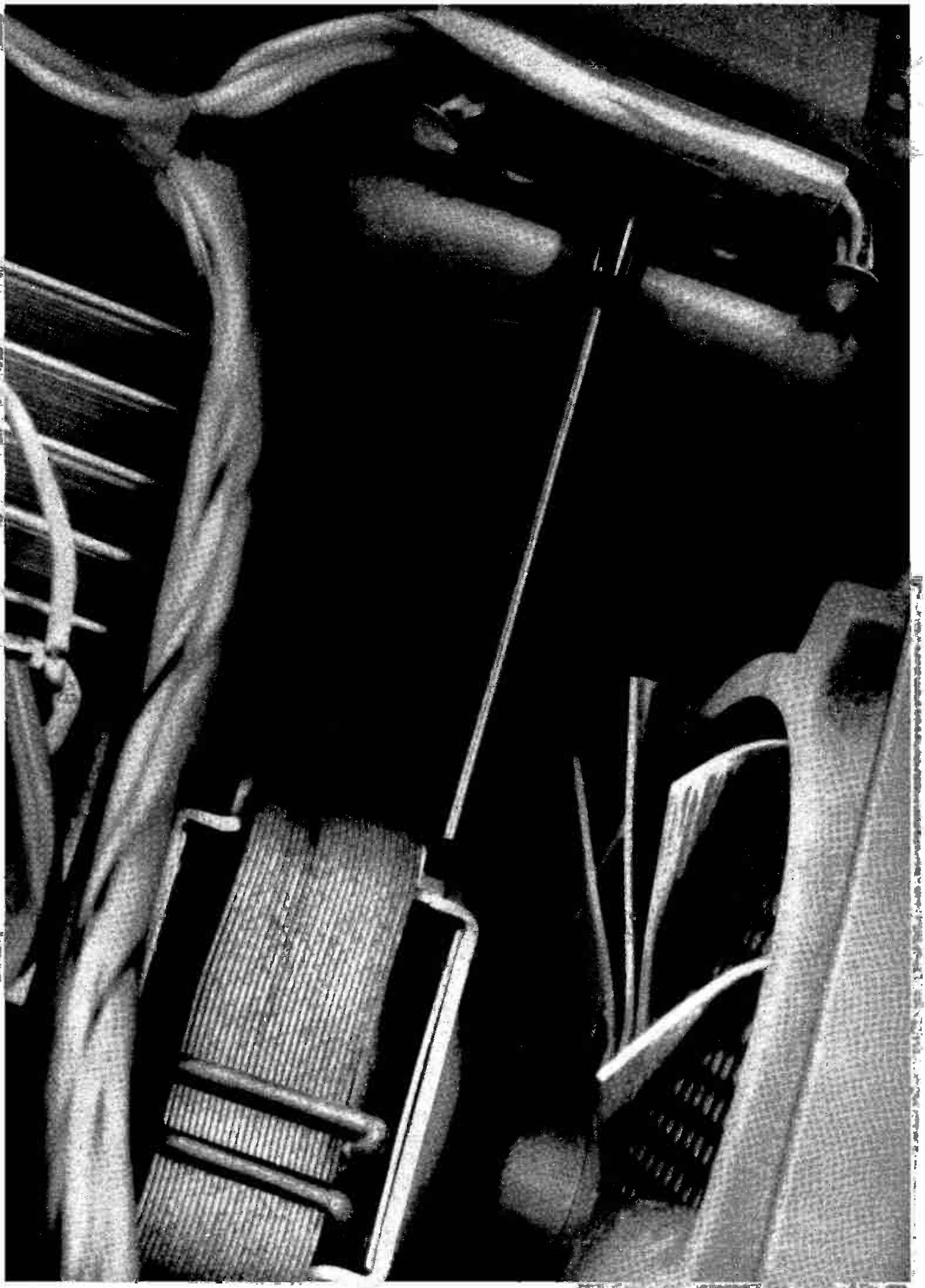
The new "Trans-Jet" display is a brokerage-size, self-contained unit that can be mounted on a wall or hung in the middle of the room for viewing from both sides. It takes incoming signals directly from the stock exchange communications network and converts them to a moving display via a new electronic-electromechanical-pneumatic system.

The new system incorporates Texas Instruments low-cost industrial integrated circuits, Silect™ plastic-encapsulated silicon bipolar and unijunction transistors, germanium transistors, silicon diodes, SCR's and semiconductor light sensors.

In the conventional display an electromechanical tape-feeding system and film projector require a separate console. The new "Trans-Jet" built-in electronic control is only 12" x 10" x 6". And maintenance has been reduced from bi-weekly to semi-annually.

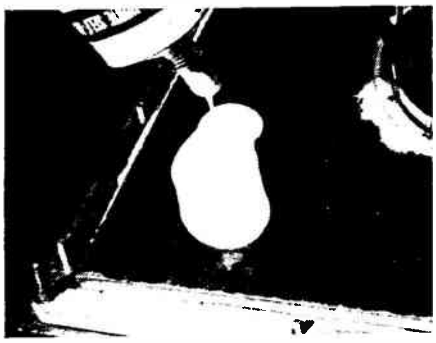
Semiconductors offer a wide range of opportunities for miniaturization reliability, efficiency and economy. For information and application assistance circle reader card 490.

TEXAS INSTRUMENTS
INCORPORATED



There's a G-E silicone

Bonding

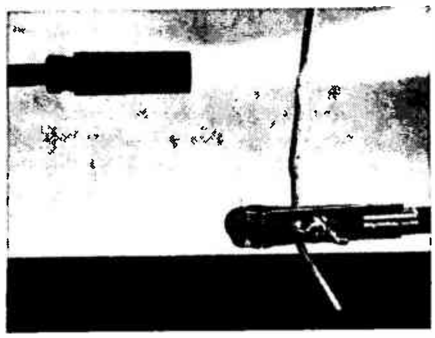


Laminated layers of mica sheeting are securely bonded with G-E RTV silicone sealant. Ready to use, it bonds to most materials.

Screws and drilling are eliminated by adhering identification plates with RTV sealant. It won't harden, soften, crack or shrink.

Insulating

G-E RTV translucent sealant provides excellent see-thru insulation instantly. UL-recognized, the sealant also comes in colors.



Silicone rubber wire and cable insulation passes UL vertical flame tests and is frequently used in high-voltage circuits.

G-E silicone dielectric greases, ideal heat transfer media, are easily brushed, painted, sprayed, dip-coated or applied directly from tube.

Damping

G-E RTV-7 silicone rubber foams on the spot to provide mechanical support, shock and vibration damping, and light weight electrical insulation.

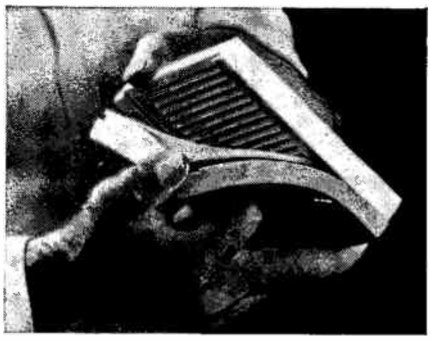
Sealing

G-E two-part RTV, available in a range of viscosities, seals filament condenser plate in dielectric heater. Also protects against vibration.

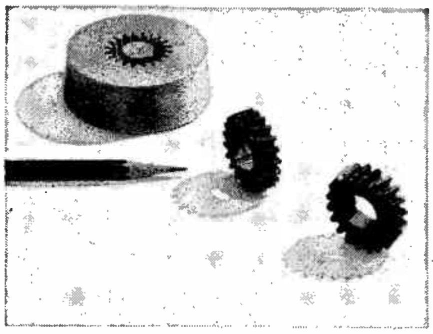
G-E RTV is ideal for high temperature moisture sealing of heating elements. It withstands temperatures as high as 600°F, as low as —75°F.

design solution for:

Moldmaking

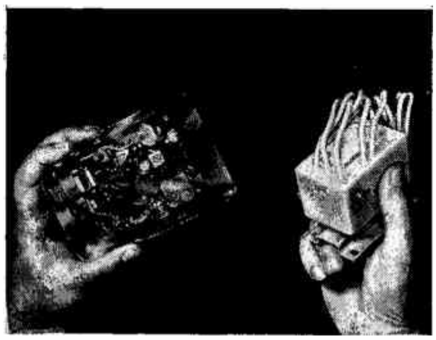


Tough, flexible G-E RTV silicone for moldmaking reproduces detail accurately and minimizes tooling costs.

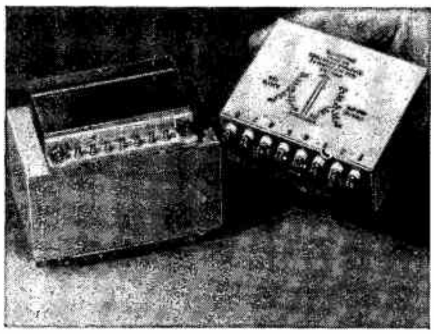


For prototypes or short-run parts production, G-E RTV is an excellent flexible moldmaking material. And it needs no release agent.

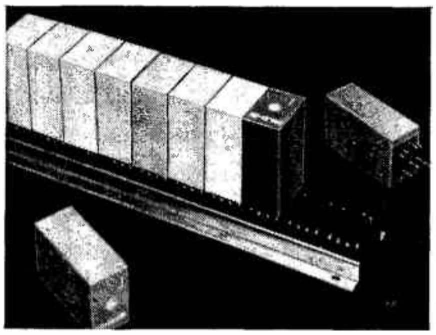
Potting and Encapsulating



Many G-E RTV silicone compounds are available—all with good strength, outstanding electrical properties and resistance to temperature extremes.

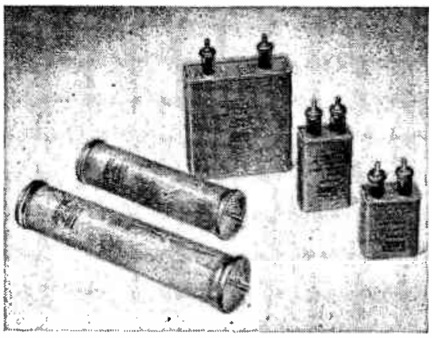


Impregnation of transformer coils with G-E RTV provides electrical insulation and environmental protection at high temperatures.



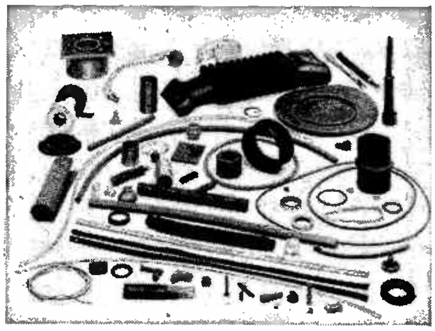
G-E RTV provides attractive, protective packaging for components. Each unit is encapsulated in a different color RTV for easy identification.

Fluids Applications



G-E silicone dielectric fluids provide excellent electrical properties and thermal stability for many types of components.

Fabricating



G-E silicone elastomers are easily used to make numerous silicone rubber parts by standard rubber fabricating techniques.

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As we said, Celanese Nylon *is* coming.

Celanese benefits from twenty-five years of nylon technology. I.C.I., Ltd. and Celanese jointly own Fiber Industries, Inc., which produces nylon fiber at Greenville, S. C. Nylon salt for the new Celanese Nylon plant at Houston will be supplied from the Bay City, Texas, facility of Celanese Chemical Company which is now undergoing major expansion.

Production of a competitive high-quality Celanese Nylon, prior to start-up of the Houston plant, is possible due to existing Celanese facilities and completely integrated technology. New Celanese Nylon 66 and Celanese Nylon 610 molding and extrusion resins, plus a full range of copolymers and terpolymers, will be produced under the Celanese-developed process within a year's time.

We are also boosting production of our other major engineering plastics: Celcon acetal copolymer, regular and glass-reinforced grades. Forticel cellulose propionate. Cellulose Acetate. Fortiflex polyethylenes. So we can offer a most complete line of engineering plastics. Included in this family of engineering plastics will be glass-reinforced nylon molding compounds.

While we obviously didn't invent nylon, the addition of Celanese Nylon resins is a logical extension of Celanese Corporation's diversified line of over 100 basic products. A line which includes petrochemicals, fibers, plastics, forest products, paints and coatings, and petroleum products. The Celanese Plastics Company, alone, operates eleven plants in the United States, four more abroad, which produce high-performance plastic resins and fabricated plastic products.

We welcome the opportunity to tell you more about Celanese Nylon—now available in development quantities for your evaluation. Write Celanese Plastics Company, Dept. 133-L, P.O. Box 629, Linden, New Jersey.

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Japanese technology

Communications technology in Japan

In communications, the Japanese are pressing original development work to increase their own telephony capacity and to make better use of computers. The Japanese engineer keeps an eye on the great growth in communications taking place within his own country and the vacuum in communications which exists in most other Asian countries and in Africa. The goal is to compete favorably everywhere in the world with up-to-date hardware and techniques.

p. 134 Japanese stay with pcm to meet mushrooming growth in telephony

p. 147 Bit by bit, the Japanese speed data communications

Japanese stay with pcm to meet mushrooming growth in telephony

Communications boom in Japan is stimulating development of varied techniques of pulse-code modulation and other methods of expanding transmission networks without adding new lines

By Hiroshi Inose and Hiroya Fujisaki
University of Tokyo

Japan's need for short, high-capacity communications links between its densely populated areas is fostering the rapid development of pulse-code modulation techniques and installation of pcm systems.

Although Japanese communications systems designers did not begin extensive research in pcm until 1950, they are more than making up for lost time to meet the current communications boom. Japan now ranks second in the world in installation of pcm telephone systems; the United States is first. In the past year, Japan has installed seventy-three 24-channel systems and by September, 1967, more than 326 systems will be in operation.

The authors

Hiroya Fujisaki, an associate professor at the University of Tokyo, received his doctorate degree there in 1962 and is now engaged in research on speech and digital communications. From 1951 to 1961, he was with Massachusetts Institute of Technology in the United States and the Royal Institute of Technology in Sweden.

Hiroshi Inose specializes in digital transmission and exchange systems. A professor of electrical engineering at the University of Tokyo, he received his doctorate there in 1955. Between 1956 and 1961, he was associated with the University of Pennsylvania and Bell Telephone Laboratories. He is the holder of many awards from professional organizations.

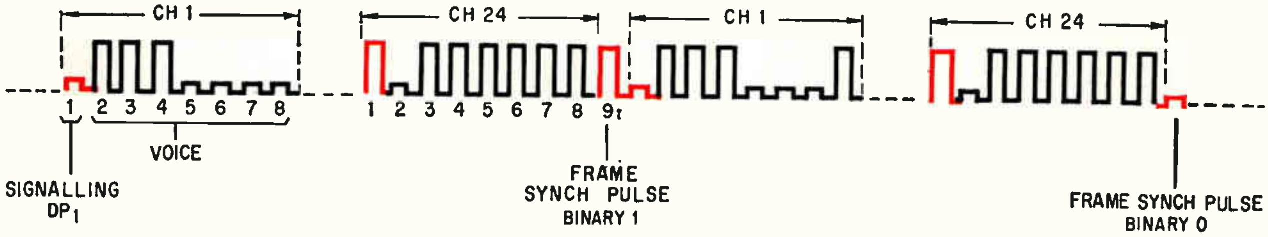
The nation's telephone network is the major user of pcm because one of the main advantages of pcm is that it allows many messages, usually up to 24, to be sent over an existing telephone transmission line; thus avoiding the great expense of installing more transmission lines. In cities, and in communications between cities, pcm is an economical way to provide for the increase of telephone subscribers.

Pcm for telemetry is also becoming a favored transmission mode in science and industry. For example, modifications that will improve signal-to-noise ratios have been proposed for the space program. Government agencies, railroads, electric companies and gas suppliers have installed pcm telemetry systems.

Computers and digital data transmission systems are being put in service in large numbers by public utilities and businesses [see "Bit by bit, Japan is speeding its data communication links," p. 147]. The users of these computers and the companies making the data processing equipment see in pcm the answer to future requirements for transmission of huge volumes of digital data at high speeds.

In development or being studied at numerous Japanese companies and laboratories are such techniques as high-speed modulation, nonlinear coding, synchronization and error-correction methods, transmission of pcm signals by radio (and through waveguide at millimeter wavelengths) and the integration of telephone switching and transmission systems. Eventually, the transmission of voice, video and data communications may be unified in the integrated networks.

Since World War 2, the buildup of communications in Japan has been remarkable—more than 10,000 miles of microwave links and 1,500 miles of



Pulse-code modulation format consists of coded pcm word from each of 24 voice channels. First pulse (color) in any coded channel is the signaling pulse that indicates the subset is off-hook or carries dialing information. This is followed by seven time slots for the coded voice signal. At the end of the 24th channel is a framing synchronization pulse which is 0 or 1 in alternate frames. In the PCM-24 telephone system 8,000 frames are transmitted each second.

coaxial cable now serve some 13 million subsets. But the decision to use pcm in telephone communications was not made until 1963.

One of the reasons for the delay was a lack of the silicon transistors that are required by practical pcm equipment. Although Japan ranks second in world production of semiconductor devices and is the home of such advances as the Esaki diode, until recently transistor production concentrated on germanium devices for radio and television sets.

In August, 1963, Nippon Telephone and Telegraph Public Corp. (NTT) began developing a 24-channel pcm telephone system, called the PCM-24. Nippon Electric Co. produced the equipment.[1,2,3] It is also being made now by Fujitsu Ltd., which recently exported 23 systems, with 200 repeaters, to the Hong Kong Telephone Co.

Test operations of the PCM-24 systems began last December with 15 systems in the Osaka, Tokyo and Mito areas. A total of 326 installations are to be in operation by September, 1967. Meanwhile, higher capacity systems are being developed.

Fujitsu is studying nonlinear coding schemes. Oki Electric Industry is working on transmission and exchange problems as well as synchronization schemes. Both Tokyo University and Osaka University and the company that handles overseas communications, Kokusai Denshin Denwa Co., are active in pcm development.

Developing the system

The system now in production, the PCM-24, grew out of a study comparing the conventional frequency-division multiplex (fdm) type of telephone system with time-division multiplexed pcm.

Pcm systems are more economical in short-haul communications that mainly go over existing lines between exchanges that normally handle audio frequencies. Pcm requires a wider transmission bandwidth but provides more channels. Greater channel capacity is possible because pcm is more immune to interchannel interference. In addition, the pcm terminals cost less because channel separation is handled by digital circuits rather than costly bandpass filters.

In the PCM-24 system, speech signals are sampled 8,000 times a second; each channel is transmitted as an 8-bit code word. Seven bits are needed to maintain a signal-to-quantization noise ratio of commercial quality and one bit is needed for signaling—off-hook, on-hook or dialing. Speech quality of the PCM-24 system is comparable to conventional fdm carrier telephony with 4-kilohertz bands. Each frame consists of 193 bits—192 for the 24 code words and one bit for the synchronization framing pulse. Since 8,000 frames are sent each second, the system clock frequency is 1.544 megahertz. These are the same basic characteristics as in the T-1 pcm system which has been used in the United States since 1962 by the American Telephone & Telegraph Co. However, the code format, shown in the diagram above, is different.

As in Bell System's unit, nonlinear quantization (compression and encoding) is mandatory to maintain a signal-to-quantization noise ratio of more than 26 decibels as the input speech levels vary over a 40-db range. For this purpose, the system compresses—that is, emphasizes—the low-level signals with a logarithmic characteristic that has a $\mu = 100$ [Electronics, Sept. 19, pp. 142-143]. Diode components for the compressor are stabilized in an oven at 120°C ± 0.3°C.

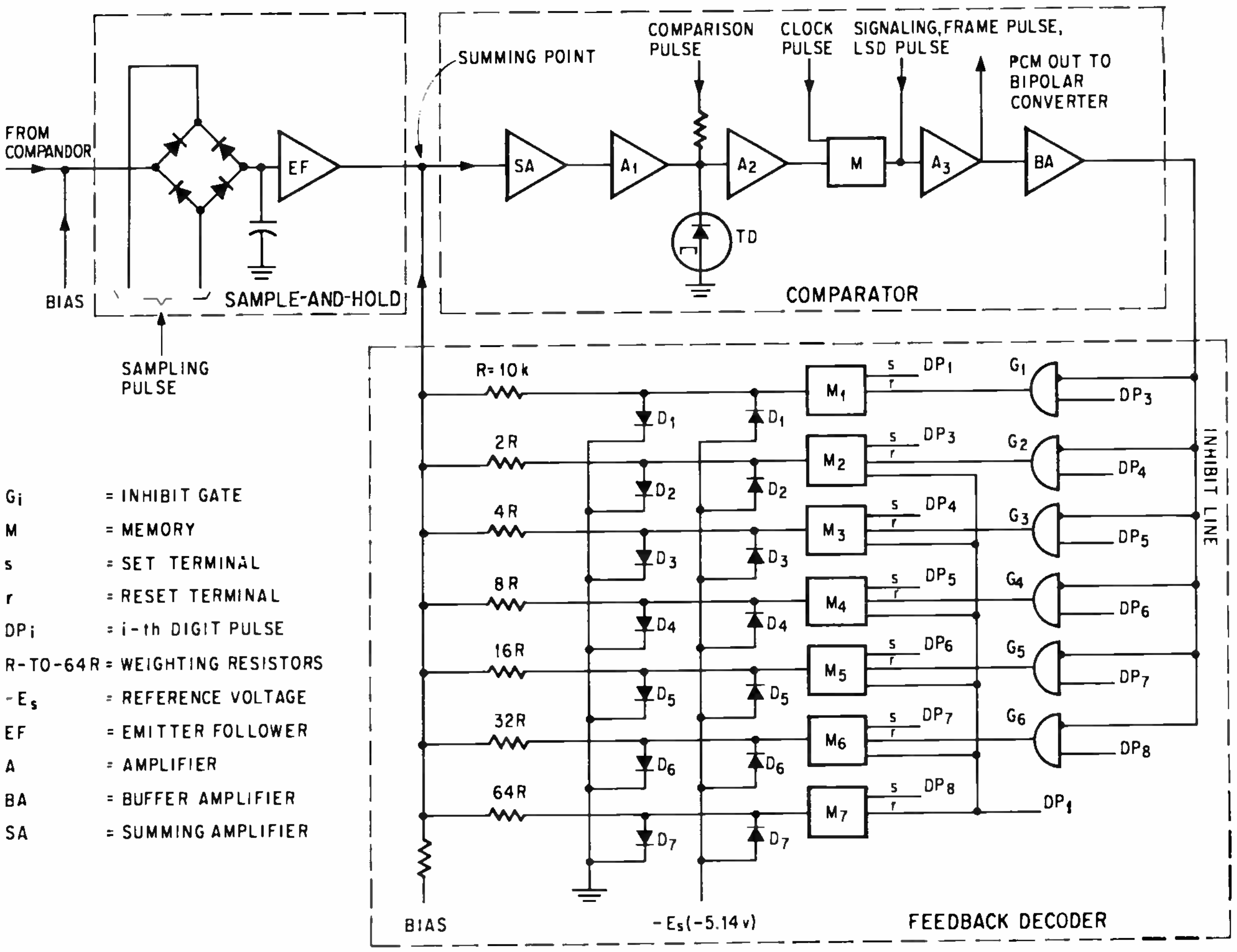
Feedback encoder

The feedback encoder in the circuit on page 136 provides the best economy, accuracy and stability. All 24 channels share one encoder and one compressor (not shown). By comparison, Bell employs one encoder for odd numbered channels and another for even numbered channels. This allows transients to die out during alternate channels and consequently reduces the circuit's speed requirements. However, the PCM-24's encoder equals the performance with less cost, less complexity, smaller size and lower power drain.

The PCM-24 encoder circuit is a digit-at-a-time encoder; it establishes the coded word by sequentially determining, in seven steps, which digits (1's or 0's) should appear in the 7-bit word.

When a sampling pulse is applied to the sample-and-hold circuit shown in the diagram, the capacitor charges or discharges to the value of the companded signal; it remains charged until the next sample is applied.

While the capacitor is charged, the signal level is summed with the currents determined by connecting the weighting resistors R to 64R to ground or to the voltage $-E_R$. A binary 1 is generated when the current that the sample signal produces is greater than the currents caused by the weight-



Feedback encoder takes compressed voice signals, samples them and then encodes them as pcm signals. Lines marked DP_1 to DP_8 refer to timing pulses. The sampled pulse at the comparator input is summed with a current determined by resistors R to 64R. If the summed current is positive, it produces a pulse in the time slot; if it is negative, there is no pulse. Feedback decoder at the bottom essentially reconverts the pcm output signal to the analog signal that appears at the summing point.

ing resistors. Otherwise a binary 0 is generated.

For example, consider encoding a signal level equivalent to the number 84. The desired pcm output is 10101000. The first digit on the left is called the most significant digit (msd). The circuit first determines this digit and then works its way down until it has determined the least significant digit.

During the first pulse in the code word format, a clock pulse called digital pulse 1, DP_1, resets the memories M_2 to M_7 and sets the memory M_1 so that the most significant digit can be determined. The lines, DP_1 to DP_8, correspond to time slots in the channel. Because the first memory is triggered during clock pulse DP_1, there is no DP_2 line, which would normally correspond to the most significant digit.

When memory M_1 is set, the output of the memory goes more negative than voltage $-E_s$ at the bottom of the diagram. Therefore, diode D_1 at the right conducts, causing a reference current to flow in resistor R. This current which is equivalent to decimal number −64 is summed with the current caused by the signal sample, which in this example is 84. Since the sum current is positive [84 + (−64) = 20], the comparator generates a 1 for the most significant digit. Because a 1 is generated, diode D_1 will continue to conduct for the remainder of the encoding process. If a 0 were generated for the msd (signal level less than 64), an inhibit pulse would reset memory M_1 which in turn would back bias D_1.

The next clock pulse makes D_2 conduct, lowering the negative reference current to −96 at the comparator [−64 + (−32) = −96]. Since the input signal level is 84, the input to the summer is negative. This generates a 0 as the code word's third bit. This 0 also results in an inhibit pulse which resets M_2 and turns off D_2. As a result the reference voltage returns to −64 since only D_1 is conducting. The other digits in the code word are generated in a similar manner by the next five clock pulses.

Framing synchronization

Timing or clock pulses at the repeaters—pulse regenerating circuits—must coincide with the transmitted pulses. This is called bit synchronization. Also, since 8,000 frames are sent each second, the repeater must determine the start of each frame—a group of 24 coded words. This is called "framing synchronization" or simply "framing." The terminals at the exchange use the framing signal—the 193rd bit position in the frame—as a timing reference to steer signals to their proper destinations. Repeaters appear both in terminal equipment an on the transmission line. On the lines, repeaters are spaced 2 kilometers apart except near exchanges where the higher impulse noise levels requires spacing of 1 km.

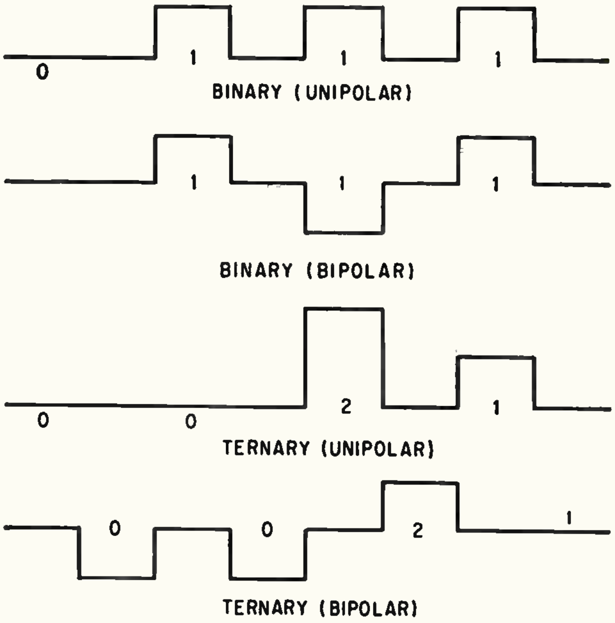
For framing, the network uses the so-called backward acting system, as does Bell's T-1 system. Once the repeater knows where the framing time slot occurs, it merely checks each subsequent frame to insure that the pulse is correct. The framing pulse must appear only on alternate frames. It can be detected because its pulse pattern is statistically unlike any other bit pattern.

If the alternate pattern is lost—system out of frame—the repeater moves to the next time slot and looks for the pattern again. It repeats this one bit shift until the correct pattern is received. The scheme is simple and economical but it requires an average of tens of milliseconds to recover synchronization. Even though the signal is noisy during recovery time, on the average only a portion of a syllable in a word is lost.

To prevent the repeater from initiating a search when only a single framing pulse is in error, or if errors are widely separated, the incorrect framing pulses are integrated. Reframing won't begin until the integrated output exceeds a threshold. For example, a steady burst of errors for 3 msec will cause an out-of-frame condition. If there is a large enough spacing between framing-pulse errors, loss of framing will not occur because the integrated level cannot build up.

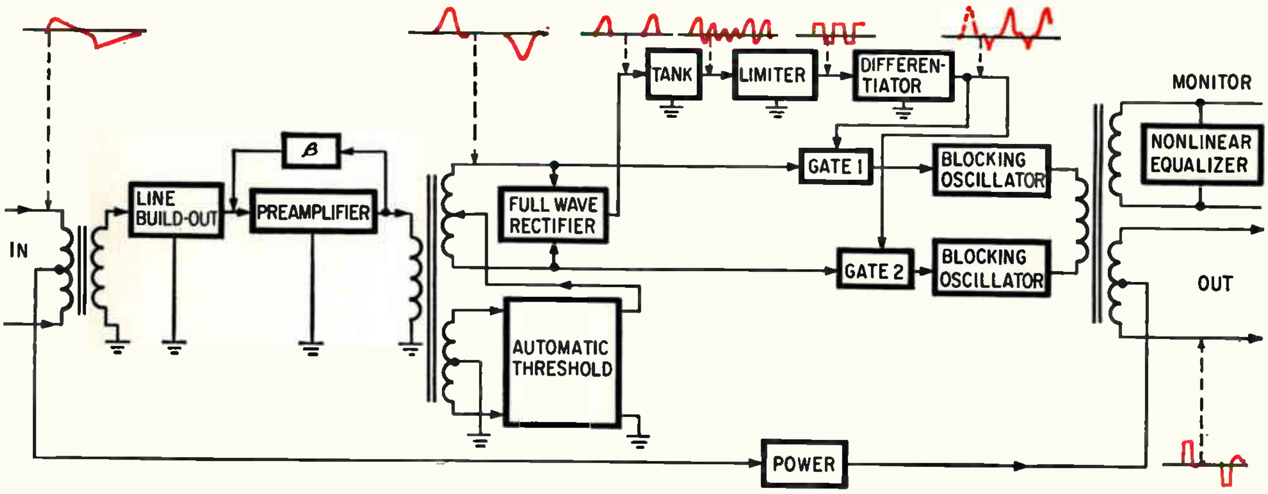
Timing and equalization

The system transmits the encoded samples as bipolar binary pulses that have a 50% duty cycle,



Binary and ternary waveforms convey digital information. All waveforms represent the decimal number 7. Unipolar binary waveform at top is encoded as 111, the binary designation for 7. In the second waveform, the polarity of each pulse—the 1's—is the negative of the preceding pulse. Bipolar binary waveforms in the PCM-24 system improve transmission characteristics. Ternary waveforms represent the code 21—the ternary designation for decimal number 7; that is $2 \times 3^1 + 1 \times 3^0 = 7$. In a unipolar ternary waveform, the code is represented by an obvious amplitude difference. In bipolar ternary, the negative pulse represents O, the baseline is 1 and the positive pulse is 2.

as in the second pulse pattern from the top in the diagram shown above. Each binary 1 digit is encoded with a polarity that is the negative of the preceding binary 1 pulse. This pulse pattern places the major portion of the pcm signal's energy at a frequency of about half the bit rate. Because the bipolar component has no d-c component it is relatively easy to transmit through transformers. Also

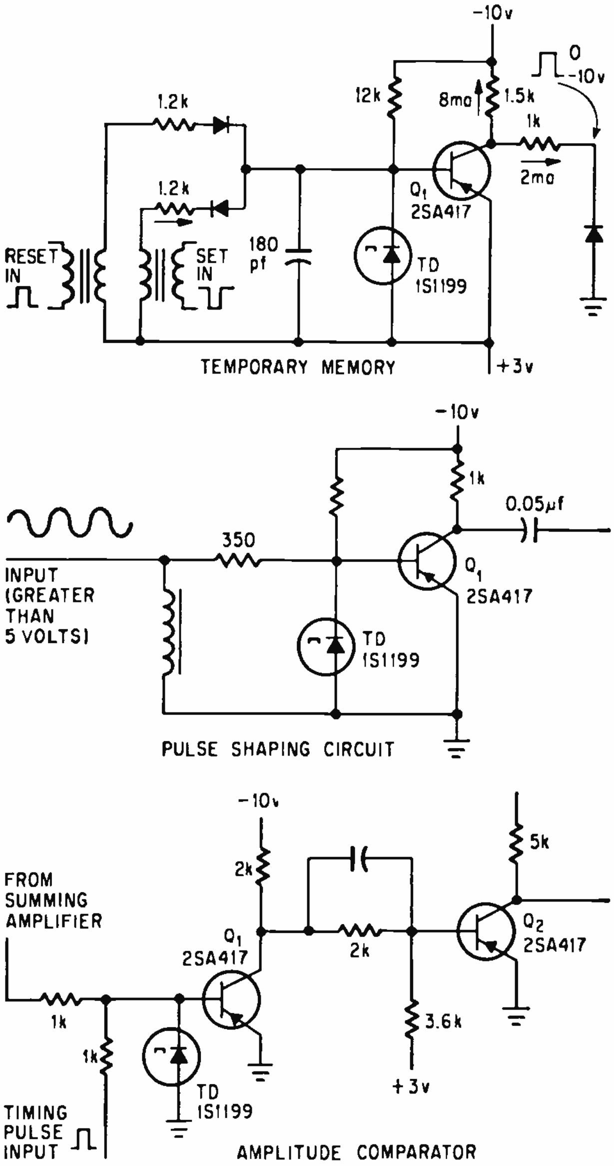


Repeater circuit equalizes the signal in the line build-out network and preamplifier, extracts timing information and reshapes the pulses. Waveform at input is a typical bipolar binary pulse that has been distorted and attenuated by the transmission line. At the output are two regenerated pulses that are sent farther down the line. Rectifier, tank, limiter and differentiator are parts of the timing extraction circuit. Waveforms at top indicate how circuit acts on equalized input pulses at the transformer's secondary.

the high-frequency energy is less, reducing crosstalk.

Normally, the transmission line will distort and attenuate the pulses. The repeater reshapes and retimes the input pulses as in the diagram on page 137. Measurements indicate that transmission disturbances are infrequent, so the repeaters can extract timing information from the signal pulses themselves. A separate timing signal is not needed, reducing transmission costs; and repeater costs are less because the retiming operation is simplified.

The line build-out network and the preamplifier form an equalizer that compensates for line attenuation. This input circuit has a 1.25 Mhz cutoff and has an over-all transfer function that is represented by a 6th-order rational function of frequency. Another equalizer, a load to the blocking oscillator's output, also reduces distortion by insuring that the output has a slightly nonrectangular pulse shape for greater immunity against crosstalk.



Three circuits in pcm terminal equipment all incorporate a tunnel (Esaki) diode and a common emitter transistor stage. Memory circuit, at top, is bistable; other two circuits are monostable.

Driving current (I_b) and switching times

	Base		Collector	
I_b (mA)	τ_{sb} (on)	τ_{sb} (off)	τ_{sc} (on)	τ_{sc} (off)
2.0	4.0	7.0	16.0	23.0
3.0	2.5	2.5	13.0	18.0
4.0	2.0	2.0	10.0	15.0

Timing or clock information is extracted from the equalized input signal by first rectifying the input signal. Rectification converts the bipolar pulses to monopolar pulses with a fundamental frequency at the bit rate. These pulses are then fed to a tuned circuit (tank) whose output is clipped and differentiated to produce the narrow clock pulses that occur at the center of the input pulse. The differentiated pulses and the equalized signal are then "ANDED" in gates 1 and 2. Therefore, blocking oscillator 1 or 2 will produce bipolar pulses that match the polarity of the equalized signal.

At the input to the gates the automatic threshold control circuit determines the threshold at which the blocking oscillator triggers. The circuit also establishes the clipping level at the input to the timing circuit. The threshold is approximately half the peak level of the equalized input signal. A threshold device is necessary to make the recovered clock independent of the signal amplitude and to reduce crosstalk in the regenerated pulses.

The repeaters and much of the timing and framing circuits in the terminals can be monitored by merely checking the timing of the framing pulses. However, monitoring other terminal equipment—such as compandors, coders and decoders—requires a pilot signal, transmitted over one of the 24 channels when the channel is idle. Failure in synchronization or incorrect transmission of the pilot is detected at the receiving terminal and the transmitting terminal is notified.

Tunnel-diode circuits

The PCM-24 system makes extensive use of digital circuits composed of transistors and tunnel diodes shown in the diagram at the left. These allow high-speed switching with relatively few elements and result in greater economy and reliability. In these circuits, the input of a grounded emitter amplifier is shunted by a tunnel diode whose negative resistance characteristic produces a bistable or monostable condition depending on the configuration of the circuit.

In the memory circuit, the 12-kilohm resistor and the transistor input impedance allow the tunnel diode to have either of two stable states. A set signal switches the tunnel diode to a high voltage state, where it remains after the set pulse is removed. A reset signal switches the diode to a low voltage state, where it remains after the reset pulse is removed. The pulse-shaping circuit is similar to a Schmitt trigger but is simpler, more stable and requires less power.

The bottom circuit is a comparator and AND gate that is used in the feedback encoder on page 136. The input from the summing amplifier must be above a specified level and the timing pulse must be present if a pulsed output is to result.

In all these circuits switching can be speeded by increasing the base driving current to the transistor. This is indicated in the table on page 138, which includes the switching speeds at the base, τ_{sb}, and at the collector, τ_{sc}.

Orthogonal transmission

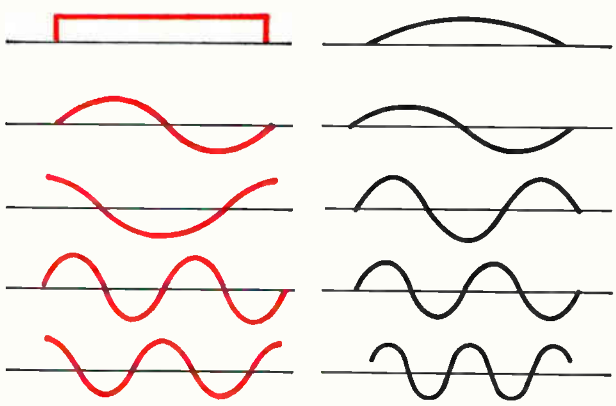
New methods of modulating and coding the information, improved repeater design and more efficient methods of transmitting signals have been developed recently in Japan. An interesting proposal for reducing transmission bandwidth is to encode the samples as a ternary pcm word and transmit the bits as orthogonal waves. Thus, all the bits in the pcm word can be transmitted simultaneously over about half the bandwidth normally needed for one channel of conventional pcm. The bits, of course, are converted from a serial format to a parallel format for simultaneous transmission.

Ternary pulses in this orthogonal transmission technique are compared with binary pulses in the diagram on page 137. The term orthogonal means that the correlation between different waveforms is zero. This, in turn, means that waveforms that are transmitted simultaneously can be separated without interference. For two sinusoidal waves, S_1 and S_2, with suitable different phase or frequency, zero correlation is equivalent to saying

$$\int_0^T S_1 S_2 \, dt = 0$$

where T is the period of the lowest frequency waveform.

In the orthogonal modulation technique, one of the waveform sets diagramed above is chosen to transmit 5-bit ternary code words. A waveform in the set is orthogonal to any other waveform in that set. In addition, each waveform can have one of three states—the one shown, one 180° out of phase and one with zero amplitude. Therefore there are a sufficient number of waveform combinations to transmit all possible combinations of a 5-bit ternary code word.



Orthogonal waveforms can simultaneously transmit all the bits in a 5-bit pcm word. Some orthogonal waves can have the same frequency as in the set in color. Phase and frequency differences allow separation.

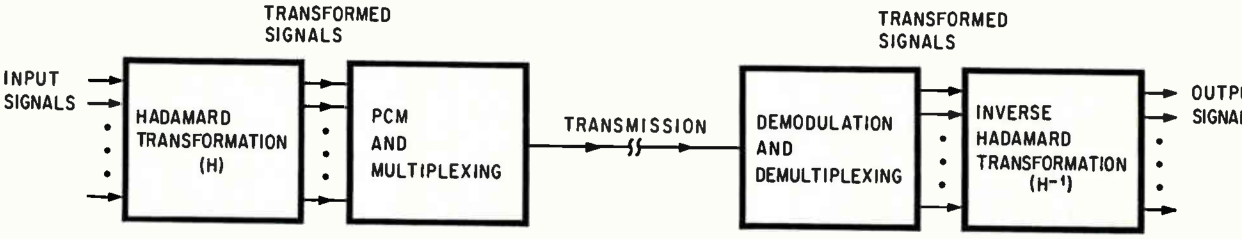
Orthogonal waves can also improve the threshold characteristics of pcm systems by making it possible to assign longer transmission times to the more significant digits in a code word.[5] Known as an orthogonal pcm with weighted bit length, this process increases the likelihood of detecting the signal correctly; so for the same speech quality, the minimum signal-to-noise ratio can be less.

An optimum assignment of bit length would improve threshold about 1 db. In conventional pcm telephone system, a 1-db improvement would require several times more bandwidth. Bandwidth economy is particularly important in long-distance transmission, such as in satellite communications.

Hadamard transformation

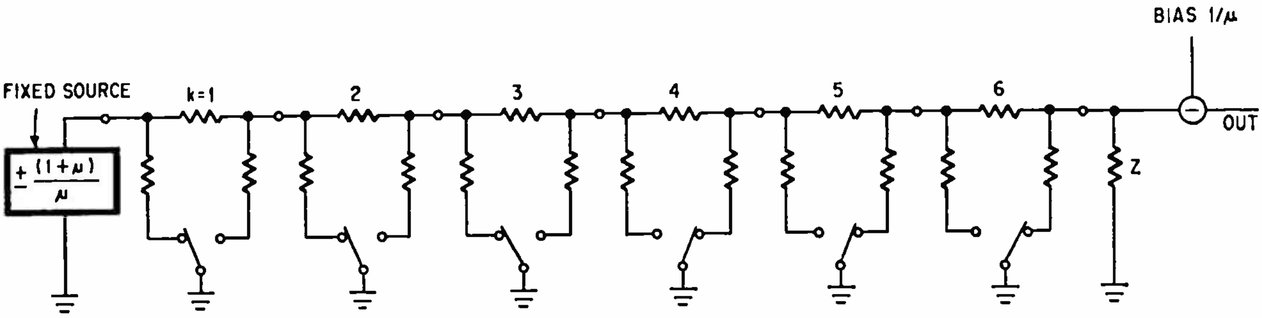
Another interesting proposal for pcm transmission is similar to compression in that it reduces the number of bits needed to provide a suitable signal-to-quantization noise level.[6]

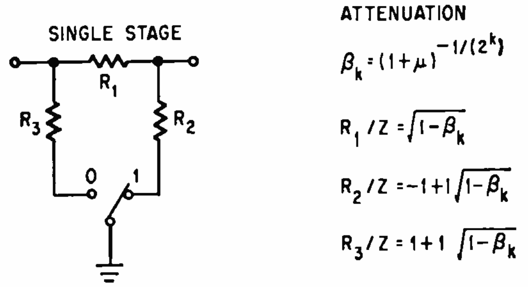
A set of n signals of greatly varying levels can be transformed into a new set of n signals whose levels are more equal. Consequently, less digits are needed to maintain a given signal-to-quantiza-



Hadamard transformation matrix, H, in color at right, makes input voice signals more uniform. The transformation is simply implemented as a weighting network. As in the block diagram in a pcm system, it may improve the signal-to-quantization noise. Both the transformation, H, and its inverse, H^{-1}, are identical; therefore the same type of network is placed on either end of the line.

$$H_8 = H_8^{-1} = \frac{1}{\sqrt{8}} \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{pmatrix}$$





Logarithmic decoder utilizes fixed impedances and switches controlled by pcm word to decode a 6-bit pcm signal. Switch in the k=1 stage is controlled by pcm's most significant digit. Impedance relationships at the bottom are normalized to the load impedance, Z, and show how each component in the stages is selected. Source and bias voltage are related to parameters of the logarithmic companding characteristics.

tion noise level. As in any companded system, this is also a bandwidth reducing scheme since less digits implies smaller bandwidth.

A matrix known as the Hadamard matrix in the diagram on page 139 is especially suited to serve as the transformation because it can be realized by a simple weighting network. This matrix is written for eight channels but can be set up for any integral power of 2 such as 2,4,8,16 or 32 channels. Theory and experimentation show that as the number of channels increases, the maximum increase in the signal-to-quantization noise ratio is 24 db.

Nonlinear encoding

Since levels of speech signals may vary as much as 60 db, it is difficult for an encoder to quantize low-level signals as accurately as high-level signals, unless the quantization steps are nonuniform. That is, changes of a few millivolts in a low-level signal must be as significant as a change of tens of millivolts in a high-level signal. Speech quality will be poor after the pcm signal is decoded unless low-level signals are emphasized by nonuniform quantization or compression.

Generally, a diode's nonlinear voltage-current characteristics compress the signal at the transmitter and then expand it at the receiver. However, it is difficult to get exactly matching characteristics at the compressor and expandor.

In 1963, an ingenious technique was developed to eliminate diodes from nonlinear pcm encoders.[7] The pcm signal controls switches that make a network's impedance or immittance proportional to the pcm code word. Combining both variable and fixed impedances or immittances makes possible many different expandor characteristics. Attenuation is controlled to obtain logarithmic characteristics; immittance is controlled to obtain hyperbolic and modified (or weighted) hyperbolic curves. The latter consists of two hyperbolic curves that follow different equations for high-level and low-level signals and results in better characteristics than a single curve. The expandor may serve as an analog-to-digital converter in the feedback path of the encoder to get the desired encoding characteristic.

The circuit shown above is a simplified 6-bit logarithmic decoder that can be made of cascaded attenuators. Resistor values are given by the equations at the bottom of the diagram. In this circuit k is the bit position and k=1 is the most significant bit position. The bias and source are fixed voltages.

Independent work on encoders with modified or weighted hyperbolic characteristics has extended the dynamic range of hyperbolic encoders to meet the specifications for the PCM-24 system.[8,9] A 7-digit pcm word will provide greater than 26-db signal-to-quantization noise level, even if the input signal varies by 40 db. Compared to a logarithmic encoder, hyperbolic encoders can be made with simpler relays, fewer transistors and fewer and less precise resistors.

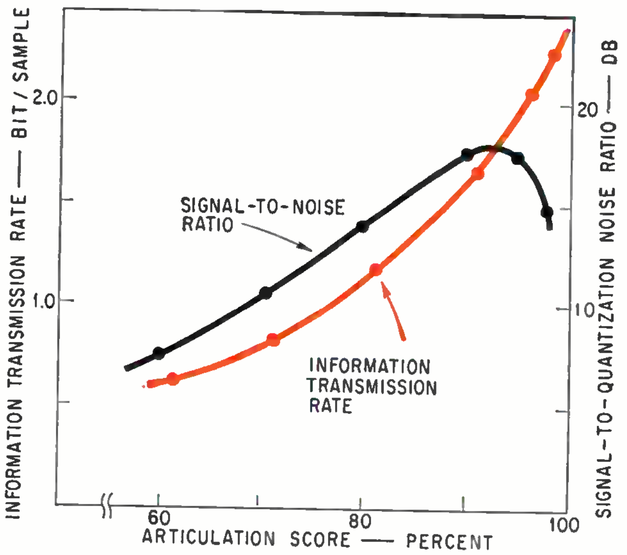
Evaluating nonlinear encoding

A basic measure of speech quality is the articulation score, the percentage of unrelated syllables correctly understood in a message. This score can disclose the effectiveness of the companding in a pcm system.

In 1962, tests of delta pcm and conventional pcm with the same companding characteristic showed that delta pcm, also called differential pcm, had a better articulation score and signal-to-noise ratio than conventional pcm.[10] Theoretical analysis of delta pcm led, in 1965, to the proposal of an optimum companding characteristic.[11]

A more plausible criterion than signal-to-noise ratio is needed to evaluate nonlinear coding characteristics for speech signals. For example, when the signal-to-quantization noise ratio is calculated using conventional theory, the results cannot be correlated with the articulation score.[12] The problem is that conventional theory neglects unvoiced sounds because unvoiced sounds are assumed to have less power and contribute less to quantization noise. However, this assumption is not correct and the quantization noise must be considered separately for voiced and unvoiced sounds. The discrepancy is evident in the black curve in the graph shown at right which erroneously indicates that the signal-to-quantization noise ratio could decrease for the highest articulation scores.

To correct this anomaly, the authors related the articulation score with the information transmission rate in a speech sample, averaged over the voiced and unvoiced intervals of speech signals. The resulting curve, shown in color, indicates that signal-to-quantization noise must increase with articulation score.



Two ways are shown to relate properties of the pcm signal to articulation scores—the percentage of unrelated syllables correctly understood in a message. Curve in black, based on conventional theory, erroneously indicates that the signal-to-quantization noise ratio decreases at the higher articulation scores. It is more meaningful to relate scores to average information and transmission rate of voice and unvoiced sounds, as in the curve in color.

Improving delta modulation

Although the delta modulation technique is considered simpler than pcm, it was also considered inferior until recently because of its wider bandwidth requirements. However, current studies make it clear that there are many ways to improve this single-bit modulation technique.

In the basic delta modulation technique, each sample is transmitted as a single pulse which represents a change in level from the prior pulse.

A simple delta modulator as in the diagram shown below incorporates timing or clock source and therefore is a synchronous system. At the sampling time, the input signal is compared with the integrated output and, if the difference exceeds a predetermined amount, a pulse is generated. The amplitude difference and clock frequency must be chosen so that the system can follow the fastest-changing signal that is to be transmitted. To improve signal-to-noise ratios, the difference level is reduced and the clock (timing) is made correspondingly faster. If the difference between the input and integrated level is below the predetermined level, the pulse modulator delivers a negative pulse that reduces the integrated level.

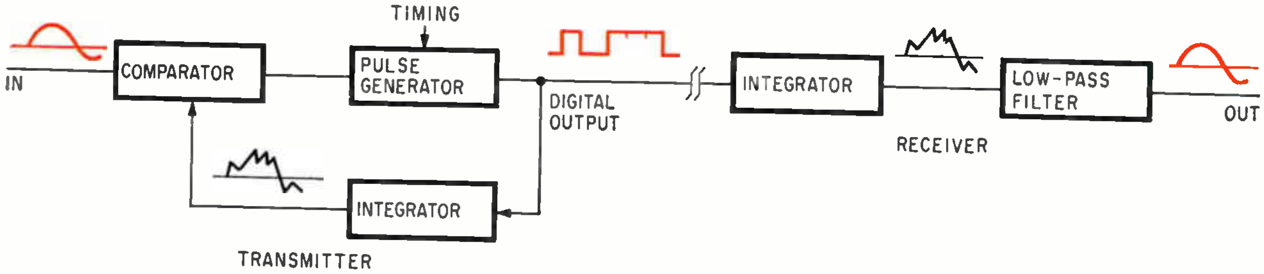
The digital output is proportional to the derivative of the signal instead of the signal's amplitude; therefore, delta modulation is not suitable for transmitting d-c signals.

To recover the original signals, the receiver integrates the bits and filters the resultant integrated waveform. Because of the integrator's time constant, the effect of transmission disturbances that change the pulse pattern will be evident in the recovered signal even after a relatively long time interval. That is, errors caused by transmission disturbances tend to accumulate.

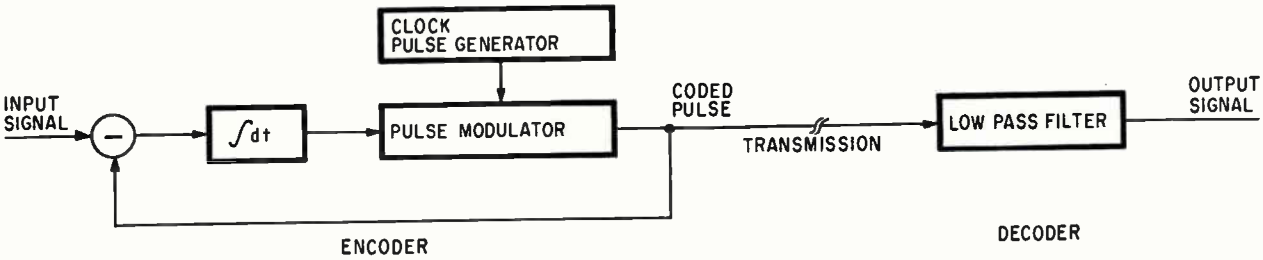
In delta pcm, the comparator is replaced by a quantizer. Rather than just generating a pulse, the difference in level is quantized and transmitted with a few bits. As indicated earlier, delta pcm can produce better signal-to-noise and articulation scores than conventional pcm.

If delta modulation, delta pcm and conventional pcm are compared, it is found that conventional pcm requires the most complex equipment; but its bandwidth utilization is the most efficient of the three methods. Delta modulation requires the simplest equipment but is the least efficient in utilizing bandwidth. Delta pcm is intermediate between delta modulation and conventional pcm both in equipment complexity and efficient utilization of bandwidth.

A variation of delta modulation, called delta sigma modulation, reduces the effect of cumulative errors.[13] As in the diagram on page 142, the integrator is removed from the feedback path and is



Delta modulation circuit, at left, integrates output pulses and compares resulting wave with the input signal (curve in color at the left). Output pulses, also in color, represent derivative of signal waveform—not the amplitude. In the receiver at the right, input pulses are integrated and filtered to recover original waveform.



Delta sigma modulation places the integrator in the forward loop. In conventional delta modulators it would be in the feedback loop. The change causes output pulses to indicate the amplitude of input signal instead of the derivative, so the received signal does not have to be integrated. Signal is decoded by passing pulses through a low-pass filter. Because the delta sigma modulator has no integrator in the receiver, cumulative errors that occur in conventional delta modulation are eliminated.

inserted in the forward path of the modulator. To generate the output pulses, the output of the integrator is compared with the fixed reference.

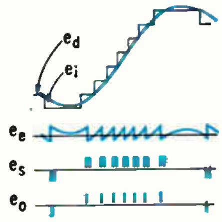
The output pulses now represent the signal's amplitude, instead of the signal's derivative. At the receiver of the delta sigma system, the signal is recovered by merely reshaping the pulses and passing them through a low-pass filter. Since there is no integration, transmission disturbances cannot cause cumulative errors.

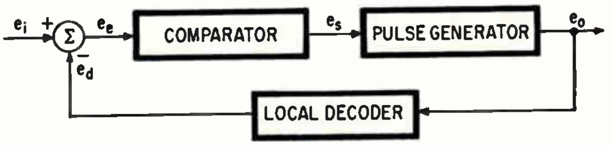
Furthermore, since the system's dynamic range is independent of the input frequency, delta sigma modulation can transmit d-c components with the same facility with which it transmits audio or video signals.[14]

Adding a compandor to the feedback path is another way of improving delta modulation. The signal-to-quantization noise ratio is improved about as much as in a conventional pcm system. If syllabic rather than conventional (instantaneous) companding is used, then delta modulation has a higher signal-to-quantization noise ratio than ordinary pcm with the same clock frequency.[15] A 5-db improvement was measured in one experimental system. Conventional companding is based on the instantaneous speech level; syllabic companding implies that the compandor's output depends on the average level in the voice signal.

Still another method to improve delta modulation is encoding the signals in an asynchronous ternary

Asynchronous delta modulator generates a pulse whenever the difference between the output of the local decoder and the input signal exceeds a predetermined value. Therefore the pulse output is asynchronous. As waveshapes indicate, the number of pulses decreases when the waveform is not changing rapidly. Because fewer pulses are transmitted, the system is suited for asynchronous multiplexing.





code instead of a binary code with a fixed sampling frequency.[16] The modulation scheme, which has been under development since 1964, is illustrated in the diagram below.

The system, which has no clock, generates a pulse whenever the difference between the signal and the output of the local decoder exceeds a predetermined value; thus the output is asynchronous. Furthermore the sign of the difference determines the pulse's polarity so that the signal is coded in a ternary form.

The ternary waveform requires less bandwidth, making this scheme particularly advantageous for time-sharing and frequency-sharing systems such as random access multiplex communications. Each digit would be transmitted as two radio-frequency pulses of different frequencies and spacings. By assigning independent combinations of spacings and frequencies, the channels can be separated.

Separating the frames

It is essential to rapidly extract framing information from the incoming pulse train and to maintain frame synchronization regardless of transmission disturbances. If the communications link is noisy, several synchronization pulses are inserted in a frame—usually either in time slots that are equally separated by information pulses (interlace framing) or in consecutive time slots (sequence framing). Two reframing procedures are possible if synchronization is lost.

In an interlace scheme, the system may first lock onto any pulses at the required interlace spacing. While maintaining the spacing between pulses, the system will shift one bit at a time until it locks onto the pulses with the proper framing code. It is also possible to shift by two or more bits if the code format allows all bit positions to be scanned.

In sequence framing, the system may lock onto the required number of pulses—say five pulses. If these pulses do not have the correct framing code, the system resets or locks onto the next five pulses and so on, until it finds the pulses with the proper framing code. One-bit or multiple-bit shifting may also be used.

In 1960, it was found that as the number of synchronization pulses per frame increases, a resetting-sequence system will reframe faster than an interlace single-bit shift system. The optimum code pattern for the resetting-sequence mode is a series of bits in which the first and last bit are the same and all the intermediate bits are different. For example, a code word with the sequence 0111110 or 1000001 is suitable. Experiments with a simulator confirm the analysis.[17]

Maintaining synchronization with a minimum number of pulses is desirable because the fewer framing pulses the smaller the bandwidth. A technique that meets this objective was proposed for a time-division multiplexed system that employs either delta modulation or pcm.[18]

The system consists of logic circuits and a delay line with a delay time of one frame length. The circuit includes five main sections—a synchronism pulse extractor, a sync detector, a lost sync detector, an erroneous sync detector and a hunting initiator. The framing sync pulse is extracted by checking all channels in parallel, resulting in fast reframing. Pulse extraction is accomplished by taking the logical multiplication ("AND" operation) of the pulses in successive frames. After several frames, the result of this logical multiplication is "0" for every channel except the framing channel; only the framing pulse circulates in the delay line circuit that is in the sync extractor circuit.

The synchronization detector monitors the delay line circuit and confirms synchronization if only one pulse recirculates. Synchronization may be lost either because of faulty circuit operation or because the framing pulse is lost in the transmission line. The lost-synchronization detector detects this and initiates hunting. Similarly, hunting is also initiated if the system is erroneously synchronized.

Experiments on a simulator indicate that with a 20-bit frame containing one sync bit, frame separation is completed within six frames. With a 40-bit frame containing two sync bits, framing is completed within three frames.

The general characteristics of frame synchronization have also been analyzed.[20,21] Synchronization schemes that utilize information in all the pulses in the frame are superior to those that observe only a part of the frame. If all the pulses are observed, average synchronization time is proportional to the logarithm of the number of channels.[22] If only part of the frame is observed, synchronization times are directly proportional to the number of channels rather than to the logarithm.

Faster repeaters

High-speed regenerative repeaters will be important in future long-distance communications systems. In areas of high density traffic, it should be economical to modulate signals onto a carrier in the millimeter wavelength region and to transmit the signal through a waveguide system. Because it is difficult to make efficient bandpass filters, frequency-division multiplex techniques would not be practical. Consequently, if the bandwidth is to be efficient, it is necessary to go to high bit rates such as 160-million or 320-million bits per second. Repeaters will have to regenerate these bits with a minimum of error.

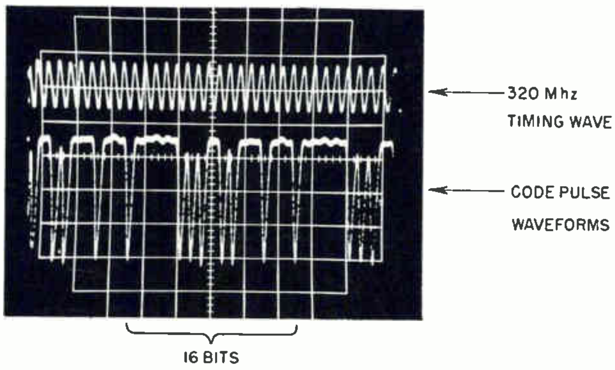
Studies of high-speed pulse regeneration of these high bit rates were made in 1963.[23] The pulses consisted of bursts of an 11 gigahertz oscillator. This 11-Ghz signal simulated the intermediate frequency of a millimeter wave system.

One part of the repeater is a partial amplitude regenerator whose main elements are two silicon diodes, in a wideband detector, and a hybrid junction. Another element is a high-speed timing gate (microwave switch) that uses silver-bonded diodes developed at the Electrical Communications Laboratory of NTT. The diodes have very favorable characteristics for switches that operate in nanoseconds.

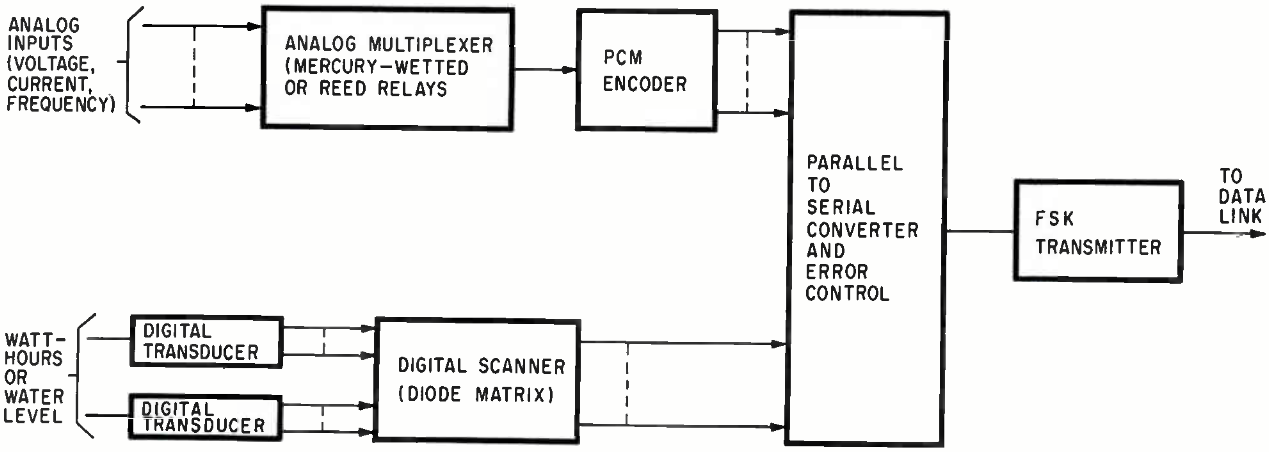
A long chain of repeaters was simulated by placing the circuit in a loop that had a 50-nsec delay. Thermal noise and interference signals were added to simulate a practical communications link. Error rates were checked by free-running operation in which the pulses were allowed to circulate in the loop. When the ratio of the peak pulse power to the mean thermal noise power was greater than 22 db, measured error rates were less than 0.6×10^{-10}. The photograph (see below) is an example of 320-megabits per second pulse waveforms that have been detected after numerous regenerations. The pulses show only a small amount of intersymbol interference and the information can be extracted without an error.

Data and telemetry systems

In many industries the demand for on-line data processing equiment—integrated with the manufacturing process or the system—is stimulating the development of pcm telemetry. In the block diagram (shown on p. 144) is a typical pcm telemetry system used by Japanese electric power utilities. Frame rates are several seconds long and the number of time slots range from 30 to 256. The higher bit rates are for quantities, such as watt-hours or the water level in the reservoir, which require four or five binary coded decimal digits to transmit accurately. Other data—such as current, voltage, power and frequency—is coded in three binary coded



Regenerated pulse-code waveforms produced by a 320-megabit per second repeater circuit. Scope trace shows no loss of information.



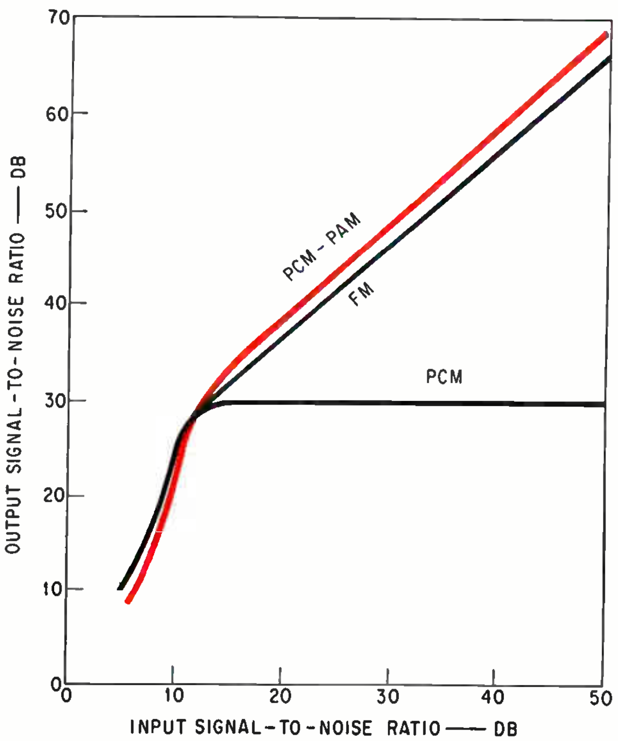
Pcm telemetry system gathers data in electric power system. Current, voltage or other signals that can be transmitted in a relatively few bits are time-division multiplexed as analog signals and then converted to pcm. Signals requiring more bits are converted to digital form before multiplexing. The parallel inputs are then brought out in a single line. These pulses frequency-shift key a transmitter and the modulated signal is transmitted. Essentially the reverse process occurs at the receiver.

decimal digits to which error control bits are added. Similar systems have been installed by the Ministry of Construction, gas companies and Japanese National Railways.

Since the data sources are often far apart in some of these systems, it has been proposed that digital data concentrators be added to the system to make the network more efficient. Then all the data could be transmitted at a rate fast enough to permit serial transmission to a central processor.

The Japanese National Railway maintains a private microwave and cable network throughout the nation. In combination with a duplicated central processor, this communications link provides a nationwide reservation service [see "Bit by bit, Japan is speeding its communications links," p. 147].

Another example is a 2,000-bit per second data link that electronically controls the Tokaido Super-express train which travels between Tokyo and Osaka at 130 miles per hour. The electric power industries—including the Tokyo Electric Power Co., whose 8,100-megawatt generation capability makes it the world's largest privately owned utility—also maintain their own microwave, cable and power-line carrier networks.



Comparison of pcm, pcm-pam and frequency-modulated systems that all occupy the same bandwidth. For pcm-pam and pcm systems each code word consists of 5 bits. Signal-to-noise ratio is markedly higher for pcm-pam system than for pcm. Pcm-pam also has slight improvement over f-m system.

Space telemetry

A digital telemetry system, known as a pcm-pam (pulse-amplitude modulated) hybrid system, has been proposed for Japanese sounding rockets.[24] The system adds a pam pulse that improves the signal-to-noise characteristics of the received signal. The pulse modulation is the difference between the actual signal level and the voltage equivalent of the 5-bit pcm word; that is, the modulation is proportional to the quantizing error.

The data's signal-to-noise ratio is increased a maximum of 7 db over a pcm word with 6 bits. This improvement occurs when the rocket is at maximum distance from the ground receiver and the carrier signal is at the receiver threshold.

When the input signal is above threshold, the pam pulse is recovered more accurately. As a result as in the diagram at left, the output signal-to-noise ratio increases. Conventional pcm, in contrast, is limited by the quantization noise and therefore does not improve with higher carrier level inputs. The pam-pcm system also shows an improvement over analog transmissions—frequency modulation—represented by the curve marked FM.

The pcm-pam scheme is similar to a pcm system with a pulse-position modulation (ppm) vernier but results in a better signal-to-noise ratio and simpler circuitry. In the ppm technique, noise makes it difficult to determine the exact time of arrival of the ppm signal.

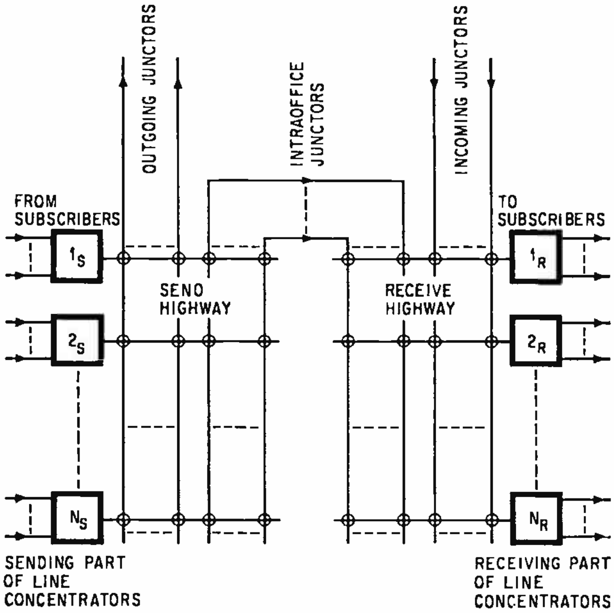
The experimental pcm-pam system has a bit rate of 160 kilobits per second. The sampling rate is 1.25 khz and the number of time slots, including the synchronizing channel, is 16. By using supercommutation—sampling and encoding a signal more than once during a frame—it is possible to increase the sampling rate to 10 khz.

Integrated pcm system

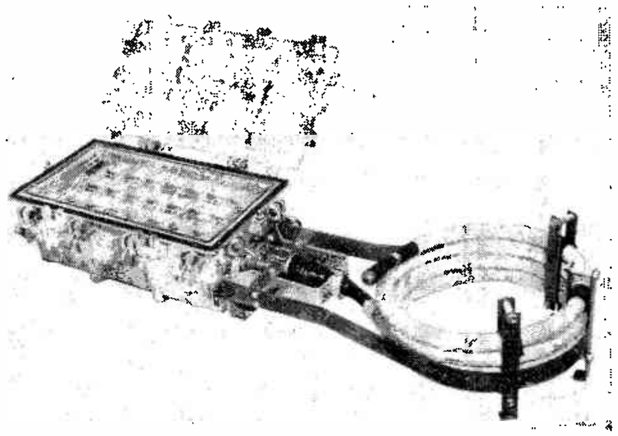
Japan is making an intensive effort to develop an integrated telephone system which would incorporate switching pcm signals in an exchange. It will consist of pcm central offices having a number of pcm remote line concentrators interconnected by pcm repeated lines. Since such a system would allow many more telephone subscribers to be served by present transmission lines, it is an attractive communications network for Japan—a densely populated nation with large metropolitan districts. For this reason the Electrical Communications Laboratory maintains a large research and development group on pcm integrated systems.

An integrated network is not commercially possible at present with the frequency-division multiplex (fdm) because frequency separation and conversion devices are costly. However, the rapid growth of short-haul, pcm networks, is a good basis for the marriage of the switching and transmission technique. Eliminating recurrent modulation and demodulation processes is one of the major economic advantages of the concept.

In addition to ECL, research in this field is also being conducted at the University of Tokyo and



Essex type, three-stage time-division exchange requires an unused time slot to be simultaneously available at the sending and receiving part of the line concentrators and at the junctors need for switching. As a result, connections are often blocked and exchange is inefficient.



Repeater housing for manhole installation contains 21 repeaters to regenerate pcm signals that were attenuated and distorted by transmission line.

by the major telecommunications manufacturers—Nippon Electric, Fujitsu, Hitachi and Oki Electric companies. These manufacturers also produce the majority of the nation's electronic computers and professional quality semiconductor devices; therefore all the developments are coordinated. This is important for a complex system such as the pcm integrated communications system, which has almost every characteristic of a real-time, integrated data-processor.

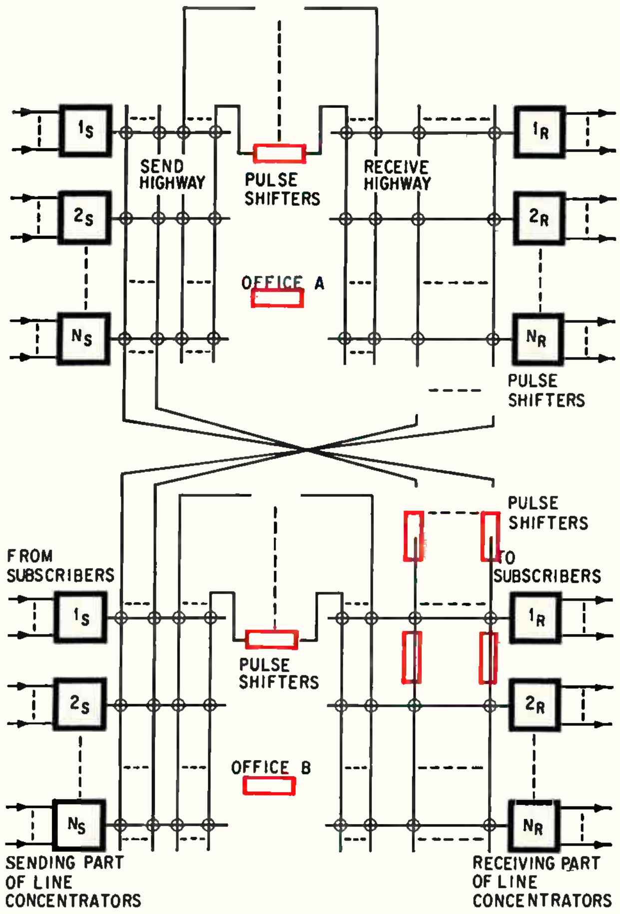
Another factor favoring an integrated network is the potential capability of integrating speech, visual and data communications. Computer manufacturers are particularly interested because a pcm integrated system may provide superhighways for an enormous flow of data between remotely located data processors. However, there are many problems to be solved before effective integrated systems are practical. Most of the problems are concerned with switching networks and system synchronizing.

Switching networks

In a nonintegrated network, speech samples are coded and decoded at each exchange; in an integrated network, speech samples pass through in coded form. For efficiency, the integrated exchange must transfer as many coded signals as possible in the time slots that are available.

When discussing an integrated exchange, time slots refer to the intervals during which the exchange can transfer a coded voice sample. For example, conventional pcm with serial pulses in 24 channels would correspond to 24 time slots per frame. Effiiciency can then be defined as the ratio of the number of incoming channels per frame to the number of time slots per frame.

A prototype integrated exchange developed by Bell Telephone Laboratories is the experimental Essex exchange, represented in the diagram at the left. In it, a connection between a calling and called party was established only if an unused time slot was simultaneously available in three places: at the line from the sending concentrators, at the pairs of junctors that are needed for switch-



Exchange arbitrarily assigns time slots, thus reducing blocking and increasing efficiency. Pulse shifters, color, at the junctors store the incoming signal until a time slot is available on desired line. The diagram represents two offices.

ing and at the line to the receiving concentrators.

Since the input words are time-division multiplexed, all these elements are also time-division multiplexed; they may not be simultaneously available even though each may be idle at some time during the frame. When time slots are not simultaneously available (in phase), the connection is blocked.

To prevent excessive blocking in a three-stage, time-division exchange such as Essex, the efficiency of the exchange is deliberately kept below a certain limit. For example, if the blocking probability is to be less than 1%, the efficiency of a network with 24 time slots is limited to 50%.

However, efficiency can be increased if the number of time slots per frame is increased. Consequently in 1960, it was proposed to increase the number of time slots by transmitting the code words in parallel rather than in serial form.[25,26] Instead of the conventional serial pcm stream, the 8-bit words are transmitted in parallel through eight lines. Without increasing the clock rate (1.544 Mhz), this parallel technique increases the number of time slots to 192 per frame.

Another important concept is interchanging time slots so that information is transferred even if the time slots are not in phase.[27] In this technique, incoming pulses are stored in delay devices, which may be called pulseshifters, and interchanged whenever a time slot is available. In this way arbitrary time slots may be assigned to the calling and called subscriber and blocking may be reduced or eliminated. Each device has a total delay of one frame period and provides a range of outputs that are delayed one time slot from each other.

The diagram at the left is a proposal for a time-division switching network that includes pulse shifters at all the junctors.[28] For a blocking probability of less than 1%, the efficiency of a network with 24 time slots is increased to about 60%.

It has been found that similar improvement is obtained by installing pulse shifters on some, but not all, of the junctors and using the junctors with pulse shifters as alternate routes.[29] The use of additional junctor stages (four or five) with pulse shifters increases the efficiency of the network up to 80%. In 1961, an experimental exchange demonstrated the feasibility of the time slot interchange principle.[30]

System synchronization

In an integrated communications system, the clock frequency of each pcm office should be in synchronism; also each interoffice delay should be adjusted to an integral multiple of the frame period. If these conditions are satisfied, the time slots of all the pcm lines are precisely in time phase.

The traditional forced-synchronization scheme in which the offices are controlled by a master office through a hierarchial structure is apparently unrealistic. Such a system gets very complicated when it is necessary to protect the network against a possible failure in the master office.

An independent synchronization technique was proposed in 1964, in which each office maintains a very stable clock source.[31] Minor errors in clock frequencies are adjusted during pauses in speech so that speech information is seldom lost.

In 1964, it was proposed to establish frequency synchronism by mutual interaction of all clock sources in the system.[32] The clock source at each office would be a multiple-input, phase-locked oscillator. The entire system can operate at a single frequency. In comparison to other synchronism schemes, system parameters fluctuate less and there is less chance of partial failures.

A method for phase synchronization has also been proposed and the feasibility demonstrated by an experimental simulator involving three offices.[33] Research and development efforts on mutual synchronization are also being carried out at ECL, Oki Electric and other companies.

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Japanese technology

Bit by bit, Japan is speeding its data communications links

Computers, like people, require fast, accurate communications to get along with each other and Japan is developing transmission techniques to squeeze over 100 telegraphic signals onto a voice-grade line

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Nippon Telegraph and Telephone Public Corp., Tokyo

If speed and accuracy are the keys to new techniques of data communications, then Japan is well on the way to becoming keeper of the gate. Faster data communications links, new methods to control accuracy and more channels to transmit data are being developed in Japan to keep up with the nation's rapidly increasing computer installations.

Japan now ranks third in computer installations, behind the United States and West Germany, and its economic boom and labor shortage are pressing computers into service in many diverse fields. Computers are recording railroad reservations and controlling rail traffic, they are keeping records in banks and utilities and the machines are aiding the government's employment services.

As the volume of data communications mounts communications companies are seeking ways to increase the capacity of transmission lines by stepping up the transmission speed and the capacity of terminal equipment. Present facilities of the Nippon Telegraph and Telephone Public Corp. (NTT) can transmit data between any two locations at rates up to 1,200 bits per second. This is adequate for present demands but is only considered a first step. Among the systems being tested is one to transmit up to 6,000 bits of data a second over a single voice line—a new technique for submarine cable communications called Rectiplex. The system is too costly to use with conventional land lines but integrated circuits may make that possible too. Production of integrated circuits for third-generation computer is picking up speed as part of an engineering effort that has given Japan a thriving computer industry.[1,2]

Still another facet of the communications progress in Japan is the development of new and more efficient forms of pulse-code modulation. This work, described in the article that begins on page 134, has as its goal a unified communications and switching network that will be able to handle digital data at high speed, as well as voice and video transmission.

Studies of data transmission and error detection and correction began in the early 1950's and led to the standardization, in 1963, of a data-transmission equipment for 200-baud and 1,200-baud leased

Data transmission networks in Japan[1]

User	Number of Channels[2]			Main Computer	Applications
	50 (bits per second)	200 (bits per second)	1,200 (bits per second)		
Ministry of Labor[3]	276	9	8	Facom 230-50	Employment research
Japanese National Railways[4]	210			MARS-101 MARS-102	Seat reservation
Kinki Nippon Railway Co.	18			NEAC 2203	Seat reservation
Central Cooperative Bank for Agriculture and Forestry	47		4	Facom 230-30	Exchange control
Fuji Bank, Ltd.		14		IBM 1440	Current deposit
Shizuoka Bank, Ltd.		31		IBM 1440	Exchange control
Fuji Photo Film Co.		14		IBM 1440	Inventory
Japan Air Lines Co.	37			NAEC 2230	Seat reservation
Nikko Securities Co.	152			Facom 323	Stock brokerage
Tokai Bank, Ltd.	227			Hitac 3030	Exchange control
Hachijuni Bank, Ltd.	44			Facom 230-30	Exchange control
Daishowa Paper Mfg. Co.		4		IBM 1440	Inventory
All Nippon Airways Co.	99			Hitac 3030	Seat reservation
Okamura Manufacturing Co.		21	2	IBM 360-40	Inventory
Sumitomo Bank Ltd.	310		65	NCR 315	Current deposit
Heiwasogo Bank Ltd.		9		NAEC 2200 IBM 360-20	 Current deposit
Tokyo Kogyo Co.		13		IBM 360	Inventory
Tokyo Sangyo Shinyo Bank		17		IBM 360	Loan control
Mitsubishi Shoji Kaisha, Ltd.	14	21	2	GE Data net 30	Inventory
Sanwa Bank, Ltd.	250		2	Hitac 4010	Exchange control
National Broadcasting Association in Japan		50		....	
Local Bankers' Association[5]	31	25		Facom 230-50	Exchange control
Japan Monopoly Corp.	200		10	....	
Yachiyo Bank, Ltd.			8	NCR 315	Current deposit
Daiichi Bank, Ltd.			100	IBM 360-50	Current deposit
Fuji Bank, Ltd.			110	Univac 418	Current deposit
Kinki Nippon Tourist Corp.			2	Univac 418	Seat reservation
Kawasaki Steel Corp.			4	Univac 494	Inventory
Total	**1,912**	**228**	**317**		

1. The table includes several systems now under installation and not yet in operation.
2. More than 600 channels in point-to-point off-line data-transmission service are not included in the table.
3. This system will expand to about 620 channels before the end of the year.
4. JNR uses its own data transmission lines; all others use services supplied by NTT.
5. This system's computer is the property of NTT, and marks NTT's advance into a new service.

lines. (These lines are permanent connections between two terminals, as contrasted with ordinary switched telephone lines that are routed to their destinations through exchanges.)

Data transmission today

In the second half of 1962 NTT began investigating data transmission over switched telephone networks. Data transmission service over these lines will probably begin soon. One problem with such service is that no time charge is made on local telephone calls in Japan. This isn't a problem with voice messages because most people will converse only for limited times. But machines transmitting data could tie up a line for days at the price of one 5-minute telephone call.

The higher-speed services have by no means made obsolete the older 50-baud data transmission circuits whose primary application is in private message services. At present more than six hundred 50-baud point-to-point data transmission circuits are in service in Japan—about 8% of the total number of private telegraph circuits. These systems generally use the same equipment as ordinary telegraph facilities, including line transmitters, reperforators and telegraphic carrier systems. Some systems include error detecting and correcting equipment. Customers install terminal equipment, transmitters and reperforators in their offices, as authorized by NTT. The service is called first regular-class private-circuit service.

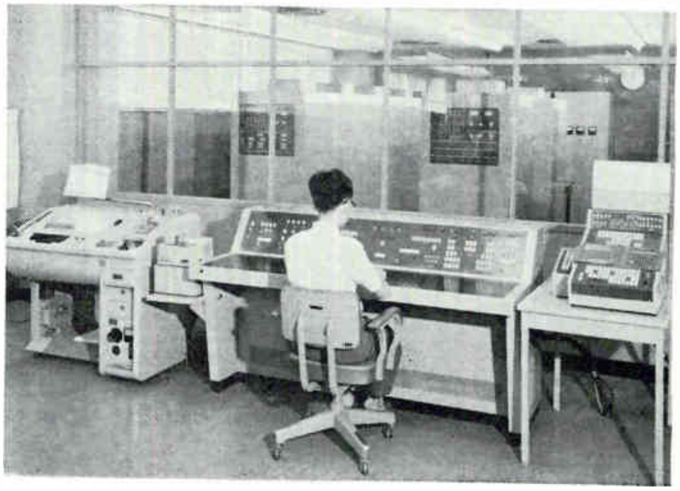
The 200-baud and 1,200-baud circuits are called second regular-class and third regular-class private-circuit services respectively. Demand for these services, now occupying only a few channels, is growing rapidly; in another year about 500 channels of 200-baud service and 150 channels of 1,200-baud service should be in operation on point-to-point circuits.

Of course, these data transmission systems serve not only for point-to-point transmission but also for the central-computer on-line network services shown in the table on the preceding page.

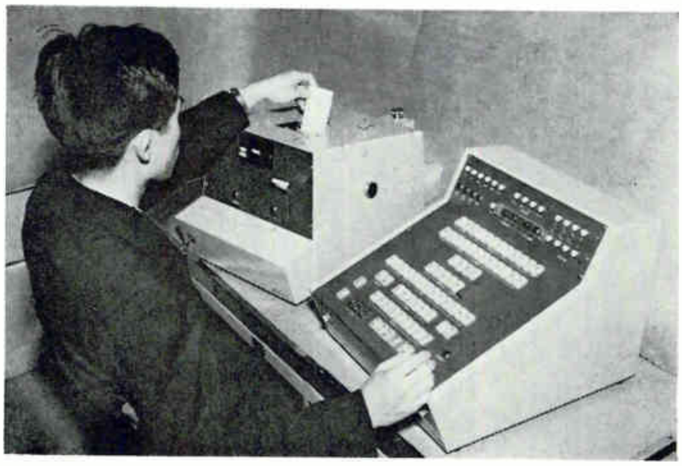
Although data communications in Japan is still in its infancy, several significant systems are now in use, including railway and airline seat reservation systems, a government employment center, and a centralized railway traffic control system.

Reserving a seat

One of the leaders in data communications has been Japanese National Railways, Japan's government-owned backbone railway system. The Railway Communications Committee of JNR began studies in 1956 to improve communications on then existing lines and to pave the way for even better communications on planned high-speed lines. From these studies JNR's large-scale seat reservation systems, MARS 101 and MARS 102, have arisen. Smaller-scale reservations systems have been installed by Kinki Nippon Railway Co., a private regional railways system, by Japan Air Lines Co. and by All-Nippon Airways Co.



Central computer installation for JNR's seat reservation system.

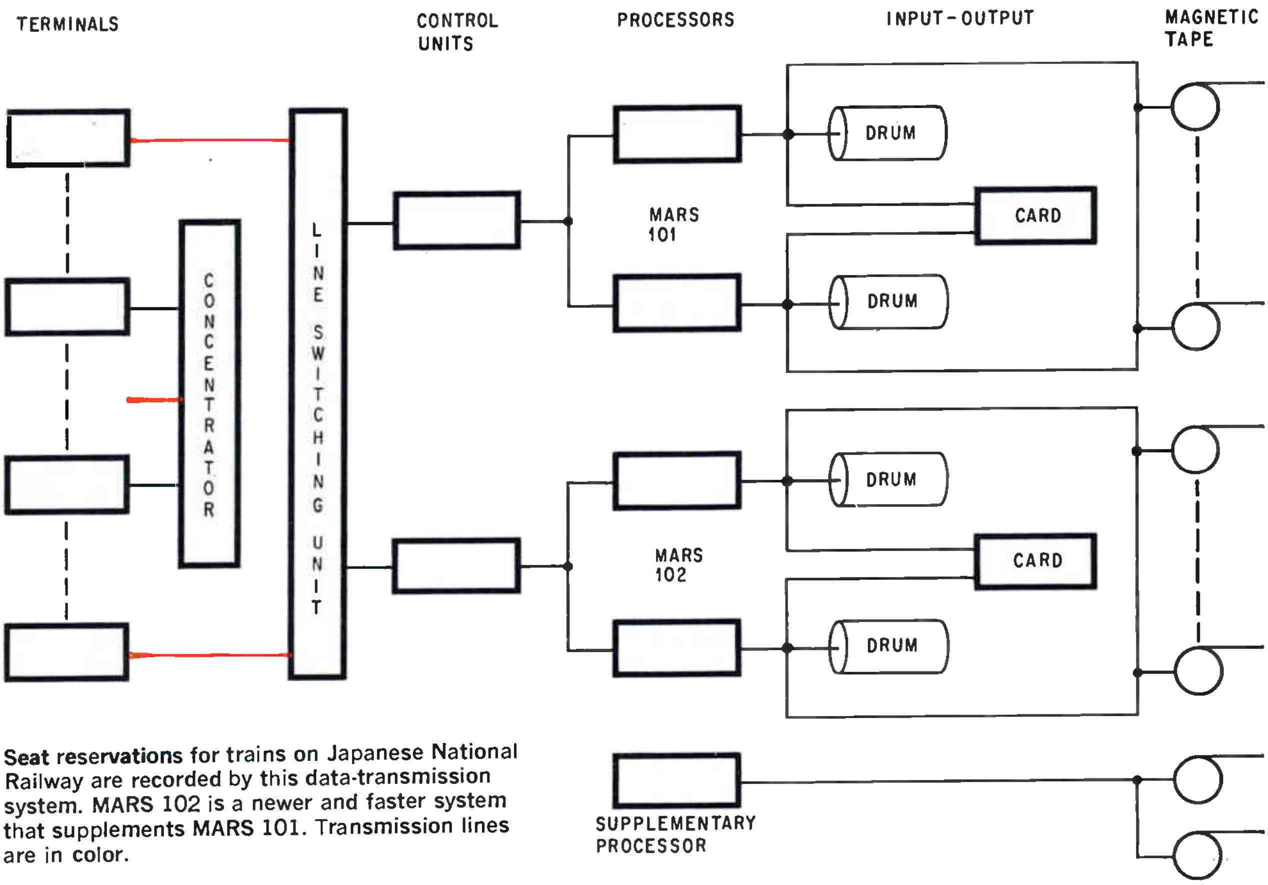


Agent set that connects the local JNR ticket office with the central computer system for reserving seats in railroad trains.

The computer systems in JNR's central reservation office in Tokyo can process 1.4 million seats each week [see block diagram on next page and photos above]. Some 467 agent sets, or consoles, are the remote input-output terminals to the central processors, which are five Hitac 3030 computers built by Hitachi, Ltd. Each agent, through his set, requests the desired number of seats, train name, date and class of travel, and specifies the stations of origin and destination. The processor searches its bulk memory, containing 16,000 words in magnetic cores and 32-million words on magnetic drums, for the requested seats; if space is available the agent's console prints out tickets while the passenger waits. Total elapsed time is about 26 seconds. With the former manual system, waiting time averaged about 2 minutes and was frequently much longer during busy periods.

Train control

On the new Tokaido line of the Japanese National Railways between Tokyo and Osaka, a centralized traffic control system supervises all trains [see block diagram, bottom p. 150]. The positions of each train and the condition of the route are



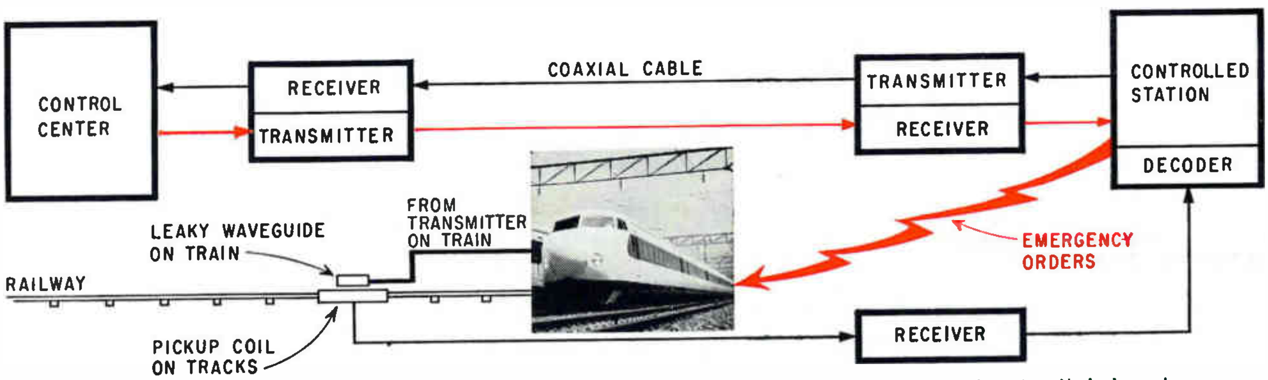
Seat reservations for trains on Japanese National Railway are recorded by this data-transmission system. MARS 102 is a newer and faster system that supplements MARS 101. Transmission lines are in color.

transmitted to the computer at the control center. A pencil-size coaxial cable with a capacity of 300 circuits installed between Tokyo and Osaka—a distance of 515.5 kilometers—transmits the coded data.

Coils are installed between the rails of the track on each side of every station; these coils pick up a signal from the passing train that indicates the number of the train. The signal is a 200-kilohertz carrier, modulated by five of 11 frequencies between 1.125 and 2.115 khz, and provides up to 462 different train identities. It is coupled inductively from a coil on the train to a coil on the track. The track coil relays the signal to a control terminal at the station, where it is decoded and retransmitted by cable to the central control center at 2,000 bits per second. The control center determines from these signals when each train enters and leaves each station and how many trains are in a particular section between stations. Using this information, the center controls the speed of the trains, commands them to start and stop and sets track switches. In emergencies, the control center can communicate with the train by radio, again through the local control terminal.

The centralized traffic control system was installed on the new Tokaido line in 1965. Similar systems are scheduled for installation on other JNR lines in the near future.

Centralized traffic control should not be confused with automatic train control, another feature of trains on the new Tokaido line. Automatic train



Centralized traffic control system of JNR controls spacing and routing of trains. Emergency signal path is in color.

control prevents collisions between trains; it does not involve data communications.

Labor and money

Banks and securities companies began the second round of data communications applications in the early 1960's. Other industries and government agencies followed their example, using data communications for various applications like inventory control and placement services.

The Labor Market Center was established in July, 1964, in the Ministry of Labor, to streamline employment security administration, to promote labor mobility and to foster a modern labor market as an integral part of the active employment policy.

The Labor Center's data processing equipment [photo, p. 152] is a Fujitsu Facom 230-50 electronic computer and communication control unit. The Prefectural Employment Security Offices record, on paper tape, data on jobs available and jobs wanted and various reports on unemployment insurance. The data is then transmitted at 50 bauds to the line concentrator at the prefectural office, then to the time-division multiplexer at the relay station and finally to the Labor Market Center at 1,200 bauds [see block diagram p. 152].

The central exchange equipment at the Labor Center classifies the data according to destination. All data addressed to the center is recorded on magnetic tapes for processing by the computer. This is a store-and-forward exchange, typical of systems in which signaling speed is slower than computer input-output speed. Data or messages addressed to other prefectural offices are transmitted immediately to these offices without being recorded on magnetic tapes. The electronic computer sorts, computes and collates the data recorded on the magnetic tape for permanent storage or for retransmission to the prefectural office through the central exchange's equipment.

Transmission circuits

Although Japan has the usual problems connected with transmitting data over telephone lines, fortunately most telephone circuits in the small island nation are new and of high quality. The majority of the older circuits were destroyed during World War 2 and the circuits were rebuilt with nationwide expansion of the network in mind. The number of subscribers has been growing very rapidly in recent years.

To keep the error rate low and to standardize signals for compatibility, NTT usually supplies its subscribers with all equipment needed for first, second or third regular class data transmission.

Sometimes, however, NTT supplies only the modem (modulator-demodulator), the signal converter that connects a telephone transmission line with terminal equipment. The customer provides his other equipment under authorization from NTT. Since the modem should match the transmission line, NTT provides no data transmission lines without modems. Four standard modems are now available, differing principally in their line frequencies.

NTT's data transmission services

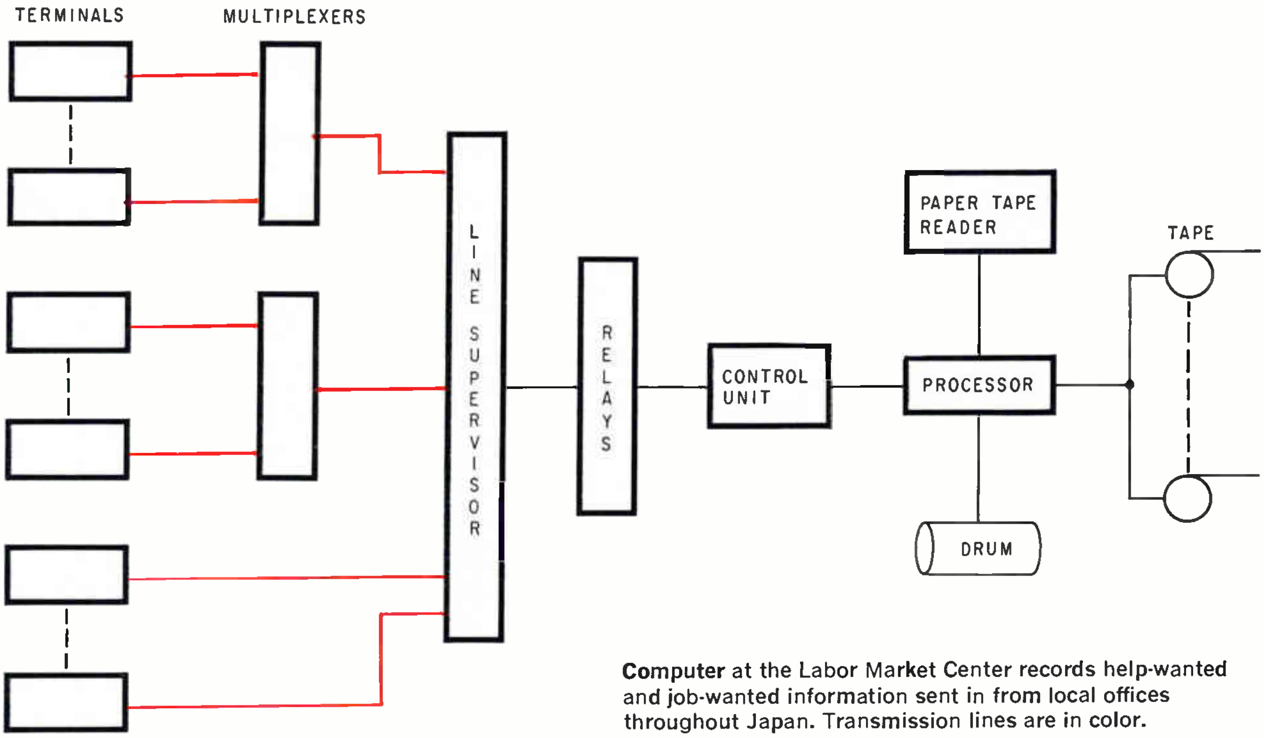
Circuits	Remarks
Leased circuits	**Private use**
Local line (two-wire or four-wire circuits)	Up to 1,200 bits/sec.
Toll line	
First regular class	Up to 50 bits/sec.
Second regular class	Up to 200 bits/sec.
Third regular class	Up to 1,200 bits/sec.
Wideband circuit	See note 1.
Switched circuit	
Telex	50 bauds only
Telephone circuit	
Semileased circuit	See note 2
Ordinary switched telephone circuit	See note 3
Dedicated network service	See note 4

Note: 1) Bandwidth is 48 khz; the service is available to government agencies and enterprises. This is not a high-speed transmission system, but a telephone group of 12 voice-band channels leased as a single unit.
2) For private use over distant direct dialing telephone network.
3) Undergoing field trial and not yet generally available.
4) Will go into service in 1968 as a private network for a group of customers.

Error rates indicate data transmission quality and are a realistic measure of how well the system and transmission network match. With NTT modems, error rates on nonswitched circuits range from 10 to 30 bits per million in telegraph circuits at 50 bauds, and 1 to 5 bits per million in 200-baud and 1,200-baud circuits. The error rate may be greater in switched telephone circuits because of the numerous exchanges through which a signal may pass. In this case the rate is specified in blocks, because error-detecting equipment causes the retransmission of entire blocks whether they contain one or 100 errors. The average block error rate on switched telephone circuits is less than 5 blocks per 1,000 for a block length of 60 characters each with 10 elements.

Modems whose data signaling rates are 2,400 bits per second on voice-band circuits have been developed cooperatively by NTT and communications equipment manufacturers and are now undergoing field tests. Commercial application may follow in the near future. Modems for 3,600 and 4,800 bits per second are now under development in the laboratory and may eventually see service. The most technologically advanced unit on the market is the Rectiplex system, developed by Fujitsu Ltd. and the Kokusai Denshin Denwa Co., Japan's overseas cable and communications system. Its speed is almost 6,000 bits per second over voice-band circuits—an information capacity five times

Labor Market Center's computer system links local labor offices with central bureau.



Computer at the Labor Market Center records help-wanted and job-wanted information sent in from local offices throughout Japan. Transmission lines are in color.

that of the simplest pulse-modulation circuits. Capacity equals 108 telegraph channels operating at 50 bits per second.

Tests of the Rectiplex system between Tokyo and San Francisco have been excellent. However, the highly efficient terminal equipment is very expensive—costing more than an additional overland transmission line. But the system is much cheaper than additional submarine cables for international communications.

The system has 18 carrier frequencies, ranging from 540 hertz to 2,580 hz at 120 hz intervals, for data transmission. Each carrier handles six channels. A 19th carrier, at 2,820 hertz, transmits a synchronizing signal for automatic phase-control circuits. Differential phase modulation of the individual carriers provides excellent performance with respect to noise and line interruption. Rectiplex increases the signal rate in two ways:

- First, it combines three input channels into one without increasing the modulation rate.
- Second, each of the three inputs has twice the signal rate of ordinary 50-baud channels because two such lines are combined with conventional time-division multiplexing.

Therefore the total capacity of a single carrier in the Rectiplex system is six times the standard 50-baud line. Eighteen carriers handle a total of 108 lines.

Data transmission equipment

Several kinds of equipment are available for data processing applications. Data transmission equipment is usually identified by a code that denotes the transmission rate; for example, series 200 data transmission terminals are designed for 200-baud data transmission.

A widely used data transmission terminal is the DT-51. It transmits and receives binary information on punched paper tape, detects errors and automatically retransmits incorrect blocks. Data input and output are on six-hole or eight-hole paper tape. The equipment can simultaneously transmit in both directions over 50-baud telegraph or telephone circuits.

A block-check method detects errors. At the receiving end, each block of 60 characters is checked for errors. When errors from transmission faults are detected, a cancel character is punched after the block to show that an error is present and the receiving terminal automatically requests the transmitter to retransmit that block.

The DT-202 data transmission terminal can handle 200 bits per second, and the DT-1202 terminal is designed for 1,200 bits per second data transmission. These terminals have photoelectric six-hole or eight-hole tape readers, asynchronous tape perforators and electronic transmission controllers. The tape reader is the input and the perforator is the output. The transmission controller is installed between the modem and the tape reader or perforator and controls both the reader and perforator. The controller also detects and corrects errors due to faulty equipment as well as transmission.

The tape reader sends a character in parallel to the transmission controller, which converts the parallel signal into serial form, adds start and stop elements to each character and sends the character in serial to the modem. Each serial character is composed of 10 pulses; dummy pulses are inserted when six-hole paper tape is the data source.

Line switching

The DT-10 line-switching control equipment comprises an automatic calling unit, a line-connecting unit and a control unit. Data transmission terminals read the address codes punched on paper tape and transfer it to the control unit. When the code addresses a terminal station on a switched network, the automatic calling unit "dials" the receiving terminal. When the address is that of a terminal station on a point-to-point line, the line-connecting unit connects the addressed line to the data transmission equipment. Then the line is extended from the line-switching equipment to the data-transmission equipment, which reads the punched paper tapes and transmits the data until it finds the next address code.

The DT-20 communication control equipment can perform remote data collection, storing batched input data in a central processing unit. It addresses and transmits to terminals any data that is queued in the central processing unit.

It is designed for concurrent use of switched and nonswitched networks and controls message traffic from various types of communication terminals. Its automatic calling unit enables the central processing unit to call any number in the network.

The new PT-2 tape-controlled teleprinter [lower

Baud, bits and hertz

A binary digit—a bit—can have only two values, 0 or 1; therefore a bit can be represented on a transmission line by the presence or absence of a unipolar pulse at a specified time. Sometimes more complex waveforms are used to improve transmission characteristics [see page 137]. However, basically the shorter the pulse's duration, the higher the information transfer rate.

If τ is the pulse duration in seconds, then the modulation rate is $1/\tau$, as in the diagram below. Modulation rate is measured in bauds, named after the French originator of the 5-bit teletype code, Emile Baudot. Numerically, the modulation rate in bauds equals the number of binary pulses transmitted per second.

A signal modulated at B bauds has a fundamental frequency and minimum bandwidth of B/2 hertz. Transmission of both sidebands in an amplitude-modulated system requires a bandwidth of B hertz.

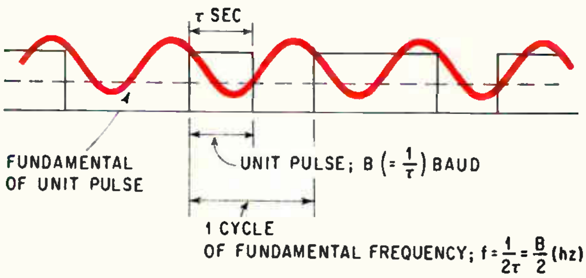
Recent data transmission systems have more complex transmission parameters; for example, a single pulse may not be a pure binary quantity, and the transmission system may have several parallel channels to carry data. For a system of this type, the data signaling rate is:

$$S = \sum_{i=1}^{p} \frac{1}{\tau_i} \log_2 m_i$$

where p = the number of channels; τ_i = unit duration in the i-th channel in seconds; and m_i = number of possible values of the i-th channel pulse.

If $m_i = 2$, then the channel is binary, and $1/\tau$ is properly measured in bauds.

The baud concept dates back to telegraphy and telegraph line ratings. Today, ratings are expressed more meaningfully in terms of the system using the transmission line; so that data transfer rate in bits per second is often used instead of the modulation rate in bauds.



Modulation rate in bauds is essentially the same as signaling rate in bits per second and is half the equivalent frequency in hertz.

Rectiplex system shifts phase for high bit capacity

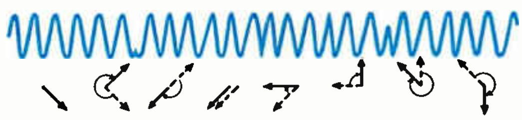
To modulate three binary channels onto one carrier, the Rectiplex system shifts the phase of the carrier by some multiple of 45° depending on the state of the binary inputs. These binary inputs may have any one of eight possible combinations, corresponding to the eight possible 45° shifts in a single cycle. The phase for a particular signal combination is established relative to the phase of the preceding signal; the system therefore employs differential phase modulation, as contrasted with some systems that shift the phase relative to an absolute phase.

Conventional carrier telegraph systems also modulate only one binary channel onto a carrier; but if more than two states of the carrier are possible, multiple channels can be transmitted simultaneously.

Differential phase modulation has been studied in Japan for about a quarter of a century, but has not been used because of the difficulty of demodulating phase-modulated signals. Efficient methods have been recently developed for demodulation and for automatic phase control, and electronic components have been improved; the Rectiplex system then became feasible for high-cost data links such as the transpacific cable.

The relation between the combinations of signal polarity and the amount of phase shift from the preceding element is shown in the vector diagram below. How phase shift affects a typical series of bits on three channels, and the resulting waveforms are shown above.

ELEMENT NO.	m−1	m	m+1	m+2	m+3	m+4	m+5	m+6
CH 1		1	1	0	0	0	1	1
CH 2		0	1	0	0	1	0	1
CH 3		1	0	0	1	1	0	1



Typical string of bits on three channels shows the corresponding pha shift for each combination of three. The resulting waveform is shown in color.

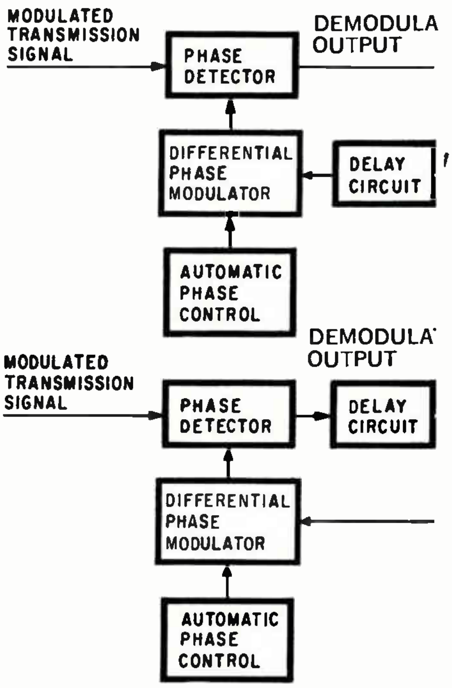
Phase demodulation. To demodulate the signal the phase difference of an element is compared with the preceding element. The principle of demodulation is shown at right. The automatic phase control circuit is actually similar to the carrier oscillator at the transmitter. It is synchronized with the transmitter by the 19th carrier mentioned on page 152. It drives a differential phase modulator that modulates a signal and compares it with the received signal. The difference between the phases of the incoming signal and the local phase modulator produces a demodulated output.

In the top diagram part of the demodulated output feeds back through a delay to the local phase modulator. The delay permits a signal element to be compared with the preceding element in the phase detector. In the bottom diagram the delay is applied to the entire demodulated output instead of just to the portion fed to the local modulator.

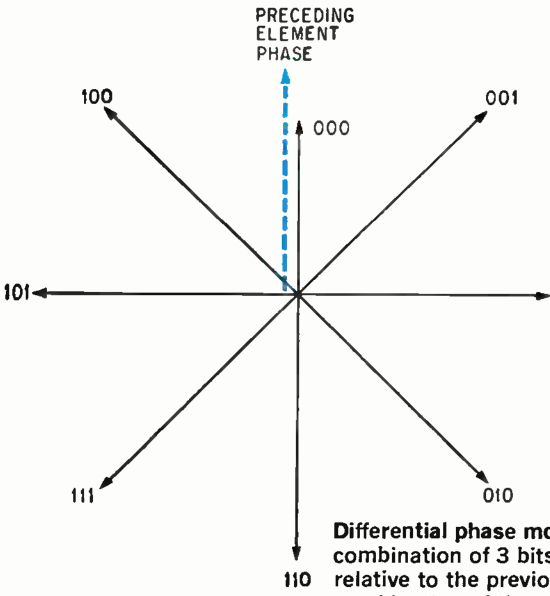
Four demodulating circuits demultiplex the three channels on one carrier. The phases of the reference signals of each demodulator differ by 45°. The vectors indicated by broken lines [top, left, page 155] are the four reference signals. The demodulated outputs of two channels are obtained by comparing the input signal with the reference phase signals R_1 and R_2 respectively. The demodulated output of the third channel is obtained by comparing it with both R_{3a} and R_{3b} and taking the exclusive OR of the result—that is, the output is a binary "1" if the R_{3a} or the R_{3b} output is 1, but not both. If both are 1 or both 0, the output is 0.

Channel filtering. In conventional frequency-division multiplex systems, a bandpass filter separates the various channels. Consequently the characteristics of the system depend on the characteristics of the filter. The Rectiplex system contains no bandpass filter. The filtering function is performed by an integrator with a reset function, enabling efficient demodulation and utilizing the active channel bandwidth.

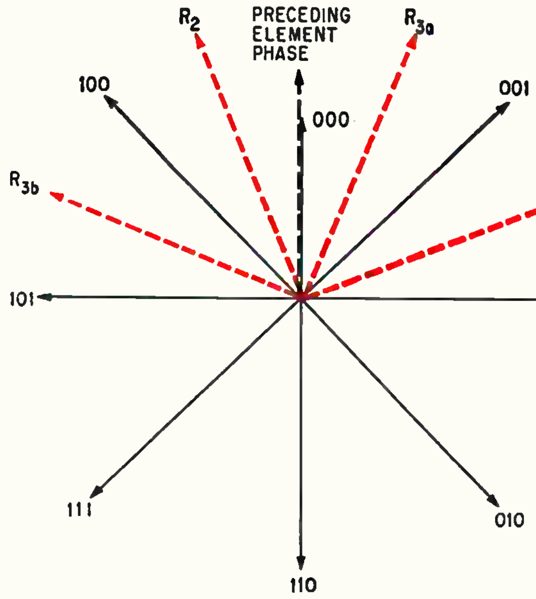
The carrier frequency for each of the 18 channels is allocated at intervals of 120 hertz. These multiple signals are sent together to the phase detector. Then the desired signal for any given refer-



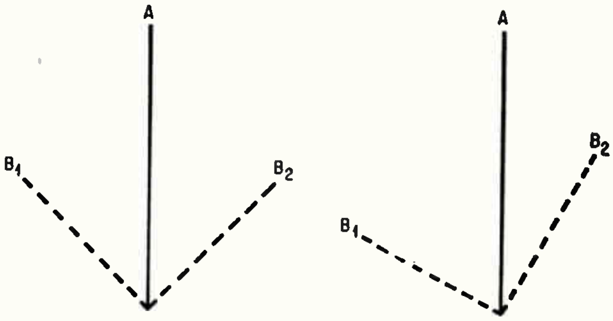
Demodulation of a differential phase modulated signal requires each element to be delayed for comparison with the following element. The demodulator's output may be connected either before or after the delay.



Differential phase modulation shifts the phase for each combination of 3 bits on three independent channels, relative to the previous phase, shown in color. Thus the combination of three zeros (000) repeated over and over causes no phase shift; the combination 001, if repeated, causes successive phase shifts of −45°.



Demultiplexing the three channels carried by the demodulated signal requires comparison with four reference signals (color) displaced in phase 45° from each other and 22½° from the possible phases of the signal.



Reference signals are maintained in proper phase for demultiplexing by comparing them with the phase of a data signal that should be equally out of phase with two references.

ence is obtained as a d-c component from the phase detector, but those of the adjacent channel show up as a-c components with frequency differences of 120 hertz. These a-c components are integrated out. No influence of the adjacent channels appears at the integrator output and only the demodulated output of the desired channel is obtained.

Automatic phase control. The demodulating carrier producing the reference signal is regenerated from the modulated signal by the automatic phase control (APC) circuit. The demodulating carrier must have the same frequency and phase as the modulating carrier at the transmitter. In order to obtain the signal, the APC circuit supplied for all demodulating circuits maintains the demodulating carrier in normal condition.

Signal A [at right above] coming in on one of 18 carriers is phase-detected by the reference signals B_1 and B_2, which differ in phase. The two d-c outputs of the detector are compared. Normally the two d-c outputs are equal. If they become unequal, the phase of B_1 and B_2 can be altered to equalize the two d-c outputs, bringing the phase of signals B_1 and B_2 into the proper relation to signal A.

As described previously, the most recently received element (corresponding to a bit in a binary system) modulated the reference signal and is compared with the next element. The phase difference between the last received element and the next element identifies the next element. But in the Rectiplex system's demodulating circuit there are four reference signals [above, left] and eight possible last elements on each carrier, corresponding to the eight combinations of bits on three channels. Any one of these eight defines two of the four references that are ±67.5° or ±112.5° out of phase with the last element [table below]. These two references give two differences. The references are adjusted so that the two phase differences are equal at all times, thereby maintaining the demodulating carrier at a constant phase.

Demodulation. To synchronize the demodulating circuit with the modulating one, a synchronous signal is transmitted by means of phase reversal modulation of the 19th carrier. This form of modulation generates several upper and lower sidebands. Narrow bandpass filters in the receiver separate the first upper and lower sidebands from which a ring modulator derives the beat frequency components—the sum and difference of the two sideband frequencies. The difference frequency is filtered and shaped, and becomes the demodulating clock pulse.

Time-division. The Rectiplex system transmits six independent signals by phase modulation on a single carrier frequency. These signals are brought together in pairs by a time-division multiplex circuit that also synchronizes the signals, which otherwise have no common timing reference.

The incoming signals arrive on 50-baud lines; the multiplexer interweaves two of these into one 96-baud signal containing the characters from the two channels alternately. Three 96-baud signals are then phase-modulated onto one carrier. A demultiplexer following the demodulator at the receiving end separates the incoming signal into two parts for output on 50-baud lines.

Modulated signal	Amount of phase shift	Selected signal
000	0°	R_1, R_{3b}
001	−45°	R_{3b}, R_2
011	−90°	R_2, R_{3a}
010	−135°	R_{3a}, R_1
110	−180°	R_1, R_{3b}
111	−225°	R_{3b}, R_2
101	−270°	R_2, R_{3a}
100	−315°	R_{3a}, R_1

right photo, p. 157] is an off-line unit that can read paper tape and edge cards, and punch paper tape. It uses the 7-bit coded character set for information processing interchange, as proposed by the International Organization for Standardization (ISO) and other associated international organizations. In Japan, domestic communications are usually in the Japanese national character syllabary called katakana but all international traffic uses the Roman alphabet. Both of these are permitted with the ISO and both, plus graphic characters up to a total of 192 characters, are available on the PT-2.

The code includes two special characters called shift-in and shift-out. The new teleprinter interprets code characters following the shift-out character as outside the standard code table. Katakana characters are printed until a shift-in character is received, then other characters are printed.

The keyboard and printing mechanisms are quite different from those of older tape-controlled teleprinters that use 6-bit coded characters on 50-baud transmission circuits; however, the PT-2 is almost identical with previous teleprinters from the operator's viewpoint.

A faster-on-line teleprinter now being developed prints 1,200 characters per minute received over a 200-baud transmission line. Its mechanism differs from both the PT-2 and older teleprinters.

Two pulse motors make the character selection mechanism relatively simple. Both motors operate at the same time, so that the time to position each character is less than 36 milliseconds. Actual printing time is less than 10 msec per character. The transmission time for a 10-bit character is 50 msec. The maximum time needed for carriage return is 500 msec, so that no data can be transmitted for ½ second following each carriage return character sent over the transmission line.

Special terminal equipment

Several interesting types of special data terminal equipment have been developed in Japan for customer-owned business machines.

A data terminal developed by Nippon Electric Co. detects errors and, if necessary, retransmits an entire block of data so that only clear data appears on the output tape. The terminal is a remote input-output terminal connected to a computer by a telegraph or telephone circuit. To maintain clear data, a magnetostrictive delay-line buffer stores data in both the receiver and transmitter. Incoming information is stored in the memory until the acknowledge signal is received, and then the memory controls punching of the paper tape. If a negative acknowledge signal is received, the message in the memory is discarded and the block is retransmitted.

The terminal can be operated by relatively unskilled personnel. It comprises a transmission controller, tape reader, tape punch, card reader, card punch and teleprinter.

A new and unusual sprocket magnetic tape transport was design by Oki Electric Industry Co. for data storage or conversion of signaling speed in high-speed data transmission circuits. A sprocket controls the tape motion in the same manner as ordinary paper tape, character by character, either forward or backward. The maximum reading and writing speed is 1,500 characters per minute. One reel of tape holds up to 140,000 characters.

Parallel transmission, rather than the conventional serial transmission, can be a useful function in some data-gathering applications. A study of parallel transmission equipment is being conducted by NTT to reduce terminal equipment cost.

The D-600 prototype equipment designed under this project to read paper tape transmits data

Checking for errors

Data-transmission equipment can include hardware to protect against disturbances that are likely to occur on any transmission line, such as interruptions and impulsive noises. These disturbances cause bursts of errors in received data; that is, a group of successive pulses is more likely to be lost or obscured than is a single pulse.

Because errors occur in bursts, any error in a block of data is considered to invalidate the entire block, which is then retransmitted as a whole. This mode of correcting errors, sometimes called block checking, is more efficient in data transmission systems than individual character checking.

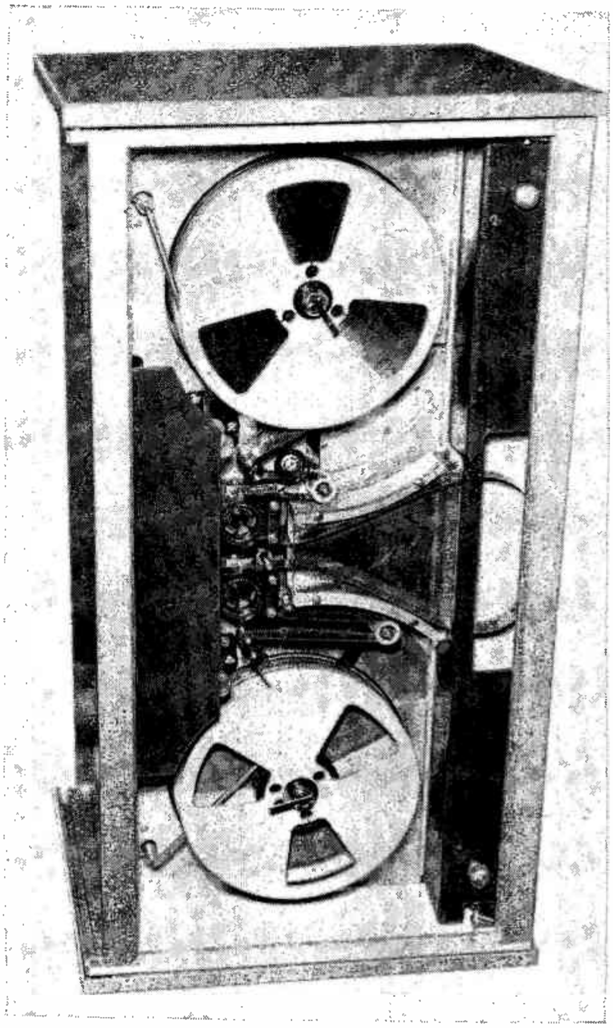
Nippon Telegraph and Telephone Public Corp.'s equipment checks each block's accuracy in two ways: a vertical parity check and a longitudinal modulo-four check. Each character normally comprises seven bits and one parity bit, defined so that each character contains an even number of 1 bits. In the vertical parity check, if a character in a block is received with an odd number of 1 bits, the entire block is retransmitted.

Each of the eight parallel data channels in a block undergoes the modulo-four check. The 1 bits are counted by fours at the transmitter and the receiver, both discarding all carries. After the block is completed the transmitter sends its count and the receiver compares the two counts. If the counts do not match for all eight channels, the receiver punches a cancel character in the paper tape at the end of the block and the entire block is retransmitted.

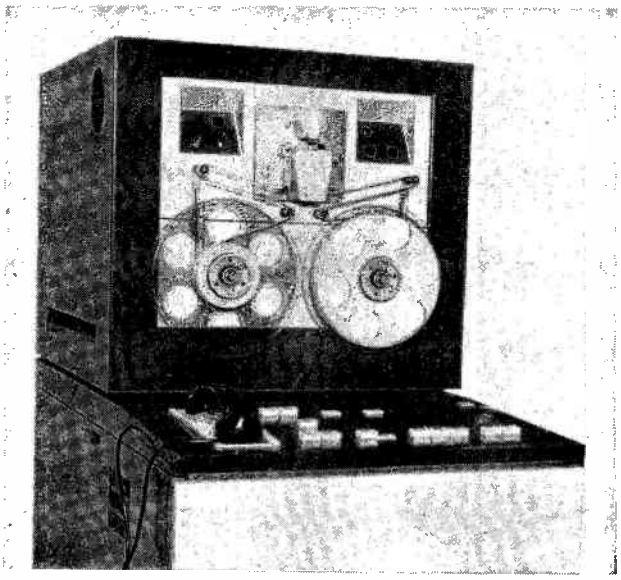
Field trials made by NTT scientists in 1959 proved the reliability of block checking, which is based on work begun in 1951 by Zenichi Kiyasu. These tests and other work justified the present standard of 200 and 1,200 bauds for data transmission, in addition to the older 50-baud telegraphic standard.

Unfortunately the cancel mark is behind the erroneous data, not before it. For some applications this is only slightly inconvenient, because all the correct information is available and any erroneous information is marked. In off-line computer transmission the computer can store data as it comes in and discard blocks that contain errors. For on-line applications, where the presence of erroneous data may be intolerable, NTT and its manufacturers are developing a paper tape punch described at the left that does not punch erroneous data.

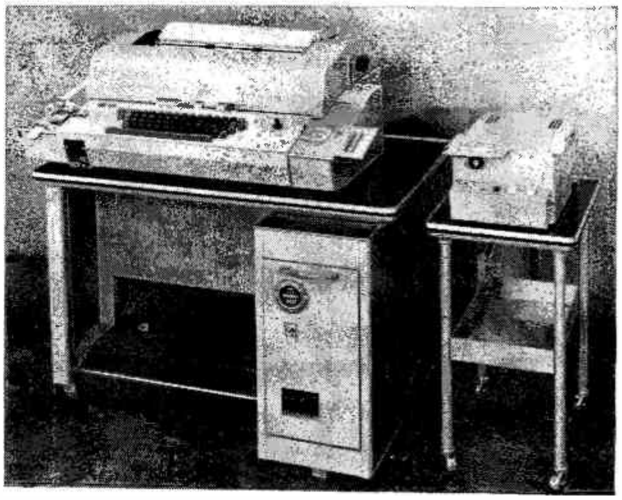
New Japanese terminal equipment



Sprocket magnetic tape handler reads magnetic tape in much the same way that similar machines read paper tape. It stores data or converts signaling speed.



Parallel data transmission unit reads standard eight-hole paper tape and transmits the data in parallel over eight telephone lines. Two more telephone lines transmit control signals between the transmitter and receiver. This unit is a prototype.



Tape-controlled teleprinter is shown with an associated data tape reader at right. The machine can print data read from tape or edge-notched cards. It prints both Roman and Japanese characters.

in parallel format over switched telephone networks at 600 bits per second. A total of 10 channels are used. Eight channels correspond to the eight parallel information bits in standard eight-hole punched paper tape. The ninth and tenth channels transmit control signals, one in each direction.

Compatibility with the data processing speed of computers and the information transfer rates of input-output equipment peripheral to computers require wideband modems. A 42,000-bit-per-second wideband modem, one approach for 48-kilohertz transmission lines, has been developed at NTT's Electrical Communication Laboratory, using phase modulation techniques. The modem accepts data at arbitrary rates up to the maximum simply by setting an adjuster. The input data is converted in a series of phase shifts of the carrier, either 0°, 90°, 180° or 270° with respect to the preceding signal element carrier phase. The modem processes bits in pairs; each of the four possible pairs of binary digits—00, 01, 11, and 10—generates a signal embodying one of the four possible carrier phase shifts. This is a quaternary phase modulation technique somewhat similar to the differential phase modulation technique in the Rectiplex.

A timing regeneration circuit keeps the timing clock in phase when no phase shift is received for a long time. The receiver has a crystal oscillator whose frequency is controlled by the received carrier only when phase variation is detected. During bursts of constant phase or short interruptions, the timing clock is regenerated by the oscillator of the receiver alone.

Another quaternary phase modulation system employs phase shifts of 45°, 135°, 225° or 315°, so that a phase shift occurs even for a steady burst of pairs of zeros, simplifying synchronization. The signal-to-noise ratio is the same for either method;

however, the second system is really a type of eight-phase modulation and requires logic circuits to determine phase shift. Moreover, the carrier frequency must be fixed and the modulated carrier bandwidth must be wider to regenerate the timing signal. The receiver for the modem employs synchronous detection, in which a logic circuit and two modulators identify pairs of bits and deliver them serially to the receiver data output circuit under control of a timing signal.

For two years, the NTT laboratory has been conducting series of point-to-point data tranmission tests over 48-khz bandwidth lines. The modem has performed satisfactorily and will soon become available as the standard modem for wide-band data-transmission service.

Research, development and the future

Japan's data communications services will expand tremendously soon, as more channels of greater length become available operating at higher speed and as entirely new services are offered.

Complete data communications services, including electronic computers, will be supplied by NTT —not only data transmission services. The decision to do so was based on NTT's long experience with direct distance-dialing networks. The first customer for NTT's computer services is the Local Banker's Association, which requires nation-wide communications for the exchange of drafts.

Research is continuing in other applications including remote processing systems, process control systems, information retrieval systems, open-to-the-public computers on communications networks. The demand for these services during the next five years will require an estimated tenfold increase in the capital investment for necessary equipment. Because of the magnitude of the investment, many organizations are cooperating on the needed research; these include the computer centers at several universities, the Electrotechnical Laboratory of the Ministry of International Trade and Industry, the Electrical Communication Laboratory of NTT and laboratories of several electronics firms.

The largest single research project now under way is development of a giant time-sharing computer for a nationwide data-communications network. Engineering knowhow from the leading electronics research organizations in Japan is being integrated in this government-sponsored project and the budget during the five years allocated to research, developing software and debugging is expected to reach about $37 million.

In addition to the central and terminal equipment for the network, NTT and the communications equipment manufacturers have many problems in establishing more efficient data transmission systems. These problems include:

- Finding the best transmission medium for multiple and public-access computer services. Choices include coaxial cable, microwave, wave-guide or light beam transmission.
- Determining how to use telephone networks most effectively for data communications. The alternatives include applying existing frequency-division multiplex telephone networks to data transmission, using pulse-code-modulation electronic switching systems jointly for telephone service and for data communication or establishing separate high-performance networks for data transmission.
- Developing new terminal equipment with a lower cost-to-performance ratio.

To solve these problems, a variety of computers, communication mode controllers, modems, remote data terminals, transmission lines and networks are being developed and studied.

In the more distant future, Japan will probably develop an integrated communication network, with an electronic switching system, in which transmission paths concurrently operate for telephone, telegraph and data-transmission. Such an integrated network could offer the cheapest service for public customers, because of multiple use and flexibility of facilities. To assure compatibility among data-transmission and data-processing equipment from different manufacturers, international standards will be prepared to define the operating features and technical specifications.

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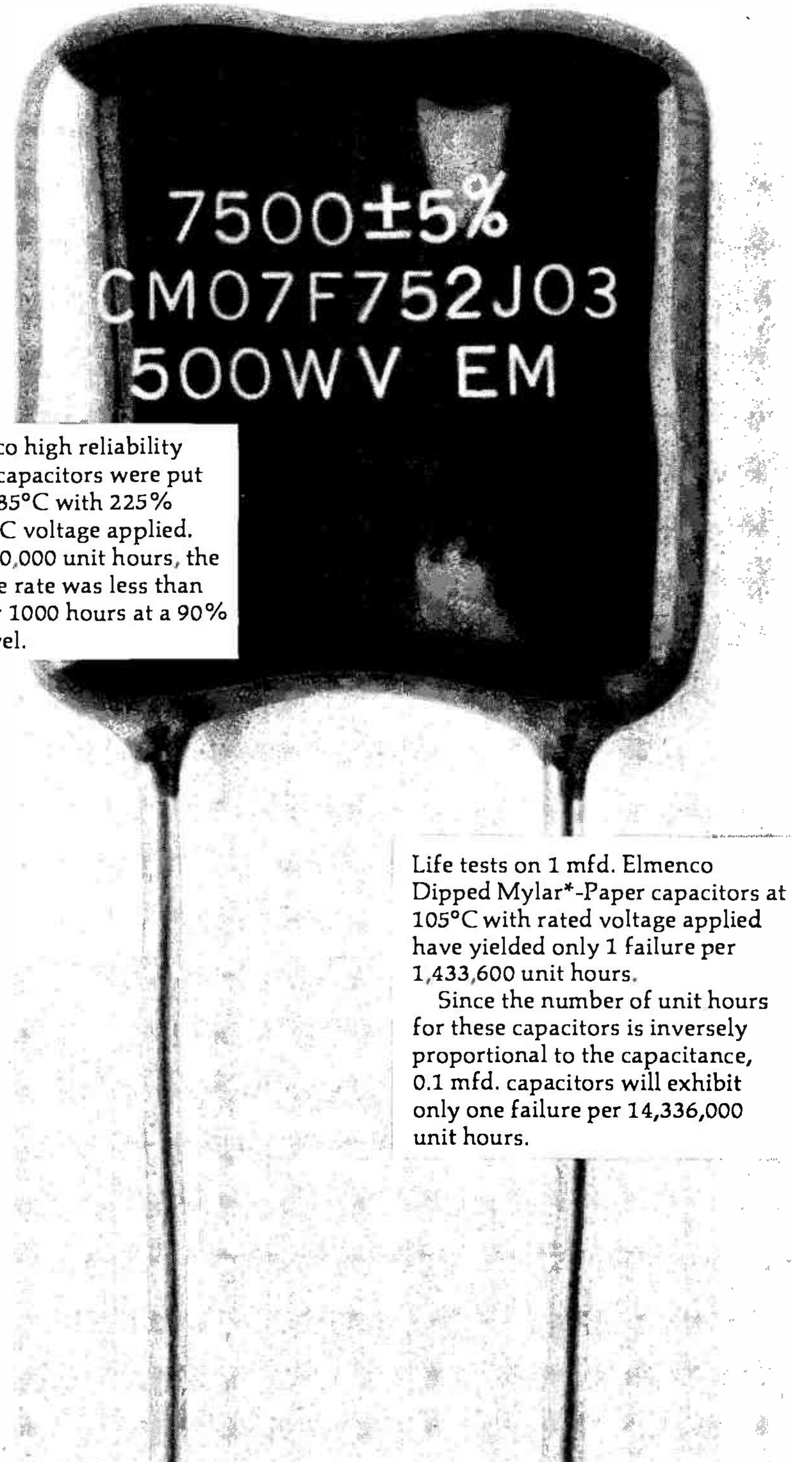
1. Katsuhiko Noda, "Success story: Japanese originals," Electronics, June 27, 1966, p. 93.
2. Electronics, "Onward and upward," Oct. 3, 1966, p. 257.

The authors

Mitsuru Yokoi is a staff engineer in the data communications engineering group at NTT. He has a doctorate from Hokkaido University and has been with NTT since 1948.

Shigehiro Hirasawa is a staff engineer for data transmission at NTT. He joined the company in 1951 and has worked on a telecommunications system for the National Defense Ministry.

Yoshiyuki Mima is a staff engineer for information processing at NTT. He has been studying telephone switching systems for the company since 1950.



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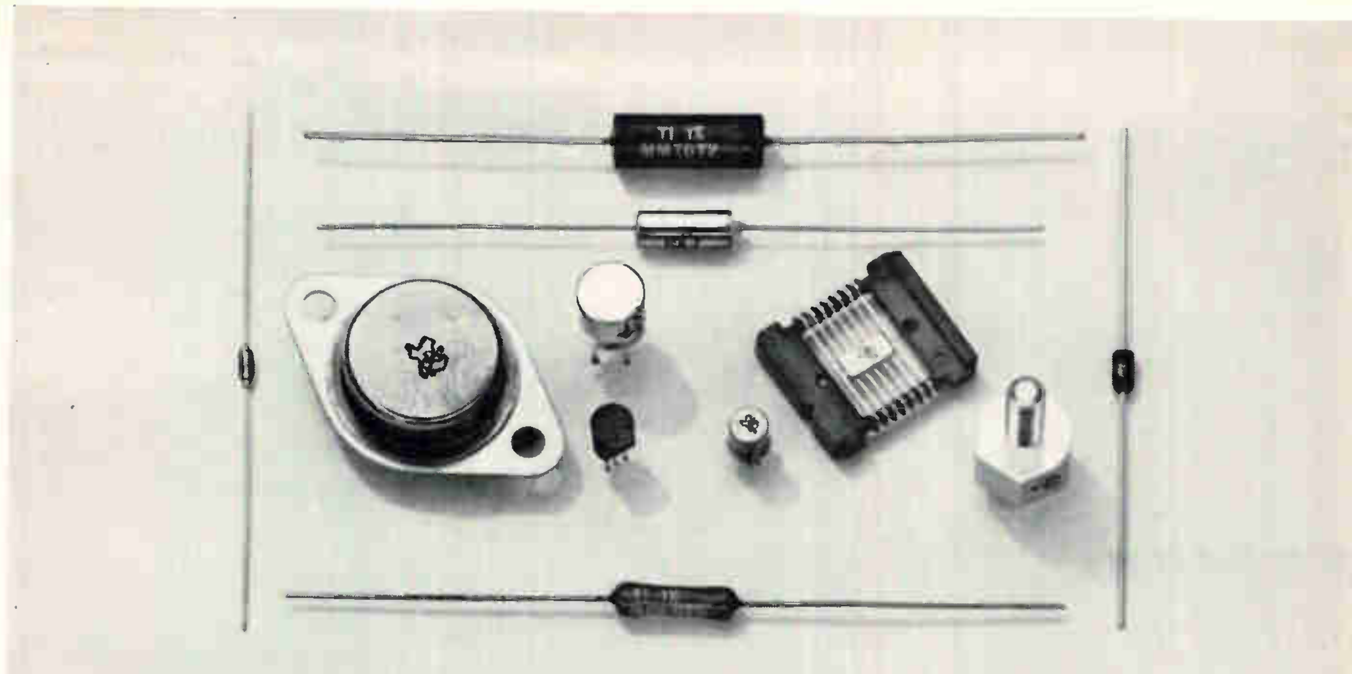

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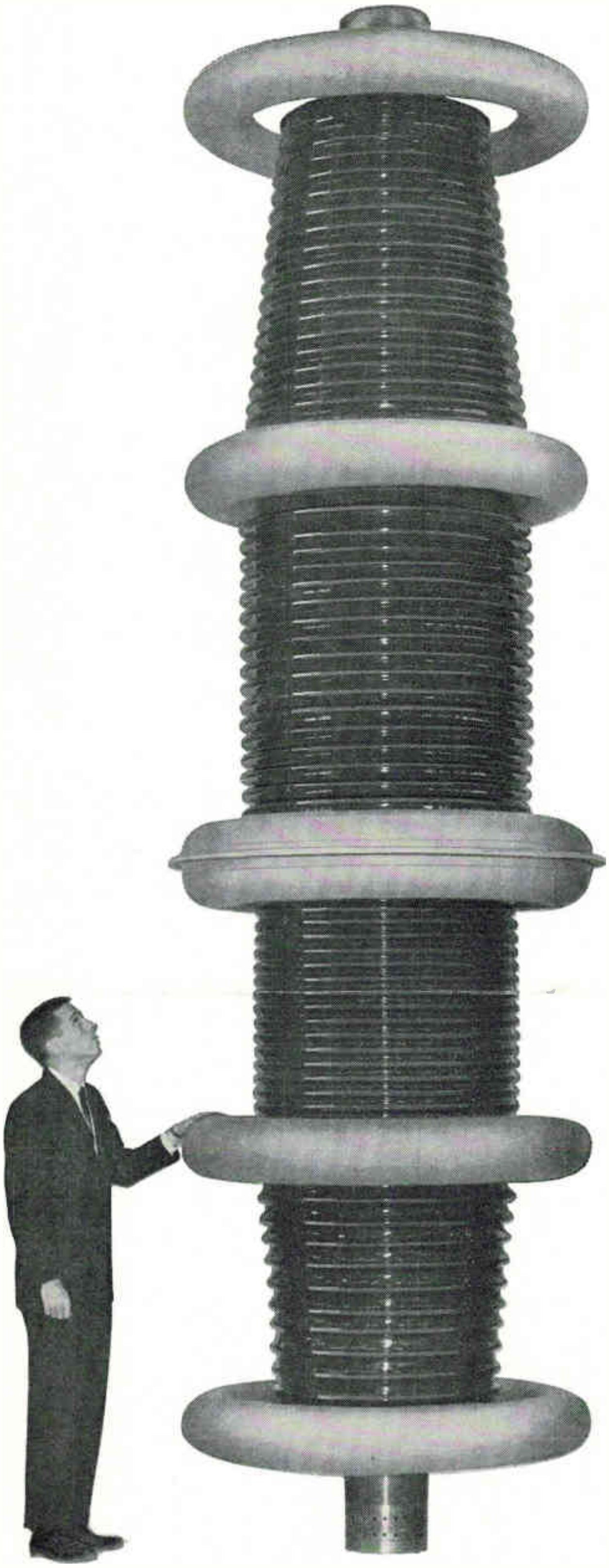
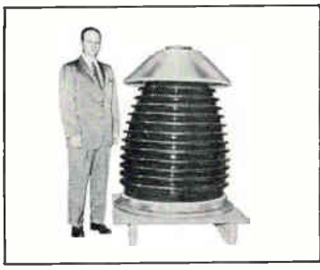
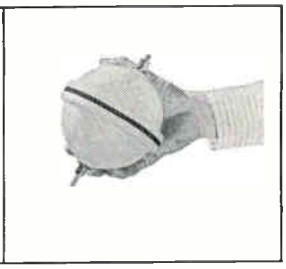


Lapp? Yes, Lapp Insulator of LeRoy, N. Y. Matter of fact Lapp has been designing and producing Feed-Through Bushings for 42 years. They get bigger, *and* more intricate, all the time. Demanding, unusual specifications don't bother us. Why? Because when it comes to radio frequency insulating components we've got plenty of "know-how" . . . and ingenuity . . . and *ability* to produce the finished product.

Getting back to that "world's highest power" bushing, we designed and made three of these for Continental Electronics Manufacturing Company. They are a vital part of the U. S. Navy VLF transmitter at Northwest Cape, Australia. Each one is rated for 2545 amperes continuous duty at 140 kv RMS at 15.5 kc and is both internally and externally graded to assure uniform voltage distribution. These bushings are approximately 16 feet tall and weigh about 7000 pounds each.

Two other Feed-Through Bushings we've made are shown here. But there have been hundreds of others. Write or call us with *any* radio frequency insulating problem. Radio Specialties Division, Lapp Insulator Co., Inc., Dept. E, LeRoy, N.Y. 14482.



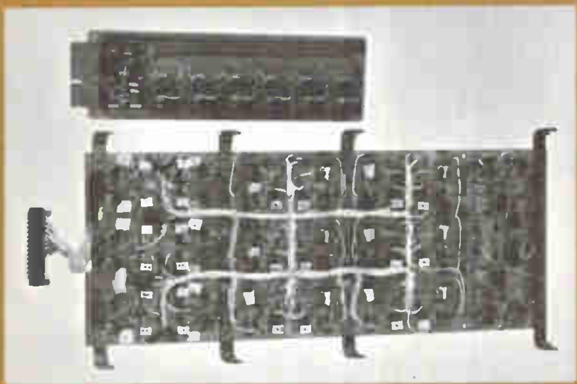


Lapp

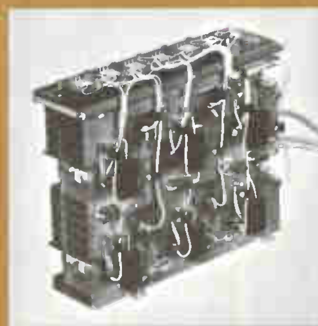
Integrated Cycloconverter

A cycloconverter is a step-down static frequency converter that produces a constant or a precisely controllable output frequency from a variable frequency AC power input. The device is not new in concept. In the past mercury arc rectifiers were used to implement cycloconverters, resulting in severe shortcomings: mercury arc cycloconverters were large and heavy, relatively inefficient, and sensitive to shock, vibration, and operating position. They generated a lot of heat, and required constant maintenance and tube replacements. They also required complex and cumbersome control circuitry. For these reasons cycloconverters were considered a lab curiosity, unsuitable to practical applications.

The Power Equipment Division of Lear Siegler, Inc., Cleveland, has overcome these limitations by building a lightweight, compact cycloconverter utilizing silicon controlled rectifiers (SCRs) in place of the mercury arc tubes, and using integrated circuits for control purposes. The resulting cycloconverter has an efficiency of up to 98.5% at full load, provides frequency control with accuracy as high as 0.00001%, and has improved reliability by an order of magnitude. The development of this unit has made practical the use of AC power in such applications as aircraft generating systems, variable speed squirrel cage motors, and many others (see below). The Lear Siegler cycloconverter consists of two groups of SCR's mounted in a full-wave configuration, on high efficiency aluminum heat sinks. A three-phase AC power supply provides the input frequency. Monolithic integrated circuits mounted on top of the unit provide firing and blanking control. The blanking control inhibits firing signals to the positive group of SCRs while the negative group is conducting, and vice versa. This eliminates the need for interphase chokes, and considerably improves the efficiency of the unit. The output frequency can be precisely varied from dc to one half of the input frequency. A total of 185 components, of which 30 are integrated circuits, are used for firing and blanking control, compared to 1324 discrete components previously required, a saving of 7 to 1. Furthermore, only three circuit types of the DTL family and one linear circuit type are used. Cost data developed to date indicates a reduction in fabrication costs of frequency converter board assemblies by a factor of 2.5 to 1. The unit has been subjected to severe reliability tests, and has operated without interruption for 4200 hours at 100kW from a plant power line with a 100 volt transient.



Comparison of firing and blanking control logic boards as implemented with IC's and with discrete components.



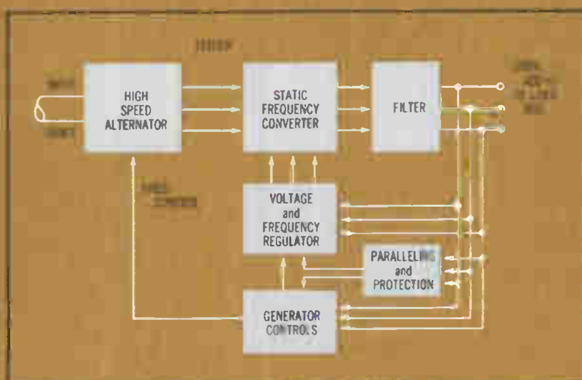
Cycloconverter module made by Power Equipment Division, Lear Siegler, Inc.

Cycloconverter Applications

VSCF GENERATING SYSTEM FOR AIRCRAFT: A variable speed constant frequency (VSCF) generating system for helicopter and fixed wing aircraft using the integrated cycloconverter has been built by Lear Siegler (see block diagram). Power is provided to the system from a high speed alternator driven by the aircraft engine. The alternator speed can vary over a 3:1 or 2:1 speed ratio without affecting the quality of power delivered to the load bus, so long as the alternator frequency remains above 800 Hz for a 400 Hz system. A full wave bridge configuration is used for the cycloconverter, to give the unit improved performance characteristics. This configuration is possible because of size and cost economies achieved through integrated circuit firing controls. The single phase frequency converter module is less than 8 pounds, and it supplies a 100 KVA load in a 50°C ambient, and a 50 KVA load in an 85°C ambient.

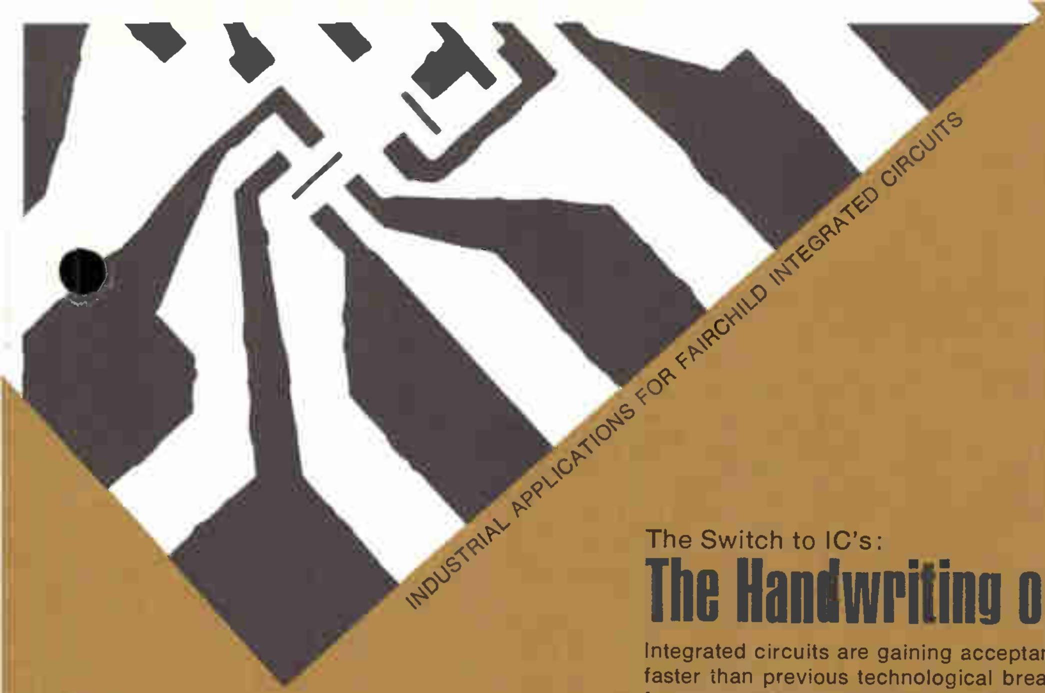
VARIABLE SPEED SQUIRREL CAGE DRIVE: The availability of a practical solid-state frequency converter has made possible the use of a polyphase squirrel cage motor as an adjustable speed drive. Such a system provides superior weight to horsepower ratios of less than one pound per horsepower. It has the added advantage, when applied to multi-wheel land vehicles, of automatic torque control. This is accomplished by means of a tachometer signal which is fed back into the firing control circuitry. The effect is to transfer any excess power from a wheel which is slipping to the wheel with the surest footing. A similar system can also be used to furnish power to locomotive drive systems such as rapid transit railways and diesel locomotives.

OTHER APPLICATIONS: The cycloconverter opens the door for utilization of AC power drives in a wide variety of applications. Wheeled vehicle drives, tracked vehicle drives, antenna drive systems, industrial process drives, and rapid transit railway drives are currently being built by the Power Equipment Division of Lear Siegler. Many other applications are under investigation and in various stages of completion.



Variable speed constant frequency generating system block diagram.

FAIRCHILD SEMICONDUCTOR



6 of a series

The Switch to IC's:

The Handwriting on the Wall

Integrated circuits are gaining acceptance in industry at a rate much faster than previous technological breakthroughs. It took transistors, for example, about 10 years to get from the drawing boards to electric guitars. But integrated circuits, which only two years ago were in the highly exotic, state-of-the-art category, are already making a limited appearance in home television sets, and are rapidly gaining a position of dominance in the industrial market. There are some technical reasons for this accelerated pace of acceptance, but there are also compelling marketing reasons. In the competitive electronics industry, these reasons tend to dominate.

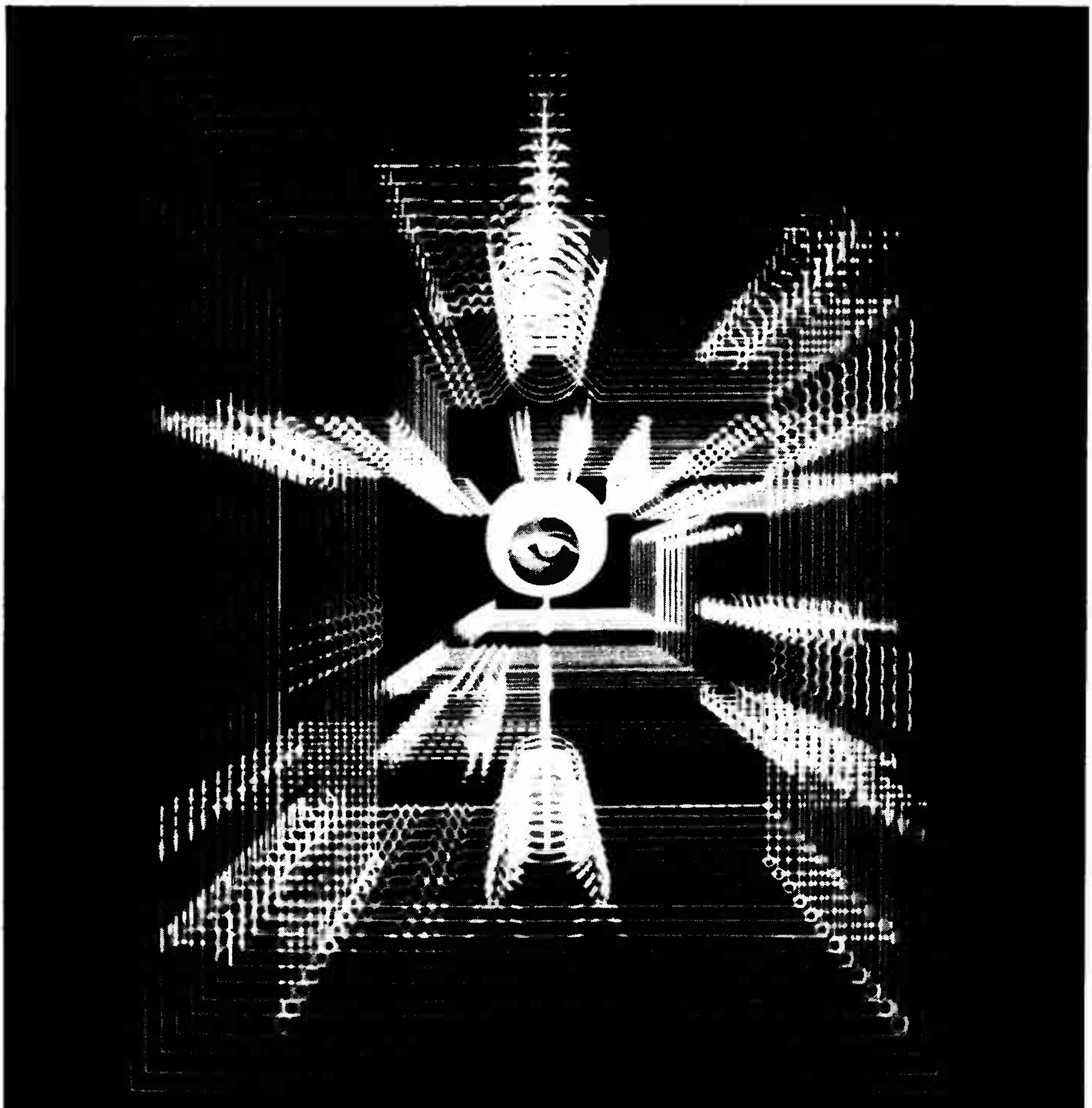
TECHNICAL REASONS: When transistors started to replace vacuum tubes they brought with them a whole new manufacturing technology: printed circuit boards, flow-soldering techniques, automated insertion tools, and the like. No such change in manufacturing procedure is necessary when you switch from transistors to integrated circuits. The technology exists, and can be readily adapted, especially since most integrated circuits are available in standard transistor packaging.

Some applications made the switch because of size and performance advantages. Modern computers operate in the nanosecond range, and a nanosecond is about the length of time it takes electric current to flow through a foot of wire. The size reduction possible with integrated circuits often eliminates enough wire to have a significant effect on the speed of the computer.

MARKETING REASONS: In industrial electronics, where the speed of light is rarely an important criterion, the reason for the rapid changeover to integrated circuits has been an improved cost/performance ratio. A manufacturer of test equipment, for example, recently discovered that he could add a function to his instrument by simply adding one additional integrated circuit. Previously the same function required a board which was offered as a $100.00 option. Now the instrument includes it in its base price, which is still below what the discrete component equivalent sold for. This case is typical. Obviously, more performance at less cost is a sales story every manufacturer is eager to make his own. And so the switch to IC's is on.

CUSTOMER DEMANDS: Most important, the word has reached many customers that integrated circuits are more reliable, perform better, and cost less than discrete component equipment and systems. Consumer appliance manufacturers who include even a single integrated circuit in their electronics are quick to advertise their more advanced, more reliable equipment to the public. And so both industrial and consumer manufacturers find that they must switch to integrated circuits to give their customers what they want.

THE MORAL: The question for a company making equipment containing electronics is therefore not whether to switch to integrated circuits, but when and how. The when is simply answered. If you're not already planning the changeover, start now, while you may still get a jump on competition, or at least keep up. The how is not so simple: you'll need some basic information. The enclosed postcard will bring you an abundance.



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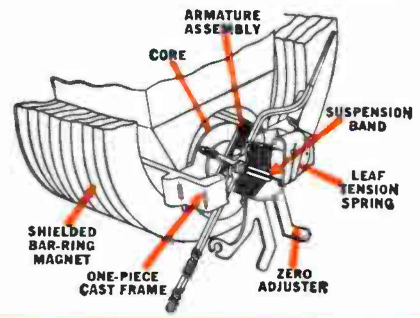

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A.C. VOLTS	0-3-12-60-300-1200 at 10,000 Ohms/Volt. 0-1.5-6-30-150-600 at 20,000 Ohms/Volt.
DB	-20 to 77 in 10 ranges.
D.C. MICRO-AMPERES	0-5 at 300 MV. 0-60-600 at 150 MV. 0-120 at 300 MV.
D.C. MILLI-AMPERES	0-6-60-600 at 150 MV. 0-1.2-12-120-1200 at 300 MV.
D.C. AMPERES	0-6 at 150 MV. 0-12 at 300 MV.
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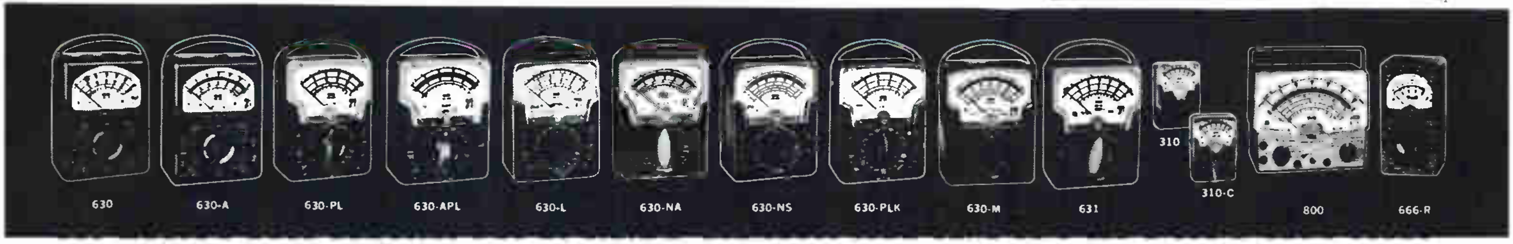
MEGOHMS	0-1-10-100 (4400-44,000-440,000 Ohms center scale)

OUTPUT: Condenser in series with A.C. Volt ranges.



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14C	1.3400	19	12	.0007	24	.0004	—	—
18C	1.8000	35	23	.0013	46	.0007	—	—
23C	2.3000	60	40	.0022	80	.0011	—	—
27C	2.6093	71	47	.0026	94	.0013	140	.0007
40C	4.000	180	100	.0055	200	.0028	300	.0019
50C	5.000	183	120	.007	240	.004	360	.0025
70C	7.000	377	250	.015	500	.0075	750	.005
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(cost: $2.75)

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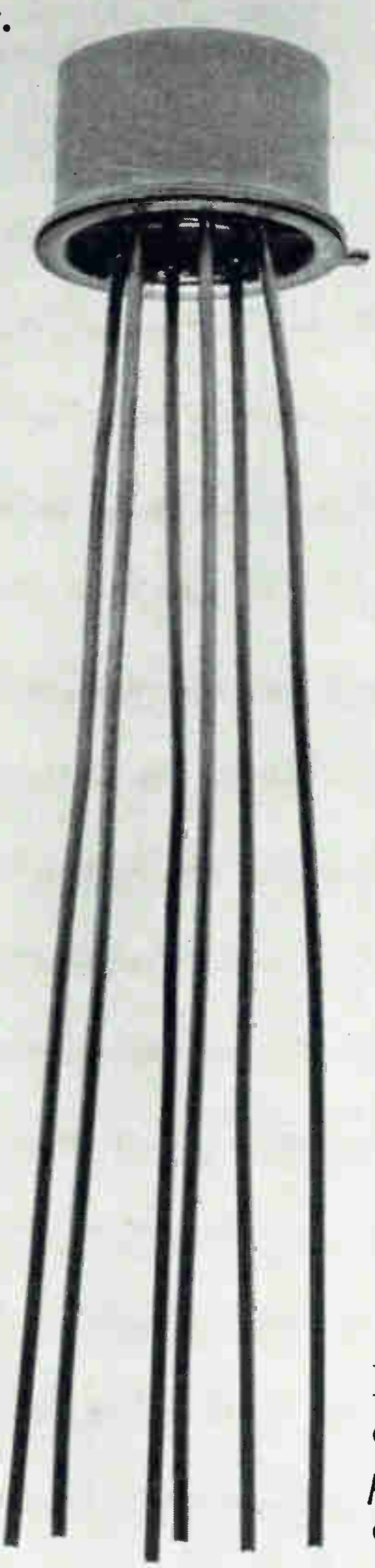

This is the μA703 TV I-F amplifier.

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Use it in the audio stages of your TV receivers or as a voltage controlled oscillator for color sets.

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Probing the News

Chief of an electronics laboratory, Rima V. Vasilyeva walks through machinery hall of institute building in Moscow.

People

Engineers call her boss

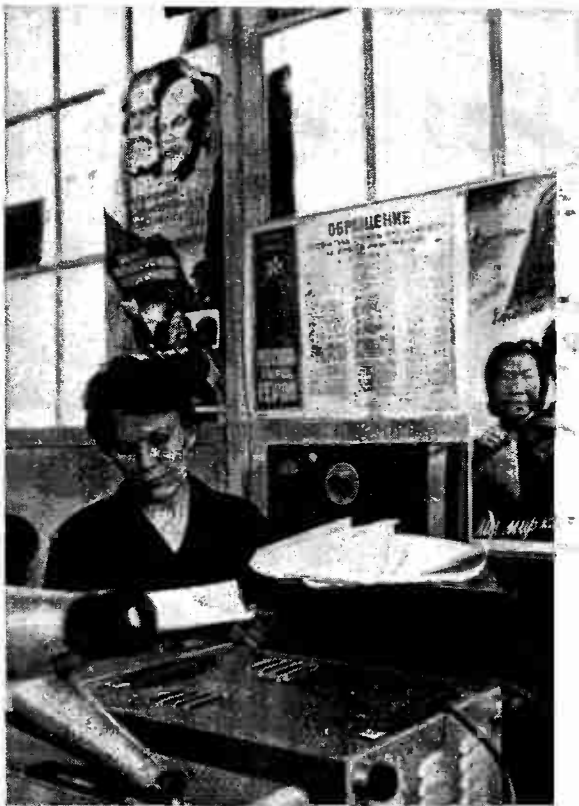
Rima V. Vasilyeva supervises a key electronics instrument lab doing research for Soviet machine-building plants

By Howard Rausch

Moscow News Bureau

When the chief arrives for work at one of the Soviet Union's leading electronics instrument laboratories she has already prepared breakfast for her family and tidied up her three-room Moscow apartment.

Rima V. Vasilyeva walks briskly through the machinery hall of the Central Research Institute of Technology and Machine Building, up a narrow flight of stairs and toward one of her two desks. They symbolize her dual roles as administra-



Engineer Vasilyeva checks reports in her office at the laboratory.

Mrs. Vasilyeva keeps up with technology by reading American and British journals that are translated and sent to institute.

She assists a lab technician doing a sensitivity test on a pickup.

tor and as technical supervisor of the institute's electronics instrument laboratory.

As administrator she studies research problems and decides on instrumentation that may help to solve them. As electronics specialist she supervises the work of 16 engineers and technicians—all but three are men—who design, build and test the new instruments.

The electronics lab is one of four at the institute which conducts research for about 500 machine-building enterprises throughout the country. The other labs specialize in materials, technical processes, and machine construction. Frequently two or more labs cooperate on a project.

"If an enterprise needs an instrument for machine design," she says, "we consult with the plant's design people, find out which parameters of the new machine are to be measured or controlled, then formulate technical plans for doing the job."

The institute and the enterprise sign an agreement based on these plans; the agreement then must be approved by the Ministry of Heavy Machine Building. The research and development typically takes 18 months.

Academy function. No research and little development is done at the enterprises themselves. Basic research is concentrated at research institutes operated by the Soviet Academy of Sciences and by various science academies run by the 15 Soviet republics. The industrial research institutes, including the Moscow facility, emphasize applied research and development, including construction of prototypes and even of pilot plants.

From the quiet administrative office which she shares with a senior engineer, Mrs. Vasilyeva often takes visitors to the electronics laboratory where seven engineers and nine technicians design instruments for testing and controlling the machinery of the future.

The two rooms are connected by a long walkway lined with a gallery of posters: big, colorful safety posters, the closest Soviet counterpart to Pop Art; bold exhortations to

work better and harder, citing goals of the one-year and five-year plans; and international slogans such as "Peace" and "Hands off Vietnam."

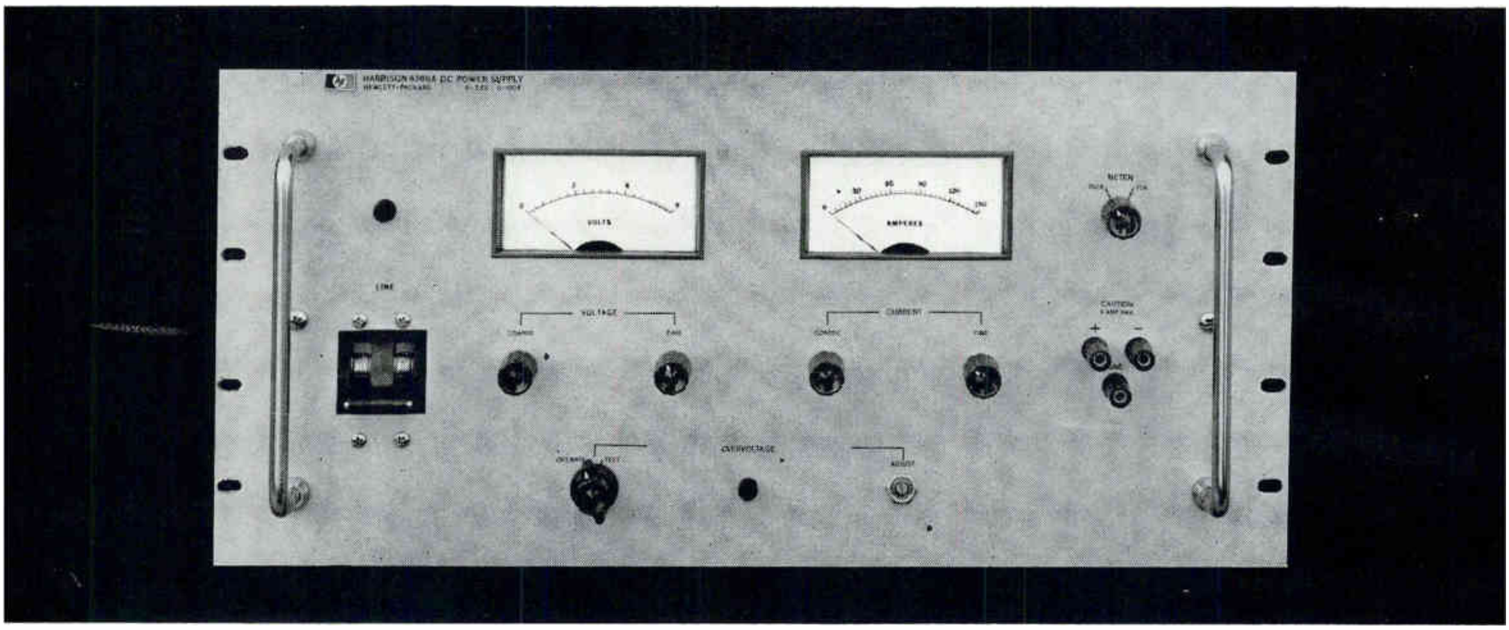
The lab, about 22 by 16 feet, is cluttered and cramped. Most of the instruments are Soviet-made, but there are several from Britain (a Pye amplifier was noted), Denmark (a millivoltmeter made by Bruel and Kjaer), Japan, East and West Germany, and Czechoslovakia.

Mrs. Vasilyeva, who helped to found the electronics lab in 1948, is particularly proud of a stationary gauge, now in mass production, that automatically measures and records vibrations of turbine bearings and shafts. In case of excessive vibration it can sound a warning or halt the turbine altogether.

It employs a 4.8-pound induction-type vibration pickup 4.9 by 4.9 by 3.3 inches, with a seismic mass whose natural frequency is 6.5 to 8.5 hertz. At 100 hz the instrument measures maximum amplitude accurately to 300 microns; at 150 hz. accuracy is up to 100 microns.

Components include eight 2-vibration pickups for each measurement point, up to eight points; a

new disciplines in DC



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H07A

Circle 182 on reader service card

The electronics specialist is also a domestic engineer. She serves breakfast to her daughter, Olga, 14, before going to work.

two-channel amplifier; a choice of two potentiometers for recording vibration amplitudes, one weighing 101 pounds the other only 48.4; also an indicator for measuring all vibration amplitudes. The indicator is fitted with a brush-type switch.

Foreign influence. Although she speaks almost no English, Mrs. Vasilyeva reads British and American technical publications regularly. These are reproduced in Moscow and circulated to technical institutions about three months after original publication.

Under the glass top of her desk Mrs. Vasilyeva has a list of 16 management tips translated from an American magazine. One suggestion is: "Never do yourself what your assistant is able to do."

Her lab is divided into four groups of vaguely defined specialties, and Mrs. Vasilyeva generally works only with the group leaders. Most of her attention goes to groups specializing in transducers and in amplifiers.

Mrs. Vasilyeva also works closely with the institute's design bureau, where six engineers and 12 draftsmen transform ideas into working drawings.

Work at the lab starts at 8:30 a.m. for the director, who finishes at 4:30 on weekdays and a bit earlier on Saturday. "Next year we hope to go to a five-day week," she declares. For running the lab she is paid 400 rubles a month—$440 at the official, inflated rate of exchange. Senior engineers receive $200 a month, ordinary engineers $122 to $133, senior technicians $111, junior technicians $90, and lab assistants $67.

Comfort and convenience. The Vasilyeva home is a comfortable, tastefully furnished apartment five minutes' walk from the lab.

Mornings she cooks and serves breakfast for her husband, a radio engineer, and for their 14-year-old daughter, Olga, an aspiring artist. The Vasilyevas also have a married son of 26, also a radio engineer, and a two-year-old grandson.

There are many signs that the Vasilyevas are well-to-do by Moscow standards. Outside the apartment house is a Moskvitch, a Soviet compact car that costs $5,000 in rubles; inside are a quality radio and a television set beside a glass-doored case in which is displayed, among other things, a medal for successful labor earned recently by Mrs. Vasilyeva.

As Olga gets ready for school at 8:15, Mrs. Vasilyeva gives her "directives" for the day: what to eat for lunch and supper, where to go after school, and so on. After Olga has dashed out the door her mother says: "She goes to an English-language school. Classes are conducted in English, and she should speak only English there; I stress "should" because I suspect they don't always do it."

What's new with A-New

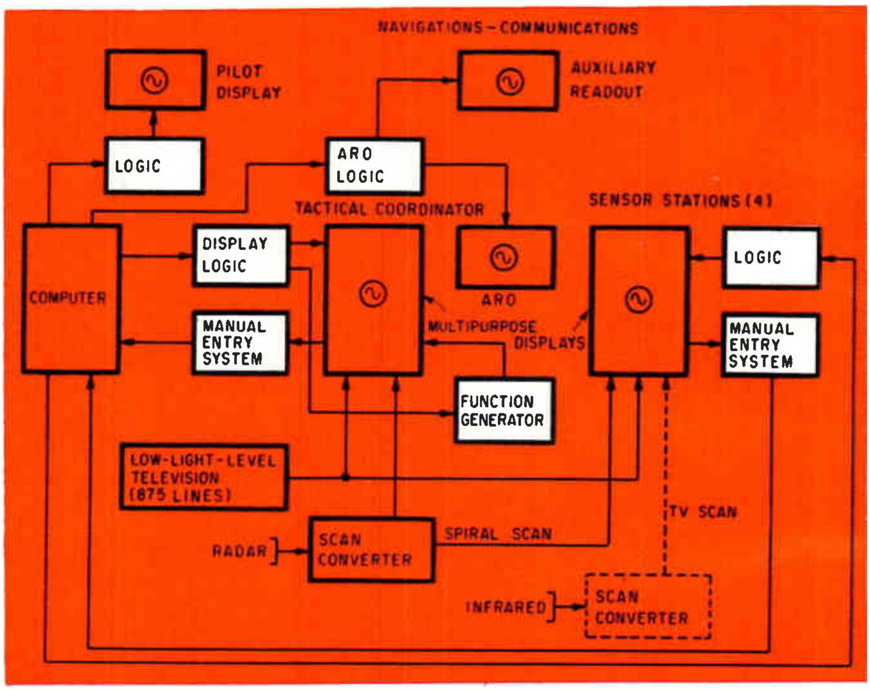
The Navy's totally integrated airborne ASW system gives battle commander coordinated information from his sensors

By W.J. Evanzia
Avionics editor

A number of advances—including a pint-sized digital computer, multi-purpose display consoles, a data processing system, and a sonic analyzer—are bringing a totally integrated airborne antisubmarine warfare (ASW) system closer to operational status for the Navy.

Some of the improvements are incorporated in the engineering prototype of the new system called A-New on which flight tests began in October. Others will be installed in time for the service acceptance tests scheduled for 1969.

The Navy has already invested more than four years and over $20 million in the A-New project which is intended to ease the lot of the battle commander of an ASW aircraft. The system is designed to give him quick access to information. Because of the deluge of data from a number of different sensors the battle commander, or tactical coordinator, has had the almost impossible job of working rapidly and accurately. But with an assist from A-New, he will be in a stronger position to hunt and kill enemy submarines.



In the A-New system now being evaluated, computer-generated commands and data are transmitted through logic boxes to cathode-ray tube displays. In the production model the interface hardware, shown in white, will be replaced by a single unit. The infrared system is still being evaluated.

Checkout. After having passed feasibility and simulation tests, the A-New system [officially designated Mod. III at this stage of ts development] was installed aboard a Lockheed P3A. It is being put through its paces at the Weapons System Test Facility, Naval Air Test Center, Patuxent River, Md. These checks will form the basis for the service acceptance tests of the production A-New system which will be installed in a new version of the Orion—the P3C.

The A-New system, Navy officials say, is doing an impressive job in furnishing the battle commander with more usable data and achieving greater accuracy in target identification during the present tests.

Although A-New is not intended to advance the state of the art, it incorporates some entirely new elements. The most notable is general-purpose digital data processing.

Computer key. Early in the program, the Navy decided that a digital computer processor was needed to correlate and display data from the surveillance, navigation and communication equipment carried aboard the ASW aircraft. The development job was turned over to the Univac division of the Sperry Rand Corp., which came up with the small, fast and versatile Univac 1830. This unit is installed in the current test bed. It will, however, be replaced by an advanced version incorporating integrated circuits—the 1830A—in the production A-New system.

The 1830A occupies only about three cubic feet of space, weighs less than 300 pounds and operates in real time. A general-purpose, stored-program computer with performance characteristics exceeding those of many large ground machines, it has a 2-microsecond cycle time [1 usec with overlap]. The 1830A's 48,000-word memory is expandable to 131,072 30-bit words.

In the Mod. III system now under evaluation, the computer is connected through logic boxes to four sensor stations. [See block diagram]. Among other things, the operators at these stations collect data on low light level television,

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Want some helpful new design information? Ask your nearest AE representative for Circular 1070-B. Or drop a line to the Director, Electronic Control Equipment Sales, Automatic Electric Company, Northlake, Illinois 60164.

AUTOMATIC ELECTRIC

SUBSIDIARY OF GENERAL TELEPHONE & ELECTRONICS GT&E

. . . one input-output channel of the A-New computer services 16 peripheral units . . .

sonobuoys, radar, electronic countermeasures equipment, magnetic anomaly detectors and photographic reconnaissance gear. They furnish information inputs to the computer.

Less talk, more action. However, there will be some changes in the production model A-New for the P3C. For instance, it will require only three sensor stations, as against four in the Mod. III version.

The ASW battle commander can present a variety of stored information on his display console at will. Cathode-ray tube displays largely eliminate the need for vocal coordination between the commander and sensor station operators.

Included are:

- Multipurpose displays at the battle commander and sensor stations. These units along with their Charactron beam tubes were made by the Stromberg-Carlson Corp., a division of the General Dynamics Corp. Computer-controlled digital data, tactical and geographic vectors, low light level television, scan-converted radar and infrared video as well as computer-generated circles and ellipses are presented.
- Auxiliary readout (ARO) units at both the commander and navigation-communication stations. The 5½-inch crt display, which incorporates a Charactron, was also manufactured by Stromberg-Carlson. A 256-word buffer, the ARO is used to amplify target data as well as weapons and stores status. In addition, it indicates data link messages, Teletype and computer-generated information automatically or on demand.
- A pilot display, an 9-inch crt unit made by the Electronics Systems division of the Loral Corp. Limited tactical data in the form of 36 computer-generated alphanumeric numbers and symbols—fly-to points, sonobuoys, action cues and aircraft position—are presented. In the P3C configuration, the pilot will also have access to low light level televsion and radar pictures on his display.

Consolidating gains. Interface hardware [shown in white in the block diagram] between displays, computer and sensors, including display controls, was supplied by Loral. On the P3C, these subsystems will be replaced by a single piece of equipment called the data processing system, incorporating a digital multiplexer that will enable a single input-output channel of the A-New computer to service 16 peripheral units. The Navy believes this arrangement may be the first in a series of A-New subsystems to be consolidated. As yet, no contract has been let for the system.

The P3C, which carries the production A-New, will also be equipped with a new sonic analyzer that will use sophisticated correlation techniques to extract signals from noise. It will be used with sonobuys to enhance their detection capabilities. Loral supplied the dark tube display on which information is presented in the form of high-contrast black lines and up to 10 shades of gray on a green background for the Mod. III version of A-New. Proposals for the new system which will have a dark trace tube, logic driver, frequency translator and spectrum analyzer are being evaluated.

In addition to its other functions, the Univac computer serves as a navigation aid, enabling the A-New aircraft to maintain course even when a smooth sea gives poor doppler radar returns. Moreover, with A-New, the position of a sonobuoy is automatically fed into the computer the minute it is dropped. This information, together with sea condition and wind velocity inputs, allows the computer to make an accurate plot of the buoy pattern and guide aircraft around the station.

A modified Collins Radio Co. FD-108 flight-director unit will further improve the teamwork between pilot and battle commander in the A-New-equipped P3C. During tactical maneuvers, for instance, the commander will no longer have to check the position of his aircraft and fly-to-point before ordering a change of course. The maneuver itself will automatically order the computer to calculate the bearing and distance. The commander simply observes the computer-generated information on his multipurpose display console.

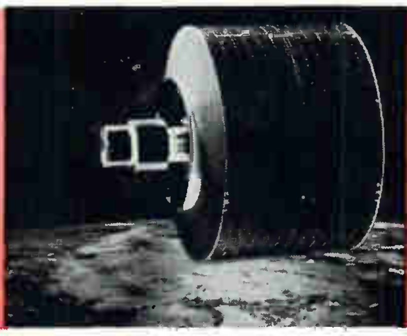
Serviceability. While the A-New aircraft is on station, the Univac computer will diagnose faults in the avionics digital circuitry. Analog circuits will be checked with separate manual test equipment that is built in. The A-New system gear will be easy to get to and maintain on board the aircraft. It will be mounted on open racks and the equipment packages will have removable side panels so modules can be easily replaced.

The Navy hopes that real-time, computer-to-computer communications will eventually permit A-New aircraft coming on station to absorb, in seconds, all of the information it took hours of submarine hunting to gather. The means of communication—the Naval Tactical Data System—is already available as are most of the equipment and modulation techniques. But the language is not, and the Navy is undertaking to devise one. Software engineers are also seeking to develop new tactical algorithms for the A-New system to abet the battle commander's decision-making.

Development. Since the conventional sensors proposed for A-New had never before worked together, no one really knew at the outset whether such a system would be effective under combat conditions. This prompted a deliberate, three-stage approach. During the first phase, a flying breadboard established the feasibility of the A-New concept. The second stage concentrated on down-to-earth laboratory simulation. Finally, the Navy began flight testing the Mod. III prototype system.

Simulation studies, with a large assist from a real-world-problem generator supplied by Sylvania Electric Products Inc., a subsidiary of the General Telephone & Electronics Corp., are continuing on the A-New configuration for the P3C as well as for carrier aircraft and helicopters. The generator is preprogramed so the authentic problems and tactics that have been created can be repeated in identical formats to assess changes in the A-New system as it evolves.

Carrier-based planes will probably have to wait until after 1970 for A-New gear and it appears likely that helicopters will have an even longer wait.



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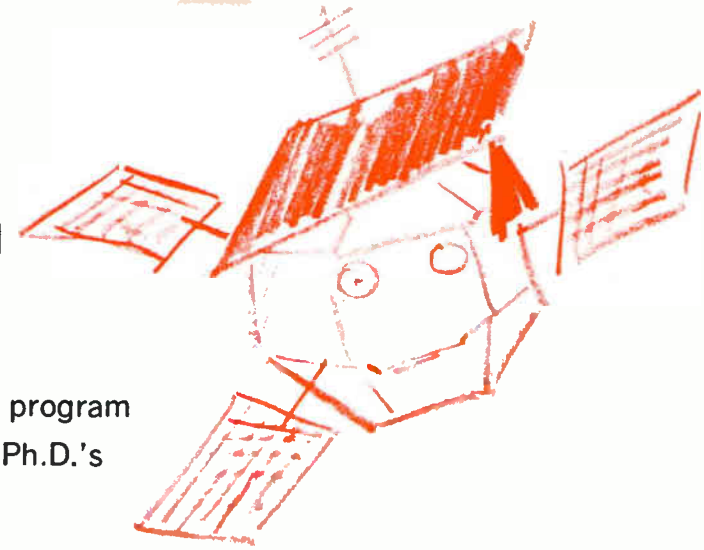

Space agency sponsors satellite-building program to train new scientists by giving budding Ph.D.'s responsibility for their own spacecraft

A winning football team, a nuclear reactor and a large-scale computer no longer guarantee prestige to a major university. These days a school must have its own satellite.

But there's much more than prestige at stake. The National Aeronautics and Space Administration is now financing satellite-building projects to train the next generation of space scientists.

Many institutions already participate in space experiments. But having complete responsibility for their own satellites gives them, and their graduate students, experience over a broader range of space science. Since universities lack the facilities to produce and test spacecraft, they are going to electronics and aerospace companies for their hardware.

The academic space club is currently more exclusive than the Ivy League. Only one school, the University of Iowa, has orbited a satellite. Rice University has launched a program but no spacecraft. Four others have study contracts: Harvard University, the Massachusetts Institute of Technology, the University of Michigan and the University of California at Los Angeles.

Preliminary studies are under way at the University of California campuses at Berkeley and San Diego, at Stanford University and at the University of Southern California.

The satellites are designed to do a variety of scientific jobs in space, depending on the universities' interests. All, however, are relatively cheap—around $3 million—and use the Scout launch vehicle. Scout is considered too small for all but a few of NASA's projects, but has proved ideal for newcomers to space.

At all the schools, students do the work and faculty members supervise. Four doctoral candidates at Rice will base their work on the satellites, which are nicknamed Owls for the school's mascot. "They'll get a feel for the spacecraft rather than just the individual experiment," says Brian J. O'Brien, the project manager. "Before a graduate student publishes a scientific paper or conducts a discussion, he has to know how well he can trust a spacecraft. He'll have to worry about weight, power—the whole engineering facet."

Alexander J. Dessler, chairman of Rice's new Department of Space Science, stresses the need for training future space scientists. "This is a critical time," he says. "Just as the major space programs are whipping along on Apollo and beyond, we will be turning out a significant number of graduates to help direct and work on them. There's a real shortage now."

Paul J. Coleman Jr., director of UCLA's satellite project, agrees with his colleagues at Rice University that a satellite is an ideal way for students to become involved in every phase of space science. He hopes the UCLA project will swell graduate enrollment and produce as many as 10 Ph.D.'s.

A helping hand. Since it was established in 1958, NASA has encouraged universities to participate in space projects and has flown a number of their experiments on its spacecraft. James Van Allen of the University of Iowa developed radiation counters for the nation's first successful satellite—Explorer 1, launched Jan. 31, 1958—that discovered the radiation belts bearing his name. Van Allen and his colleagues were working on a satellite of their own, Injun, when the National Academy of Sciences met on the Iowa campus in the summer of 1962 to plan space goals. On the basis of the Iowa work, the academy recommended that other universities have their own satellites and that NASA provide them with the launch vehicles as well as support equipment.

The Iowa satellite was a joint project of the university and the space agency's Langley Research Center, Hampton, Va. It was designated Explorer 25 and went into orbit Nov. 21, 1964 carrying a magnetometer and 16 radiation sensors to conduct further studies of the Van Allen belt.

1. Ground rules

Shortly after the 1962 planning conference NASA set up a small university satellite organization within its Office of Space Science and Application. The group is far down the agency's organizational chart, falling under the Explorers and Sounding Rockets branch of the Physics and Astronomy division.

A university proposing a satellite first talks to the NASA scientific discipline branches to see how the project would fit into the over-all space program. After discussions on the merits of the project and the budgetary outlook, the university submits a formal proposal the way any industrial company would. If it is accepted, the school receives its money from the Grants and Research Contracts division and begins working out the details of schedules and subcontracts with NASA's university satellite group.

Rice was the first university to get its satellite project officially approved and funded under the new program. Two Owls will study the

... Owls will keep watch over auroras as well as Van Allen radiation belt ...

auroras and their relationship to the Van Allen belt and energetic space particles hitting the earth.

Rice has a $3.6-million cost-reimbursement contract from NASA and is serving as a prime contractor. The subcontractors are: the Lockheed Electronics Co., a division of Lockheed Aircraft Corp., for the tape recorders and the electronics in the television camera system; Westinghouse Electric Corp. for the vidicon; the Space-General Corp., a division of Aerojet-General Corp., for the data distribution system; and the Northrop Corp. for spacecraft chassis and the antenna.

East of the sun. Two Owl satellites will be launched about a month apart early in 1968 during a period of peak solar activity. Each 175-pound satellite will be oriented by a permanent bar magnet so that one axis is continually aligned with the earth's magnetic lines of force. A television camera will photograph the auroras below while Geiger counters on the upper side of each satellite measure particles on their way to earth. Other detectors on the lower side of the satellite will measure Van Allen radiation.

Power will be supplied by the 9,000 solar cells that cover the spacecraft. Their output will average 30 watts while the satellite is in the sunlight and will be fed into two nickel-cadmium batteries.

II. Western branch

The UCLA project, as yet unnamed, got under way in October with a $55,000 grant from NASA. The university has issued 60-day study contracts to three aerospace firms: the Hughes Aircraft Co.'s Space Systems division; the General Dynamics Corp.'s Convair division; and the Philco-Ford Corp.'s Western Development Laboratories.

The proposed satellite will carry 20 pounds of scientific equipment grouped into four experiments. An energized particle detector will determine direction and density of protons and electrons. Dual magnetometers, one a flux gate for direct current and low frequency and the other for d-c up to 1 kilohertz, will measure magnetic fields. A plasma detector will measure the direction and density of ions. The fourth experiment is an electric field meter. UCLA is aiming for a launch in 1968 from the Vandenberg Air Force Base in California.

Another redskin. Meanwhile, Iowa is preparing a more sophisticated version of its earlier Injun for a launch late next year at Vandenberg Air Force Base. And the university is again working with the Langley center. The satellite, called Injun 5, will carry three Langley experiments and one from the Air Force Cambridge Research Laboratories, Bedford, Mass.

University satellites

School	Satellites
Iowa	Injuns
Rice	Owls
Harvard	Pilgrims
Michigan	Michaels
MIT	Sunblazers
UCLA	Unnamed

One of the Langley experiments consists of two low-energy proton-electron differential energy analyzers to measure trapped particles in the range of 75 electron volts to 75 kiloelectronvolts (kev). Another consists of two 20-foot-long dipole antennas to measure very low frequency emissions, the so-called "whistlers" and other radio noises, at three frequencies: 30 to 750 hertz, 750 hz to 4 kilohertz and 4 to 16 khz. The third is an array of solid-state detectors to measure protons at 250 kev to 21 megelectronvolts (mev), alpha particles at 1.5 to 10 mev and electrons at 200 kev to 1.2 mev. The Air Force experiment consists of a low-energy electron detector.

The Iowa satellite will weigh about 150 pounds and be launched from Vandenberg. Once in orbit, Injun will be magnetically stabilized like the Owls and will receive an Explorer designation. Cost of the program, excluding the launch vehicle is about $2 million.

III. Cambridge contingent

Harvard College Observatory professor Richard Huguenin is in charge of a study project aimed at orbiting a satellite, dubbed Pilgrim, to observe solar radio bursts at frequencies from 250 khz to 16 megahertz. "It will enable us to see a portion of the radio spectrum that is not observable from the ground," says Huguenin. "There is no window in this range."

Pilgrim will use proven components—principally recorders and telemetry equipment. It will carry devices to keep it pointed toward the sun within a few degrees, says Huguenin. The sun is a sporadic emitter. But Pilgrim is expected to stay up one year, taking data continuously, so it will probably gather a fantastic amount of data for processing here on earth, he adds.

MIT's Center for Space Research has a NASA grant to design a satellite called Sunblazer to explore the interplanetary plasma and its influence on deep-space communications. This project is to be conducted with the interplanetary and solar probes branch of NASA and the Pioneer spacecraft program management office, rather than with the university satellite office.

Sunblazer is intended to carry a radio transmitter into an orbit around the sun so that scientists can observe the effect of the interplanetary medium on signals transmitted to earth as the spacecraft passes behind the sun.

Bantam rooster. The spacecraft will weigh only 10 to 15 pounds and will be just large enough for a solid-state two-channel transmitter and a solar-cell power source. Because signals will be coherent, observers can detect the relative delay between pulses on different frequencies and thus determine the electron densities along the path of transmission. The transmitter will emit pulses 26 milliseconds long on carrier frequencies of 100 to 300 Mhz. Several shots a year are planned to get a continuously operating network of Sunblazers.

The University of Michigan project, called Michael for Michigan Aeronomy Experimental Laboratory, is also covered by a NASA study contract. Michigan took an informal approach and has been asked to restudy the satellite and submit a formal proposal. The Michael would conduct aeronomy studies—ionization, dissociation and chemical reactions.

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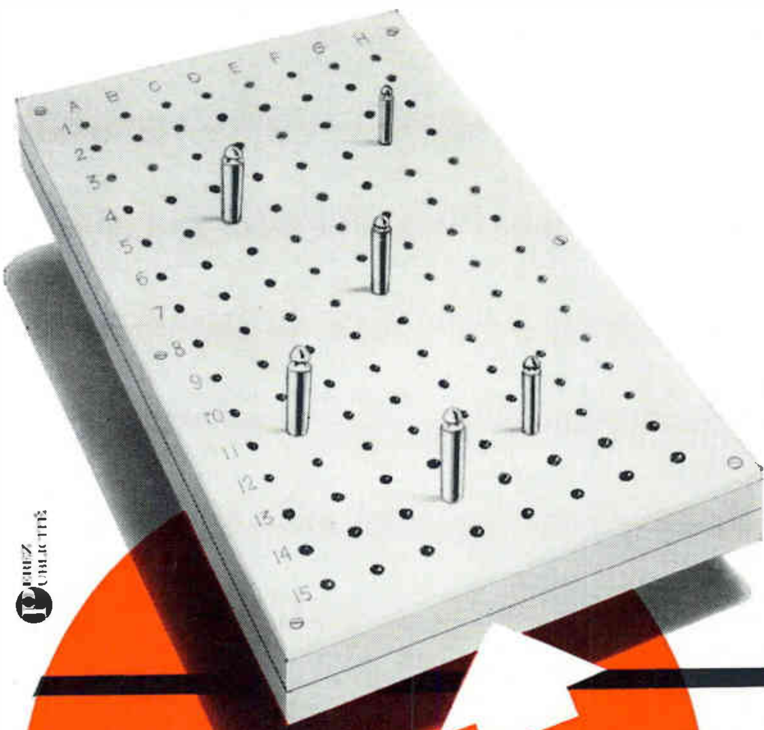

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Army enlists IC's for artillery fuzes

It has asked electronics companies to help in a crash program to develop cheap proximity fuzes using integrated circuits

By William D. Hickman
Electronics Washington Bureau

If the Army could make cheaper proximity fuzes for ordnance, artillery batteries in Vietnam would have two to five times more effective firepower at their disposal than they do with conventional ammunition. Proximity fuzed rounds will never completely supplant their impact-fuzed counterparts, but they have proved their mettle in countless barrages. Unfortunately, cost has been the biggest obstacle to employing them more widely. So a crash program is under way to get the price down by using integrated circuitry.

The Harry Diamond Laboratories, a division of the Army Material Command, is spearheading the research and coordinating the efforts of electronics and aerospace companies to apply IC technology to ordnance.

The mother of invention. Although, as one Diamond Labs official puts it, "no one expects the war in Vietnam to go on forever," the added punch of artillery with proximity fuzes against dug-in enemy troops gives the undertaking particular urgency.

So far, the Army has committed about $750,000 to the project which it hopes will provide an economical hybrid proximity fuze—incorporating both IC's and discrete components—within 21 months. The IC development will be complete in 11 months and production-model fuzes will be coming off the line 10 months later.

The meeting of such a tight schedule would represent a signal accomplishment since the normal lead time from laboratory to battlefield for the IC work alone would have been three years or more.

One-chip ante. The unit cost of the vintage printed-circuit, vacuum-tube fuzes now available is about $10—even in quantity—and no reduction is in store. Their high cost limits them to large shells for crucial Vietnam targets. Although bulky, the fuzes could be adapted for the Army's smaller shells. But the cost is prohibitive.

Proximity fuzes could be built with discrete transistors similar to the conventional, epoxy encapsulated types used in audio-frequency equipment for about $5 apiece. But the Army, going all out to reduce cost, does not find this saving sufficiently appealing. Accordingly, discrete semiconductors have been passed over for promotion.

Diamond Labs has blocked out timetables and cost calculations of circuit development as follows:

- The hybrid configuration, with IC's as well as vacuum tubes and other discrete components, should be ready in less than a year at a cost of $4 or less a unit.
- A single-chip assembly on which the entire fuze circuit—including transmitter, receiver and switching gear—will be integrated should be within reach in two years. The relatively low outputs that are anticipated will probably keep the price at about $2 apiece.
- Greater technical savvy and larger production runs should give the Army single-chip IC assemblies priced at 50¢ each by 1971.

Bursting in air

The proximity fuze, a product of a top-priority World War 2 project, was perfected in time to give Allied forces highly effective new ordnance.

It detonates a shell's warhead before impact, spewing lethal shrapnel over a wider target area than can be covered with conventionally fuzed ordnance.

A proximity fuze assembly is simply a tiny transceiver that measures the doppler shift between shell and target. At a preset distance—generally 10 to 50 feet from the target—its detector circuit trips the detonator.

I. On and off the line

Diamond Labs is overseeing pilot production of IC's for the hybrid proximity fuze from its Washington, D.C. base. Pilot production is under way at the Westinghouse Electric Corp.'s Molecular Electronics division in Baltimore and Motorola, Inc.'s Military Electronics division in Phoenix, Ariz. Westinghouse is investigating equipment and processes while Motorola is concentrating on how to design the fuze mechanism to introduce IC components.

To date, the two companies have each delivered 12,000 IC units for evaluation and demonstration purposes. The deliveries were made under $400,000 worth of contracts, awarded to answer engineering and cost questions. The Army is, for example, vitally concerned about the expense involved in turning out the amplifier firing-circuit switch in quantity. Westinghouse and Motorola are supplying assemblies with slightly different installation characteristics. The units incorporate a temperature-sensitive gain control to keep them stable over a broad environmental range. They also have a differential analyzer, a signal detector and a 4-layer, silicon-controlled-rectifier switch.

The IC's now coming off the line will go into the hybrid proximity

. . . discharge capacitor and other discrete units will have to wait for a berth on the chip . . .

fuzes for 81-millimeter mortar rounds. The IC's may subsequently take their last rides on such Vietnam workhorses as 2.75-inch rockets, 40-mm artillery shells and ammunition for the 40-mm cannon on helicopters. Diamond Labs has proved the feasibility of equipping 20-mm rounds with proximity fuzes, although the Army has not yet established an operational requirement for such relatively small-bore ammunition. Once costs are brought down to the desired levels, consideration will be given to equipping the smaller, and less expensive, rounds with proximity fuzes.

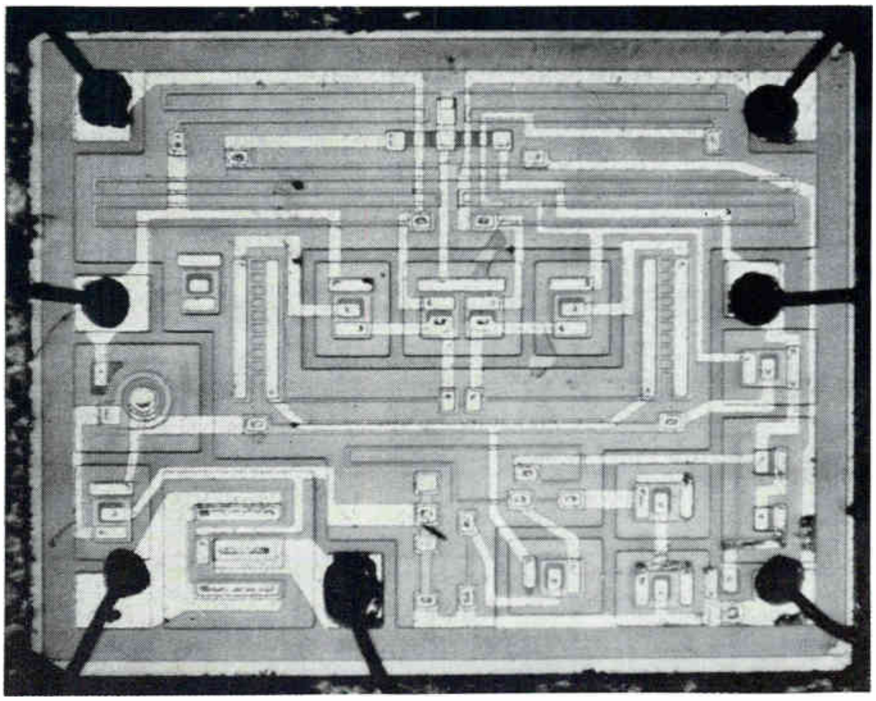
Cost conscious. Price is the Army's principal preoccupation and the cost of the Westinghouse IC is now being negotiated. Diamond Labs is shooting for an eventual cost of $3 or possibly much less per unit.

Westinghouse already has another contract with Diamond to develop a more advanced SCR amplifier switch. Specifications call for it to have some bandpass control-frequency capability.

While Westinghouse and Motorola are now the most important parties in the crash effort, they are by no means the only companies to which Diamond Labs has turned. Philco-Ford Corp.'s Lansdale division is working on a new type of amplifier and an electronic timer, involving metal-oxide-silicon techniques, for proximity fuzes. The General Electric Co.'s Electronics Laboratory, also at work on a timer, has elected to approach the problem through bipolar technology. Finally, Texas Instruments Incorporated, which submitted an unsolicited proposal, has been rewarded with a token $1,000 contract. The company will tackle basic IC problems with an approach that is different from the ones taken at Westinghouse and Motorola. Additionally Diamond Labs is itself working on some of the problems.

II. Blocks off the chip

Army engineers still have a way to go before they get all the discrete components they would like on a single chip; for instance, a bandpass frequency-control unit, radio-frequency detector, discharge capacitor and radio-frequency oscillator. It is now impossible to put the discharge capacitor on the



First IC for proximity fuzes will be installed on 81-millimeter mortar shells and later on 2.75-inch rockets. This circuit is being made by the Molecular Electronics division of the Westinghouse Electric Corp.

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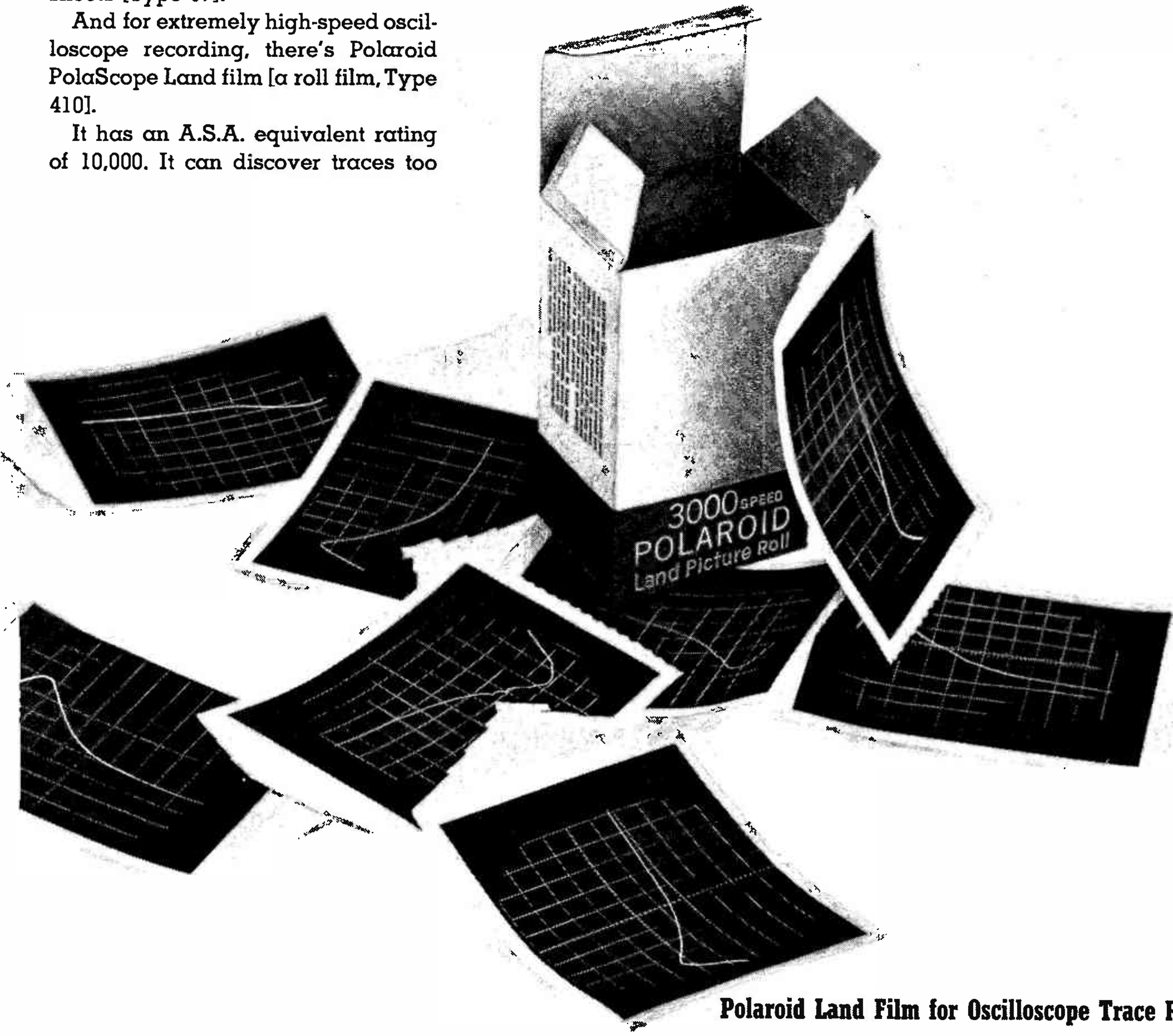


Polaroid Land Film for Oscilloscope Trace Recording.

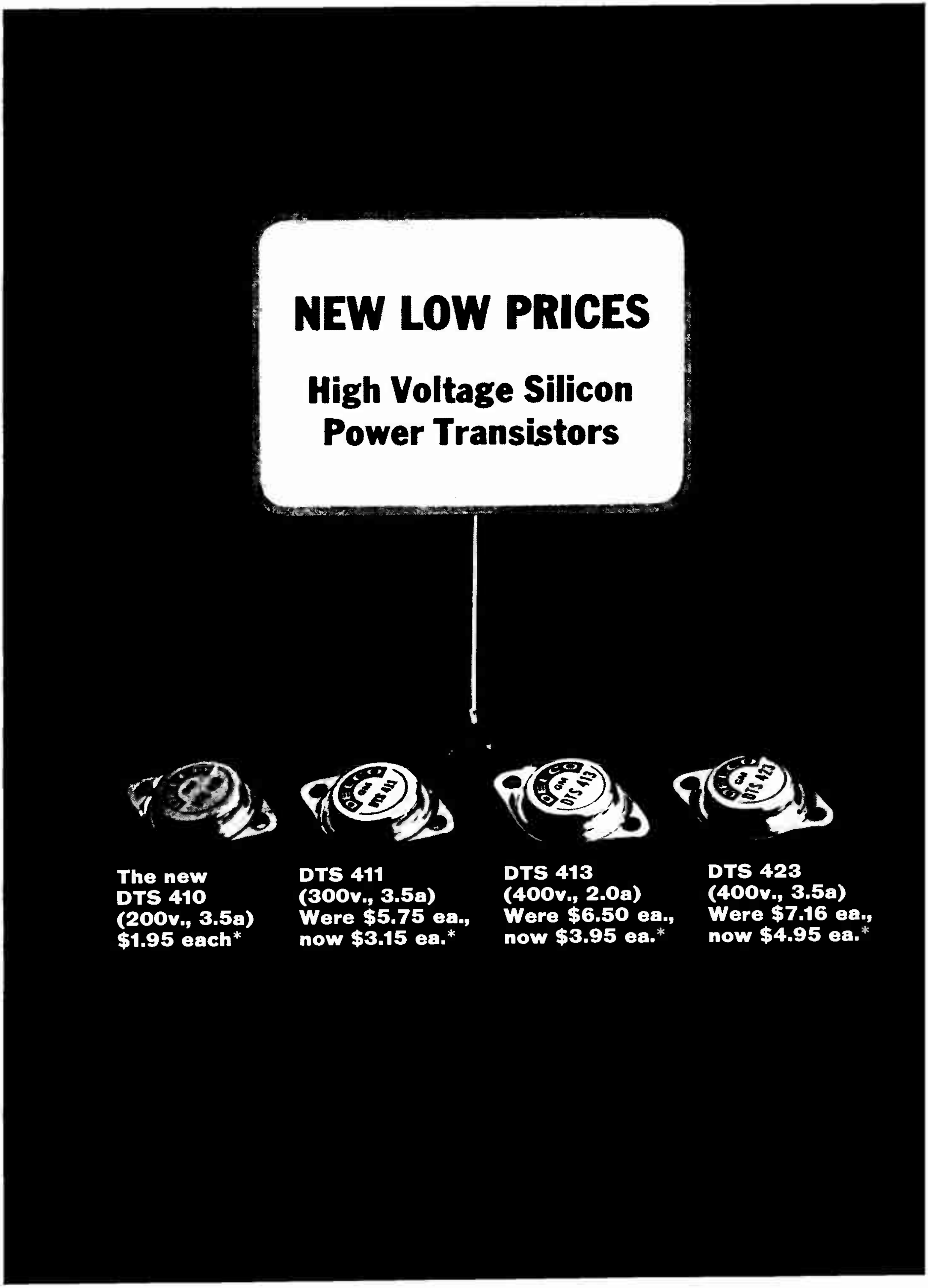
chip that stores the power to trigger the detonator. This is because the wattage available from the long-life storage batteries, which are not activated until the ordnance is fired, is still insufficient for such an application.

In addition, a debate is shaping up over the building block. There are currently two types in the running: the Westinghouse and Motorola prototypes and one that was developed in-house at Diamond Labs. Since the Westinghouse and Motorla assemblies are being built into the first hybrid proximity fuzes for 81-mm ammunition, they appear to have at least a temporary edge.

Diamond Labs built its chip on a pilot basis only to stockpile some design data against a possible future need. Critics of the simpler Army-developed chip note that it experiences frequency shifts that can trigger detonation before or after the preset distance is reached. But an official at Diamond Lab says the variations are tolerable in an operational fuze. On the other hand, the Westinghouse and Motorola entries permit virtually no variation in gain.

In addition to proximity fuzes, the Army is developing IC's for electronic timer fuzes. These fuzes will have a variety of uses, including the detonation of flares and antipersonnal ordnance. Officials at the Picatinny Arsenal, Dover, N.J., which is handling most of the development work, are interested in electronic fuzes that will be more precise and accurate than the mechanical clocks now in use. Among the companies at work on this project are Radio Corp. of America, Litton Industries, Philco-Ford Corp., Burroughs Corp. and Texas Instruments.

Bonus. There may well be some technological fallout from the proximity fuze venture. The development pace of analog IC's has trailed that of digital assemblies, largely because the former have lacked a volume outlet. With the Army turning to analog assemblies for proximity fuzes, however, production techniques may be refined to where lower prices permit an expansion of both military and commercial applications. The Air Force's Minuteman missile program had such a salutary effect on the development of digital IC's.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Solid state devices improve electrometer

Vibrating reed electrometer uses field effect transistor as replacement of input tube to increase reliability

A solid state vibrating reed electrometer (VRE) that has a sensitivity of 10^{-17} amperes is now available from Cary Instruments, a subsidiary of Varian Associates. Model 401 is a solid state version of the company's successful model 31 VRE. "Both instruments," says Don Parker, manager of Cary's electronic products section, "are at least 50 times more sensitive than any competitive vibrating reed device and about 1,000 times more sensitive than electrometers that use only tubes."

A VRE is primarily used to measure very minute electric currents and charge density, in such applications as determining Hall effect in organic and inorganic semiconductors and photoconductors; transistor leakage, the gate resistances of metal-oxide-semiconductor field effect transistors, and the electrical and electrochemical properties of materials. The instruments are also used to amplify the outputs of mass spectroscopes for easier reading.

In addition to its extremely high current sensitivity, the model 401 can detect charges as small as 5×10^{-16} coulombs, potentials down to 2×10^{-15} volts and resistances as high as 10^{16} ohms. A single switch on the instrument's front panel automatically makes the necessary circuitry changes for measuring current, charge and voltage.

The instrument detects current by measuring the electrons (charge) collected on a gas dielectric three-terminal capacitor. A small portion of the d-c voltage across this capacitor is converted to a-c by the vibrating-reed capacitor. The a-c signal produced is proportional to the collected charge. This signal is passed through an a-c amplifier, synchronously rectified, filtered and used to drive the indicating meter. A portion of the d-c output is applied as negative feedback to null the input signal and provide very high gain stability, low insulation leakage and rapid response.

Since voltage measurements are read directly on the instrument's meter, the amount of current can also be determined by reading the voltage across one of the three built-in calibrated input resistors. Resistance is measured by applying a known potential across the unknown resistance and measuring the resulting current.

Charge measurements are obtained by multiplying the meter reading by the value of the capacitor, which is 2×10^{-11} farads.

Cary reports that the key solid state device in its new model is a field effect transistor that replaces the input tube of conventional VRE's. The input tube is generally the hardest-worked component and tends to be the least reliable because of microphonic problems. The FET's noise level remains constant even with rough handling.

The 401 has five different recorder and digital voltmeter outputs (10, 25 and 100 microvolts, and 1 and 30 volts) and three power options: 117 v, 60 hertz; 220 v, 50 hz; and a 12 v, d-c battery.

Zero stability is rated within 100 microvolts for 24 hours with the input shorted and less than 10^{-17} amperes with the input open. The instrument has an inherent accuracy of ±0.1%, ±10 microvolts, and a meter accuracy of ±1% of full scale. These specifications remain constant while operating at temperatures ranging from 4°C to 40°C.

Included as standard equipment in the model 401 are a number of features which are available only as options for the earlier model 31, including remote resistor switching with three input resistors, remote input shorting, critical damping for faster response and a master-or-slave capability. The 401 is priced at $1,950, which is $300 more than the basic price, without options, of the model 31.

A high-voltage probe that extends the voltage range up to 30 kilovolts is available as an accessory. The probe is essentially a 0.02-picofarad capacitor that is isolated by an optically polished sapphire.

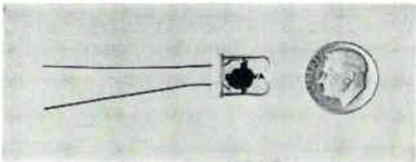
In addition to its primary use in electrical measurement, the 401 can measure soft beta radiation from such sources as carbon-14, tritium and sulphur-35; and it can make alpha particle counts even in the presence of substantial beta and gamma background radiation. Because of its high sensitivity, it should be useful in gas chromatography, where it could measure small amounts of carbon-14 in doped compounds. The instrument could also be used in biomedical research to measure ion transfer, skin potential and resistance across membranes.

Specifications

Voltage range	From 2×10^{-5} to 30 v
Current range	From 10^{-17} to 10^{-5} amps
Resistance range	From 10^{6} to 10^{16} ohms
Charge range	From 5×10^{-10} to 6×10^{-16} ohms
Zero stability	
with shorted input	100 μv for 24 hours
with open input	10^{-17} amps
Accuracy	±0.1%, ±10 μv
Operating temperature range	4°C to 40°C
Price	$1,950
Available	February, 1967

Cary Instruments, subsidiary of Varian Associates, 2474 S. Peck Road, Monrovia, Calif. 91016.
Circle **348** on reader service card.

Glass-encapsulated precision crystals



Higher Q, greater reliability and better frequency stability are offered by a series of miniature glass-sealed crystals than are obtained from crystal units in soldered containers.

The 76AX series units, measuring ½ x ⅜ x $\frac{5}{32}$ in., have aging rates of less than 1 part in 10^8 per day after initial stabilization, and are available in frequency ranges of 7.5 to 200 Mhz. They meet tolerances of 0.0025% over a temperature range of —55° to +105° C.

The new series is the equivalent of the HC-26/U leads and the HC-29/U pins.

Bulova Watch Co., Inc., 61-20 Woodside Ave., Woodside, N.Y., 11377 **[349]**

Vacuum relay offers variety of applications

A vacuum relay that, according to its manufacturer, is both tough and versatile—and a midget too— has a number of applications such as communication multicouplers and transmitters, laser power supplies, microwave-power, tube test equipment and high-voltage power supplies.

The unit is a single-pole, double-throw Kilovac relay with a rated operating voltage of 8 kv in air and 12 kv in oil. It will carry up to 15 amps rms continuous current at rated voltage. The relay has a maximum operating time of 18 msec and a maximum contact resistance of 0.015 ohm. It applies a standard 26.5-v d-c coil with resistance of 250 ohms. Other coil operating voltages are available upon special order.

The relay is compact and can withstand a 4,000-g shock for a

0.3-msec pulse. This makes it particularly advantageous in airborne communications systems and other severe environments. Reliability is enhanced because of operation in a high vacuum dielectric.

Other advantages are short contact travel, low contact mass, contacts free of oxides and pitting and minimum contact bounce.

Delivery of the H-12/S4 is 30 days after receipt of order. Price of the unit is $110 each in quantities of 1 to 9.

High Vacuum Electronics, 538 Mission St., South Pasadena, Calif. **[350]**

New products in this issue

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202 Vacuum relay

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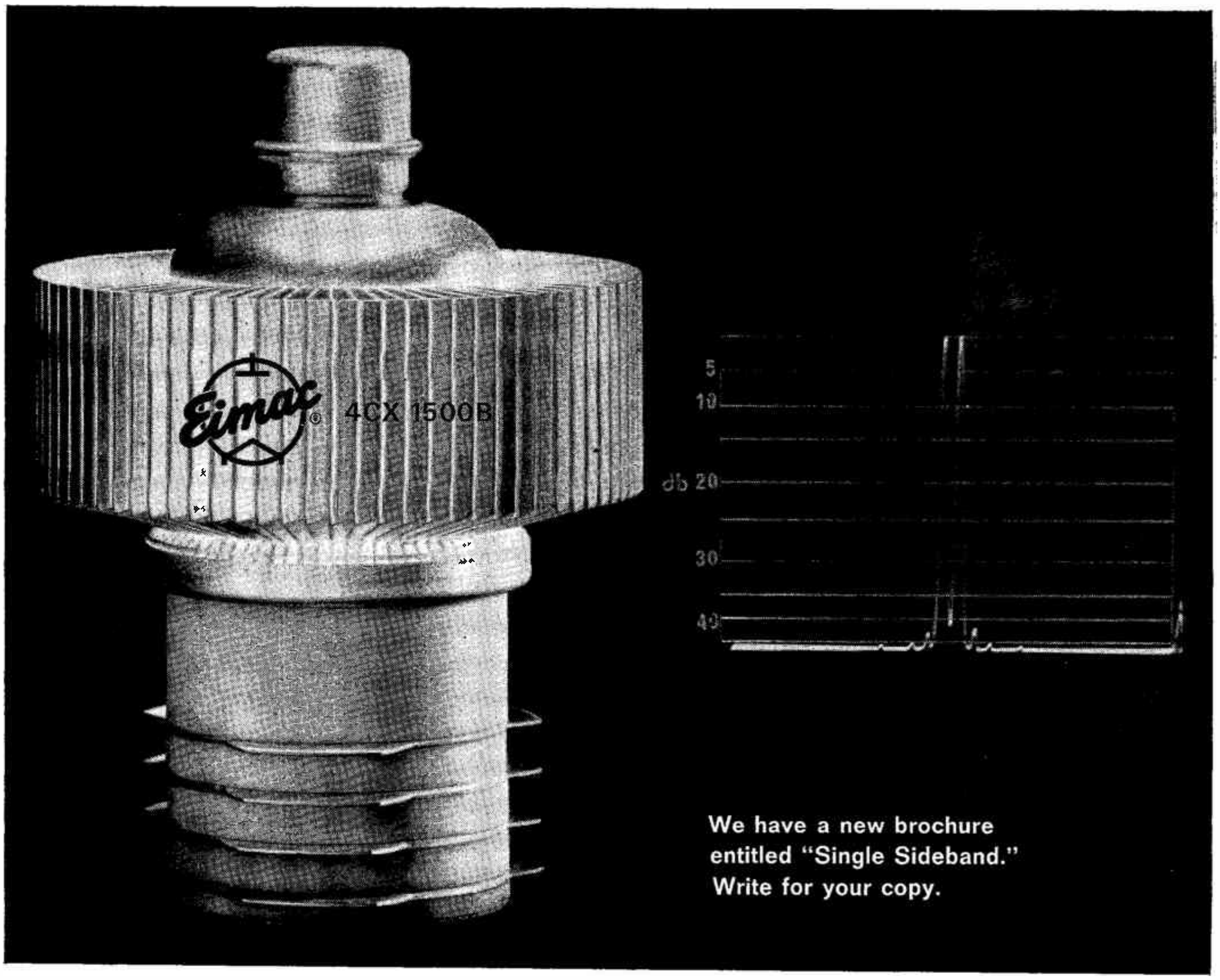
EIMAC offers new 1 kW PEP tetrode for SSB with highest linearity—at least -40 db in typical operation

EIMAC's new 4CX1500B power tetrode is the most linear tube on the market; intermodulation distortion characteristics under typical operating conditions are at least −40db at all drive power levels from zero to maximum. The new tube is ideal for advanced single sideband transmitters demanding high linearity to avoid channel-to-channel interference. The 4CX1500B is the product of a four-year development study which included optimization of internal tube geometry by computer techniques. Rated maximum plate dissipation of this radial beam tetrode is 1500 watts, and control grid dissipation rating is 1 watt maximum. Because the 4CX1500B has very low grid interception (typically less than 1.5 mA grid current), it is possible to drive the grid positive without adverse effects upon the distortion level; the tube is therefore recommended for Class AB_2 linear amplifier service. For further information, write Product Manager, Power Grid Tubes, or contact your nearest EIMAC distributor.

TYPICAL OPERATION (Frequencies Below 30 MHz)

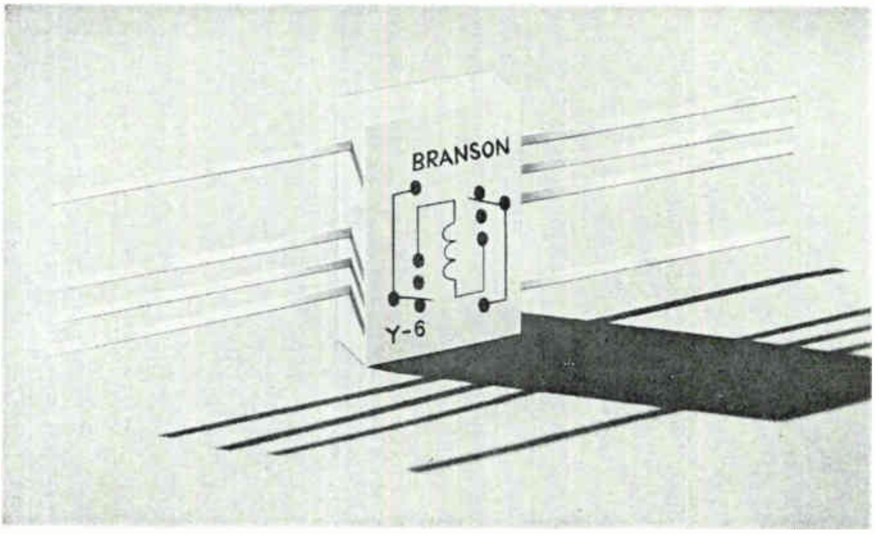
DC Plate Voltage	2500	2750	2900 volts
DC Screen Voltage	225	225	225 volts
DC Grid Voltage	−34	−34	−34 volts
Zero-Signal DC Plate Current	300	300	300 mA
Single-Tone DC Plate Current	720	755	710 mA
Two-Tone DC Plate Current	530	555	542 mA
Driving Power	1.5	1.5	1.5 watts
Useful Output Power	900	1100	1100 watts
Intermodulation Distortion Products			
3rd Order	−38	−40	−40 db
5th Order	−47	−48	−48 db

EIMAC
Division of Varian
San Carlos, California 94070



Circle 203 on reader service card

Fitting relays into flatpacks



Relays that are compatible with integrated flatpack circuitry are the latest offering from the Branson Corp. The devices have been squeezed into TO-87 flatpacks, ⅜ by ¼ by 1/10 inch, with ½-inch long ribbon leads.

Branson believes its relays are the first to be packaged this way, and reports that the packages are a third to a half the size of conventional crystal can relays. The company sees initial applications in portable communications systems, weapons delivery equipment and high-density printed circuit boards in aircraft and missile control systems, where small size is mandatory.

The relay is entirely contained within an alumina case that is insulated from ground, and provides the thermal conductivity needed to dissipate any heat from the coil. The coil itself is wound directly on the one-piece, soft iron core over an insulating film. The ends of the core are the magnetic poles which mate with the center-pivoted balanced armature.

As the actuating voltage, either 6, 12 or 24 volts, is applied to the coil, glass-tipped actuators move the gold-plated contacts, made of silver, magnesium and nickel, within each pole of the relay. Only 250 milliwatts of coil power is required. The unit operates and releases in one millisecond.

The small relay, Branson says, is extremely rugged. The armature itself can withstand vibrations of up to 3,000 hertz at levels of 50 gravities. The shock rating for the entire relay is 50 g's for 11 milliseconds. The devices will work at class B military temperatures—from −65° to +125° C.

Branson Corp., P.O. Box 845, Denville, N.J., 07834 [351]

Specifications

Coil voltage	6, 12 or 24 volts
Contact resistance	About 50 milliohms
Contact and lead resistance	Less than 100 milliohms
Rated contact life	100,000 operations
Price	$45
Delivery	60 days for sample quantities

Patch panel features high contact density

A patch panel, accommodating 800 pin and socket contacts in a space approximately 12x8x5 in., has been developed for telemetry and missile and spacecraft instrumentation systems as well as for data processing applications. The same design principle can provide 1,200 circuits in a single unit.

Previously, contact densities of this magnitude have presented problems due to the excessive mating forces required, contact bending, misalignment, molding and

New Components

manufacturing tolerances. In this patch panel excessive mating and unmating forces are overcome with a cam-type engaging device that converts rotary motion into axial motion and provides a mechanical advantage to allow easy manual mating and unmating.

Misalignment, contact bending, molding and tolerance difficulties are solved by dividing the contacts into smaller groups. Multiple insulation blocks contain independent guide-pin systems that automatically align the individual groups of contacts. Socket inserts are held firm while pin inserts float for proper contact alignment. Inserts have closed entry to prevent marginal continuity problems.

The patch panel is claimed to be the first of its size with pin and socket contacts that offer an inherent reliability and low millivolt drop (1 mv maximum at 1 amp d-c). This drop is less than the maximum mv drop specified by MIL-C-26500 for connectors. The crimp type removable contacts employ a standard MS3191 crimping tool.

Versatility in design allows many combinations of circuitry to be pre-programed and sealed, permitting permanent, removable programing to coincide with data processing tapes. The unit also functions as an in-work patch panel since the inserts can be reprogramed while mated or unmated.

The plug and receptacle inserts are identical and can be inserted in either position allowing maximum freedom in combining pin and socket applications and reducing spares and logistics problems. Inserts can also be mounted indi-

Today, Hughes is one of the nation's most active aerospace/electronics firms: Projects include: F-111B PHOENIX Guided Missile System, TOW Anti-Tank Missile, SURVEYOR Lunar Spacecraft, SYNCOM, POLARIS, VATE, Hard Point Defense and others.

This vigor will assist the qualified engineers and scientists towards more and better opportunities for both professional and personal growth.

Many immediate openings exist. The engineers selected for these positions will be assigned to the following design tasks: the development of high power airborne radar transmitters, the design of which involves use of the most advanced components; the design of low noise radar receivers using parametric amplifiers; solid state masers and other advanced microwave components; radar data processing circuit design, including range and speed trackers, crystal filter circuitry and a variety of display circuits; high efficiency power supplies for airborne and space electronic systems; telemetering and command circuits for space vehicles, timing, control and display circuits for the Hughes COLIDAR (Coherent Light Detection and Ranging).

If you are interested and believe that you can contribute, make your appointment today.

For immediate consideration, please airmail your resume to:

Mr. Robert A. Martin
Head of Employment
Hughes Aerospace Divisions
11940 W. Jefferson Blvd.
Culver City 20, California

Creating a new world with electronics

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vidually with a single engaging mechanism for stationary data processing applications where substantial quantities of inserts would be required.

The stainless steel patch panel box contains a seal for r-f interference shielding and an environmental seal. A pressure relief valve compensates for sudden changes in altitude during environmental testing. Weight of the unit is 15 lbs.

Amphenol Space & Missile Systems, a division of Amphenol Corp., 9201 Independence Ave., Chatsworth, Calif. [352]

Crystal oscillators offer high stability

With the help of an integrated-circuit, proportionally-controlled oven, the model CO-204 crystal oscillator provides a mean-time-between-failures exceeding 100,000 hours. The 2x2x4-in. plug-in module offers a stability (aging rate) better than 1×10^{-9} per day, and operates over −20° to +71° C, with −54° to +75° C operation optional.

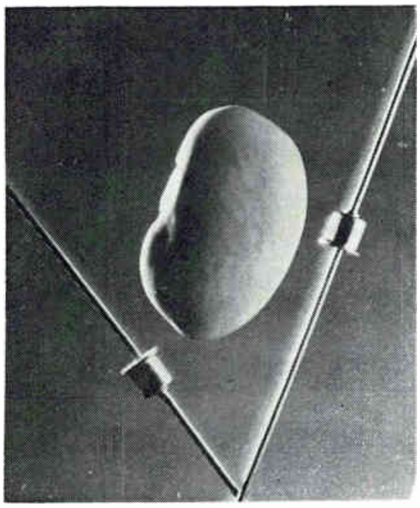
Despite low power drain, the CO-204 has fast warm-up characteristics. Within 60 minutes after turn-on, the output frequency is typically within 1×10^{-9} of its output several hours thereafter.

Other units in the company's newly announced line range in stability from 1×10^{-8} per day through 3×10^{-9} per day.

Vectron Laboratories, Inc., 146 Selleck St., Stamford, Conn., 06902. [353]

New Semiconductors

Low-cost, high-speed tunnel diode



A new batch manufacturing technique, developed by the Semiconductor Products department of the General Electric Co. has broken the price barrier for tunnel diodes in high speed logic circuits. Prices are as low as 50 cents in quantities of 100,000 and clock rates are typically 100 megahertz, with rates as high as 400 Mhz being reported for the devices in some hybrid logic circuits.

The new diodes are the latest link in a chain of tunnel diode developments. Early tunnel diode structures were extremely fragile, looking much like a golf ball placed on an inverted tee. Also they had to be made one at a time, a requirement not conducive to low costs.

About a year ago the Semiconductor division of Sylvania Electric Products, Inc. developed a batch process for making tunnel diodes in what it termed a "solid structure." The structure was rugged and opened the way to low-cost manufacture of tunnel diodes. But the Sylvania devices were designed chiefly for the microwave market, and their prices range from $10 to $75.

There are five diodes in the GE's TD 700 line, with peak currents of 0.5, 1.0, 2.2, 4.7 and 10.0 milliamperes. Their military counterparts, the TD700-H line, are identical but will operate at temperatures up to 125°C. Power dissipation is about 40 microwatts.

General Electric's batch process technique starts with wafers of germanium. Using conventional photomasking, a thin film of silicon oxide is first laid down, then a thin film of chromium. The junction-forming metal is deposited next; it overlays the chromium and the exposed germanium. The wafers then go through an oven where all the junctions are alloyed. After dicing of the wafers, the resulting pellets are mounted to headers and the leads are attached. Finally the germanium is etched away to provide the proper peak current value and a cap is welded to the header.

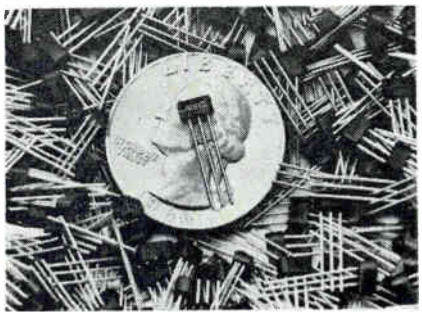
The diodes are available either in the axial lead package shown at the left (with a navy bean for size comparison) for conventional circuits or in pellets for use in hybrid IC's.

Specifications

Peak currents	0.5, 1.0, 2.2, 4.7 and 10.0 ma
Current rate	100 Mhz, typical
Peak voltage	90 mv, max.
Power dissipation	40 μw, typical
Price range	50¢ to 90¢ in 100,000 lots
Availability	Sample quantities from stock

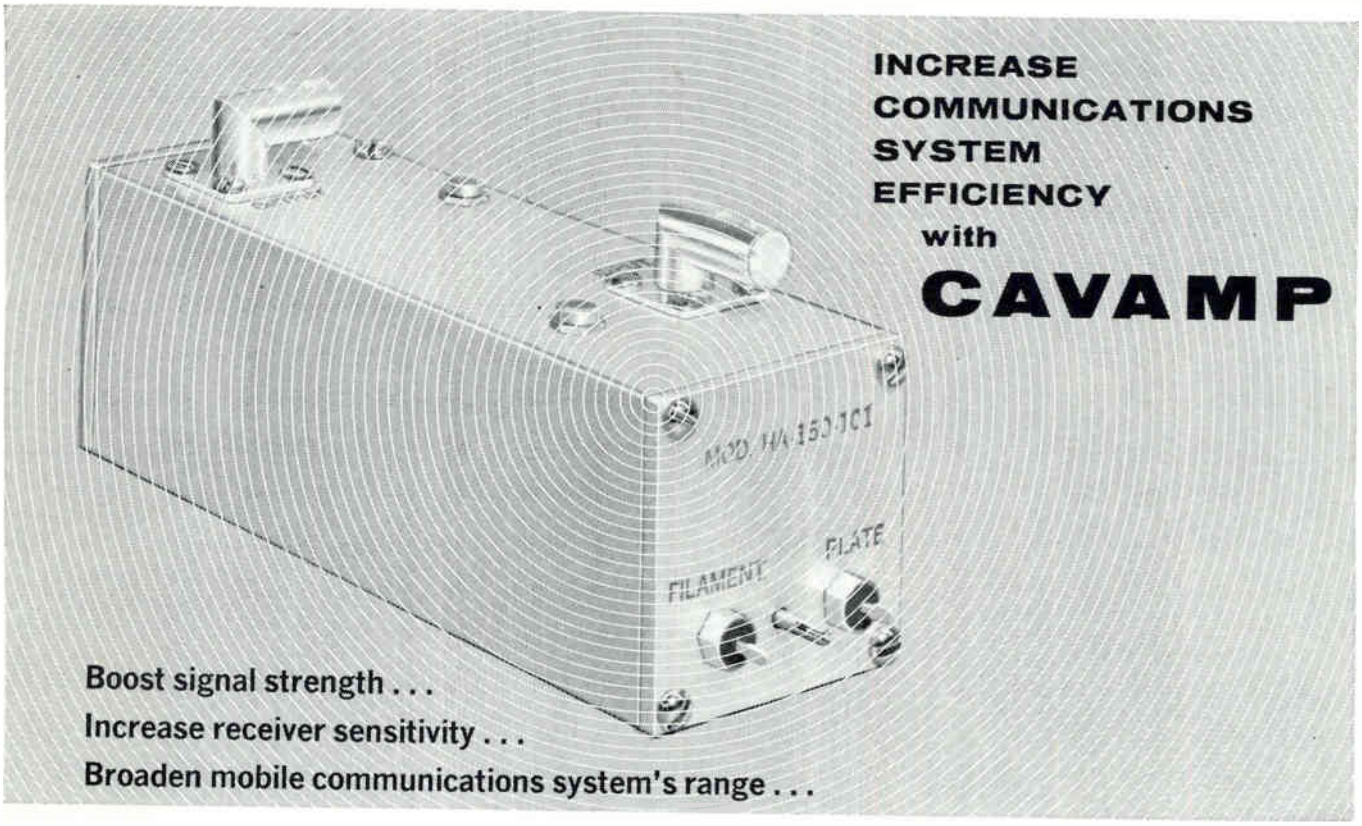
General Electric Co., Semiconductor Products department, Schenectady, N.Y. **[361]**

Npn, pnp transistors come in 10 models



New materials, assembly techniques and automated testing have made possible a line of 10 npn and pnp general-purpose transistors priced at about 25 cents each.

The transistors have the usual inherent performance and stability characteristics of silicon devices.



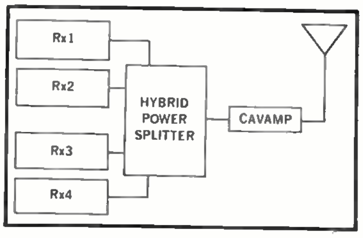
How? With Sinclair's Cavamp. For use in compact duplex or multicoupler systems, Cavamp combines amplifier with filter to reduce noise while boosting signal strength.

Cavamp is capable of quieting receivers of .6 microvolt sensitivity with less than .2 microvolt signals, supplying gains of up to 14 Db at a 5Db noise figure. It incorporates a double-ended 8058 nuvistor that insures greater overload protection (1 milliwatt maximum input) and lower intermodulation product levels.

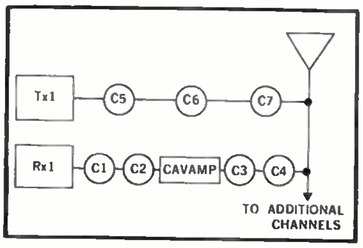
Cavamp incorporates a narrow band pass filter to increase receiver selectivity.

Transmission line losses are offset, or receiver front end sensitivity is increased, improving system performance.

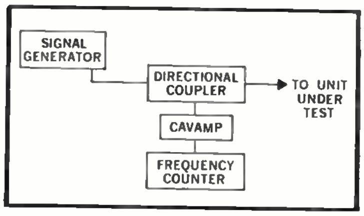
Designed for the 150 and 450 MHz range, Cavamp is factory tuned to your specific frequency, however, can be easily field retuned to any frequency in the band by making two screwdriver adjustments.



Receiver multicoupling for closely spaced receivers:
Four receivers, separated by 50 KHz, connected to a hybrid power splitter providing each with 25 Db isolation: power splitter loss of 6.5 Db offset by Cavamp with 12 Db gain. Band pass filter characteristic also protects receivers from nearby transmitters.



Receivers and transmitters connected to a common antenna with a passive multicoupler for an expandable system:
Transmitter, Tx1, separated from receiver, Rx1, by 500 KHz. Cavities C1,2,3,4 insert 6 Db loss at Rx1 frequency, 80 Db attenuation against Tx1. Cavities 5,6,7 insert 1.5 Db loss at Tx1 frequency, attenuate Tx1 noise at Rx1 frequency by 35 Db or more. 6 Db insertion loss not degrading to receiver operation: Cavamp offsets filter losses, provides 6.0 Db gain on Rx1.



Increasing sensitivity of frequency measuring system:
Where frequency counter is used, high signal strength is often required to drive the counter. Cavamp increases counter sensitivity while the selectivity reduces false triggering from unwanted signals.

Clip the coupon and attach to your letterhead for full details and prices.

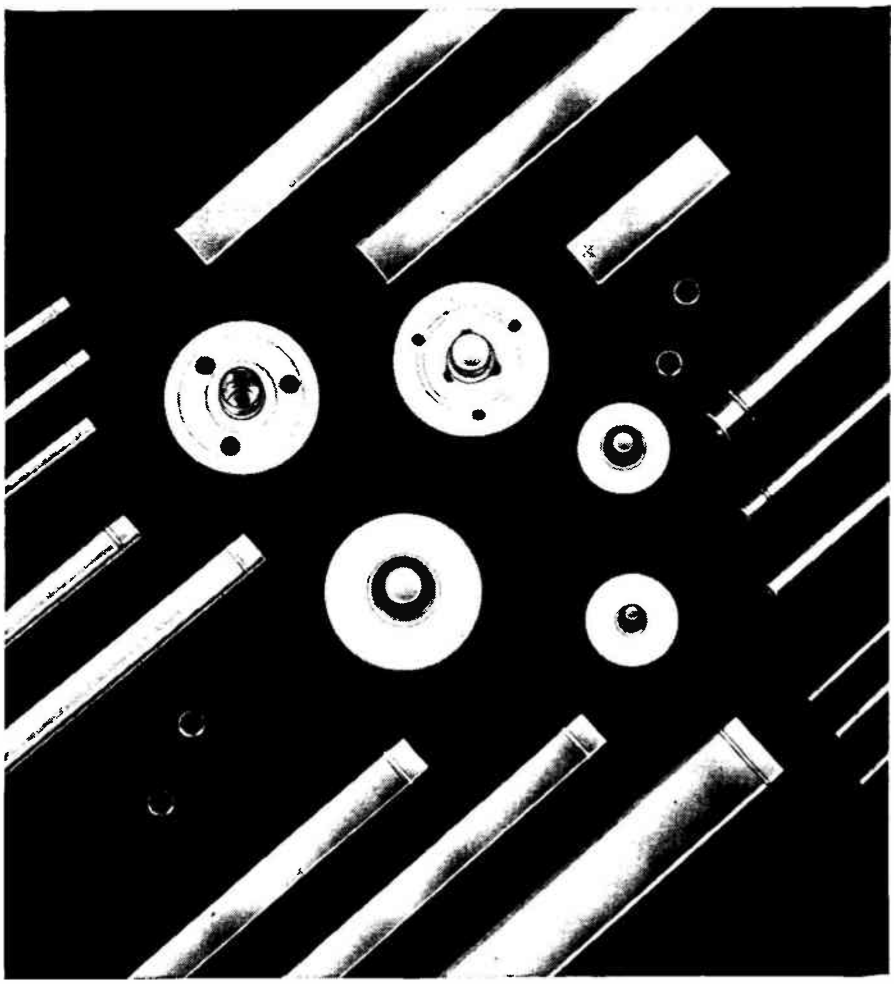
SINCLAIR RADIO LABORATORIES, INC.

523 FILLMORE AVE. DEPT. 101-P TONAWANDA, NEW YORK

FREE LITERATURE

TO: SINCLAIR RADIO LABORATORIES, INC.
Dept. 101-P 523 Fillmore Avenue
Tonawanda, New York 14152

Name:__________
Title:__________
Company:__________
Address:__________
City:__________
State:__________ Zip:__________



The line includes low-level, high-gain units, uhf transistors and diffused epitaxial types. Applications include data processing, communications, radio, television, and home entertainment products.

Type numbers for the GEM transistors are 2N3793, 3794, 4284, 4285, 4286, 4288, 4290, 4291, 4292 and 4293. Power dissipation is typically 250 mw.

Additionally, the construction of the units permits access to the transistor connections from the top of the p-c board for testing and troubleshooting. Standard lead configuration is in-line (E-C-B). The leads can be bent to standard TO-18 or TO-5 configurations at a nominal cost.

National Semiconductor Corp., Danbury, Conn., 06810. [362]

Npn transistors offer large d-c safe area

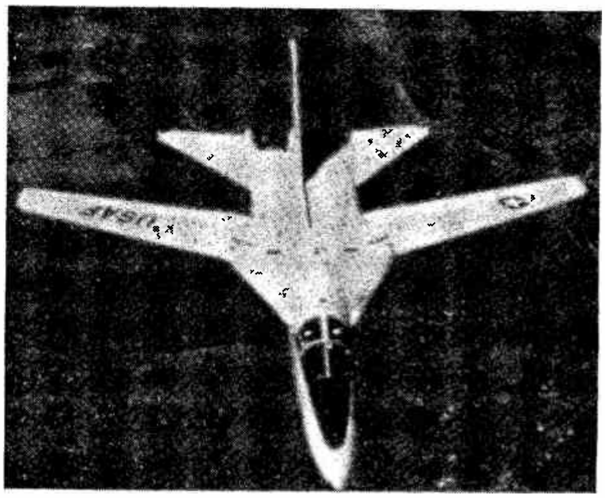
Two silicon npn transistors of planar epitaxial construction offer 30-w d-c safe area at 100°C case temperature with a 5-amp capability.

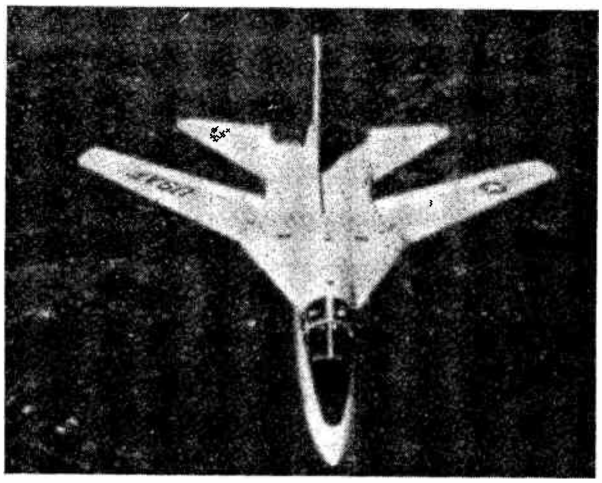
The 2N4115 and 2N4116 link Nichrome resistors in series with the emitter to provide a larger d-c safe area than previously possible; this in turn broadens the applications of planar devices in military and aerospace systems.

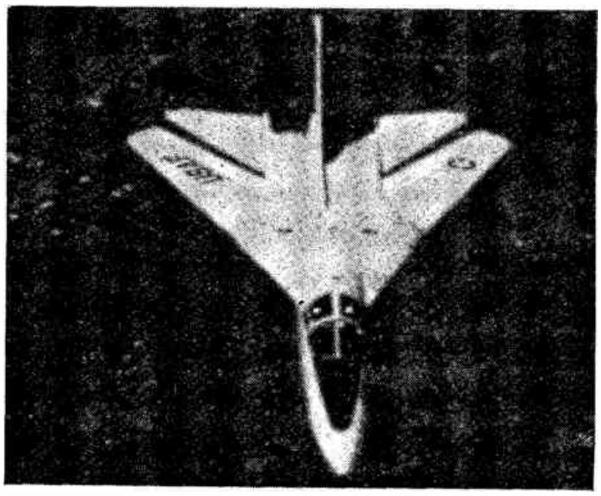
The devices have a breakdown voltage (BV_{CEO}) of 80 v minimum and a low 5-amp collector-saturation voltage of 1.5 maximum. The 2N4115 offers a beta of 40 to 120 at 2 amps and a high gain bandwidth product of 70 Mhz; the 2N4116 offers a 100 to 300 beta at 2 amps and a high gain bandwidth product of 80 Mhz.

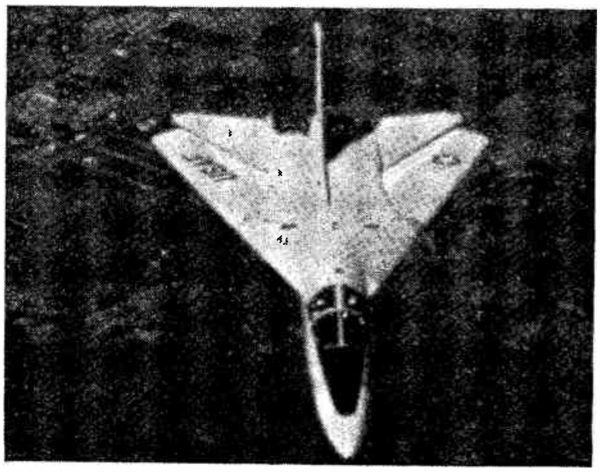
Available in the isolated collector TO-59 package, the transistors are guaranteed over the full military temperature range. Prices for the 2N4115 are $36 for 1 to 99, $24 for 100 to 999; for the 2N4116, $48 for 1 to 99 and $36 for 100 to 999.

Fairchild Semiconductor, a division of Fairchild Camera and Instrument Corp., 313 Fairchild Drive, Mountain View, Calif. [363]

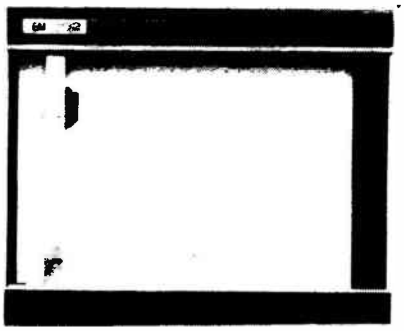








X-y recorder priced for equipment market



A single-range, 11x17-in. x-y recording system has been introduced for the original equipment manufacturers' market. The Variplotter is particularly suited for displaying outputs from special-purpose systems, such as material and engine-testing machines and aircraft simulators, says the manufacturer. Access to data input connections and some controls is from the rear to facilitate system application. All primary controls are accessible from the front.

Features of the plotter include a ±0.1% of full-scale static accuracy, a 10 x 15-in. plotting area, 20 in. per sec slewing speed on each axis. Any sensitivity between 1 mv per in. and 20 v per in. may be specified by the customer for each axis; 100 mv per in. is standard.

The series 1132 Variplotter is priced at $1,190, a cost normally associated with smaller units the company says. Delivery is 30 days from receipt of order.

Electronic Associates, Inc., West Long Branch, N.J. [371]

Precision phasemeter covers 30 hz to 20 khz

A wideband primary precision phasemeter is accurate enough for laboratory work and is also suitable for more general applications or in production testing.

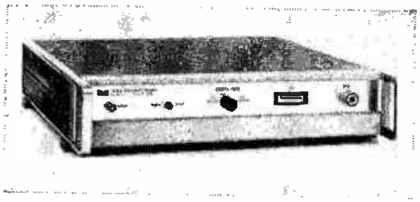
Specifications include an accuracy of ±0.1° absolute; frequency

range, 30 hz to 20 khz continuous coverage; phase range, 0 to 360°; resolution, 0.01°; input voltage, 0.5 v rms to 10 v rms for the basic unit; permissible harmonic distortion, 1% second, ½% third; input impedance, 10 megohms shunted by 25 pf; recorder output, 50 μa per degree on 600 ohms (approx.); power supply, 105 to 125 v, 60 hz, 250 w.

The unit, model 910, measures

20x15x15½ in. and weighs approximately 90 lbs.
Bramson Instrument Co., 176 Federal St., Boston, Mass., 02110. [372]

Frequency divider gives direct display



An automatic frequency divider enables high-frequency electronic counters to measure microwave frequencies through X band. The display is direct and complete, requiring no further calculations.

Model 5260A operates over all of the most used portion of the microwave region, 0.3 to 12.4 Ghz. It accurately divides input frequencies up to 1.2 Ghz by a factor of 100 or, when the input is within the range of 1.0 to 12.4 Ghz, by a factor of 1,000. The divided-down frequency (1 to 12.4 Mhz) is supplied to the counter. The divider introduces no error of its own and measurements thus are as accurate as the electronic counter, according to the manufacturer.

The new frequency divider is, in a sense, an automated transfer oscillator but contains elements of both heterodyne converters and transfer oscillators. An internal oscillator is phase locked to a submultiple of the input frequency. A second oscillator is phase locked to the first one in such a way that exactly 1/100 or 1/1,000 of the input frequency can be derived. No frequency error is introduced and measurements are made with the basic accuracy of the associated counter.

The frequency divider works with input signal amplitudes greater than 100 mv and a front panel meter indicates when the signal level is within the proper amplitude range (—7 dbm to +10 dbm). Input impedance is 50 ohms and the vswr is relatively constant and less than 1.6:1 up to 10 Ghz. Vswr is less than 2:1 up to 12.4 Ghz. Price of the divider is $3,250.
Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif., 94304. [373]

Linear transducer features long life

A linear position transducer, with the Infinitron resistance element providing continuous resolution, has a much longer life than an equivalent wirewound unit, the company claims, and retains many of the desirable qualities of wirewound elements.

Specifications of the model 177 include: resistances, 250 to 15,000 ohms; resistance tolerances, ±5%; noise, 100 ohms; power rating (40°C), 1.5 watts per inch; temperature coefficient, 300 ppm/°C maximum; insulation resistance, 50 megohms; independent linearity, 0.75%.

In addition, the model is designed with a self-aligning shaft and is rated at 40 g for vibration, 100 g for acceleration and 50 g for shock. It has a resistance change with humidity of less than ±5% and meets environmental conditions of MIL-E-5272. The transducer ranges from 0.5 in to 1 in. and is available with single or dual potentiometric output.

Bourns, Inc., Instrument division, 6135 Magnolia Ave., Riverside, Calif., 92506. [374]

Digital voltmeter provides BCD output

A low cost, solid-state digital voltmeter features an accuracy of ±0.05% of reading ±1 digit; reading time of 0.6 sec filtered, 20 msec with filter bypassed; constant input impedance of 10 megohms; automatic polarity selection and indications and BCD output.

A reading storage feature provides bidirectional tracking without blinking. The meter is of modular construction and consists of a basic unit and plug-ins specific to the measured parameter.

Models 251 and 252 with their applicable plug-ins are multirange digital voltmeters. The 251 is characterized by resolution to 1 part in 10,000 (0.01%) and three ranges, 9.999, 99.99 and 999.9 v. Resolution to 1 part in 3,000 and ranges of 2.000, 20.00, 200.0 and 1,000 v are basic to the model 252. Because of its fast reading time (20 msec) the model 252 is well suited for systems applications.

Basic model 251 lists for $525

and model 252 lists for $435. The plug-in units, 251-1 and 252-1, list for $150 each.
United Systems Corp., 918 Woodley Rd., Dayton, Ohio, 45403. [375]

Sweeper divider occupies small space

A sweeper divider, model SD-10, accepts input from any standard h-f sweeper or signal generator and provides output at either 1/10, 1/100, or 1/1000 of the drive frequency. This frequency division not only translates the range of a sweeper to the lower frequencies, but also multiplies the effective stability so that narrow band measurements are feasible. Marker generators within the h-f sweeper are useful at their divided frequencies using this technique.

The SD-10 is housed in an enclosure 5½ in. long x 1½ in. wide x 4¼ in. deep, occupying very little bench space. All connectors are BNC, except for the power input which uses a standard banana plug.

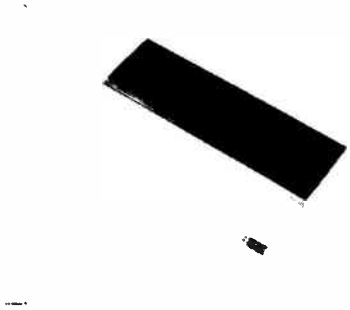
A d-c supply of 3.6 v is required. Other models are available with internal a-c supply.

The sweeper divider is priced at $99.50. Delivery is from stock.
Aerospace Research, Inc., 130 Lincoln St., Boston, Mass., 02135. [376]

Capacitance probes measure precisely

A series of capacitance probes, capable of measuring to 20 billionths of an inch, have been developed for industrial and laboratory use. The largest (shown at top of p. 218) is rectangular in cross section, 6 in. long, and is used for measurement in nuclear reactors. The two smallest probes (with different terminations) can measure to 0.1% of their

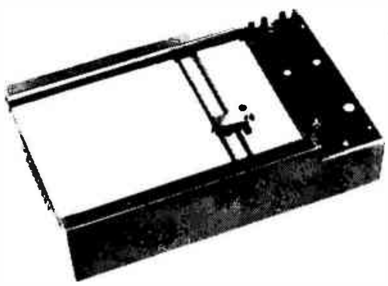
Circle 217 on reader service card



total displacement range, which can be as small as 20 millionths of an inch, and were developed to measure within gas bearings. They have a diameter of less than 20 mils and are part of a complete system which has a long-term stability of less than 0.25% and a frequency response of 10 khz or over.

The probes have a linearity of 0.2% and can measure significantly less. Probes and leads are available for temperatures to 1,900°F. The manufacturer has experience in applying these probes to measurements in almost all environments. Leads of up to 50 ft have been used. MTI Instruments division, 968 Albany-Shaker Road, Latham, N.Y., 12110. [377]

X-y plotter designed for flight applications



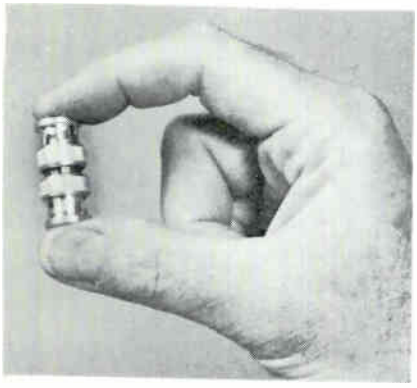
An 8½- by 11-in. low-cost analog x-y plotter operates from 400 hz a-c power. The transistorized Plotamatic Model 680-400 is suited to aircraft ground-support and flight applications, operating directly from the aircraft power supply.

Model 680-400 incorporates a new servo amplifier design which improves reliability and frequency response, with full-scale accuracies of 0.2% (both axes) and repeatibility of 0.1%. Increased stability is assured by a temperature-compensated zener bridge voltage reference circuit. A voltage range of 100 mv/in. is standard; other ranges are available on order. Operating temperature range is 0° to 50°C, and input impedance is constant at 1 megohm.

Other standard features include full-scale zero adjust plus 100% offset, sealed follow-up potentiometers, new nonclog vacuum paper hold-down and easily replaceable ink cartridge.

Data Equipment division, Bolt Beranek and Newman, Inc., Santa Ana, Calif. **[378]**

Universal multiplier covers 0 to 10 Ghz



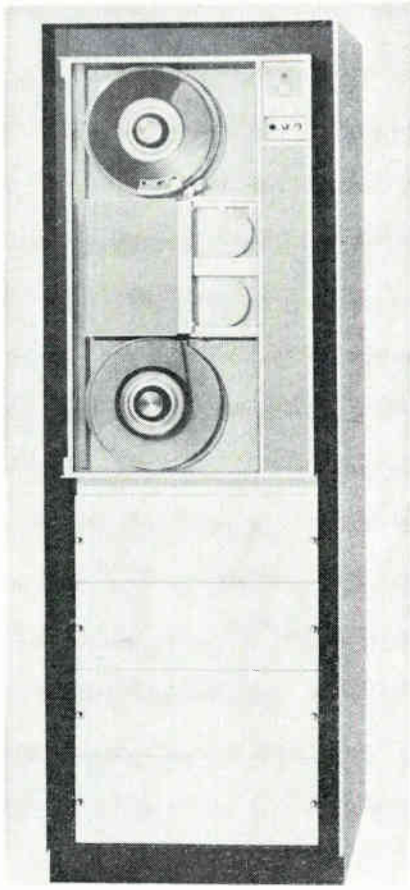
A universal, step-recovery diode multiplier has been designed to meet the need for a single harmonic generator and pulser that covers the entire 0-to-10 Ghz spectrum from audio frequencies through radio frequencies to vhf, uhf and shf. Model BS30 also is extremely light weight, 0.5 oz, and features very high conversion efficiency, approaching 200% divided by the harmonic number, and relatively high power output (10 mw at 500 Mhz produces 7.0 mw at 1,000 Mhz).

For high efficiency output at a single frequency, an external cavity, tuning stub or tank circuit is used. Conversely, for a comb of harmonics, the external output circuit should have a low Q.

As the basis of a pulse generator, the instrument provides pulses with less than 1-nsec rise and fall times and pulse amplitude in excess of 10 v into 50 ohms.

Somerset Radiation Laboratory, Inc., 2060 North 14th St., Arlington, Va., 22216. **[379]**

Digital recorder handles data bursts



The ADR-100 Asynchronous Digital Recorder with four times the acquisition speed of presently available equipment for the same purpose, marks the entry of the 3M Co. into the computer equipment field. The ADR-100, developed by 3M's Revere-Mincom plant at Camarillo, Calif. is a data processor, designed to allow more efficient use of expensive computer time, without loss of even random data. It's claimed to be adaptable to nearly 90% of the computers now on the market.

Basic advantage of the ADR-100 is its ability to handle information in random bursts an dat irregular rates. Typical inputs can be temperature, pressure and flow signals, light intensities, or accelerations. In addition to engineering and scientific data, it can also process stock control records and other business information, and can be incorporated into computer systems for warehouses, banks and credit systems. The unit organizes input information and records it on magnetic tape for a standard output, making maximum use of computer running time. Such tapes remove certain performance burdens from the computer, and eliminate time delays between data groupings.

Design of the ADR-100 has eliminated the need for an internal core memory, which with extensive use of integrated circuits has brought the price of the unit down to the $10,000 to 15,000 range. Reliability of IC's is also expected to reduce downtime and maintenance, providing further savings.

The recorder provides another important service as an information converter: punched tape to magnetic, cards to tape, and optical inputs to tape. Data conversion rates are estimated to be up to six times those of present units, and forseeable improvements could increase the ratio to 100 to one.

The unit will be available early in 1967, either in standard 19-inch equipment rack form, 69 inches high, or in a castored console with horizontal tape deck.

Specifications

Format	IBM-compatible 7- or 9-channel
Write mode	Asynchronous, 0-2000 characters per second
Read mode	Continuous at 12.5 inches per second ±2% forward
Packing density	Up to 800 bits per inch
Improved skew	Less than 250 microinches
Start time	Less than 5 milliseconds
Stop time	Less than 5 milliseconds
Tape	½-inch, 10½- or 8-inch plastic reels

3M Co., Revere-Mincom division, 300 South Lewis Road, Camarillo, Calif. 93010 **[381]**

System selects peaks, then memorizes them

A solid state electronic peak selector and memory (PSM) system uses noncontinuous signals for closed-

loop process control. The system, consisting of the model 91-100P peak selector unit and one or more model 91-100 M memory units, is designed primarily for chromatographic readout, but it may be used in rapid rise industrial processes requiring peak picking and electronic memory storage. A memory unit is required for each signal that must be memorized.

The system senses the momentary peak value of a standard noncontinuous 10 to 50 ma d-c signal, locks onto the peak and continuously transmits it to a receiving device. The peak picker holds the maximum peak, or input, value until the peak selector encounters a new peak with a positive slope. The new peak can occur at the elution of the next component in chromatography or it can be a programed signal in an industrial process. Storage loss of the locked signal is less than 0.25% per hour, permitting long delays between input signals.

The PSM system converts the chromatograph's pulse signal into a continuous signal for trend recording and for analog or digital control. It also converts the peaks of a flash-point analyzer saw-tooth record into a continuous signal.

In digital control, the noncontinuous milliamp output signal from a chromatograph is transmitted to a peak selector. As the peak signals appear at the peak selector output, the chromatograph programer sends a "come read" signal to the digital computer. The computer scans the output and locks onto the peak signal.

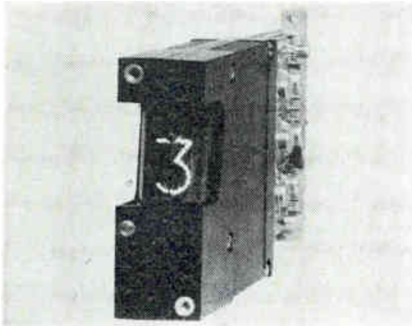
Units in the system are virtually identical. The peak selector can be changed to a memory unit by removing a jumper, across two easily accessible terminals on a board, at the front of the instrument.

The system has a wide range. Peaking time of the input signal may vary from a minimum of ½ second to a maximum of 5 minutes.

Repeatability is 0.25% of span. Accuracy is ±0.5% of span. Deadband is ±0.5% of span.

The Foxboro Co., Foxboro, Mass., 02035. **[382]**

Decade counter goes forward, backwards



A bright, clear in-line numerical display (plus decimal point), base preset and 8-4-2-1 bipolar binary-coded decimal outputs are some of the features of a high-speed, forward-backward decade counter. Model IC-803 will accept forward, backward and reversing signals, either periodic or aperiodic, over the range of 0 to 3 Mhz and requires no additional circuitry or modules for reversing. Since the unit has no reversing delay, it will change count directions at the full 3-Mhz counting rate.

Packaged in modular form, the 3x1x6¾ in. unit is available individually or mounted, with other similar units, in complete modular packages for original equipment manufacturer instrumentation applications.

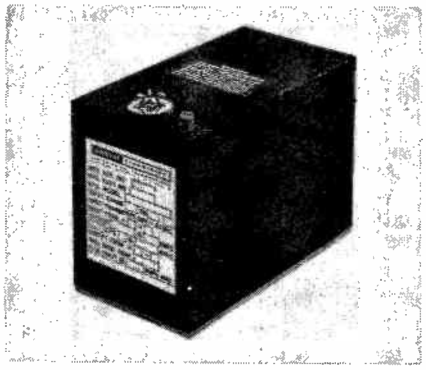
The BCD output is 0.3 v for a binary 0 and 4.5 v nominal for a 1.

Price in quantities of 100 is $96.90 each; delivery, from stock.

Janus Control Corp., 296 Newton St., Waltham, Mass. **[383]**

Static inverters power 400-hz devices

A Hi-Temp static inverter, model S6D, converts 28 v d-c to 400 hertz sine wave voltages of 115 or 26 v



a-c. With continuous full-load operation at 212°F, it supplies an output power of 60 volt-amps.

Modular design techniques are used to provide a package as small as 3x5½x4 in. which weighs less than 4.2 lbs. Components include all silicon semiconductors assembled with thermal design to produce a highly reliable inverter, according to the manufacturer. True hermetic sealing and full encapsulation enable the unit to meet the environment of MIL-E-5272C at the higher temperature of 100°C.

Regulation is 0.2% for input variations of 24 to 30 v d-c. Frequency stability is less than 1%. Other features include complete isolation of inputs and outputs and an output voltage adjustment range of 12% from the nominal output voltage. The module is also protected against short circuit conditions, input voltage transients and reverse polarity damage. These inverters can power 400-hz motors, gyros or any other 400-hz devices.

Price is as low as $675 each.

Abbott Transistor Laboratories, Inc., 3055 Buckingham Road, Los Angeles, Calif., 90016. **[384]**

L-v supplies protect against overloads

All-silicon, well-regulated d-c power supplies are designed for use with integrated circuits, micro-modular circuits and other low-voltage semiconductor circuitry. An over-voltage crowbar protection circuit monitors the voltage and shorts the output terminals within 10 μsec in the event of an incipient overload condition. No damage can occur regardless of how long the overload is imposed.

Five compact models are offered in half and full rack widths. The model 6384A, with output of 4 to

5.5 v at 0 to 8 amps is available for immediate delivery. Price is $220. Four other models with outputs of 0 to 7.5 v at 0 to 15 amps, 0 to 30 amps, 0 to 60 amps, and 0 to 120 amps respectively, will be available later in the year.
Hewlett-Packard/Harrison division, 100 Locust Ave., Berkeley Heights, N.J., 07922. [385]

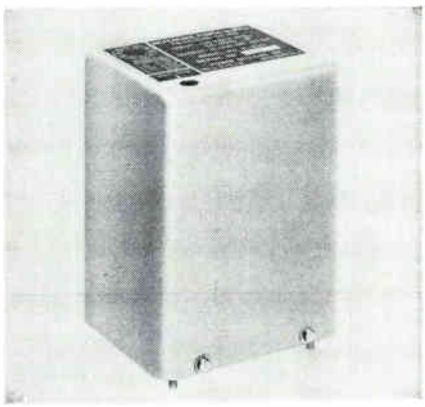
Miniature r-f filters meet military specs

Low-pass, high-pass and bandpass r-f filters are maximally flat and meet or exceed requirements of MIL-F-18327. With a frequency range of from 20 khz to 100 Mhz, source and load impedance is 50 ohms.

The completely shielded units are available in a 3 to 40 db shape factors of 10.2, 4.8, 3.3, 2.6 and 2.2.

Other specifications of the series F-11 include: bandwidth (bandpass only), 5% of center frequency minimum and 100% maximum; mounting, 4-40 screw inserts; terminals, 0.031 p-c type, ⅜ in. long and minimum insertion loss, 0.5 db for the low-pass filter.
Vanguard Electronics Co., 930 West Hyde Park Blvd., Inglewood, Calif., 90302. [386]

Reference source boasts high stability



The description of this reference source, which appeared in the Oct. 31 issue, page 133, contained a typographical error. The output voltage of the model X-336 is nominally 10 volts, not 10,000 v d-c.
Power Designs Inc., 1700 Shames Drive, Westbury, N.Y.

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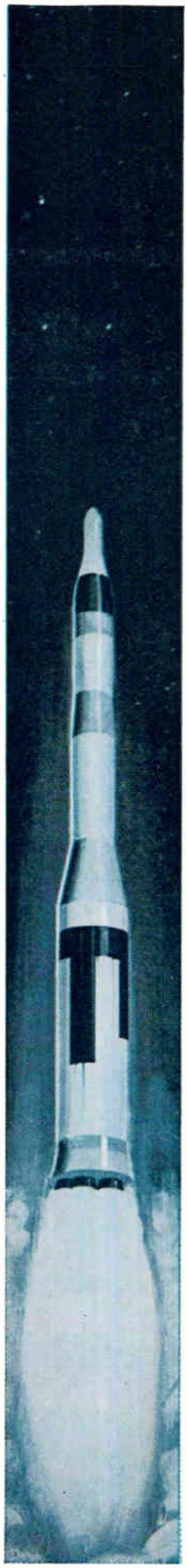
Circle 253 on reader service card



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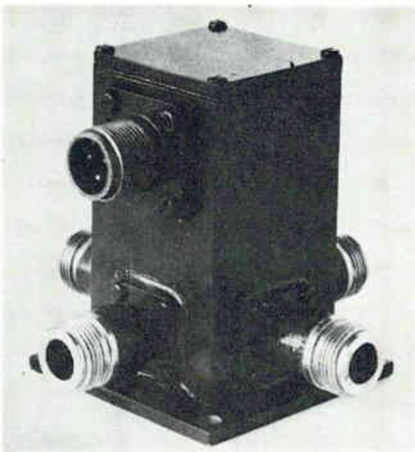


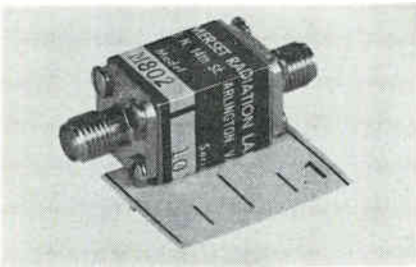
A four-port, fail-safe coaxial transfer switch provides 50-db isolation minimum from d-c to 1.4 Ghz. A solenoid operates the switch with a maximum switching time of 10 nanoseconds. The vswr is less than 1.2 and insertion loss is less than 0.2 db. This switch meets all applicable environmental requirements of MIL-STD-202B.

Model F7223 (N connectors and 28 v d-c solenoid) is priced at $270 in quantities of 1 to 9. Orders can be filled in 30 to 60 days.

Alternative requirements, such as other connectors, other solenoid voltages, different electrical specifications, etc., can be met upon request.

Sage Laboratories, Inc., 3 Huron Drive, Natick, Mass. [391]

Step-recovery multiplier covers 0 to 10 Ghz



A step-recovery diode multiplier meets the need for a single harmonic generator and pulser that covers the entire 0-to-10-Ghz spectrum. Called model M802, it features a very high conversion efficiency approaching 200% divided by the harmonic number and relatively high power output. Volume is less than 0.3 cu in. and weight is only 5 oz.

For high efficiency at a single frequency, an external cavity, tuning stub or tank circuit that has high Q is used. Conversely, for a comb of harmonics, the external output circuit should have a low Q. Model M802 can also produce pulses with less than 1 nsec rise time and fall time and pulse amplitude in excess of 10 v into 50 ohms.

Specifications include a diode transition time of 100 picoseconds; input voltage 15 v peak and a maximum input power 250 mw average. In typical operation, 10 mw at 500 Mhz produces 7 mw at 1,000 Mhz and conversion efficiency is about 70%. Connectors are OSM female 50 ohms; operating temperature range −65° to +175°C.

Price is $160 each with availability five days from receipt of order.

Somerset Radiation Laboratory, Inc., 2060 North 14th St., Arlington, Va., 22216. [392]

Klystron power supply takes little space

A universal, solid state klystron power supply is only one-fourth the size of its predecessor. Model 819 is a primary klystron power source for laboratory, production and field operation. It features versatility of available voltages and currents, as well as choices of either amplitude or frequency modulation.

Variable beam voltages from 200 to 3,600 d-c can be obtained at up

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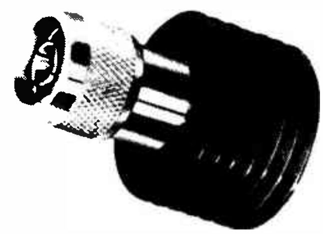
to 360 w. Also available are well-regulated low-ripple reflector, grid and d-c filament supplies, all variable and referenced to the high voltage. A modulator for use with internal square, sawtooth or sine-wave and external signals can apply up to 200 v peak-to-peak to the reflector circuit. Also, the current-limit setting on the beam supply is continuously variable.

Single range tuning is provided for the beam and reflector voltages, and these voltages can be read out either on meters or on digital counters as desired. Beam voltage and current, filament, reflector and calibration voltages may be monitored on front-panel meters.

PRD Electronics, Inc., 1200 Prospect Ave., Westbury, L.I., N.Y., 11590 **[393]**

Coaxial termination rated at 20 watts



Coaxial terminations, series TB-6, that operate from d-c to 6 Ghz, have an average power rating of 20 watts; peak power handling capability is 5 kw.

The terminations contain a beryllium oxide element within a carefully matched coaxial housing. As a result, maximum vswr is only 1.15 up to 5.5 Ghz, and 1.20 from 5.5 to 6 Ghz.

Cooling fins minimize the temperature rise of the terminating element, and the units operate over a temperature range from −55 to +125° C. They are available with type N connectors at $60 each, and with type BNC or TNC connectors at $65 each. All are in stock for immediate delivery.

Microlab/FXR, 10 Microlab Road Livingston, N.J., 07039. **[394]**

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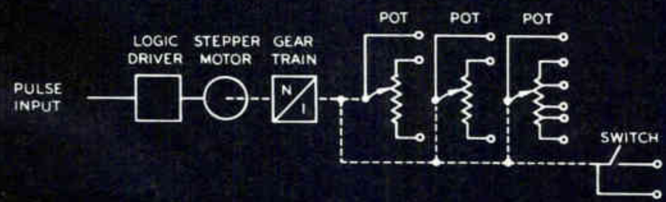

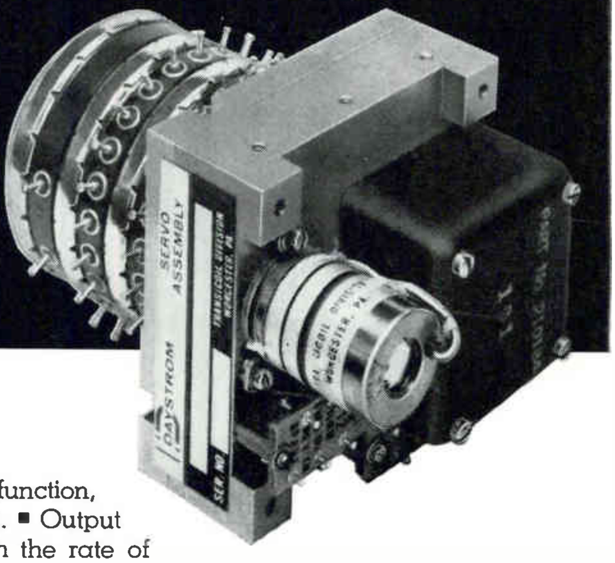

Transicoil digital pot drive

Transicoil incremental servos effectively perform an inegration function, since they produce a finite shaft motion for each input command. ■ Output of this servo package is an analog function synchronous with the rate of input pulses to the stepper motor. Extremely low time constant is assured because the unit accelerates to full speed in less than one pulse. Stopping time is equally short. ■ This compact unit includes a size 8 stepper motor, precision gear reduction, solid state logic driver, and 3 gang tapped pots with internal limit switch. ■ The assembly, except for pots, is manufactured by Transicoil. It offers the quality and reliability typical of Transicoil's broad line of standard and special-purpose servo assemblies. ■ Write for our 16-page brochure, SERVO ASSEMBLIES. It describes Transicoil products and design capabilities.

Weston Instruments, Inc., Transicoil Division, Worcester, Pa. 19490.

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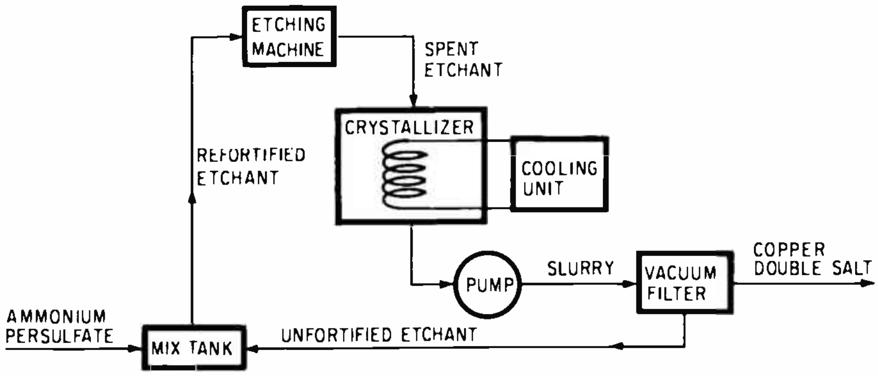
Getting the most out of an etchant



Etching liquid, once it has served its purpose in the manufacture of printed circuit boards, is usually dumped. However, the FMC Corp.'s Inorganic Chemicals division has developed a new process that allows the spent etchant to be continuously recovered and reused while the printed circuit boards are made. It is designed for manufacturers who use ammonium persulfate etching solutions. In addition to eliminating entirely any waste liquid, which FMC says is being done for the first time, the process recovers a double copper salt—copper ammonium sulfate hexahydrate—which can be sold.

Just before the ammonium persulfate etching solution is completely spent, the FMC process transfers it to a crystallizer. Although this occurs when there is about half of the persulfate still in the etch the etching reaction slows down to the point where, in the past, the entire solution was thrown away.

In the crystallizer, the products of the etching reaction are cooled and the copper salt crystallizes out of the solution. Next, the slurry, which consists of the crystallized salt and the remaining liquid, or liquor, is filtered. The liquor, still containing some ammonium persulfate, is fed back to mixing tanks where more of the persulfate is added. This brings the liquor back up to its original etching strength and it is ready to be used again in the etching machine.

After the process has cycled through a few times, a stable amount of copper sulfate remains permanently in the solution. But there is not enough of it to affect the etching reaction, according to FMC. The company has also developed a control method for the process which assures that the solution is etching the circuit boards at a constant rate.

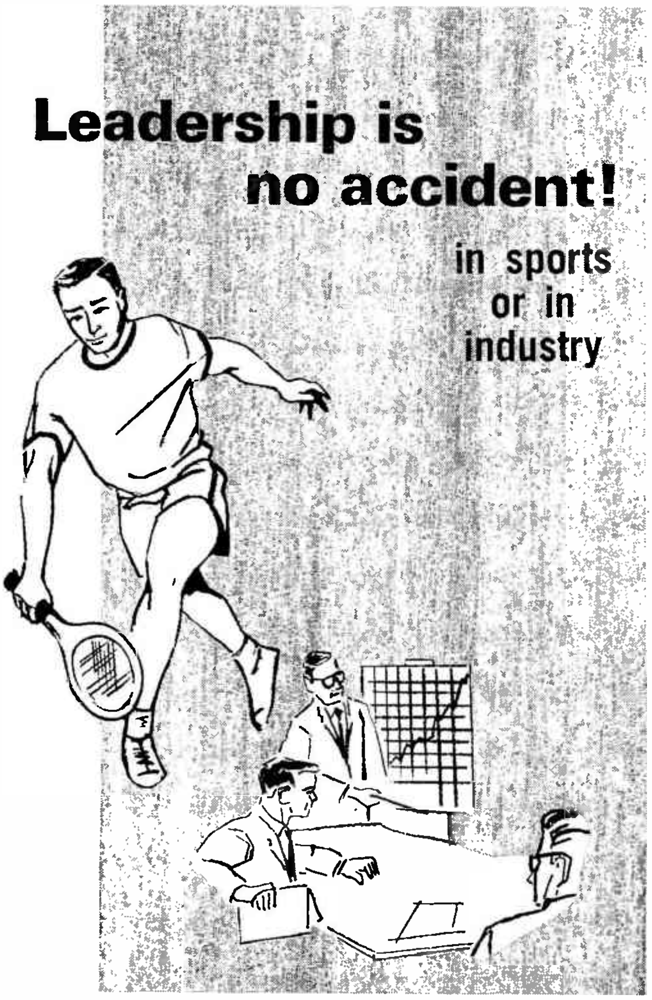
FMC says that the new process increases the persulfate use efficiency from the present 50% to 95%. Thus it can substantially reduce the amount of persulfate required to etch a given number of circuit boards.

For manufacturers who etch about 10 pounds of copper per hour, installation of the process equipment would cost about as much as an etching machine—about $15,000—according to FMC.

FMC Corp., Inorganic Chemicals Div., 633 Third Ave., New York, N.Y. 10017 [401]

Thickness grader for memory cores

The Ramsey Engineering model MR-301 Mike-O-Roll is a roller type grading micrometer developed for automatic height grading of ferrite memory cores at high speed production rates. Sorting rate is 120,000 cores per hour for core sizes ranging from 0.012 in. to 0.080 in. outside diameter. The ma-



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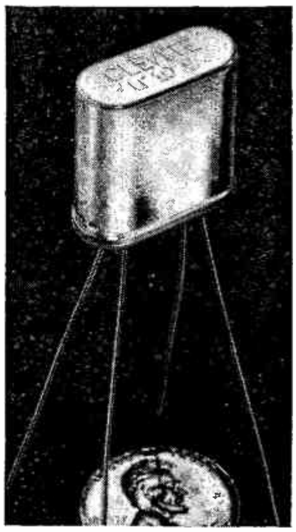
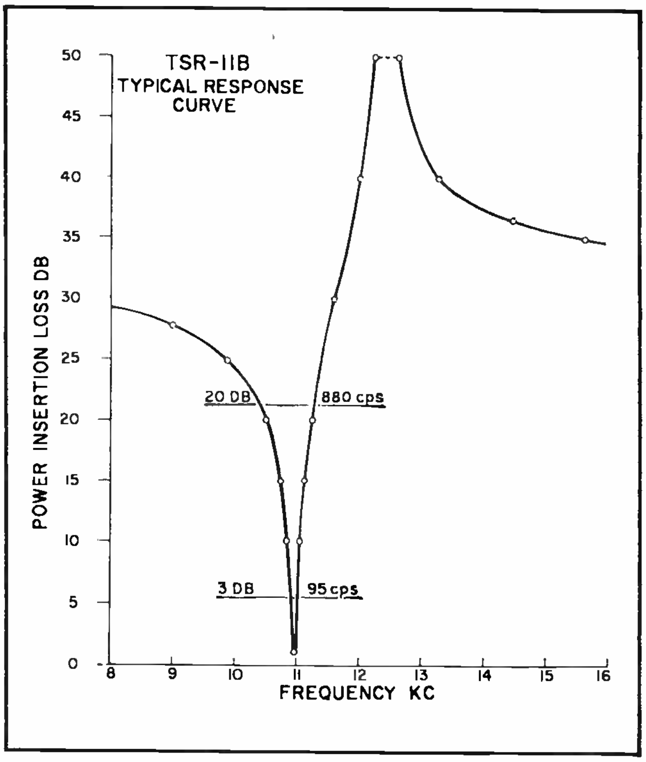
Circle 284 on reader service card

NEW. Low Frequency Ceramic Band Pass Filter.





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Shock — 20g any axis 20-2000 cps per mil std. 202B.

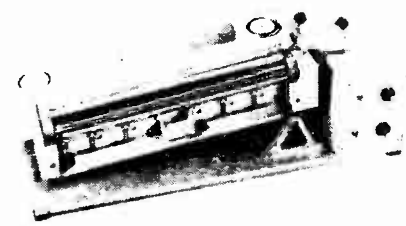
As we said, look no more for a high performance, low frequency filter. This new one from Clevite is the perfect choice. Write for free Technical Bulletin 94023. Clevite Corporation, Piezoelectric Division, 232 Forbes Road, Bedford, Ohio 44014.

CLEVITE

Circle 231 on reader service card

chine grades the cores into five different size classifications plus undersize and oversize grades.

The MR-301 offers a low cost mechanical technique for presorting large production quantities of cores, eliminating those which are too thick, too thin or which have manufacturing defects, such as firing flash or die fins. This preliminary test for physical rejects helps reduce over-all memory core production costs by speeding up "throughput" on electrical parameter test systems.



In operation, cores placed in the feeder bowl pass down an inclined "V", formed by two counter rotating chrome-plated cylinders which are separated by a progressively widening air gap. Individual cores advance along the rollers until they reach a suitable opening for their particular thickness. They then drop through the air gap and into the proper grading drawer.

Computer Test Corp., 3 Computer Drive, Cherry Hill, N.J. [402]

Work station uses 3-plane manipulators

A work station serves as a platform to hold a component in place when very fine manipulation is required. Magnifiers or stereo microscopes can be used with the work station.

The manipulators have rack and pinion movements with 2-in. travel in all three planes. The section holding the pin vise can be tilted to approach the work piece at an angle. The table can be adjusted to various heights. Electrical insulation can be provided between the base, work table and platform.

Price of the unit is $425.

C.H. Stoelting Co., 424 North Homan Ave., Chicago, Ill., 60624. [403]

New Materials

Glass seals diodes safely

Sealing miniature diodes with glass wouldn't be much of a problem if the glass would only behave. But often it doesn't, spreading unwanted contaminating materials that affect the properties of the diode the glass is supposed to protect or changing its own properties so that the seal itself degrades.

A new sealing glass developed by Corning Glass Works reportedly combines in the same glass for the first time two desirable properties—low alkali content and no lead—which should make for more reliable, longer-lasting seals. Coupled with this is another advantage—it can be sealed quickly with infrared energy. The glass is used to seal both molybdenum and tungsten.

For Corning's new code 4070 glass, maximum alkali content is limited to 0.05% for both sodium oxide and potassium oxide and to 0.01% for lithium oxide. Alkali content in a sealing glass should be kept low because the alkali tends to migrate from the glass and onto the semiconductor chip, changing its characteristics. This could cause the maximum peak inverse voltage the diode can withstand to decrease, for example. The voltage also would tend to be unstable at higher temperatures.

Lead content is important in a sealing glass because when heat is applied during the sealing operation, any lead oxide the glass may contain is reduced to lead. This, unfortunately, makes for a much poorer seal. It is an advantage, then, that the new glass is lead free.

Any infrared radiation source—a quartz-iodine lamp, for example—can be used to seal the glass which absorbs radiation from 0.75 to 4.75 microns. Although the sealing temperature is higher than for other low-alkali glasses Corning had previously developed, the infrared heat can be focused onto a small area. Heat sensitive devices can be sealed quicker and safer than if encapsulation was made with a direct flame or in a furnace.

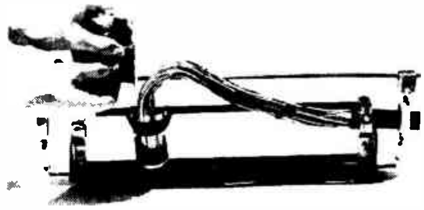
Code 4070 glass is available in cut tubing with an outer diameter of up to 150 mils. In high volume the cost is $5 per 1000 pieces, with sampling quantities also available.

Properties

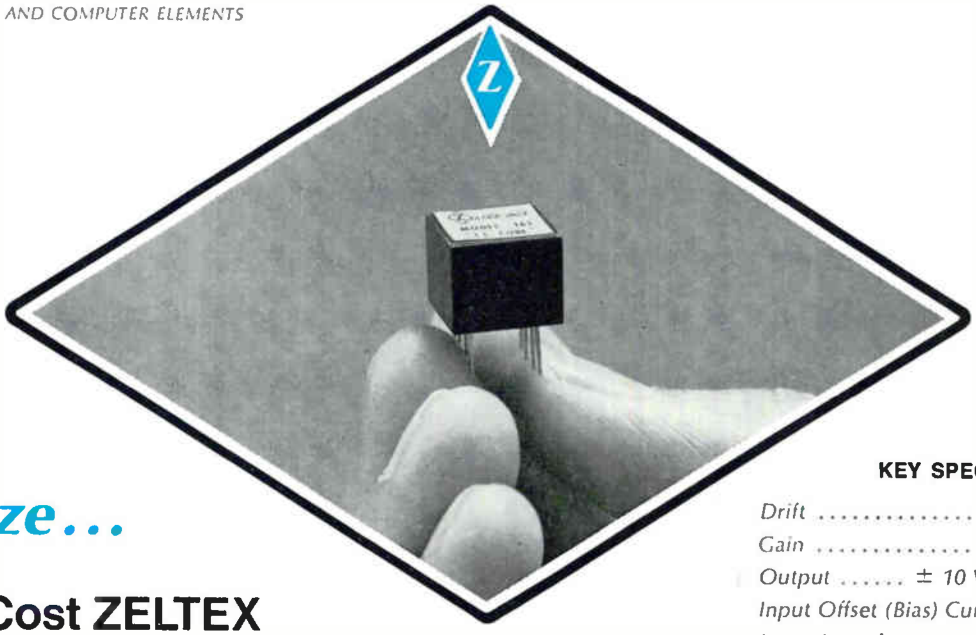
Softening point	816° C
Annealing point	622° C
Strain point	582° C
Expansion 0-300°C (in/in/°C)	47×10^{-7}
Density (gr/cc)	2.76
Transmission	
1.1 microns	5.0%
0.56 micron	17%

Communications Products Sales, Corning Glass Works, Corning, N.Y. **[406]**

Two-part resin seals communications cables



A two-part resin is designed for capping and sealing communications cables and for capping drop-wire stubs in direct burial splices. Known as Scotchcast-brand elec-



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First of a family of Hybrid Integrated Circuit Differential Amplifiers, ZELTEX's new Model 161 is an exceptionally stable device in a new, easy to mount epoxy package at a price you'll find hard to resist. In addition to the low initial cost of only $47.00 (100 lots), Model 161 offers savings in engineering and assembly time. All internal resistors and capacitors are built into the 161. And, the new ZELTEX (0.5" x 0.5" x 0.4") IC Cube package fits flush to the board without time consuming lead splaying.

Units for evaluation are available immediately. Order yours today!

*IC CUBE is a tradename of ZELTEX, Inc.

KEY SPECIFICATIONS

Drift .... 25 μV/°C
Gain 80,000
Output ...... ± 10 Volts at 4 mils
Input Offset (Bias) Current . . 150 nA
Input Impedance .... 20 megΩ
Short Circuit Proof

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Phone (415) 686-6660

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IO-14 $299.00
wired
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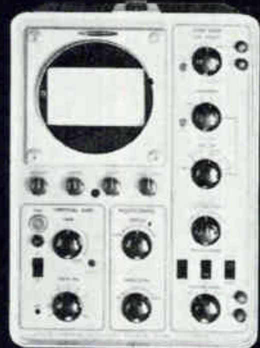

• DC to 8 mc bandwidth — 0.04 usec rise time • Triggered sweep — 18 calibrated rates • Delay-line vertical amplifiers for fast-rise signal analysis • 3% calibrated vertical attenuator — 0.05 v/cm to 20 v/cm, 600 v. (max.) input • Electronically regulated power supplies • Forced air ventilation • Built for continuous-duty industrial & lab use

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Circle 235 on reader service card

trical insulating resin No. X3598. it is a fast curing, flexible polyurethane material especially designed for telephone and other communications applications where low-voltage systems are used.

The resin cures within 2 to 5 minutes at 75°F; low enough not to harm sensitive plastic wire insulation. It comes packaged in a Unipak container for easy handling and mixing and is available from stock.

3M Co., 2501 Hudson Road, St. Paul, Minn., 55119. [407]

Standard substrates made of alumina

Alumina has been finding wider use as an IC substrate material because of its high thermal conductivity, excellent dielectric properties, mechanical strength and fine finish. However, important IC research is often delayed by lack of immediate availability of alumina substrates. Hence this new series of standard substrates in over 600 different combinations available within a few days from receipt of order.

The C-100 standard substrates are offered in sizes from 0.007-in. thickness to 0.050-in. thick in square areas up to 2 sq in. They are available to the integrated circuit engineer with three finishes: bare (unmetalized), metalized and gold plated on one side and metalized and gold plated on both sides. The gold plating, 0.000150 in. minimum thickness, is directly on the moly metalizing, with no nickel interlayer, thus permitting direct die attach.

Prices on the C-100 series will

vary with square area, thickness, and metalizing specifications. A typical 0.250 x 0.275 substrate, 0.007-in. thick, metalized on both sides, is priced at 12 cents each for a minimum lot of 500.
Glass Beads Co., P.O. Box 266, Latrobe, Pa., 15650. [408]

Narrow line garnet at low temperatures

An aluminum doped yttrium iron garnet material is offered with narrow line widths at low temperatures. Line widths at 6.2 Ghz are approximately 33 oersteds at 300°K, 280 oersteds at 77°K, and 340 oersteds at 4°K. Other features include: saturation magnetization, 560 gauss ±5%; X-band loss tangent, 0.002; Curie point, 150°C.

YAF-17 is useful in low temperature applications including circulators used with masers and parametric amplifiers.

The bars measure ½ x 1 x 6 in. and are priced at $245 each. However, other sizes and shapes are available to customer specifications.
Airtron, a division of Litton Industries, 200 E. Hanover Ave., Morris Plains, N.J. [409]

Sheet deposition for selective-etch use

Sheets of conductive materials are available for the selective etch of resistor-conductor patterns. Standard vacuum-deposited resistor materials are overcoated with aluminum, gold, copper or a manufacturer's typical conductive layer which is easily etched, highly solderable and can be used in eutectic chip bonding.

Stock sizes include 1 x 1 in., 2 x 2 in., 3 x 3 in. ceramic or glass substrates nominally 0.03 in. thick.

Basic film specifications are: sheet resistance, 50, 100, 200, and 400 ohms per square; tolerances, ±10% and ±20%; noise level, matching and tracking comparable to high-quality discrete-metal film resistors. Conductor resistance is less than 0.1 ohm per square.
Alpha MicroElectronics Co., Inc., 10501 Rhode Island Ave., Beltsville, Md., 20705. [410]

Technical Abstracts

Semiconductor testing

Optical scanning techniques for semiconductor device screening and identification of surface and junction phenomena

C.N. Potter
Sperry Rand Research Center
Sudbury, Mass.,
and D.E. Sawyer
National Aeronautics and Space Administration
Electronics Research Center
Cambridge, Mass.

A flying-spot light beam tracing a raster pattern on the surface of a semiconductor device can provide a minutely detailed record of its electrical behavior, directly related to its physical structure. As a nondestructive testing system, it can be used between successive steps in manufacturing integrated circuits, to isolate the causes of failures or substandard performance.

The light source is a helium-neon laser. Sinusoidal scanning of the beam is accomplished by two mirrors mounted on magnetically-driven vibrating reeds. The light pattern is optically demagnified and projected on the surface of the device under test. The electrical output stimulated by the light beam is amplified and used to modulate the intensity of a cathode-ray tube electron beam. Reflection of the electron beam is synchronized with the light raster to correlate the electrical output trace with the light-spot position. This produces a response map that can be directly compared with a photomicrograph of the device for interpretation. Device phenomena that have been identified and studied by means of this technique include localized surface and junction breakdown, channeling and uniformity of avalanche multiplication in silicon avalanche photodiodes.

A different presentation can be obtained by feeding part of the device output to the vertical input of the crt, resulting in a topological map of the photoresponse of the sample. Or if the vertical deflection mirror is stopped, the light spot continuously retraces the same path. This allows observation of a single cross section of the device.

Additional information can be obtained by using microwave modulation of the laser beam. A mixer, local oscillator, i-f amplifier and a second detector are inserted in the circuit between the sample output and the oscilloscope amplifiers, and tuned to a laser mode beat. The amplitude of the detached signal is proportional to the microwave response of the device to the modulated scanning spot.

Presented at the Fifth Annual Symposium on Physics of Failure in Electronics, Columbus, Ohio, Nov. 15-17.

Storing on MOS FET's

A micron bit-size charge storage device

N.C. MacDonald and T.E. Everhart
Department of Electrical Engineering
University of California, Berkeley

A new potential for MOS FET's lies in providing storage for as many as 10^{10} bits of information per square centimeter. A scanning electron microscope with a small beam (2 to 5 microns in diameter) stores and reads the information. Storage is possible in a metal-oxide-semiconductor structure because the amount of fixed charge introduced in the insulator controls the surface conductance of the semiconductor. The change in the surface conductance is monitored by incorporating two electrodes in the familiar field effect transistor structure.

If an 0 is stored, a subsequent scan of the adjacent area results in a negligible increase in the surface conductance. If a 1 is stored, however, the subsequent read cycle will produce a large increase in conductance.

With present silicon technology, electron bombardment of the gate electrode, an area typically 5 by 5 microns, permits storing 10^7 bits per square centimeter on a single, three-terminal MOS FET. With advances in thin films, particularly in stabilizing insulating layers, 10^{10} bits per square centimeter could possibly be stored.

For computers, the device provides a large storage capacity, random access and an erasable memory with nondestructive readout. Information will remain stored for months even without power.

Presented at the International Electron Devices Meeting, Washington, Oct. 26-28

New Books

To whet the appetite

System Analysis by Digital Computer
Edited by F.F. Kuo and J.F. Kaiser
John Wiley & Sons, Inc., 438 pp., $8.95

Much of today's computer programing is aimed at teaching computers how to design components, devices and systems. This activity has not yet fathered completely robot-run industries, or even totally automated design procedures; but it has led to a searching and continuing analysis of the design process and to computer-aided design algorithms.

Although the computer cannot yet do the whole job, programs for analysis and optimization are widely available and used. Most design work, of course, is done in industry. As a result, computer-aided design algorithms often do not lead to documented publication.

To disseminate some of this eagerly sought information, Princeton University and the Cosine (Computer Science in Electrical Engineering) Committee of the Commission on Engineering Education cosponsored a conference at Princeton in August, 1966. This book is a somewhat edited version of the papers presented at that conference and is, unfortunately, more apt to whet appetites than to satisfy desires.

All the authors but two are with the Bell Telephone Laboratories. The exceptions are F.F. Kuo, who this fall left Bell Labs to go to the University of Hawaii, and C. Pottle of Cornell University.

The lead paper is Kuo's introductory survey, "Network Analysis by Digital Computer." Reprinted from the June 1966 Proceedings of the IEEE, the paper provides a comparison among several available programs such as Deuce, ECAP, and NET-1. The author then reviews state-space and frequency domain analysis programs, and fortifies his paper with a list of 63 references. Omitted in this discussion are important electronic circuit design programs based on flow-graph methods of analysis, which show unique capabilities in model simplification.

In the second paper, H.C. So discusses the iterative design of an n-port, using hybrid analysis, and specifically the Bell Labs program, Hybrid.

Pottle's paper presents a general state-space active network analysis technique. The author develops necessary concepts and defines terms carefully so that the reader unfamiliar with state-space techniques should be able to follow the discussion. A related computer algorithm is described in the appendix.

The book's analysis portion ends with a paper by M.L. Liou on numerical analysis of linear time invariant equations in the time domain (state-space equations) and frequency domain (Fourier and inverse Fourier transforms).

Two papers on design follow. The first, a specific example of a design program, is an article by G. Szentirmai on a general purpose filter synthesis program. Only limited familiarity with insertion loss filter design is expected of the reader. The second is a tutorial review paper by P.E. Fleischer on optimization techniques.

Analysis, synthesis, or design of a system with a computer requires that the system's salient characteristics be represented within the computer. This is the essence of simulation, without which there cannot be much computer-aided design. Ergo, the next three papers are concerned with various aspects of simulation. In the first, J.F. Kaiser defines, explains and classifies digital filters. He develops the sampling process before going into various design methods and realization schemes. The article is heavily referenced (82 listings, most of them recent) and should be useful for engineers interested in this field.

Next, B.J. Karafin reports on Blodi, a sampled data system simulation language for use in conjunction with a block diagram compiler developed by Bell Labs. The last paper in this section is a very brief discussion of hybrid computers and techniques, followed by sample applications. The author is J. Chernak.

The final three papers are concerned with non-numeric computer

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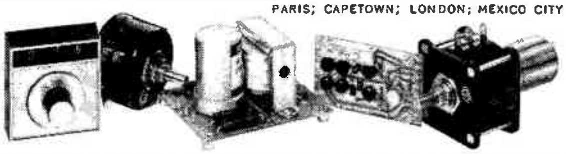

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In Plastic Tube.
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Range : .001 MFD to .22 MFD.
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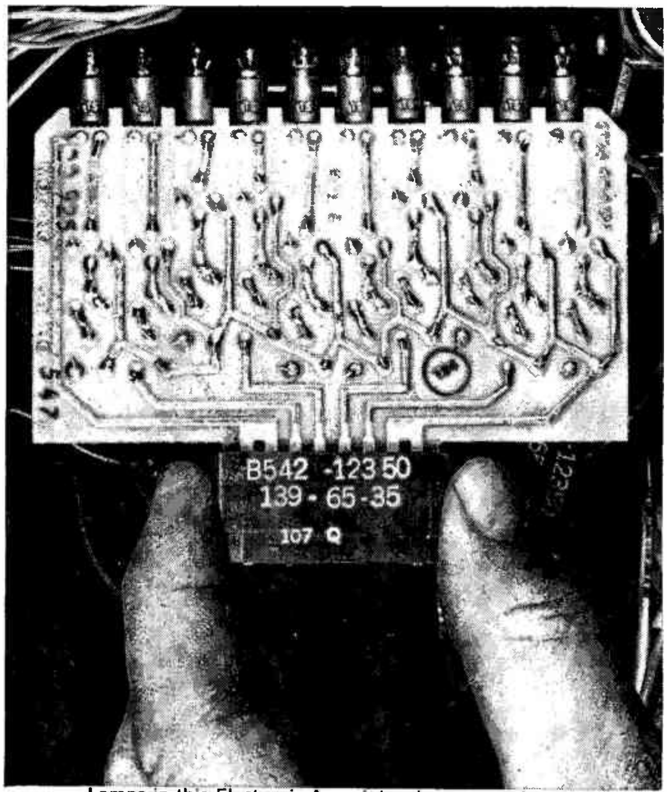

Lamps in this Electronic Associates, Inc., computer circuit board are the Tung-Sol Tu-Pin molded base types.

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Requirements of the computer industry for a compact subminiature lamp assembly, led to the development of the Tung-Sol integrally molded base lamp.

A molded nylon encapsulation replaces the conventional cemented-on metal base. This permits direct mounting of the lamp without need for the usual mated socket. Greater reliability is achieved, with obvious simplification of installation procedures.

The molded-base lamp lends itself to automated assembly and molding permits extreme flexibility of base configuration. Bases may be color-coded for accurate identification.

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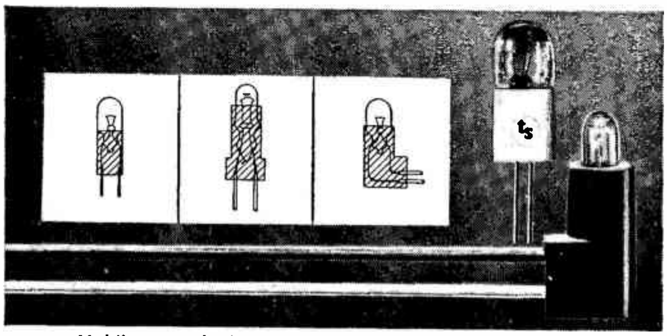

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New Books

topics. W.S. Brown discusses Altran, a language for handling symbolic algebra on the digital computer. This is followed by a short paper on computer produced movies by K.C. Knowlton and one on graphic input-output devices by W.H. Ninke.

Because the book is only a collection of papers grouped around a common theme, it will sorely disappoint those who are looking for a systematic, logical and evenly paced development of the subject. In fact, there is little cohesion—in spite of the editors' efforts—and the only noticeable perspective is supplied in the surveys by Kuo and Fleischer.

The book, then, is not an introductory text, an advanced text, or a handbook. It is a compact set of conference proceedings, relatively inexpensive and readily available for all those who think they would have liked to attend the conference but couldn't.

G.F. Paskusz
University of Houston
Houston, Texas

Recently published

Handbook of Basic Transistor Circuits and Measurements, R.D. Thornton et al, John Wiley & Sons, Inc., 156 pp., $4.50 clothbound, $2.65 paperbound
A presentation of specific circuits illustrating both the theoretical and practical aspects of transistors. This is the seventh in a series of laboratory-oriented volume, published by the Semiconductor Electronics Education Committee which was formed in 1960 to prepare educational material on semiconductors.

Dielectrics and Waves, Arthur R. von Hippel, The M.I.T. Press, 284 pp., $5.95
An excellent reference for microwave engineers concerned with the properties of ferromagnetic materials and dielectrics. Also includes discussion of crystalline structures now used in laser research. First published in 1954.

Communication Systems and Techniques, Mischa Schwartz, William R. Bennett and Seymour Stein, McGraw-Hill Book Co., 618 pp., $16.50
Each author wrote one section of this graduate text and reference book. The sections cover fundamental aspects of communications in the presence of noise, continuous-wave and pulse-modulation in modern communications systems and digital communications theory and principles.

Introduction to Nonlinear Automatic Control Systems, Rajko Tomovic, John Wiley & Sons 172 pp., $7.50
An undergraduate text by a professor of electrical engineering at the University of Belgrade, Yugoslavia. Simulation models are stressed.

New Literature

Memory products capability. Indiana General Corp., Electronics division, Keasby, N.J. A brief history of memory core development, plus highlights of memory product manufacturing facilities and capabilities are available in an eight-page booklet.
Circle **420** on reader service card.

Oscilloscopes. Data Instruments division, IEH, 7300 Crescent Blvd., Pennsauken, N.J., 08110. A six-page brochure describes two broad classes of oscilloscopes: plug-in amplifier types and built-in amplifier types. **[421]**

Silicon transistors. RCA Electronic Components and Devices, Harrison, N.J., 07029. "Specs in Brief" booklet (form number 2L1066) covers silicon transistors for a-f, r-f and switching applications. **[422]**

Interval timer. Automatic Timing & Controls, Inc., King of Prussia, Pa., 19406. Bulletin 309 describes a push-button-start interval timer with 0.2% repeat accuracy. **[423]**

Flexible couplings. Theta Instrument Corp., Saddle Brook, N.J., 07662, has released an engineering bulletin discussing flexible couplings designed to drive synchros, pots, and shaft encoders with unusual angular accuracy. **[424]**

Microwave catalog. Transco Products, Inc., 4241 Glenco Ave., Venice, Calif., 90291. A 57-page catalog contains specifications and dimensions of coaxial switches, waveguide switches, airborne antennas, and microwave components. **[425]**

Zirconium copper. American Metal Climax, Inc., 1270 Avenue of the Americas, New York, N.Y., 10020, offers a technical data booklet on Amzirc zirconium copper, a heat-treatable copper alloy developed for applications requiring conductivity and good strength at high temperature. **[426]**

P-c board production. Epec Industries, Inc., Industrial Park, New Bedford, Mass., 02745, a four-page brochure describes Protomaka, the laboratory equipment for making p-c boards, and its companion piece, Protoplata, for precious metals electroplating. **[427]**

Test equipment. Wiltron Co., 930 East Meadow Drive, Palo Alto, Calif., A 12-page catalog provides specifications, technical information and photographs of the latest in test and measurement equipment available from the company. A section is devoted entirely to new communications test equipment. **[428]**

Transfer function analyzer. Canoga Electronics Corp., 8966 Comanche Ave., Chatsworth, Calif., 91311. Model 950 Servodyne, an automatic transfer function analyzer, is described in a two-page data sheet. **[429]**

Nonlinear potentiometers. Duncan Electronics, Inc., 2865 Fairview Road, Costa Mesa, Calif., 92626, A four-page brochure details functions, output equations and circuit diagrams for a line of precision, wire-wound nonlinear potentiometers. **[430]**

Printing impulse counter. Landis & Gyr, Inc., 45 W. 45th St., New York, N.Y., 10036. Bulletin 361 contains specifications, operating characteristics, electrical and mechanical data, dimensions and wiring diagrams of typical circuits for a high capacity, 20-column printing impulse counter. **[431]**

Broad-band couplers. Alford Manufacturing Co., 120 Cross St., Winchester, Mass., 01890, has issued bulletin 608 on the Quadrids, which are broad-band, hybrid-like, 3-db couplers for use in applications requiring two signals of equal amplitude but one shifted 90° in phase with respect to the other. **[432]**

Microwave diodes. Alpha Industries, Inc., 381 Elliot St., Newton Upper Falls, Mass., 02164. Catalog D-1 provides tabulated electrical and mechanical data on more than 100 models of microwave diodes. **[433]**

Silicon controlled rectifiers. International Rectifier Corp., 233 Kansas St., El Segundo, Calif., 90245, lists a complete line of silicon controlled rectifiers in a new catalog, designated A-66, for easy evaluation and simplified ordering. **[434]**

Platinum transducers. The Lewis Engineering Co., Naugatuck, Conn., 06771. Low-cost resistance temperature detectors with platinum elements for industrial use are covered in bulletin I-402. **[435]**

Tape recorder/reproducer. Leach Corp., 1123 Wilshire Blvd., Los Angeles, Calif., 90017. An eight-page brochure details data on a 54-lb portable tape recorder/reproducer which provides instrumentation-quality recording, storage and reproduction of direct, f-m and digital data. **[436]**

Printed-circuit manufacture. Komak, Inc., Southwest Corner 9th & Ontario Sts., Philadelphia, Pa., 19140, has released a 16-page booklet showing the quality control exercised, from design to finished product, in the manufacture of its printed circuits. **[437]**.

Tool for electronics. Henry Mann Co., Box 104, Cornwells Heights, Pa., 19020. A 48-page catalog features a complete selection of specialized microminiature tools for electronics. Copies may be obtained by writing on company letterhead.

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IBM CORP.	247	7
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*These advertisements appeared in the November 28th issue.

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Home Address ....
City .... Zone.... State......
Home Telephone ....

EDUCATION

Professional Degree(s) ....
Major(s) ....
University ....
Date(s) ....

FIELDS OF EXPERIENCE (Please Check) 12/12/66

- ☐ Aerospace
- ☐ Antennas
- ☐ ASW
- ☐ Circuits
- ☐ Communications
- ☐ Components
- ☐ Computers
- ☐ ECM
- ☐ Electron Tubes
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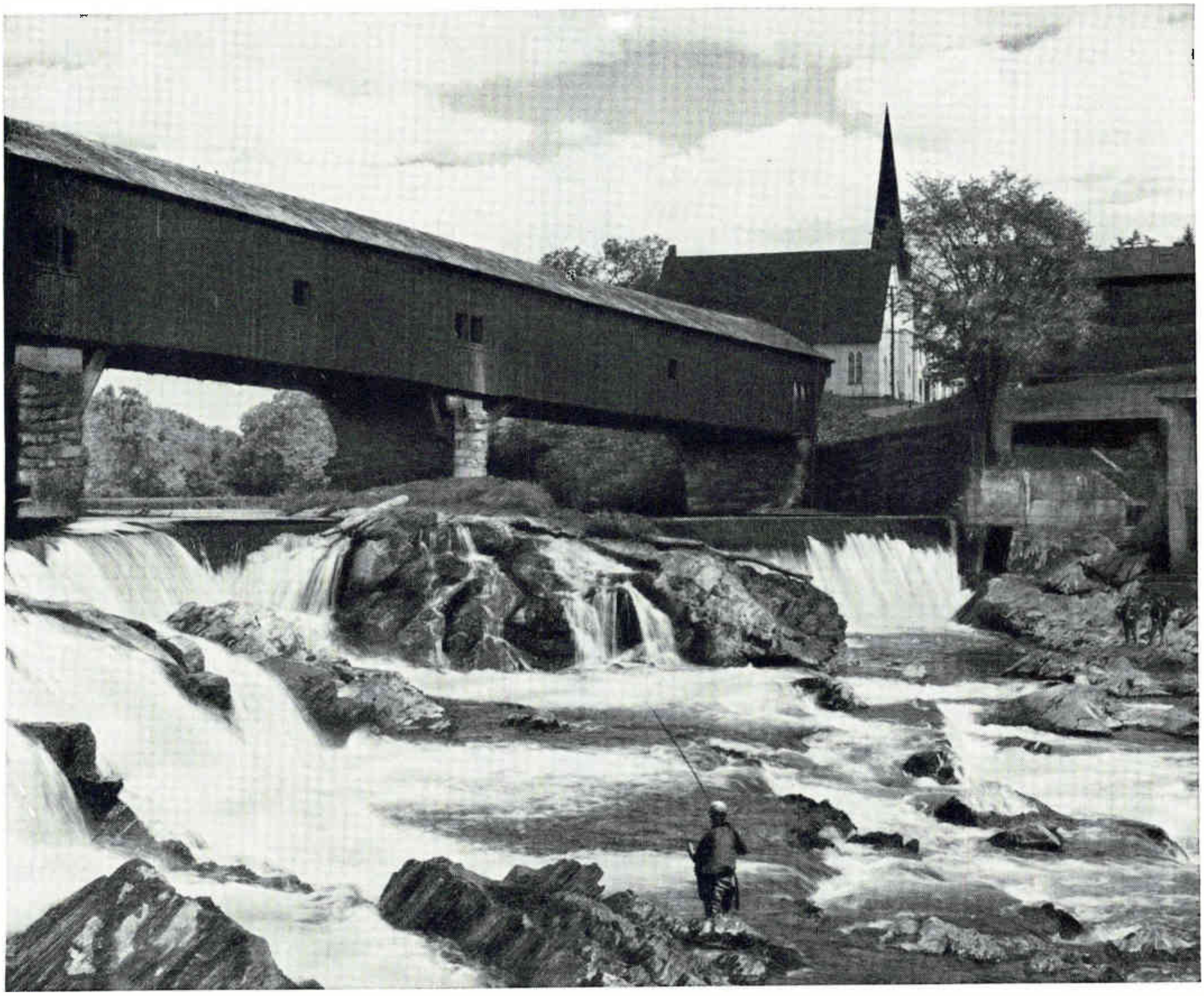

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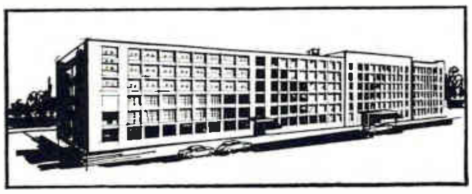

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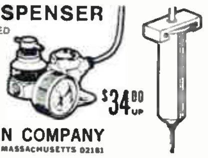

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Newsletter from Abroad

December 12, 1966

Kita diode shows continuous output at 50 Ghz

Japanese researchers continue to show a flair for diodes. Shoichi Kita, who developed the silver-bonded germanium diode named for him, reports he's discovered that Kita diodes—originally developed for parametric amplifiers—will also work as millimeter-wave oscillators.

In experiments at the government-owned Nippon Telegraph and Telephone Public Corp., **Kita has operated diodes at frequencies up to 50 gigahertz with continuous-wave output.** Bell Telephone Laboratories has pushed silicon diodes to considerably higher frequencies—85 Ghz—but only for pulse outputs.

Kita stumbled upon the "new" oscillator while checking the impedance of Nippon Electric Co. GSB-3 diodes intended for a parametric amplifier. At 11.75 Ghz he noticed a sharp rise in the figure of merit when the reverse bias reached about 7 volts. Then he boosted the freqency to 47 Ghz and found the diode oscillated.

Later Kita obtained c-w outputs of about 2.5 milliwatts at 40 Ghz and about 0.7 mw at 50 Ghz. The diode's behavior is very similar to that of a klystron. The diode frequency can be pushed by changing power supply voltage and pulled by changing tuning of the cavity in which the diode operates.

R&D reshuffle by Britain aids electronics

Britain's electronics industry should benefit from a reshuffling of government research and development facilities early next year. Under the new R&D alignment, the Ministry of Aviation will hand over its research establishments to the Ministry of Technology, the government's godfather to the electronics industry.

The shift will put under the technology ministry's wing two major British electronics research centers, the Royal Radar Establishment at Malvern and the Royal Aircraft Establishment at Farnborough. Both are now oriented heavily to aerospace applications but will diversify under the new setup. More important, **a strong effort will be mounted to get out to the industry research and development results that point to marketable products.** One main assignment of the technology ministry is to inject new technology into the electronics industry. But since the ministry took on the job a year ago little has been done, partly because of the ministry's limited research in electronics.

More Japanese sets with IC's on way

A scramble to get radio and television receivers with integrated circuits on the market has started among Japanese set producers.

The Sony Corp. was first with a miniature radio this fall [Electronics, Oct. 17, p. 22]. Late in November the Matsushita Electronics Corp. showed a pair of IC radios and a tv set well along in development. **Early this month, the Victor Co. of Japan Ltd. started selling a 25-inch color set with a hybrid IC in the sound channel.**

Victor's IC isn't as complex as the monolithic circuit the Radio Corp. of America uses in its 12-inch black-and-white receiver, first production-line set ever to have an IC. Victor's circuit serves only as the sound intermediate-frequency amplifier and limiter. RCA's IC has in addition a frequency-modulation discriminator and a first stage of audio amplification [Electronics, March 21, p. 137].

The Victor IC contains three transistors and six resistors. It replaces

Newsletter from Abroad

two tubes, five resistors and three capacitors. Although the IC—supplied by Kyodo Electronic Laboratories Inc.—costs more than the components it replaces, Victor says the IC set is cheaper to fabricate. The main saving is in the power supply. Because of the IC's low consumption, Victor is using the same supply for the 25-inch set that it normally puts into 19-inch sets.

The IC radios Matsushita has on the way will have a monolithic circuit based on a linear circuit for hearing aids developed by Philips Gloeilampenfabrieken NV of the Netherlands. Matsushita Electronics is a joint venture of Philips and the Matsushita Electric Industrial Co.

Marconi expands MOS development

The resurgence of metal oxide semiconductors has spread to Great Britain. After four-and-a-half years of small-scale development work in MOS, the **Marconi Co. this year stepped up its efforts considerably and now has devices about ready for the market.** Marconi, the electronics subsidiary of the English Electric group, already produces hybrid integrated circuits with silicon transistors for its Myriad computers.

Marconi won't disclose how much it is spending on MOS development but I.G. Cressell, manager of the company's microelectronics division, says a sizeable chunk of Marconi's $450,000 yearly R&D budget is tagged for MOS. **In pilot production, Marconi has been getting "reasonably high yields" on a J-K flip-flop and will soon be ready with a 56-element eight-bit shift register.**

Russians detect laser pulses with radio antenna

Soviet physicists have found a way to pick up laser light beams directly with a radio antenna. In the Russian technique, the radio antenna is fed a negative potential; **the antenna field then interacts with the laser beam to develop electrical impulses. Length of the output pulses exactly matches the pulse length of the laser beam.** The Russian researchers—led by Gurgen Askaryan of the Physics Institute of the Soviet Academy of Sciences—used 300-microsecond laser pulses in their experiment.

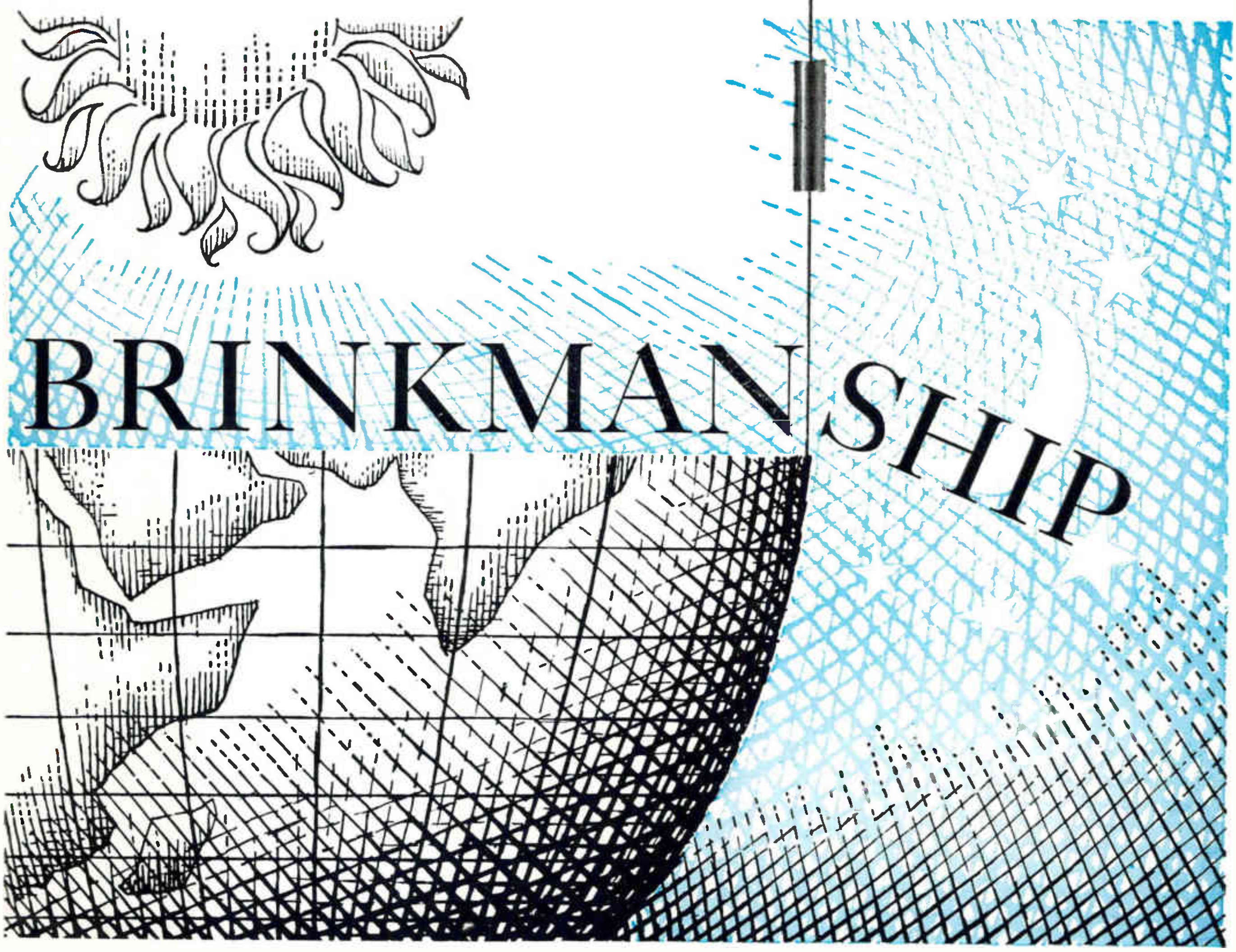
Although Askaryan sees high promise in the technique, he says there's **much more work to be done before data can be transmitted effectively to radio antennas via laser beams.**

IBM bearish on Zurich lab's double thin films

The International Business Machines Corp. has written off double magnetic thin films as a candidate for the next generation of computer memories despite the films' interesting magnetic properties. The films —originated at IBM's Zurich research facility—are too difficult to fabricate. **IBM is pushing development, though, of coupled films which have much thicker nonmagnetic separating layers than the double films.**

The double thin films have separating layers in the range of 350 angstroms compared with some 10,000 angstroms for the coupled films. Coercive force of the double films with a separating layer of silicon oxide is about one-tenth the value for a single magnetic film. The coercive force for a double film with a metal separating layer, however, is higher than for a single film. **Zurich apparently will continue some experimental work in double films, but the effort will be played down.** Device development of coupled films is being done at IBM's Burlington, Vt., plant.

courting capacitor disaster?



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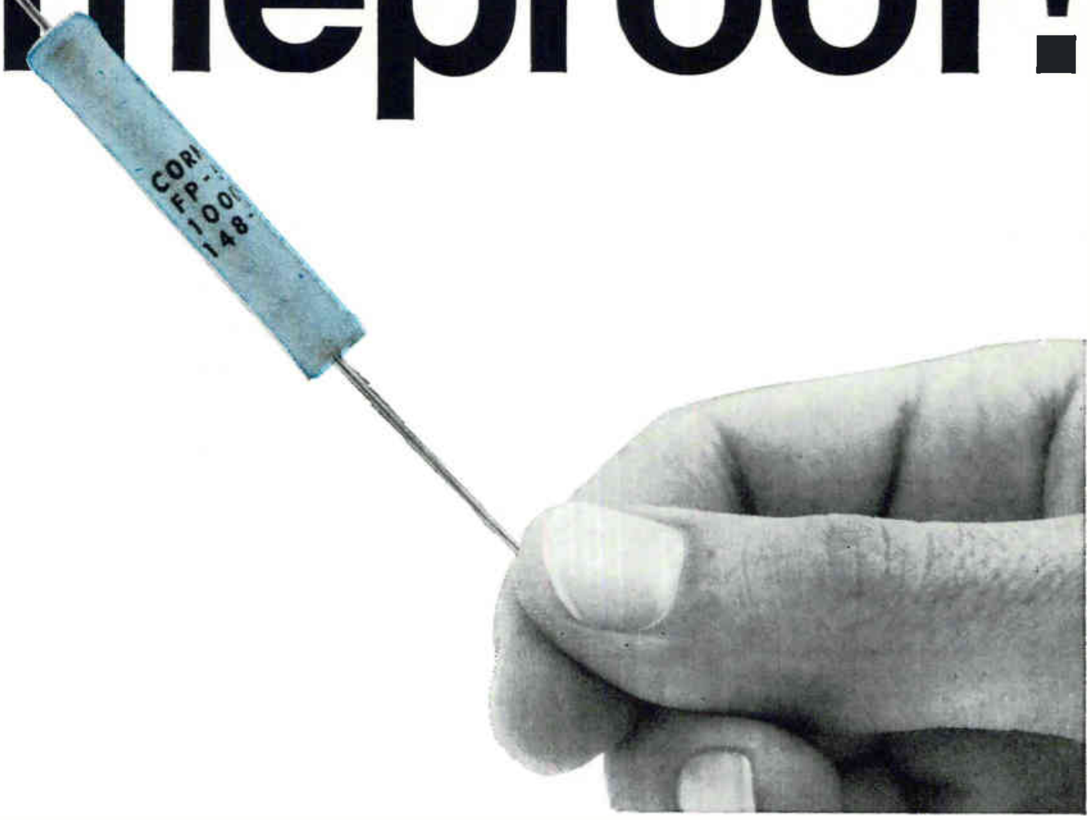

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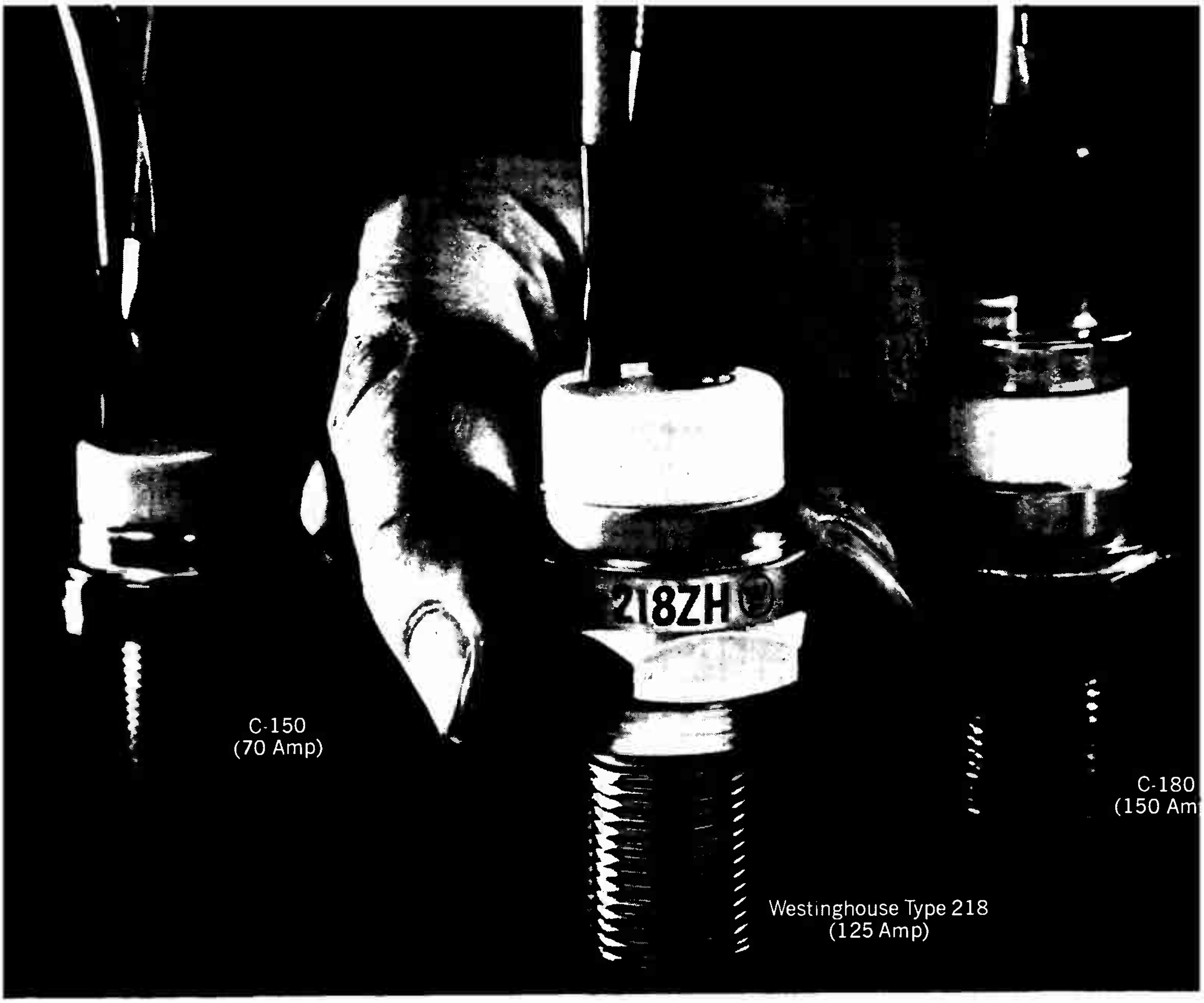
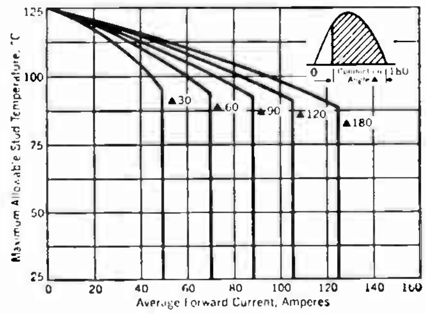


Now Westinghouse fills the thyristor amp gap



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Electronics Abroad

Volume 39
Number 25

Sweden

Soldiers' play

Except during some United Nations peacekeeping missions in the Congo during the early 1960's, Swedish soldiers haven't fired shots in anger since 1812. But Swedish conscripts nonetheless now are getting some idea of battlefield action

Infantry instructor pushes a button on his control transmitter . . .

during training. It's coming from $1.5 million worth of electronic land warfare training equipment that the Royal Army Ordnance Administration is putting into the field.

Developed by the aircraft-auto-electronics company SAAB Aktiebolag, the main battlefield props are infantry and tank targets that pop up under radio control. A hit infantry target drops at once; a hit tank target flashes a light or belches a puff of smoke. Although the "enemy" doesn't fire back at the attacking conscripts, his mock infantry sets up a racket of machine-gun rattling and his tanks menace the trainees with muzzle flames and sounds of cannon shots.

No strings. Armies around the world use battlefield simulation equipment, but most systems use cables and levers to pop up targets. Others have electrical actuation, which means stringing out wires and bringing in a field generator set to play a land war game. The SAAB targets are self-contained, with compressed-air bottles as the energy source to raise and lower targets under remote radio control.

Largely because of the target autonomy and the resulting ease of setting up a mock battle, SAAB has sold its targets to the Norwegian and Danish armies as well as Sweden's. And the company says it has negotiations under way with eight other European armies. Early next year, SAAB will demonstrate its equipment in the United States and Canada.

Through channels. The SAAB targets are controlled by a portable transmitter, about the size of an attaché case, that puts out about 1 watt—enough to actuate receivers on targets up to 3,300 yards distant. The transmitter operates in the 30 megahertz band and has 36 tone-frequency channels. Channel-selection is by pushbutton.

Each transmitter controls up to 12 battlefield receivers and each receiver is tuned to pick up only three tone-frequencies assigned to it. One receiver channel controls raising the associated targets (as many as 10 targets can be hooked up to one receiver), a second controls lowering, the third turns on and off the machine-gun sound simulator or gun-fire simulator.

The targets have sensors that pick up vibrations set up when a bullet passes through the target. On the infantry targets, an output from the sensor actuates a solenoid valve that ports compressed air to the target-lowering mechanism. The targets also can be lowered by a signal from the transmitter. On the tank targets, the sensor signal flashes an off-target lamp or triggers a smoke-puff unit that shows a hit has been scored.

Tougher enemies. SAAB is working on an improvement that will make it harder to put its targets out of action. Although the sensors on the present targets won't develop an output when short shots knock pebbles against the targets, they do score hits by ricocheted bullets. SAAB is developing a sensor that will distinguish between true hits and ricochets.

And SAAB has about ready for market an instant-scoring system for air force strafing practice. Sensors on the ground targets will be linked to a central remote scoring device and pilots will get their scores by radio immediately after their runs. On most strafing ranges, ground crews have to check the targets for hits after each pass by a strafing plane.

Hot line

The L.M. Ericsson Telephone Co. has moved into a commanding position in the scramble to stake out

. . . **Up pops** a radio-controlled target.

shares in the lucrative West European market for electronic telephone-exchange equipment. The company this month reported three new orders for computerized exchanges: one for Rotterdam, one for Helsinki and one for the Swedish Air Board.

The Rotterdam exchange will be built for the government-run Dutch telephone system at a cost of $2 million. It will handle switching between Dutch cities and some 18 district telephone centers, plus international traffic in the southern part of the nation. The station will be in operation by mid-1968 and will have a capacity of 30,000 lines.

Along with computer-controlled switching, the Rotterdam system will make possible such special services as automatic transfer of calls from one number to another number, one-digit dialing for frequently called numbers, push-button dialing, wake-up service, conference calls and the like.

Space division. The Dutch installation will be similar to an Ericsson 4,800-subscriber, computerized exchange about to go into operation in the town of Tumba, outside Stockholm. The Ericsson electronic exchange, like those in service in the Bell System in the United States, uses space division with a separate wire path for each conversation. For the electronic exchanges Ericsson developed a special-purpose digital computer and a compact code switch containing 2,000 contacts that is smaller than a conventional 1,000-contact crossbar switch [Electronics, Oct. 4, 1965, p. 213].

The Helsinki exchange, ordered by the privately owned Helsinki Telephone Co., will have an initial capacity of 4,000 lines and is scheduled to go into service in mid-1969. It is designed for fully automatic and semiautomatic traffic, both domestic and international.

Ericsson has not released technical details on the computerized exchange ordered by the Air Board, the Swedish Air Force's highest authority. The value of this contract is about $2-million. The equipment will be used in the board's own nationwide communications network.

Israel

Export expectations

Signs point to a dramatic rise in exports of electronic and electrical equipment from Israel over the next few years. The prospects are so bright that although exports for the electronic-electrical industry reached $1 million only two years ago, the Israeli Ministry of Commerce and Industry now predicts exports will exceed $18 million within the next four years.

Ministry officials offer substantial evidence to back up their prediction. Despite the ups and downs of the Israeli economy in recent years, foreign technology-oriented companies have found a stable climate for investments. Of the 30 major Israeli electronics companies, about 20 have some foreign interest. And there's been a trend recently to know-how or coproduction arrangements between Israeli electronics companies and technically strong companies in the United States, Britain, France, Germany and Switzerland. These ventures are aimed primarily at exports, since Israel, with 2.6 million people, is a small market.

What's more, the government this fall started a drive to diversify the country's exports. Israel's kingpin export products currently are polished diamonds and citrus fruits, but rising production costs are making them increasingly harder to sell in world markets. To broaden the country's export base, the government offers extra tax rebates to manufacturers who produce new products for export. The rebates range from 3.5% to 8.5% and they also apply to products that replace imports. The government is fighting a rising tide of imports.

Selective. In their export effort, Israeli electronics companies are concentrating on the gaps in the world-market product lines of the major international companies. The Israelis already are selling abroad small custom-built computers and peripheral equipment, electromedical equipment and some test instruments. Elron Electronic industries, for instance, a partner with the government in the new Elbit Computers group, forecasts its exports will run about $250,000 for the 1966-1967 fiscal year, compared to $150,000 for the previous year.

Along with its rising exports, the industry will get a lift next year when Israel establishes a television network. According to William E. Robinson, managing director of the Jerusalem-based Overseas Radio Corp., the potential market for tv sets is more than 350,000 units. Most of the market should go to Overseas Radio, in which the Zenith Radio Corp. has a minority holding.

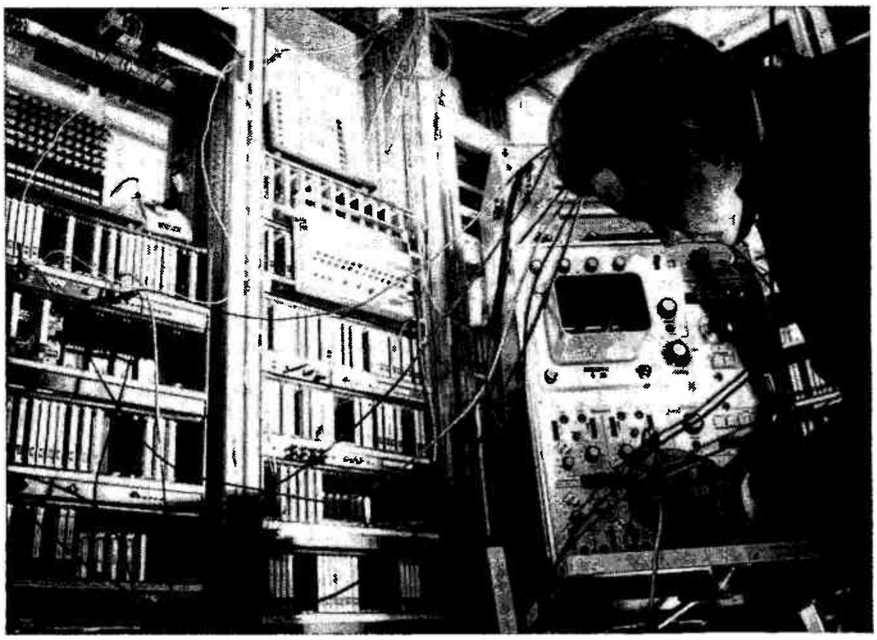
West Germany

Pipeline under control

The dozen international oil companies that are spending $185 million for a transalpine crude-oil pipeline are going to great lengths to make sure that everything will be under control when the 286-mile line goes into service next year.

The pipeline starts on the Adriatic coast south of Trieste, Italy, and stretches to Ingolstadt in southern Germany. En route, it crosses 150 rivers and cuts through the Italian and Austrian Alps in tunnels at altitudes up to 5,000 feet. Because much of the pipeline will be practically inaccessible once it's laid, its owners are making it the most closely controlled pipeline yet built.

Instead of a single main control station, the transalpine pipeline will have two, one near Trieste and the other at Ingolstadt. From these stations, operators can set the positions of 30 main slide-valves and control dozens of pumps and motors at pumping stations along the line. All in all, the main stations can send out a total of 135 remote commands to control equipment at pumping and transfer stations. And operators can keep an eye on some 50 different crude-oil parameters like pressure, flow rate, temperature and density.



Remote-control station for transalpine pipeline is built up by Siemens from some 3,000 Simatic N plug-in NOR gate circuits.

Private line. The oil data, plus valve and pump information, will be fed in from 29 telemetering stations installed along the pipeline. Part of the data sent to the two main stations will also be transmitted to a control substation in Austria for monitoring.

Because the Italian, Austrian and West German telephone networks would have been involved were the remote-control and telemetering system tied into regular telephone lines, the pipeline operators laid their own cable alongside the pipeline.

A pair of four-wire lines in the cable will handle the flow of data and control signals. Time-division multiplex and pulse-code-modulation techniques will be used to squeeze 25 narrow-band channels with 50 baud transmission speed into a normal 3 kilohertz voice channel. Each station along the line will have one channel, frequency keyed by the remote-control equipment. The main stations will interrogate the telemetering stations once every five seconds.

At the main stations, incoming data will be decoded and fed to analog displays or recorders. However, both the main station at Trieste and the Austrian substation will have digital data-loggers as well. The main stations and the substation will have limit monitors for pipeline pressure and oil flow and any of them will be able to transmit an emergency stop signal if pressure or flow starts to get out of hand.

West German's Siemens AG is supplying the control equipment. Basic building block of the system is the company's Simatic N low-frequency NOR gate.

Electronic arm

Help is in sight for the hundreds of West German children born several years ago with limb deformities caused by tranquilizers their mothers took while pregnant.

In a project financed by the Ministry of Health, the Ferdinand von Artl Academy for Psychophysiology has developed an electronic lower arm with a hand that can grasp and release objects. The lower arm is the first step toward a prosthetic device that can duplicate the movements of a complete arm. No timetable has been laid down for developing the complete arm, but work will start next year on a feedback system that will let users of the arm sense how firmly they grasp an object. The next logical step is to develop wrist rotation and, finally, an upper arm.

The research was triggered by the birth of many deformed babies in the early 1960's, later traced to the use of the drug thalidamide by expectant mothers.

Muscle control. Dieter Born, an electronics engineer at the Von Artl Academy, designed and built the arm. Called a Bioelektronikon, it can apply grasping pressure up to 11 pounds. Like the prosthetic sleeve developed in Russia [Electronics, Dec. 28, 1964, p. 111] and the experimental artificial arm of the Philco-Ford Corp. [Electronics, Sept. 20, 1965, p. 42], Born's limb responds to electromyographic (EMG) potentials. These are the tiny voltage signals transmitted when the brain orders a muscle to contract. An electrode attached to the skin picks up the potentials and feeds them to a 13-transistor amplifier whose output controls a relay. The relay, in turn, controls a 12-volt motor that actuates the hand.

The EMG voltages produced by muscle contraction have an amplitude of about 1 millivolt. However, the resistance of the layers of fat and the skin between the muscle and the electrode causes the amplitude at the electrode to drop to a level between 30 and 100 microvolts. The electrodes—one to control grasping, the other to control releasing—are foam rubber pads wetted with a low-resistivity solution.

The EMG voltages are amplified in a two-stage amplifier with a power gain of 75 decibels. The amplifier's output is fed to a pulse generator and then to a delay network. Thus, the motor relay stays closed so long as there is a pulse train triggered by an EMG voltage input from either of the two electrodes. The circuitry and the power supply, a rechargeable 12-volt nickel-cadmium battery, are packaged in an external pocket-size unit.

Adding functions. Born says that the basic circuits of the Bioelektronikon could be duplicated in parallel to build a complete artificial limb that could execute almost all the functions of a normal arm. The trick is finding enough control muscles that aren't used during normal body functions. Theoretically, even eyebrow muscles could generate the EMG voltages to control artificial arm movements. A complete artificial arm would need nine electrode-amplifier sets, each with a distinct control muscle.

Before he tackles additional functions, though, Born plans to perfect the grasping of the artificial hand. Early next year, he'll start work on a feedback network that will transmit pulses back to the brain so the limb-user can "feel" how firmly he is grasping something. The West German Ministry of Health earmarked funds for this development a fortnight ago.

Automatic underground

Add Hamburg to the list of cities like Paris and Montreal that are turning to electronics for mass-transit control. Under test now in the Hamburg subway is a system designed to stop trains at station platforms with an accuracy of three feet; the system also allows headway between trains as short as 60 seconds, about one-third the current interval between trains.

Like the automatic control complex on trial in Paris, the Hamburg experimental system uses inductive loops laid between the subway tracks as the basis of its control. The loop triggers a pulse output from a transmitter-receiver located on the train's undercarriage. The loops are installed at fixed intervals of about 100 feet so the pulse interval reflects the train's speed.

A trackside pickup logs the pulses, and through them keeps track of the train's position and its speed. When the train should speed up for a straight stretch or slow down to approach a station, the computer-like trackside equipment feeds back control pulses to the transmitter-receiver on the train's undercarriage. For the trial, the pulses are converted into a speed-indication for the train operator; later they will serve as the basis for automatic train control.

Both Siemens AG and Allgemeine Elektricitats-Gesellschaft are supplying the hardware for the test systems.

The Hamburg public transport company is running the trial on a 3.6-mile regular subway line. Unless unforeseen difficulties cause delays, the company plans to extend automatic control to all the city's subway lines at the end of 1967. The full-fledged system will have a central train describer that will display locations of all subway trains with an accuracy within 30 feet.

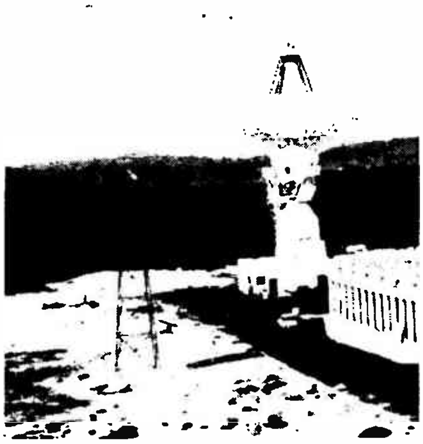
France

Keeping track

The de Gaulle government, now developing its own nuclear missiles and space boosters, is depending on the French electronics industry to outfit the top-secret missile test center under construction near Bordeaux. Although the Centre d'Essais des Landes is not due to be completed until late 1969 or early 1970, testing has been under way since February.

The site lies between Biscarosse and Mimizan on the Atlantic coast some 40 miles south of Bordeaux, and covers an area 15 miles long and three miles wide. It succeeds the Colomb - Bechar - Hammaguir test site in the Algerian Sahara that the French have agreed to vacate by July, 1967.

Primary mission of the new site is testing tactical and intermediate-range missiles and some air-to-ground and ground-to-air weapons. But it will also be used for tests of the "Cora" rocket, the French second-stage contribution to the Europa-I launcher being developed by the European Launcher Development Organization (ELDO).



Cyclope 2 precision antenna at Landes tracking center covers frequency range from 216 Mhz to 2,300 Mhz. Gain is 45 db at 2,300 Mhz.

The Landes center is equipped for both optical and microwave tracking. The optical system consists of five stations equipped both for television and film recording. Cinetelescopes are used to measure altitude changes of a missile up to 60 miles. Electronic tracking and telemetry are directed from a control center, using a CAE 90.8 computer. This is the largest digital computer made by Compagnie Européenne d'Automatisme Electronique, a major member of the new all-French computer company [Electronics, Aug. 8, p. 301].

Message center. The computer has a cycle time of less than two microseconds to permit it to receive up to 20 messages a second from supporting stations. The memory has 30,000 24-bit words. Working in real time, the 90.8 compares data, provides instantaneous information on the position and speed of the missile, calculates its probable impact point and sends the data to tracking and observation stations. The computer also prints out data for each flight for later analysis.

Other Landes electronic equipment includes the Aquitaine radar supplied by Compagnie Française Thomson Houston-Hotchkiss Brandt. This system can follow a transponder-loaded missile about 1,500 miles with an accuracy to within 33 feet. It has a peak power of one megawatt and operates in the C band. Its 10-foot-diameter Cassegrain antenna has a gain of 41 decibels. One Aquitaine radar is already in service. Another will be installed at Hourtin, some 30 miles northwest of Bordeaux, and a third at a down-range tracking ing station on the island of Flores in the Azores.

The Hourtin Aquitaine is linked to an L-shaped trajectory determination system designed for tracking both missiles and Cora rockets.

The Aquitaine radar at Landes is supplemented by two smaller radars, known as Cotal and Supercotal, which have ranges of about

400 miles. They also pick up data from the transponder. Both do more than just back up the Aquitaine; they aid it during multiple missile firings.

Signal scoop. Also at the new center is the Cyclope 2 precision antenna, successor to Hammaguir's Cyclope 1. Builder is Elecma, the electronics division of the government-controlled aircraft engine company, Société Nationale d'Etude et de Construction de Moteurs d'Aviation. The Cyclope's 39-foot diameter dish picks up telemetry signals by conical scanning at a frequency of 15 megahertz and has a range of about 1,500 miles. It covers the entire 216-2,300 Mhz band and has a gain of 26 decibels at 250 Mhz and 45 db at 2,300 Mhz.

In addition to its Aquitaine, the Flores station is now getting equipment to follow the return to the atmosphere and impact of the 1,500-mile-range weapons. This gear includes instruments for optical, infrared, photographic and spectrographic measurements. The Flores installations will also be called on to follow satellite launchings from France's new space center in French Guiana, where launchings should begin in 1969 [Electronics, Nov. 1, 1965, p. 159].

Rounding out the new equipment at Landes are three instrument-packed DC-7 aircraft to track short-range missiles. Then, in 1968, a tracking ship, the Henri-Poincareé, will complete the network. The vessel will carry Thomson Houston's newest radar, the Béarn. Somewhat smaller than the Aquitaine, the Béarn can automatically track transponder-loaded missiles traveling 18,000 meters a second at distances up to 2,500 miles with an accuracy of 10 feet.

Great Britain

Iron-horse computer

As with most railroads, British Railways expects to one day have computers controlling its train runs. That day is far off, but the government-owned line will take a first step in that direction early next

Electronics Abroad

year when it puts a group of computerized signal boxes into service.

The group—three main boxes and six smaller ones—is now being installed on a section of track west of London on the heavily traveled Bournemouth-London line. A second group of eight boxes has been ordered by British Rail for the Leeds area in the north, with Elliott-Automation, Ltd., supplying the equipment.

In sight. The central train describer for each group of boxes will be fed the signals currently used to show which trains occupy which blocks of track. The signal-tower describer will register the inputs in a core memory with a capacity of 8,000 words of 18 bits. The computer unit will process the incoming data—the logic circuits are monolithic integrated circuits—and display it on a cathode-ray tube. Each train will show up on the display as a four-character alphanumeric code that will advance across the crt as the train progresses from block to block.

British Rail's investment in the two systems is slightly more than $360,000. For the money the railroad is getting equipment that at first glance does little more than the existing gear, although it's much smaller. But the computerized signal-box setup with crt display represents a tryout of the first half of a computer system to control the signal lights themselves. The computer outputs that control the display could be the inputs to a computer that would generate signals to switch signal lights.

Japan

Numbers games

As Japan's computer industry enters the age of integrated circuits everything about the industry seems headed up—except the number of computer makers.

At the Japan Electronic Computer Show late last month, all six of the country's native data-processing producers turned up. Four had hardware with IC central processors on their stands and the other two said they'd have IC processors on the market next year. Along with the new hardware, the show brought estimates of from $85 million to $100-million—a strong gain—for deliveries of domestic computers during the fiscal year that will end next April. Deliveries of imported machines are expected to run at about the same level as domestic machines.

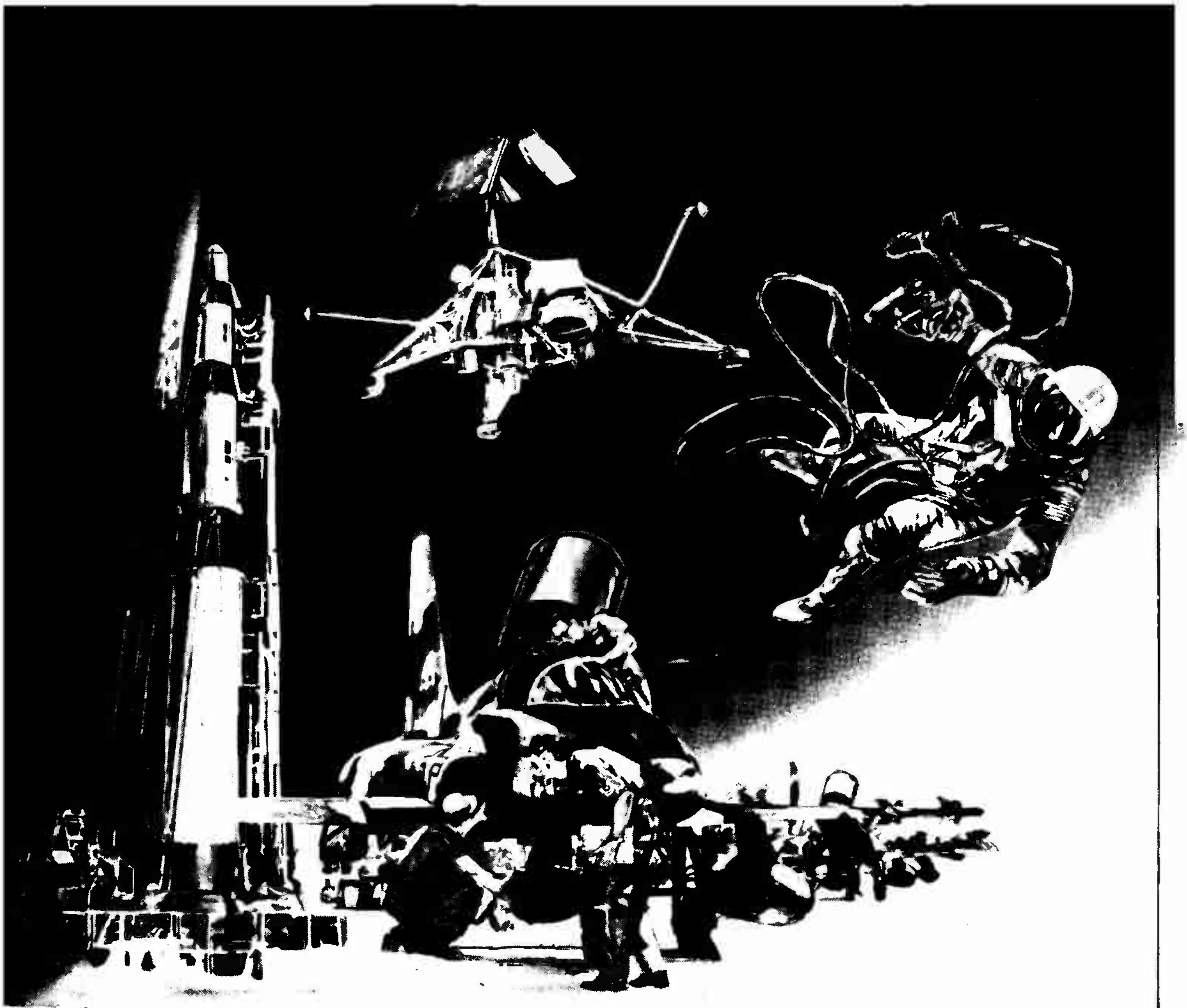
For all the brisk business in the offing, there's speculation that the number of Japanese computer makers will drop to five before too long. A trio of producers—the Nippon Electric Co., Hitachi Ltd. and Fujitsu Ltd.—holds about three-fourths of the market. All three are shooting for sales of $28 million this year, leaving fairly slim pickings for the remaining three.

Behind. Of the three companies in the lower half of the standings, only Tokyo Shibaura Electric Co. (Toshiba) remains in the same race as the first division companies. Toshiba has about an eighth of the domestic-computer market.

Oki Univac Kaisha Ltd., a joint venture of Oki Electric Manufacturing Co. and the Univac Div. of the Sperry Rand Corp., has almost an eighth of the market. But Oki has settled into a role of an assembly plant—using both imported and domestic components—of Univac-designed machines.

Mitsubishi Electric Corp. holds only 2% of the market for domestic computers and seemingly is hanging on only to strengthen its hand in negotiations to team with the General Electric Co. and Toshiba for a computer joint venture. Talks between the three companies are now underway with GE and Mitsubishi pressing while Toshiba holds back. One stumbling block in the negotiations is Mitsubishi's ties with the Westinghouse Electric Corp. Then, too, Mitsubishi and Toshiba are allied with different industrial groups in Japan.

Toshiba, though, may come around even though the company did manage to increase its market penetration this year. Compared to the leaders, Toshiba has the handicap of a mixed bag of computers—



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some are Toshiba designs, others are GE designs — rather than a homogeneous family of machines.

Accent on IC's. All three of the leaders now have third-generation computers in production. Nippon Electric Co. is putting most of its effort into its NEAC 2200 series, based on the Model 200 computer of Honeywell Inc. Most NEAC 2200 computers have discrete components, but NEC has rounded out the family with two IC machines. At the bottom of the line is the NEAC 2200 Model 50, smaller than anything Honeywell produces in the series. The top of the line is extended with the Model 500.

The Model 50 uses monolithic diode-transistor-logic circuits that NEC produces itself and the company may switch to IC processors for larger models when its output of circuits is sufficient. NEC maintains the redesign for IC's wouldn't be difficult.

For its new large computer, the 2200 Model 500, NEC opted for complementary transistor logic circuits supplied by the Fairchild Camera & Instrument Corp. The first Model 500 was delivered last month to the University of Osaka where it will be used in a time-sharing system similar to Project MAC at the Massachusetts Institute of Technology.

NEC has even larger computers in mind, but they will be built around the current-mode-logic circuits the company has in the works.

Home made. Fujitsu's bread-and-butter line is the Series 230 computers it designed itself. The four models currently on the market have discrete components, but three IC machines are in the offing. Fujitsu introduced at the show a scientific and process-control computer—the Series 270 Model 30—with Fujitsu transistor-transistor-logic circuits. Fujitsu makes the IC's itself, but its circuits are interchangeable with the TTL line of Texas Instruments Incorporated.

Hitachi's IC machine is its Series 8000, a version of the Spectra 70 of the Radio Corp. of America. Hitachi currently imports most of the IC's it needs for the computer but eventually will supply its own.

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■ For more information on complete product line see advertisement in the latest Electronics Buyers' Guide

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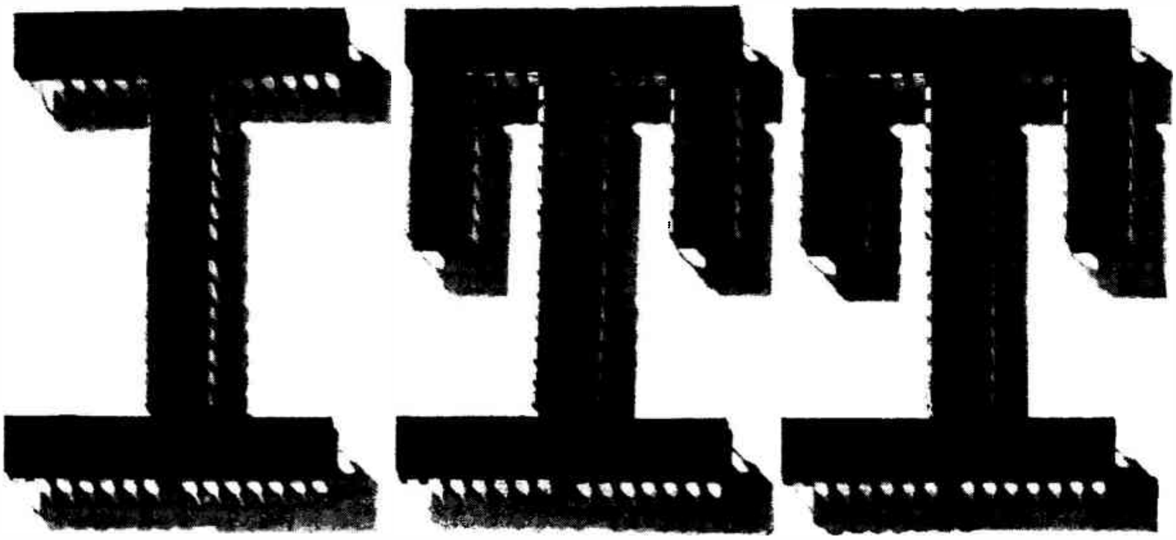

You eliminate series 930 DTL evaluation, delivery, packaging and single source troubles. Here's why:

Evaluation — Our 930 DTL circuits and test limits are identical to those of the other leading manufacturer.

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SPEED TESTING & INCREASE PRODUCTION OUTPUT

New hp Model 155A/1550A Push-Button, Programmable Oscilloscope

Speed production line testing of circuits and components with an easy, fast press / read on the new hp Model 155A/1550A Push-Button Programmable Oscilloscope! This 5 mv/cm, 25 MHz scope—the first designed specifically for production and automatic systems applications—increases production output by reducing test time per unit, simplifying test procedures, minimizing operator errors and fatigue, and shortening training time.

You can insert up to 18 test programs in each 1550A digital programmer, or cascade programmers for additional capability. Each test program can control any or all major scope functions—including calibrated vertical positioning, sensitivity, input coupling, sweep time, trigger source, and trigger slope. Change test programs in only a few minutes by changing diode pin settings or by interchanging programmers. Diode-controlled, digital programming makes the 155A / 1550A fully compatible with any contact-closure-to-ground programmer for high speed, automatic check-out systems.

Confidence in measurements is substantially increased because the unique DC stabilizer circuitry eliminates DC drift. The trace stays where it is positioned, regardless of sensitivity or sweep. Calibrated vertical positioning over ±25 cm dynamic range allows waveform to be accurately offset, magnified, and viewed in detail. Magnification with accurate offset gives big display for ease of reading and greater accuracy.

Confidence in test results is increased by push-button programming because it makes complex tests easier to make. Tests are complete—you have full confidence that you are shipping only good units and rejecting only bad units.

Find out how the new hp Model 155A/1550A Push-Button, Programmable Oscilloscope can increase your production output. Call your nearest hp sales office for a demonstration. Or, write to Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000: Europe: 54 Route des Acacias, Geneva. Price: hp Model 155A Oscilloscope, $2450.00; hp Model 1550A Programmer, $600.00, f.o.b. factory.

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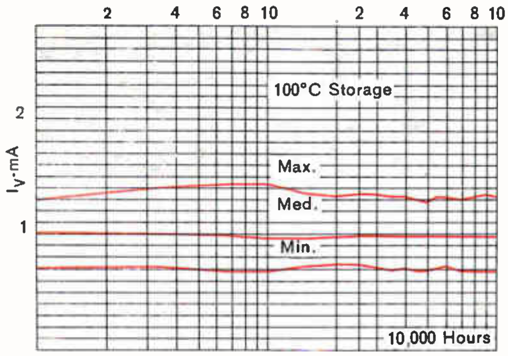
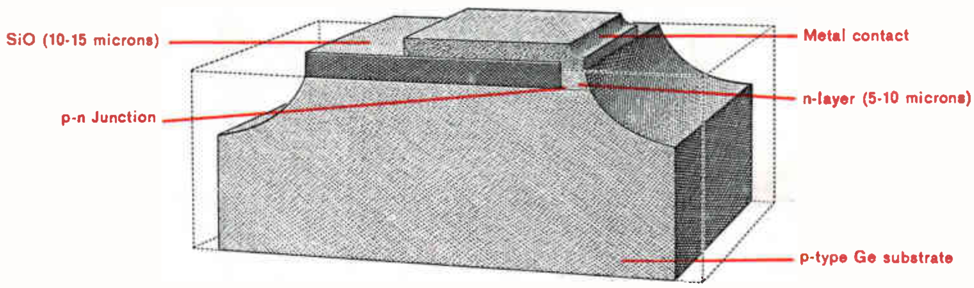
An extra measure of quality

Circle 901 on reader service card



Long range life data for typical RCA TD-II tunnel diode.

Unexcelled tunnel-diode reliability assured by RCA TD-II technology



Cross-sectional view of RCA TD-II pellet before and after etching

RCA TD-II technology introduces a new standard of tunnel-diode reliability. Life tests exceeding one-million device hours have demonstrated the unprecedented stability of this epitaxial planar structure, an RCA-pioneered first for tunnel diodes.

In the TD-II process, a SiO layer is initially used to mask the surface of a p-type germanium wafer. Then an n-layer is epitaxially grown over all unmasked or inert areas to form many device junctions simultaneously. Even after individual etching, the diode retains the support of a massive stable substrate—without the "neck" structure found on earlier, less reliable tunnel diodes. Thermal resistance is improved. And, unlike previous designs, connection to a metallized contact can be easily made without placing all force directly on the junction. Because TD-II is a batch process, you benefit further from low cost and uniform characteristics. Other advantages include:

Wide Applications—With over 15 types having I_P of 5 to 100 mA and t_r of 100 to 1800 ps, RCA TD-II devices are ideal for high-speed switching and small-signal applications.

MIL-Tested—RCA TD-II units are designed to meet MIL-STD-750 including 1500 g shock and 20 g vibration.

Immediate Availability—Call your RCA representative today for off-the-shelf delivery. For data sheet and detailed reliability information, write RCA Commercial Engineering, Section I-N-12-2, Harrison, N.J. 07029.

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