August 24, 1962

electronics

A McGraw-Hill Publication 75 Cents

TRANSISTORS BY AUTOMATION

Conducting spheres replace fine wires, p 56
(Photo below)

MACHINE READS HANDWRITING

Recognizes names of numerals, p 29

R-F HEATER TESTS MISSILES

Power oscillator simulates reentry, p 38

Now you can have a universal oscilloscope with dual trace vertical bandwidth capacity greater than 40 MC—with no sacrifice in sensitivity. Seven separate vertical and horizontal plug-in units give the new hp 175A the greatest versatility ever offered in a general purpose 50 MC scope. Available are dual-channel, single-channel and high-gain vertical plug-ins, plus these horizontal plug-ins: auxiliary, time mark generator, display scanner and sweep delay generator.

The new hp developed 12 Kv CRT presents an easy-to-measure 6 x 10 cm calibrated display without distortion or defocusing. The front panel astigmatism control common to other scopes is no longer necessary. In addition, phosphor and graticule are on the same plane—thus eliminating CRT parallax error. The front panel is engineered for the simplest possible operation.

hp 175A features simplified circuitry for more reliable performance and easy maintenance. Simple triode circuits (6DJ8 tubes) are used in the vertical amplifier. Complicated distributed amplifiers are not employed. In addition, an hp developed cable delay line eliminates still more adjustments. Only 7 tube types and 5 transistor types are used throughout.

The hp 175A Universal Oscilloscope is housed in the new hp modular cabinet . . . a single instrument for both bench use and rack mount. Cover, bottom and sides are easily removed for simple servicing and routine maintenance. The hp 175A is as easy to service as it is to use!

These Plug-ins Give Utmost Versatility to the hp 175A OSCILLOSCOPE:

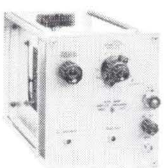
Vertical plug-ins

hp 1750A 40 MC Dual Channel Amplifier (pictured in 175A opposite)

Permits viewing of two phenomena simultaneously, bandpass dc to 40 MC, rise time 9 nsec, sensitivity 50 mv/cm. Differential input for common mode rejection. $285.00

hp 1752A High Gain Amplifier

Provides 5 mv/cm sensitivity dc to 18 MC with differential input for high common mode rejection. $225.00



hp 1753A 40 MC Single Channel Amplifier

Bandpass dc to 40 MC, rise time 9 nsec, sensitivity 50 mv/cm. $155.00

Horizontal plug-ins

hp 1780A Auxiliary Plug-In (shown in 175A opposite), normal and single sweep, $25.00

hp 1781A Sweep Delay Generator

For detailed examination of complex signals or pulse trains. Permits viewing expanded waveform segment while still retaining presentation of earlier portions of the waveform. Delay time 1 μsec to 10 sec.; delaying sweep, 2 μsec/cm to 1 sec/cm. $375.00

hp 1782A Display Scanner

Provides output to duplicate on X-Y recorder any repetitive wave appearing on scope. Resolution with permanent records higher than CRT or photograph. (Available soon)

hp 1783A Time Mark Generator

Permits easy time measurements by providing intensity modulated time markers on scope trace. Range, 10 μsec, 1 μsec and 0.1 μsec intervals, ±0.5%. $130.00

SPECIFICATIONS hp 175A

Sweep Generator

Internal Sweep:	0.1 μsec/cm to 5 sec/cm, ±3%; vernier extends slowest speed to 15 sec/cm
Magnification:	x1 and x10
Triggering:	Internal, from vertical input signal causing 2 mm or more vertical deflection, or from power line. External, from signal 0.5 v p-p or more
Triggering Point:	On positive or negative going signal; on external signal, level adjustable —10 to +10 v

Horizontal Amplifier

Bandpass:	DC to 500 KC
Sensitivity:	0.1 and 1 v/cm

Vertical Amplifier

Bandpass:	Main amplifier, dc to more than 50 MC

General

Power Requirements:	115/230 v ac ±10%, 50-60 cps. Maximum of 425 watts, depending on plug-ins used
Weight:	Maximum of 70 lbs., depending on plug-ins used
Price:	$1,325.00

Data subject to change without notice.
Prices f.o.b. factory.

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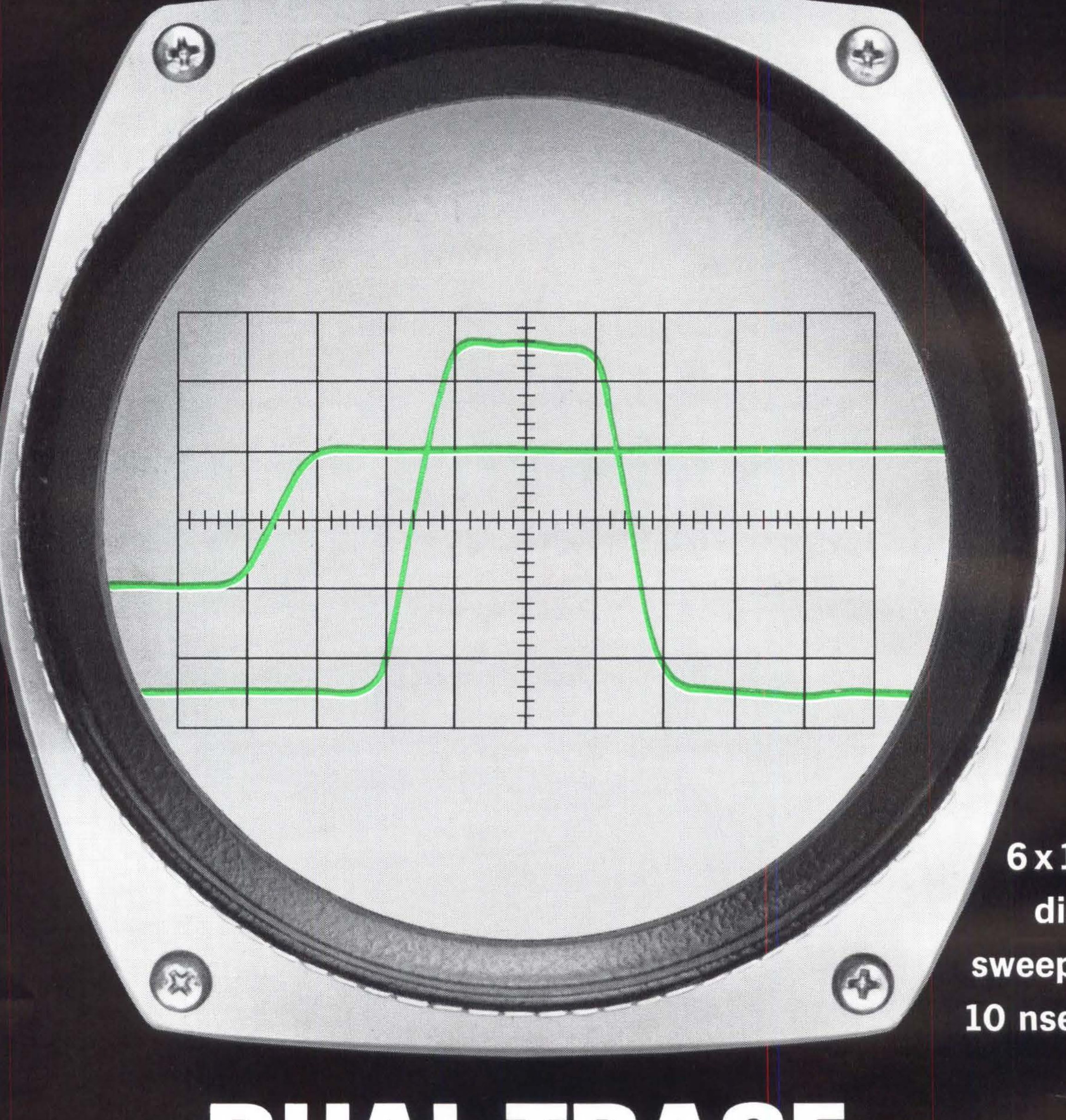
hp 175A 50 MC Universal Oscilloscope with hp 1750A Dual Channel Amplifier, hp 1780A Auxiliary Plug-in installed.

175A 50 MC OSCILLOSCOPE

- Bright, 6 x 10 cm display with no parallax, reflections or astigmatism
- Over 50 MC main vertical amplifier
- Dual trace, dc to 40 MC vertical plug-in
- Horizontal and vertical plug-ins for specific applications
- Easier to calibrate and maintain—no distributed amplifiers
- Positive preset syncing over entire bandwidth



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W. W. MacDONALD, Editor

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CONTENTS continued

DEPARTMENTS

CROSSTALK

FIELD EFFECTS. Chances are that we will soon see more major changes in the semiconductor components business and in the design of semiconductor circuits. And we are not talking about microelectronic functional devices—these are doing fine, but they are not the individual components that engineers generally use in equipment. We are talking about field effect components.

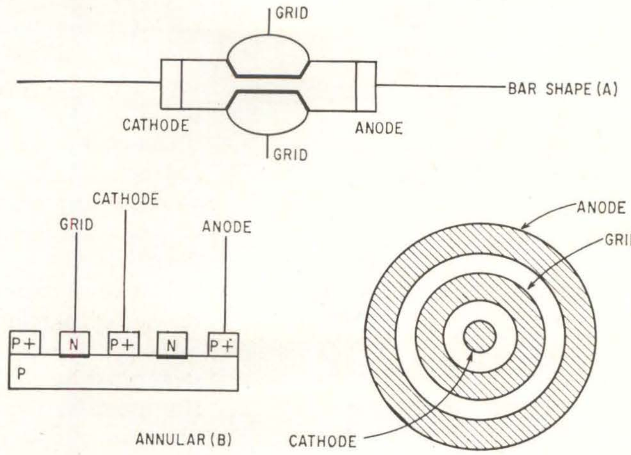
After 10 years (it was in 1952 that Shockley reported the theory of the field-effect transistor), it appears that reliable field-effect devices that can be reproduced at a reasonable price are at last at hand. Their performance capabilities have been greatly enhanced recently by the use of epitaxial manufacturing techniques. When more types of field-effect transistors become generally available, they should gain wider popularity in circuit design.

FOR A DOZEN YEARS, engineers have coped in one way or another with the problems of the transistor. Transistors have many advantages, but unlike an electron tube, the impedance between input and output is finite. This factor makes circuit design and application conceptually more difficult and, furthermore, changes in this impedance with frequency greatly compound the engineer's problems. Of course, through the years, engineers have learned to live with the transistor and its little quirks. In fact, in some instances such as complementary symmetry, they have turned the peculiarities of the transistor to advantage.

Then along comes the field-effect transistor, which behaves like a pentode tube, and engineers can have their cake and eat it too. They get small size, lack of filaments and almost infinite impedance from input to output. The only thing around with similar promise is the thin-film triode, but research workers are apparently having difficulty establishing a rationale for its operation.

SINCE YOU WILL soon hear a lot more about field-effect devices, you might like to bone up a bit on theory and practice through articles we have published in the past. A good place to start —without digging too far back in the files—is an article we published on p 66, May 15, 1959. That one reviews the field-effect triode transistor and then goes heavily into the theory and use of field-effect tetrodes.

Then there is the unipolar field-effect transistor, described on p 48, Dec. 23, 1960, as the basis for a binary full adder. Following that, you might look again at p 132, Aug. 12, 1960, an article on how photosensitive field-effect transistors can be used in oscillators and amplifiers. The field-effect transistor as a negative-resistance device, and how to make one, was reported on p 48, Feb. 2, 1962.



For an overall view of the total semiconductor picture, and how field-effect devices fit into the montage, we refer you to our special report, What's New in Semiconductors, p 89, Sept. 29, 1961. Like other transistors, field-effect types can be made in many configurations. The illustration reproduced above shows two of them, the bar shape in cross section and the annular in cross section and plan views.

HANDWRITING—Probiem of generally recognizing script writing is still far from being solved. The article in this issue by Leon D. Harmon, of Bell Telephone Laboratories, however, gives some insight into a method for analyzing handwriting that could aid development of cursive script-reading machines.

Harmon's article describes a machine that recognizes the 10 digits *zero* through *nine* written in script. The device is simple and is based on a logical analysis of certain properties of carefully written words. Other properties, such as vertical extent, retrograde strokes and closure would probably have to be dealt with in developing more sophisticated machines.

Author Harmon has been working for the past several years in such areas as automata, information processing in nervous systems and artificial electronic neurons. An article by Harmon, on p 39 of our Sept. 2, 1960, issue, described a line-drawing pattern recognizer in which a dilating circular scanner using 32 photocells recognizes opaque two-dimensional geometric figures independent of size, rotation, precision of drawing or positioning.

COMMENT

Mechanical Getter

Clean rooms and clean manufacturing techniques of all types have come into vogue as manufacturers try to make equipment and components more and more reliable. Clean-room manufacture has now reached a degree of sophistication where dust particles can be kept out of assemblies to almost any degree desired.

But the threat to reliability from unwanted particles is still with us, although now the particles are often generated by the device itself, after the manufacturing process is complete. In completed diodes and transistors, for example, loose particles are generated under vibration from minute solder globules and from small chips of various kinds of material breaking off. When these particles come to rest in the wrong places, circuit failure can occur. X-ray photography is about the only way of detecting failure possibilities from this cause.

Potentiometers, by the very nature of the wiping action of the pick-off, generate a large number of dust-like particles, which again appear to be a major cause of failure in these devices. The major parameter in potentiometer degredation is noise, and it is likely that loose particles are a major source of noise.

The problem is reminiscent of the problems of vacuum-tube makers in the early days, before it was recognized that included gases were a major source of trouble. Once this was established, electrical getters were added, and vacuum-tube reliability took a giant step forward.

By obvious analogy then, the question arises, is it time to add some kind of mechanical getter for diodes, transistors and potentiometers, to pick up particles generated after the component is out of the manufacturer's hands?

A number of ways of making such a getter come to mind at once. A small, magnetized core of iron—various shapes and modifications are possible—covered with tiny hooks of nylon or teflon of the type now used in zipper-like closures, might be suitable. If the getter is clean and inert, it will not interfere with device operation and it will pick up and hold small particles that come within its reach. In quantity production, costs for such a device would be almost negligible. Another obvious way to accomplish the same task might be a simple spiral recess, like a snail shell, which would tend to trap any particle that enters. Such recesses could be molded into many parts in relatively simple ways.

DONALD FLYNN
New York, New York

There is a porous glass dessicant, made by one manufacturer, which has been installed in enclosed relays to prevent the relay contacts from being dirtied by contaminants given off at high temperatures. According to one user, up to 99 percent of the organic contaminants remaining after production degassing are absorbed by this dessicant.

Information Storage and Retrieval

Let me congratulate you on your article, Information Storage and Retrieval, in the June 29 issue (p 39). The article is informed and informative, well-balanced, and fair.

You did succumb to a blind spot in virtually all work on retrieval in America when you said:

"Two basic techniques for indexing presently in use are classification and coordinate indexing. These include traditional hierarchical subject classification schemes such as the Dewey Decimal and alphabetical subject index systems. Unfortunately, it is not clear how to establish a hierarchy of classes which will make much search localization possible."

Your informants thought it unnecessary to refer you to any work on classification in the present century, though much such work exists, including that of Ranganathan in India and the Classification Research Group in England. A book on *non*-hierarchical classification has recently appeared (Vickery, B. C., "Faceted Classification," Aslib, London, 1960).

CLIFFORD J. MALONEY
Division of Biologics Standards
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Bethesda, Maryland

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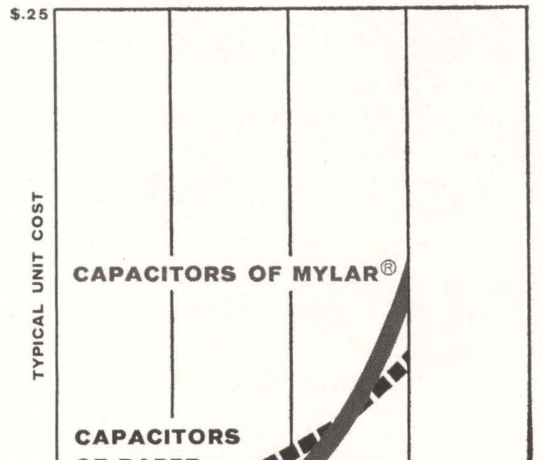

You may not realize it, but you can benefit from the higher dielectric strength, moisture resistance and reduced size of capacitors of "Mylar"* polyester film without paying a premium price. An industry study of manufacturer prices shows THAT OVER A RANGE OF SIMILAR CAPACITANCES AND RATINGS, UNITS OF "MYLAR" COMPARE CLOSELY IN COST WITH THOSE OF PAPER.

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ELECTRONICS NEWSLETTER

Satellite Communications, Inc.? Not Just Yet

WASHINGTON—Approval of the satellite communications act is only the first stage of getting the system off the ground. Forming and financing the corporation will take six months to a year, deciding on a type of system will take a year or more and—most experts predict—it will be 1964-65 before continuous, global communications are possible.

Before the type of system is decided, at least two more research satellites will be orbited and tested, in addition to Telstar. NASA is expected to launch Relay, developed by RCA, next month and to launch Syncom, a high-altitude synchronous satellite under development by Hughes, next year. Satellites orbiting 3,000 to 5,000 miles high are expected to make up the first system. Global coverage would require 27 to 50 of those.

A start will probably be made with a few such satellites, with others added gradually. The corporation may petition FCC to let it take over all experimental communications satellite in orbit, as the nucleus of a system.

While technical data on satellites is being accumulated, the corporation can move forward in establishing ground stations and getting frequency allocations and rate approvals. Rates are expected to match existing international rates at first and drop as satellite capacity rises. In the first years, the government will handle international agreements, continue research and make launchings on a cost-reimbursable basis.

Fairchild Licenses Philco On Planar Semiconductors

FAIRCHILD Camera and Instrument Corp. said last week that it has signed a license agreement with Philco Corp. under Fairchild patents for the planar process of semiconductor manufacturing. John Carter, Fairchild's president, said the company plans to license other manufacturers and that it is now negotiating agreements.

Fairchild claims that a process developed by its semiconductor division is now used by "virtually all of the major silicon transistor and diode manufacturers in the United States," and that it has made possible the building of integrated circuits. Fairchild described the process as "the introduction of impurities through and under a passivated oxide protection layer over basic silicon."

It Takes Two Pilots to Launch a Rocket by Hand

TWO OR MORE pilots could get a spaceship off the ground without automatic controls. One pilot might do it in an emergency, but he would really have his hands full.

That is the gist of a report on 1,100 simulated rocket launchings, performed by the Martin Co., which is building the launch vehicle for the two-man Gemini spacecraft. The report was given at an Air Force symposium last week in Colorado Springs.

A pilot can control the vehicle if that is his primary job, but finds it difficult if he has additional tasks, such as monitoring malfunctions. A pilot could stabilize the booster in an emergency, but he should have an automatic backup system, or other pilots to help.

Vostok III and IV Won't Push Gemini and Apollo

WASHINGTON—NASA was claiming last week that there will not be a speedup in the Gemini or Apollo lunar programs as a result of the latest Soviet space feat.

NASA says it could pump another $1 billion or $2 billion into its program and speed it up some, mainly by round-the-clock shifts and development of more parallel equipment. But James E. Webb, the agency's administrator, maintains—as a personal opinion—that the U. S. will beat the Russians to the moon.

The assessment goes like this: the Russians advanced techniques needed for a lunar landing, extended the time of manned space flight and showed they could put more than one satellite into desired orbits. They did not accomplish rendezvous or transfer. They indiorbits. They indicated they may be going to use the earth orbit ap-

Can the Russians Knock Down Samos and Midas?

WASHINGTON—There is much speculation here that Vostok III and IV demonstrated the USSR's ability to launch a satellite close to another one already in orbit with the next step the ability to destroy another satellite.

One expected effect is that more weight will be given to the Air Force's arguments for a larger role in space, but it is impossible now to predict the outcome.

If it is decided that U. S. satellites can be knocked down, one of the questions will be the fate of the Midas early warning satellite and Samos reconnaissance satellite programs.

Several of these satellites have been launched. Midas reportedly is not working well. Its development has been stretched out and apparently downgraded. Samos is reportedly working well and is being pushed harder than Midas. Specific data, however, are classified.

The Air Force is also keeping mum about how well its space tracking and detection network followed the Vostoks. The reason given: why tell the Russians how good or bad our tracking system is?

proach the U. S. has junked in favor of a lunar-orbiting system. Booster size is pacing the U. S. and USSR programs—and as yet the USSR hasn't shown a booster big enough for a lunar landing attempt. U. S. optimism rides on getting one first.

The U. S. is preparing three boosters, each several times as powerful as the Atlases used for the Mercury flights. NASA is working on Saturns C-1 and C-5 and Air Force this week awarded a development contract to Martin for Titan III, which will loft Dyna Soar and other payloads weighing up to 25,000 pounds. But they won't be ready until the mid-1960's.

Research Aims at Wet Niobium Capacitors, Too

RESEARCH PROGRAM in three types of niobium (columbium) capacitors—foil wet capacitors and both wet and solid electrolyte capacitors of the porous or sintered pellet types—will be undertaken by the Kemet department of the Linde Co. under a $357,459 Navy contract.

Kemet will work on determining causes of instability in niobium-oxide dielectric films, developing materials and capacitor manufacturing. Kemet says that it has been researching the subject for a year and has evidence that the instability is due to trace impurities in the metal.

In addition to being more available than tantalum (p. 7, Aug. 17), Kemet said niobium oxide has a higher dielectric constant (42) than tantalum oxide (27) and is less dense, promising smaller and lighter capacitors.

Hawaiian and Yankee Hams Talk By Moon Bounce

BOSTON—Amateur radio contact between Massachusetts and Hawaii by moon bounce was accomplished this month by Sam Harris, chief engineer of Tapetone Electronic Labs, Medfield, and Ralph Thomas, of RCA, in Hawaii. They exchanged a message on 1,296 Mc after three months of planning.

Harris had his equipment set up in his back yard. The transmitter used an Eimac klystron with 300-w output and an 18-foot parabolic antenna loaned by D. S. Kennedy Co. The receiver had a parametric amplifier designed by Harris.

There is an amateur in Switzerland anxious to exchange moon-bounce messages with him, said Harris, so that will be next.

Portable Radio Station to Wage Psychological Warfare

WASHINGTON—Reflecting the Pentagon's new emphasis on counter-insurgency operations (p 14, Aug. 10), the Army Signal Corps has awarded a contract to Gates Radio for a broadcasting system that can be airlifted by helicopter and set up in hours. The station would be used to broadcast to civilians or enemy forces.

The first system will cost $1.2 million and is to be delivered in 10 months. The station will include two transmitters, a receiver for monitoring hostile broadcasts and for retransmitting U. S. programs, and associated equipment, all in 21 shelters or packages.

One transmitter will be a 50-Kw standard a-m broadcaster, the other will be a 50-Kw short-wave unit with a range of 6,000 miles. A-m coverage will be up to 12,000 square miles.

FAA's Traffic Control Expansion Plan Aired

DESIGN PLAN for an evolutionary air traffic control system has been released by the Federal Aviation Agency for guidance of the agency's R&D arm. The plan is based on the general recommendations of last year's Project Beacon report.

The new plan calls for: increased segregation of visual and instrument traffic in densely traveled airways and terminal areas, more reliance on radar (using besoons) for separation and control, development of altitude transponders to provide height information to ground controllers independent of pilot voice radio, expansion of positive ground control areas, and improved data processing and display.

In Brief . . .

RECENT ACQUISITIONS include the purchase of Consolidated Microwave Corp. by Antenna & Radome Research Associates (ARRA, Inc.). Electro-Mechanical Research has acquired Solartron, Inc. Infrared Industries is taking on the radiation electronics division of Victor Comptometer Corp. Electronic Specialty gets Statham-Swearingen, a Statham Instruments subsidiary.

MERGER has been arranged between Virba Microwave and Kevlin Manufacturing, to enable Kevlin to expand into the microwave components field.

DEVELOPMENT of a 600-Gc radiometer will be undertaken by Electronic Communications under an Army contract. Project includes investigation of harmonic mixing at 600 Gc, antennas and oscillators.

RAYTHEON is developing a pencil-beam radar system with 24-Mw peak power and a 60-foot dish antenna, under a $4.3-million Air Force contract. It will be used to trace and analyze signatures of reentry test targets.

GENERAL ELECTRIC announced this week it will enter the reed switch business. It estimates total annual market is more than $4.5 million a year.

LIGHTWEIGHT materials and processes for antennas will be evaluated by Goodyear Aircraft during a 16-month study for Army. Study will include antennas for space use as well as ground structures.

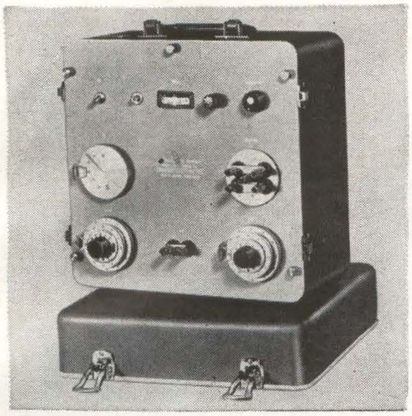
DEVELOPMENT of materials that would permit room-temperature operation of c-w, solid-state, organic lasers will be tried by Electro-Optical Systems under an Air Force contract.

PACKARD-BELL has a $1.7-million contract from Chrysler Corp. to produce automatic checkout equipment for the Saturn S-1 space vehicle booster.

LEAR-SIEGLER was awarded a $2.2-million contract by Air Force for meteorological radar systems. Radar frequency is 5 Gc.

(Advertisement)

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



The Sprague Model 1W1 Capacitance Bridge introduces a new concept in bridge design. Built *by* capacitor engineers *for* capacitor users, it incorporates the best features of bridges used for many years in Sprague laboratories and production facilities.

Special Features For Greater Accuracy

The internal generator of the 1W1 Bridge is a line-driven frequency converter, and detection is obtained from an internal tuned transistor amplifier-null detector, whose sensitivity increases as the balance point is approached. It has provision for 2-terminal, 3-terminal, and 4-terminal capacitance measurements, which are essential for accurate measurement . . . $\pm 1\%$ of reading $+ 10\mu\mu F$ . . . of medium, low, and high capacitance values, respectively.

No Damage to Capacitors

The model 1W1 Capacitance Bridge will not cause degradation or failure in electrolytic or low-voltage ceramic capacitors during test, as is the case in many conventional bridges and test circuits. The 120 cycle A-C voltage, applied to capacitors under test from a built-in source, never exceeds *0.5 volt!* It is usually unnecessary to apply d-c polarizing voltage to electrolytic capacitors because of this safe, low voltage.

Complete Specifications Available

For complete technical data on this precision instrument, write for Engineering Bulletin 90,010 to Technical Literature Section, Sprague Electric Company, 35 Marshall Street, North Adams, Massachusetts.

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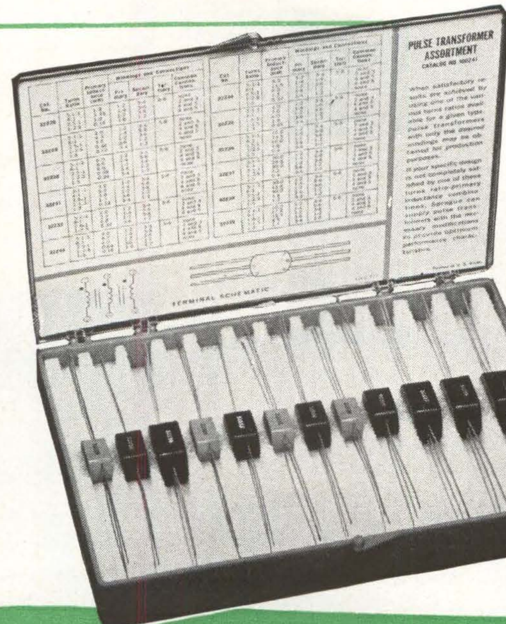

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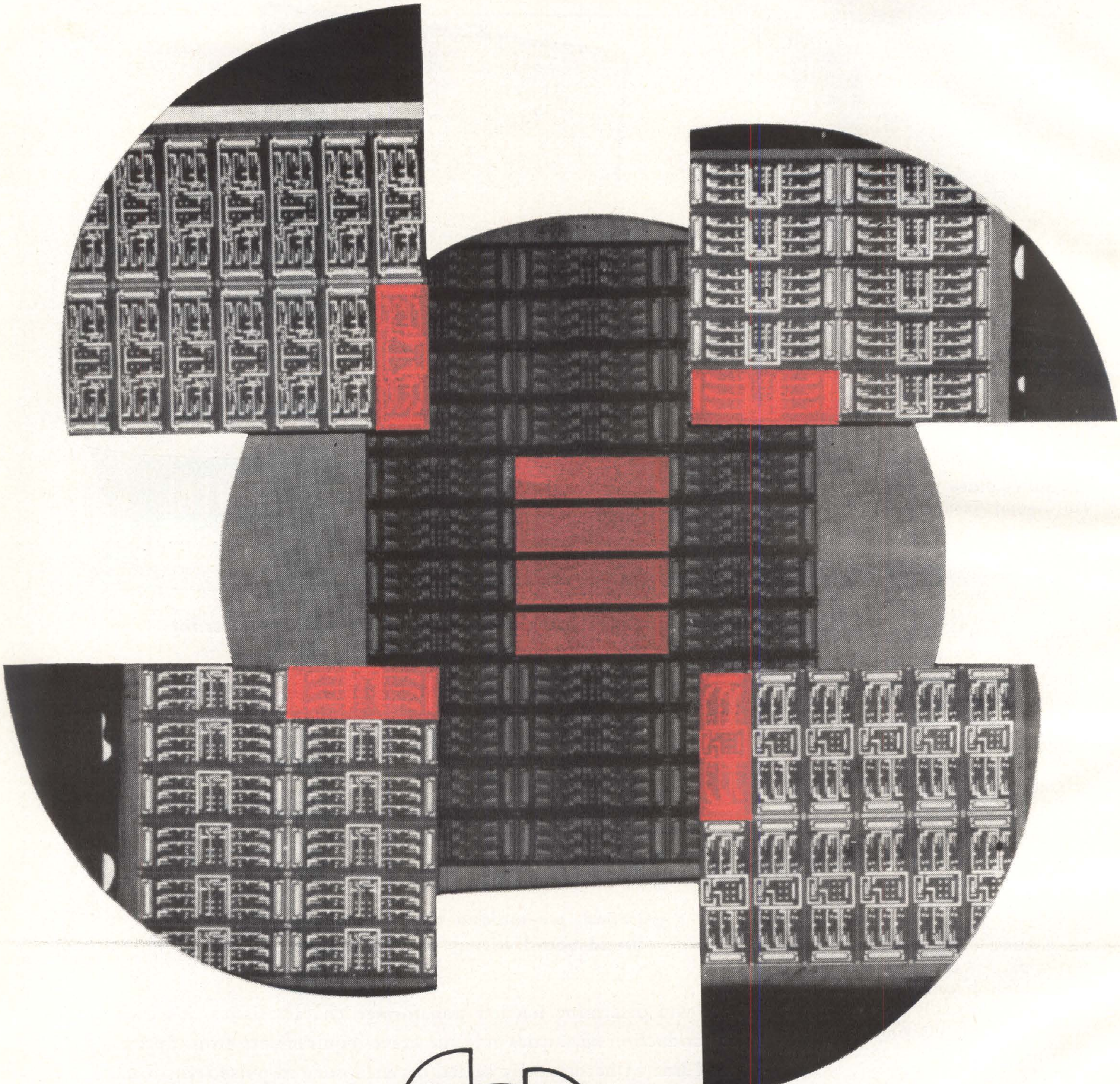

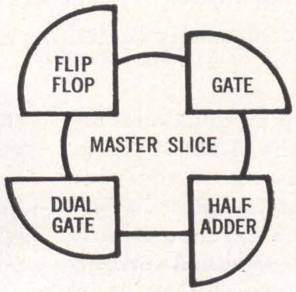

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SOLID CIRCUIT semiconductor networks are manufactured from pure silicon "master slice" wafers (center illustration) which contain more than 30 separate circuit bars. Customized interconnection patterns (four corner wafer fragments) are then photo-etched in aluminum on "master slice" wafers, producing completely integrated semiconductor networks ready for packaging.

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YOUR BENEFITS: You get a complete semiconductor network, integrating resistors, capacitors, diodes and transistors into a single, high-purity silicon wafer — to *your* specifications. Evaluation samples can be available within several weeks from final design approval. Because preparation of the special interconnection pattern is the only custom step in the manufacturing process, you get most of the economy and delivery benefits of using standard TI production units.

Of course, "master slice" variations may not satisfy all your circuit requirements. Totally custom semiconductor networks — starting with the pure silicon — can be designed by Texas Instruments to meet an even greater variety of applications.

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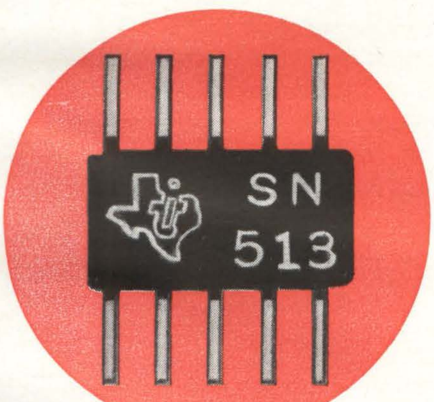
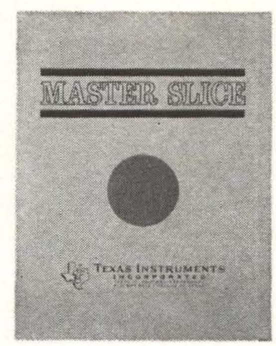


Completed *SOLID CIRCUIT* semiconductor network, enlarged $5\frac{1}{2}$ times.

For more detailed information on how "master slice" design offers you the first economical answer to custom circuits, call your local TI Sales Engineer or write to Department 370 today for this brochure.



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WASHINGTON OUTLOOK

SENATE TONES DOWN HOUSE'S MILITARY BUYING BILL

SENATE ARMED SERVICES COMMITTEE has approved a bill aimed at increasing competition and the volume of formal advertised bidding in military procurement, reducing the rate of negotiated contracting and sole-source buying, and curbing excessive profit on cost-reinbursement type contracts.

The bill is a milder version of a measure already passed by the House. The Senate version does not contain a House provision authorizing the General Accounting Office to review Pentagon decisions on negotiated sole-source procurement and advance payments and to void such contracts if it disagrees with the Pentagon's actions.

Both the Defense Department and industry spokesmen objected to the provision. EIA claimed the provision would "destroy the finality of negotiated contracts and becloud the financial stability of companies heavily engaged in defense business." House sources hint they are ready to kill or water down the GAO provision to assure passage of the bill.

By adding considerable red tape to contracting procedures, both House and Senate versions make it tougher for procurement officers to award negotiated rather than advertised bid contracts. But this is not expected to have an appreciable effect on contracting methods—some 85 percent of contracts are now negotiated through exceptions to the general rule requiring formal bidding and the major exceptions are essentially retained in the new bill.

HERE'S HOW PENTAGON RATES R&D FIRMS

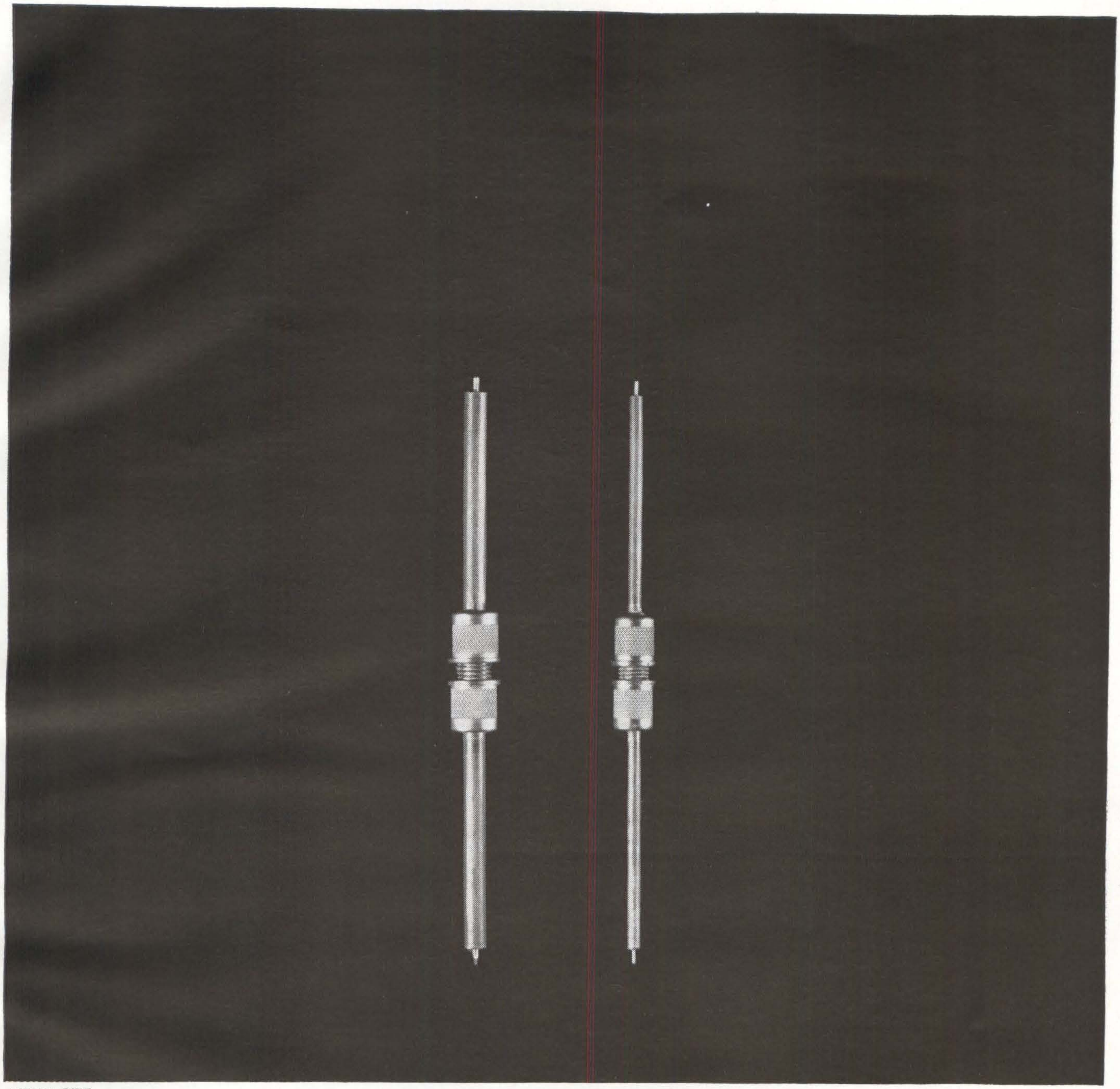
IN TESTIMONY before the House Military Operations Subcommittee, Harold Brown, director of defense research and engineering, has provided an interesting insight into his views on selection of R&D contractors.

For major engineering projects, he said, he prefers to select firms with proven reputations based on past defense contracting experience, rather than newborn companies who have been able to recruit hotshot scientists away from older companies. He also said contract performance of multiplant or multidivision corporations should be rated on the basis of individual plants or divisions rather than on an overall corporate basis.

ASTRONOMERS FIND H-BOMB MAKES NOISE

U. S. RADIO ASTRONOMERS in Jicamarca, Peru, have discovered long-lived radio noise from synchrotron radiation injected into the earth's magnetic field by the United States' July 9 high-altitude H-bomb test. They cite harm to radio astronomy and urge scientific and political review of future test plans "since the radio astronomers of the world will shortly become aware of the problem."

But high officials plan no change in test programs yet. The effect, they argue, is a calculated risk of the testing program, is minimal so far (double cosmic background on a quite day) and blankets only the equatorial region where there is little radio astronomy. The effect—which influences work below 50 Mc—was deteced with 6-megawatt pulse radar designed to probe the ionosphere and magnetosphere.



ACTUAL SIZE

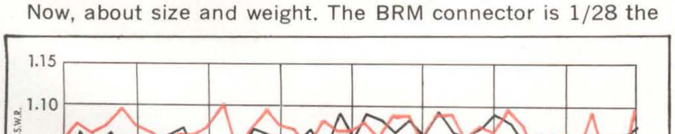
We have two new r-f connectors. They are wee ones.

They are designed to replace N series connectors in the 1 to 10 KMC frequency range where size, weight, and low VSWR ratings are critical factors.

The larger small one is the BRM. It terminates .140 semi-rigid cable either by threading or by threading and soldering. The smaller small one is the BRMM. It is for a .085 semi-rigid cable.

Talk about low VSWR ratings. Look at these curves. The black one is for the BRM; the red one is for the BRMM. The maximum VSWR is less than 1.1:1 over the frequency range of 1 to 10 KMC.

Now, about size and weight. The BRM connector is 1/28 the size of its N series counterpart. And it weighs 1/38 as much. The BRMM unit is 1/48 as large as the N series connector, 1/70 as heavy. You might call them miniatures. They are.

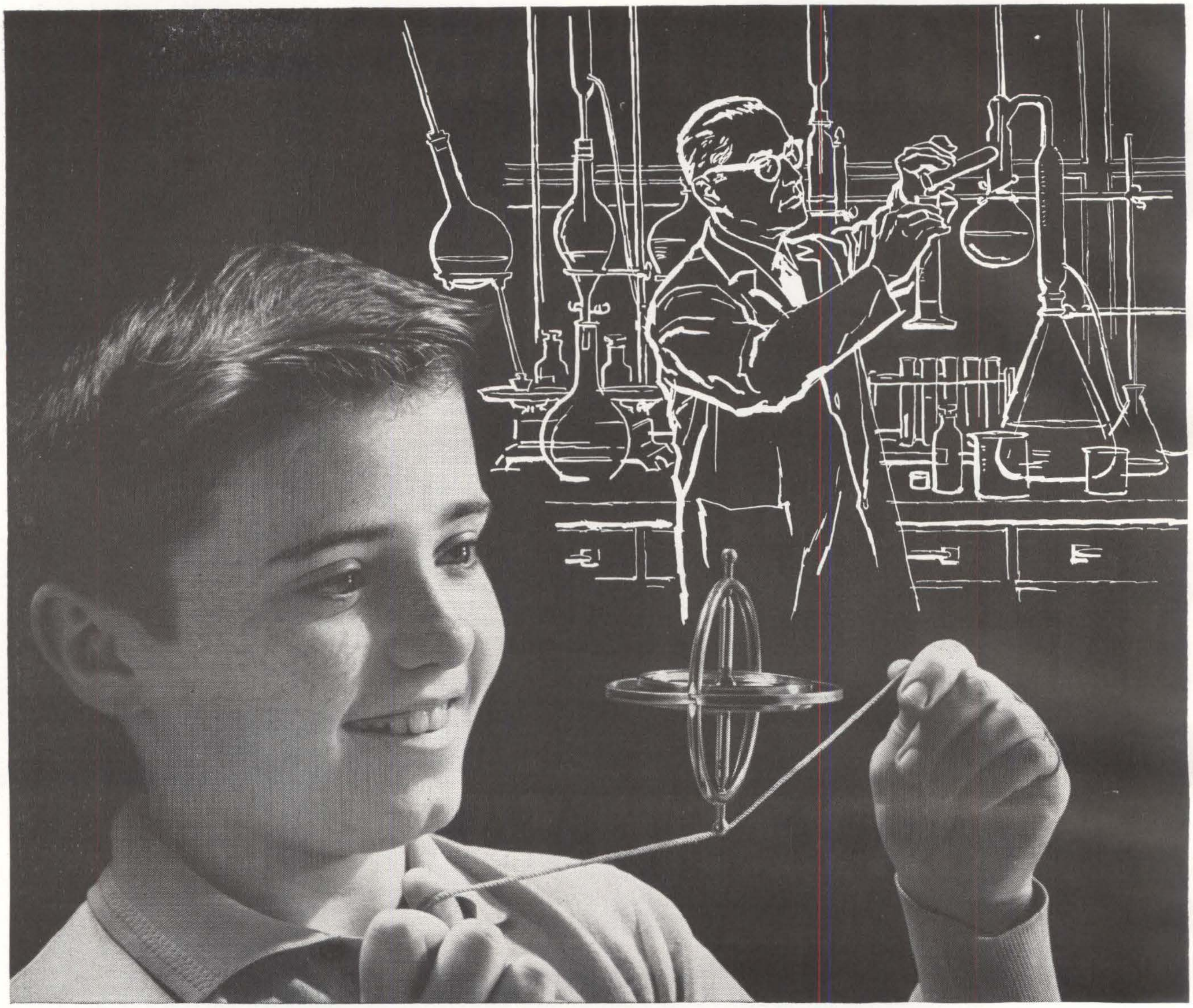


These precision r-f environmental resistant electrical connectors are machined from brass and heavily gold plated over silver underplate. The center dielectrics are electrical grade Teflon. They show high performance and excellent durability.

Developed at the Research Laboratories Division of Bendix, this new series of r-f connectors has been thoroughly production designed by Scintilla Division for maximum user satisfaction. Possibly you have an application in which the use of our new r-f connectors would be advantageous. Tell us about it. Or, write us in Sidney, New York, for technical data.

Scintilla Division

THE Bendix CORPORATION



The Future of Your Business

MAY DEPEND UPON HIS EDUCATION

The young mind which today discovers an old principle may someday reveal a new one capable of revolutionizing your business and creating undreamed of growth. But this is possible only if he gets the finest education we can offer.

By the time today's youngsters are ready for college, business and industrial technology will be even more complicated and will require many more trained specialists. To fill this order we must provide our young people with the best possible college educations.

Unfortunately many colleges are already overcrowded. In ten years applications are expected to double. We will need more and better college classrooms and libraries, more efficient college laboratories, and additional top-quality professors. *You can help assure your own future by helping the college of your choice.*

If you want to know what the college crisis means to you, write for a free booklet, "OPEN WIDE THE COLLEGE DOOR," to Higher Education, Box 36, Times Square Station, New York 36, N.Y.

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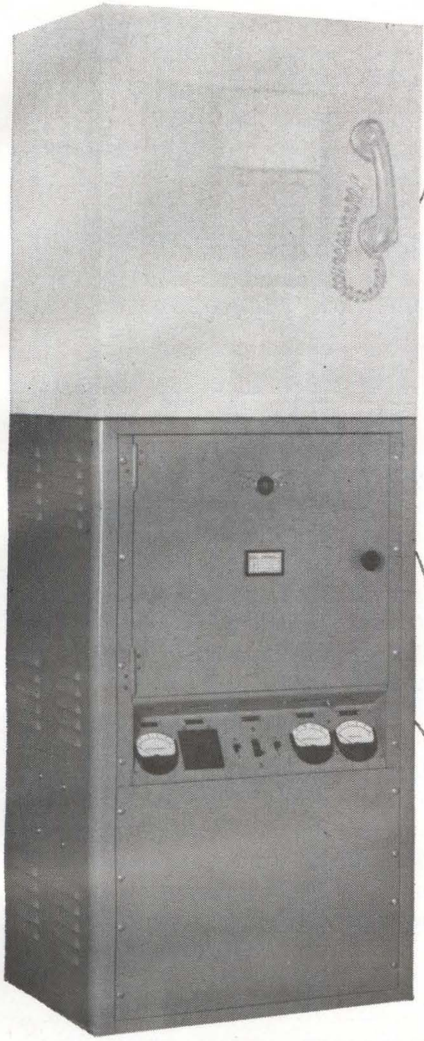
HIGHER EDUCATION
KEEP IT BRIGHT



USE AEROCOM'S AMPLIFIER FOR MORE COMMUNICATION POWER!

AEROCOM'S Linear Amplifier used with conventional low power SSB transceivers for excitation, provides power output of 1000 watts PEP, continuous service. The SSB exciter should have at least an output of 65 watts PEP to obtain maximum output of the amplifier.

The Model 10LA amplifier is housed in a cabinet (22" Wx14¾" Dx36¾" H) which can serve as a base for conventional SSB exciter, or amplifier may be placed a short distance away from the associated exciter, if necessary for convenience.

Frequency range of 10LA is from 2 to 20mc, covered in 6 bands. Up to 4 independent non-simultaneous channels are provided. These four channels are selected externally by exciter channel control. One tuning unit is provided for each frequency specified up to maximum of four.

The 10LA amplifier is designed to work into a 50 ohm coaxial feed line. One output coaxial receptacle, common to all four channels, or 4 output coaxial receptacles (one for each channel) are available; each channel normally requiring its own antenna. For multichannel operation with 1 antenna it is recommended that Aerocom Model ATU-410 antenna coupler be used.

A built-in directional coupler provides monitoring of output power and SWR. Grid current, plate current, filament voltage and high voltage are metered.

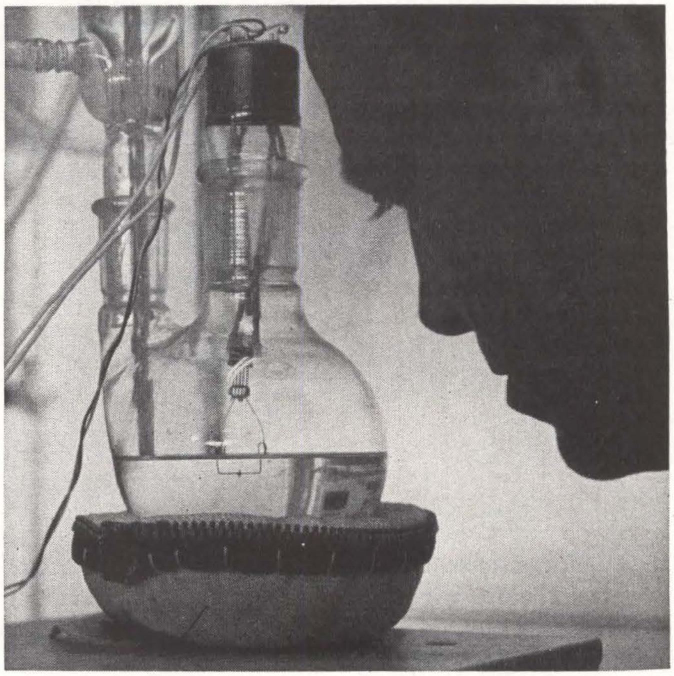
Harmonic output attenuation: second harmonic is at least 55 db down and higher harmonics are at least 70 db down. Noise level is 40 db below 1000 watts PEP output. Distortion products, in two-tone test, are at least 35 db down, depending on characteristics of exciter.

This linear amplifier, like all Aerocom equipment, is ruggedly constructed to give long trouble-free service. Additional information and technical data on request.

AER-O-COM

3090 S. W. 37th Avenue — Miami 33, Florida

Mobile Dopants Turn Germanium Resistors

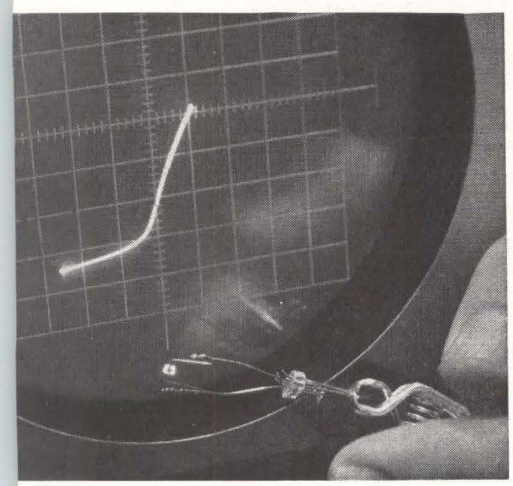


First details on how flexodes are built and how they operate

LAST MONTH, at the solid-state conference at the University of New Hampshire, researchers from RCA Laboratories reported on a new family of reversible semiconductor rectifiers called flexodes (ELECTRONICS, p 7, July 27). Last week, RCA made available to ELECTRONICS further details on how flexodes are built and how they operate.

Flexodes are made from a semiconductor crystal doped with at least one high-mobility impurity. Applying an electric field and passing heating current through the device causes junctions to be formed or destroyed, yielding rectifiers or multicontact devices with variable and reversible characteristics.

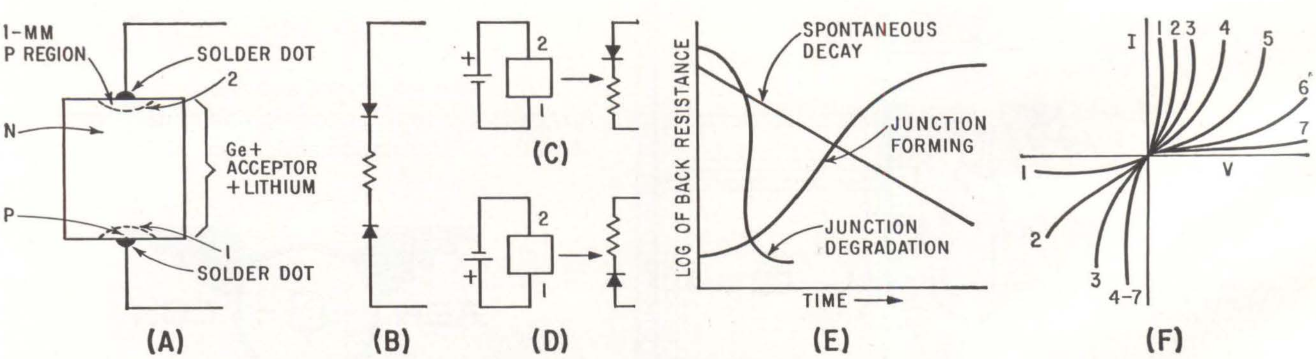
RCA SCIENTIST *observes flexode being processed in temperature-controlled silicone oil bath (photo above)*



SCOPE TRACE *indicates flexode intermediate state. Top of trace will flatten out*

FLEXODE OPERATION—For a typical two-contact, small flexode that is unpotted, application of 200 to 700 milliamperes d-c at room temperature will raise the temperature to 100 C. This is enough to convert the flexode from a resistor to a rectifier.

If pulses are applied in the reverse direction so that the device's breakdown voltage is exceeded, the flexode reverts to a resistive state and then becomes a rectifier in the



FLEXODE CHARACTERISTICS. *Immediately after construction (A), the flexode has an equivalent circuit like (B). A large reverse current will degrade either junction. If both junctions are degraded and current passes through the device, the junction in whose forward direction the current passes will rebuild, as in (C) or (D). This transformation is shown graphically in (E), while (F) shows the progression at equal processing intervals from a rectifier in one direction (1-1) to a resistor and to a rectifier in the opposite direction (7-7)*

into Two-Way Rectifiers

reverse direction. A self-limiting current supply is used to avoid destroying the flexode; typical voltage is 100 volts or more.

According to RCA researchers, it has been established that reversing the current destroys the junction near one contact and forms a new junction at the other. Decay of the old junction is relatively quick and begins as soon as a sufficiently large reverse field is applied. The new forward junction forms after an induction time that may vary from one minute to a few hours depending on the material. Forward resistances of 3 ohms to 15 ohms and final back resistances of 500 ohms to 10,000 ohms have been observed.

CONSTRUCTION—Normally, *p*-type germanium doped with lithium is used in flexodes, but in one experiment high-purity intrinsic germanium was doped, thus becoming *n*-type. After annealing, it was found the resulting flexode material required a much longer time for forming the junctions by the field. However, the resulting junction exhibited no spontaneous decrease in back resistance during one month of storage at room temperature whereas most normal flexodes decay almost completely in this time.

This illustrates it may be possible to make stable adaptable devices. Researchers report they have produced flexodes of various characteristics with fairly good reproducibility. Apparatus is being constructed to aid in understanding the fundamental physical and chemical processes involved in flexode action.

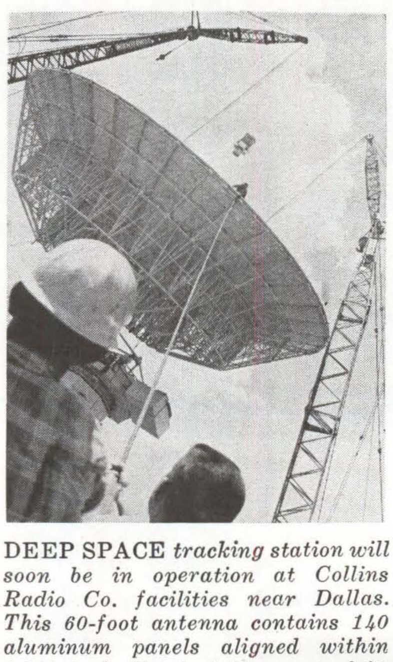
Contract Awarded For Stored Logic Computers

STORED-LOGIC COMPUTERS will be built by Thompson Ramo Wooldridge's RW division as part of an operational high-accuracy navigation set for Navy's Fleet Ballistic Missile Weapon System. Stored logic permits selection of word length, order structure and instruction repertoire, without hardware modification. The $4.5 million contract, awarded by Sperry Gyroscope, calls for delivery of 29 computers by late 1963.

French Announce Program For Electronics Research

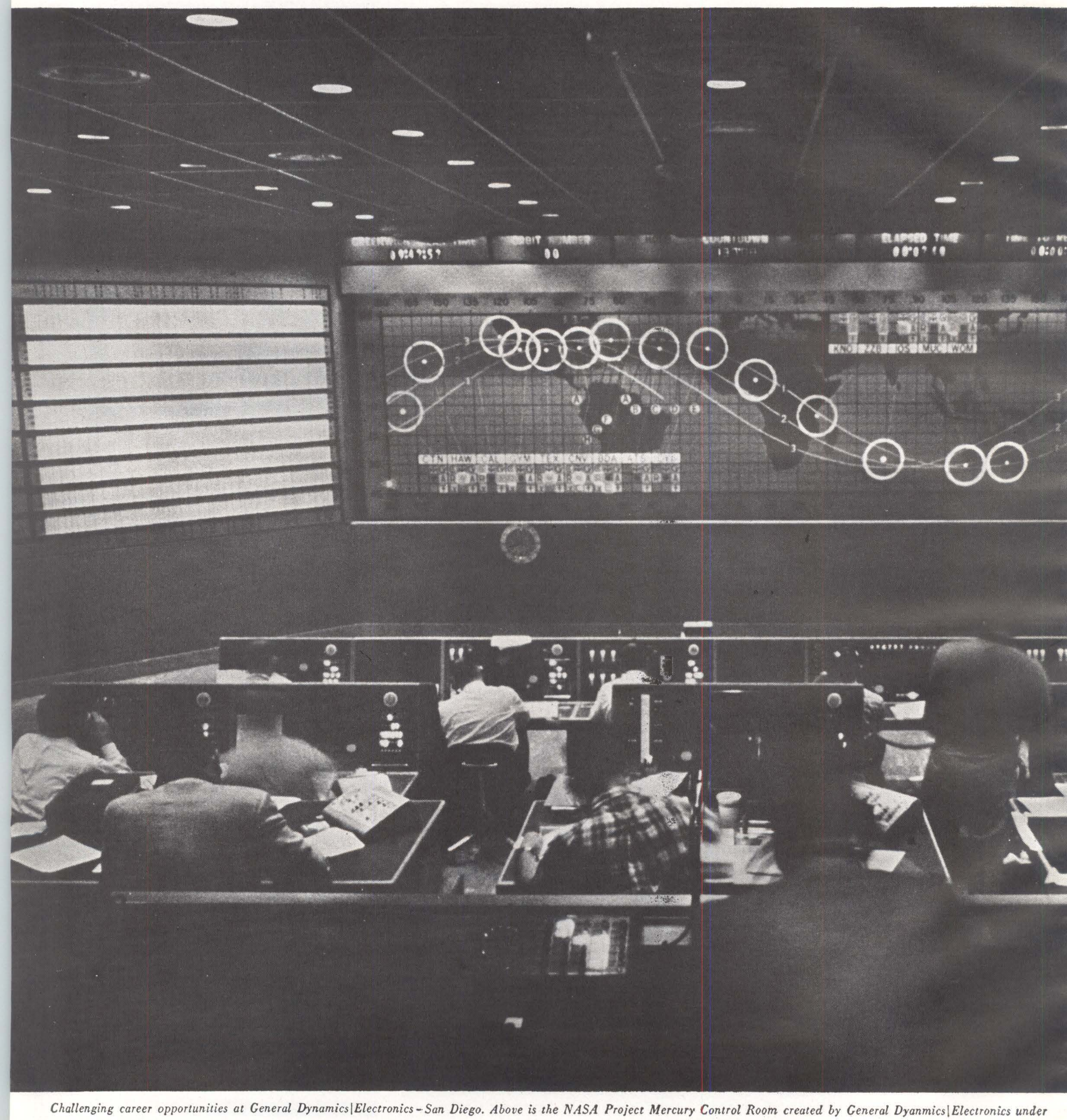
PARIS—In an effort to spur research in neglected areas and to increase effectiveness of research in electronic components, the French government has authorized a $3 million program of cooperative research. The program, set up by government, industry and university electronics experts, will concentrate on new materials and microminiaturization, with emphasis on computer applications. Work will include semiconductors, solid-state physics, masers and lasers, plasma physics and component reliability. The parts program is the first to be financed by a $60-million research fund set up by the government to aid the French electronics industry.

Texas Tracker



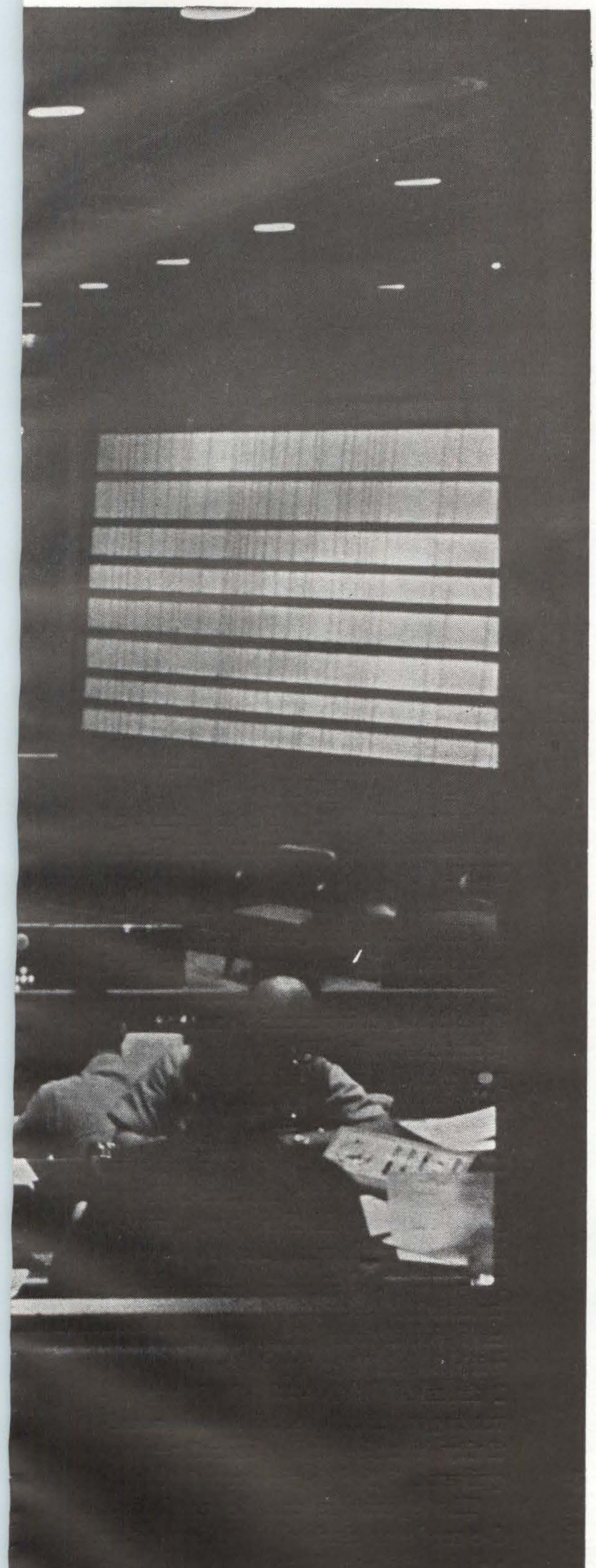
DEEP SPACE *tracking station will soon be in operation at Collins Radio Co. facilities near Dallas. This 60-foot antenna contains 140 aluminum panels aligned within 0.024 inch. Total station cost of $1 million is being borne by Collins*

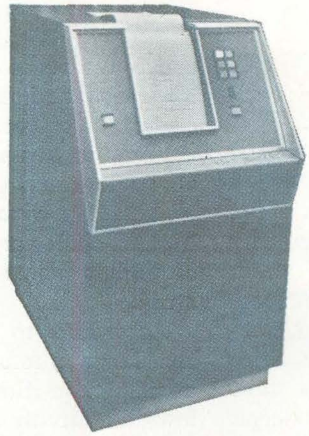
THE CREATORS OF THIS FAMOUS NERVE CENTER



Challenging career opportunities at General Dynamics|Electronics – San Diego. Above is the NASA Project Mercury Control Room created by General Dyanmics|Electronics under

UNDERSTAND COMMAND AND CONTROL PROBLEMS

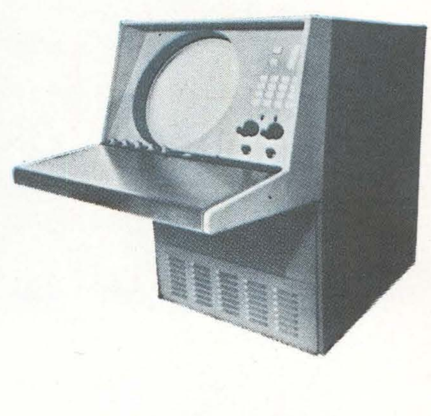




Two new communications tools, perfected by General Dynamics | Electronics research and experience, offer marked advantages to a wide variety of users in the command and control systems field. They are the 3070 Communications Printer and the 1090 Direct View Display.

The 3070 Communications Printer operates at speeds from 400 to 5000 words per minute using standard computer or communications codes over telephone, telegraph and microwave links. The unit prints asynchronously utilizing an electrostatic process to produce highly legible, permanent copy. It is compact, reliable and quiet enough to use in an office.

The 1090 Direct View Display combines high speed, high resolution, compact dimensions, low cost and large 19-inch CHARACTRON® Shaped Beam Tube capable of displaying 1000 flicker-free characters simultaneously anywhere on the tube face. The unit is capable of tabular, situation or graphical presentations and is ideal for computer intervention, monitoring and retrieval jobs, laboratory, simulation, traffic control and surveillance work. If you would like more information about how these units can help you solve your command and control problems, write General Dynamics | Electronics, Dept. C-68 P. O. Box 127, San Diego 12, California.



GD

GENERAL DYNAMICS | ELECTRONICS
SAN DIEGO

contract to Bell Telephone Laboratories for Western Electric Company.

New Entry in Microelectronics: High-Density Silicon Matrices

To exploit the concept, a new form of logic circuit is developed

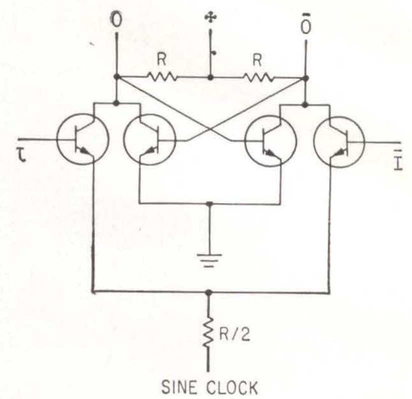
SYRACUSE—General Electric became a late entry in the growing microelectronics field last week, with the simultaneous announcement of their own functional component concept and a new logic circuit scheme designed to take maximum advantage of the concept.

Developed by GE's Semiconductor Products Department, the basis of the new approach is a general-purpose matrix consisting of a pattern of isolated transistors and resistors on a one-inch silicon wafer. The basic matrix contains 1,100 active components and 4,200 resistors.

ELEMENTS—The active elements may be used as *npn* transistors, with characteristics similar to the type 2N914, or as clamp diodes, zener reference diodes or simply low-resistance transfer points for circuit junctions. The resistors are arrayed in two-pack, four-pack and six-pack groups to permit any series or parallel arrangement to obtain higher or lower resistance values or higher power dissipation as desired.

According to a GE spokesman, the large number of components available on the basic matrix allows the circuit designer maximum flexibility in designing the circuit for his needs. It also has the advantage that test element groups of components may be set up on the same wafer as the circuit under development, thus permitting information to be obtained on parameter stability under life-test conditions for reliability data. Interconnections to form the desired circuits are made by an aluminum deposition process.

The matrix is produced by planar, epitaxial and passivation techniques.



EMITTER-COUPLED *transistor logic is used here in a half-shift register that requires only four transistors*

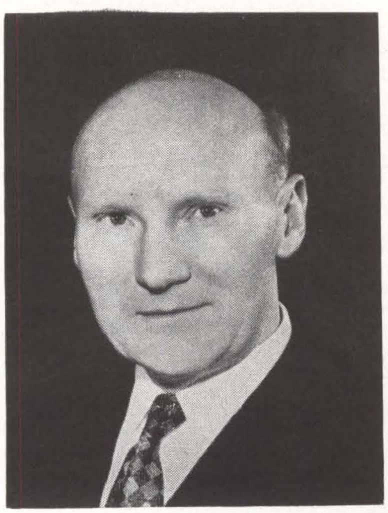
ECTL LOGIC—The new logic circuit scheme is emitter-coupled transistor logic (ECTL). It was developed by GE's Light Military Electronics department at Utica, N. Y.

According to GE engineers, ECTL was developed specifically to overcome the problems encountered in reducing other logic systems to functional component form. As implemented by GE functional components, it uses only resistors and *npn* transistors in negative logic with +0.7 and +0.1 volt being the ZERO and ONE states, respectively.

This logic uses emitter-follower gate inputs, eliminating current-hogging problems. The fan-out is proportioned to the beta of the transistor elements. Under worst case conditions, fan out is $h_{FE}/3$, with h_{FE} falling approximately 2 to 1 from 25 C to −55 C. Other advantages cited include less sensitivity to noise and, generally, a requirement for fewer transistors.

The operators can be used in a d-c mode or clocked by either pulse or sine waves. Since clock loading is constant, clock distribution and

IEEE Nominates Its First Officers



SLATE OF 25 OFFICERS *and directors for the new IEEE has been submitted to IRE and AIEE members. Nominees include Ernst Weber (left), president of Polytechnic Institute of Brooklyn, for IEEE president, and B. Richard Teare, Jr., (right), dean of the College of Engineering and Science at Carnegie Institute, and now president of AIEE, for vice president. Balloting will end Oct. 1* termination problems are minimized.

OPERATION—Low saturation resistance (below 10 ohms) permits stable operation over a considerable range of current. While the clock rate depends on the operating current, a 2-Mc clock rate has been achieved at a total dissipation of 6 to 8 mw per half-shift register.

Such a circuit is illustrated on the facing page.

Initially, GE is making seven different functional components now available in sample quantities. These emitter-coupled logic operators are priced at approximately $110 each to original equipment manufacturers. The circuits are: a half-shift register, a majority logic gate, a four inverter package, a three double-pair gate circuit, a three input AND gate circuit, a logic flip-flop, and an AND-OR double gate circuit. Test element groups, distributed throughout the wafer, are also available. They are housed in the 10-lead TO-5 type package.

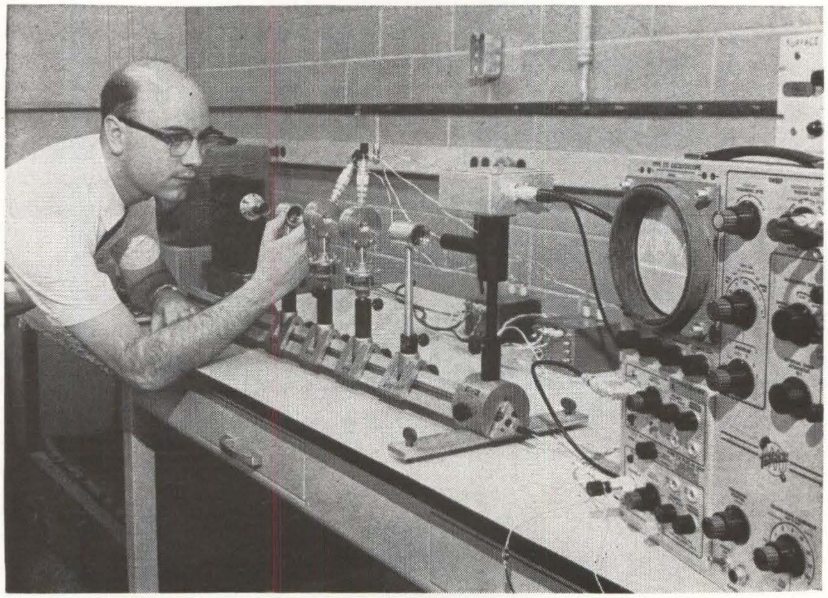
Later on, circuits designed by customers to meet individual requirements using the basic matrix can be produced, says GE.

Polarizers Modulate Laser Beam

Techniques may aid development of optical communications systems

NEW YORK—Development of a single-sideband, suppressed-carrier, optical method for modulating laser beams, permitting tuning of the laser, was announced last week by General Telephone & Electronics Corp.

Herbert Trotter, Jr., president of GT&E Labs, said the modulation technique could be used in design of a laser communications system including transmitters and superheterodyne receivers with regulated and adjustable frequencies, and for laser radar and spectroscopy.



MODULATOR ***elements, from left, are light source, birefringent plate, two KDP crystals, right circular analyzer and multiplier phototube***

TECHNIQUE—The procedure followed by C. F. Buhrer, V. J. Fowler, and L. R. Bloom, developers, was:

A helium-neon gas laser provided a plane-polarized infrared beam that was converted to left-circular polarization by passage through a quarter-wave birefringent plate. The light then was transmitted through two electro-optic modulator elements, each a single-crystal KDP bar 7 mm long and 10 mm square with transparent electrodes perpendicular to the path of the light.

Modulation voltages of about 2-Kv peak were applied to the electrodes, producing fields in the crystals and causing part of the input left-circularly polarized light to be converted to right-circularly polarized light at the modulation sideband frequencies.

Lower sideband light was extinguished by making the phase of the voltage on the second crystal lag the first by 90 degrees and having the second crystal rotated 45 degrees clockwise relative to the first. Light emerging from the second crystal was a mixture of left-polarized light at the laser carrier frequency and right-polarized light at the upper sideband frequency.

This light passed through a second quarter-wave birefringent plate and a plane polarizer that functioned as a right-circular analyzer suppressing the carrier and permitting only the upper-sideband light to pass through. This light was detected with a multiplier phototube, and the envelope waveform displayed on an oscilloscope.

VERIFICATION — Evidence of single-sideband, suppressed-carrier generation was obtained by first adjusting the device so that in the absence of modulation voltages on the crystals substantially zero light was transmitted to the phototube. Then, a 1-Kc tone used as the modulation signal produced a constant oscilloscope deflection, indicating that both the carrier and one sideband were suppressed. Tones at 1 Kc and 1.5 Kc applied simultaneously to both crystals produced two upper sidebands and a 0.5-Kc beat frequency. When phasing produced upper and lower sideband signals, beat frequency was 2.5 Kc.

Adaptive Control Helps X-15 Fly

Servo system blends aerodynamic and thrust controls in thin air

EDGE OF SPACE *is the X-15's flight goal*

MAIN PURPOSE of Major Robert M. White's recent flight in the X-15 to a record-breaking altitude of 314,750 feet was to check out a new adaptive control system developed by Minneapolis-Honeywell.

At that altitude, the air is so thin it offers almost no support to regular aerodynamic controls and reaction or thrust controls are needed. The Honeywell system, under development since 1959, automatically adapts to changes in air density and other control factors and blends the aerodynamic and reaction controls.

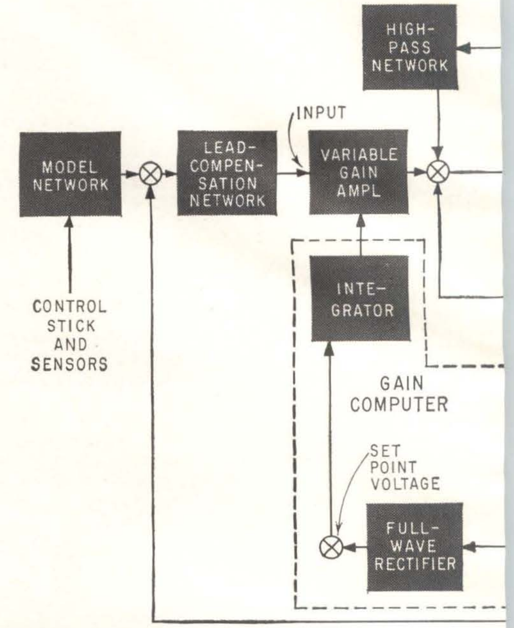
Automatic control consumes reaction fuel at only half the rate of manual blending, helping the X-15 fly higher. The system also corrects the plane's attitude.

OPERATION—The model network (see diagram) shapes control and sensor signals so they represent the desired response of the aircraft. These are compared with the plane's actual response obtained from the rate gyro. Errors are applied to the lead network and are corrected by servo action in the inner feedback loop.

The key to this corrective process is the gain computer, acting as a variable attenuator to continually adjust gain of the inner loop. The response speed is several times that of the model, to keep errors small during transient inputs. High forward loop gain provided by the computer and series-lead compensation provided by the lead network make possible high-speed response and bandwidth.

Reaction controls take over when adaptive gain is driven to a maximum, an indication that aerodynamic control surfaces are becoming ineffective.

To keep gain at its maximum stable value, the computer maintains a small, fixed-amplitude control-surface limit-cycle frequency.



GAIN COMPUTER *in the inner detected by the rate gyro and ad-*

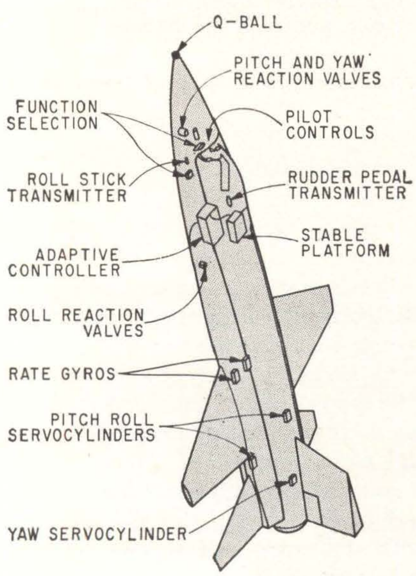
That is, it responds to small fluctuations in the rate-gyro signals caused by small and rapid movements of the control surfaces.

Any servo feedback signal whose frequency is not near this limit is removed by the bandpass filter, so the rectifier output represents the limit-cycle component of the servo feedback signal.

The d-c signal is compared with the set-point voltage representing the desired limit-cycle amplitude. The resulting error signal goes to an integrator that adjusts the forward loop gain to maintain a constant-amplitude limit cycle.

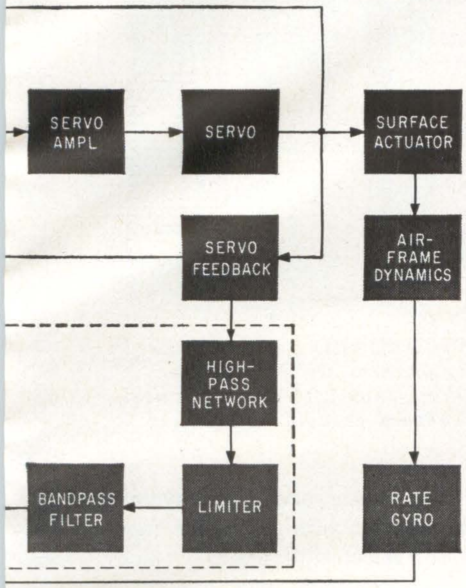
GUSTS AND BUFFETS—The integrator rapidly reduces loop gain if the limit cycle tends to exceed the set-point reference. The variable-gain amplifier's saturation varies directly with the gain set by the computer. These features reduce nonlinear gain variation during transients caused by gusts of wind. Buffeting can also be tolerated, even when the system noise input becomes periodic near the limit-cycle frequency.

The high-pass filter in the computer reduces the effect of pilot



CONTROL SYSTEM *components location in the X-15*

60 Miles High



loop evaluates performance errors justs the inner servo loop's gain

commands during landing. Servo displacement signals generated by pilot commands are amplitude limited to prevent a few large, rapid servo movements from driving the gain too low.

Notch filters attenuate signals from rate and acceleration sensors located on the fuselage, to offset the effects of fuselage bending oscillations.

COMPONENTS—More than 90 percent of possible failures in the system are expected to come from interruptions of electrical continuity, so interconnected dual redundant systems are used. Monitors detect failures and switch out offending components.

Small magnetic amplifiers with transistor stages are used extensively to increase gain and output levels. The magnetic amplifiers are made of small ribbon cores and use 3.5-Kc excitation.

Probably the most important use of a magnetic amplifier is in the gain computer as a series-connected saturable reactor. It changes d-c into a pulse-width-modulated 3.5-Kc. square wave that controls system gain attenuation.

Private Switchboard Is All-Electronic

Semiconductor devices cut size in half. Firm also sells big system

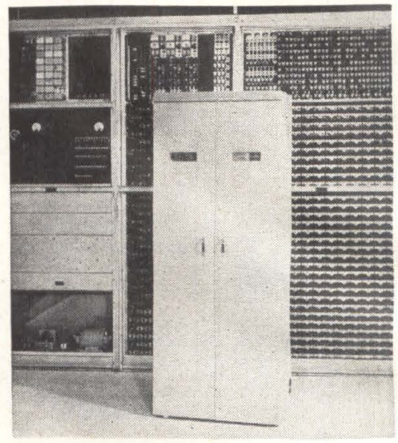
NEW YORK—ITT Kellogg's Telecommunications department demonstrated last week a 100-line model of its electronic private automatic telephone exchange, the Kelex 2000. It uses all transistor circuits, weighs about 400 lbs and is about half the size of conventional electromechanical equipment.

The exchange is installed quickly, by connecting the subscriber's lines to terminals in the cabinet and by plugging it into an electric wall socket. Features include provision for paging and conference calls. Automatic call forwarding—transferring incoming calls to another telephone—will be available next year, ITT said.

Cost of the system was described as competitive with conventional exchanges.

The system is designed as a space-division switchboard—providing a separate physical path for each simultaneous phone conversation—with time-sharing common control. For switching, ITT uses what it calls a random-selection principle, an end-marking, self-seeking switching network employing *pnpn* diodes. The network operates in microseconds.

The Information Systems division of ITT recently announced the delivery of their automatic message switching center (p 11, Dec. 15, 1961) to the Aluminum Company of Canada Ltd. The ADX 7300 automatic data exchange system will handle all administrative messages for Alcan's plants and offices in Canada, the U. S. and London.

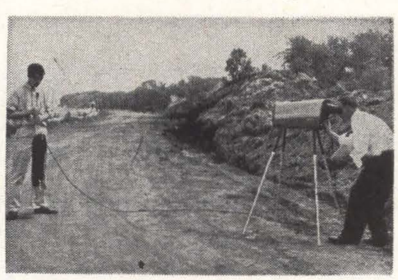


SWITCHBOARD *cabinet, filled with printed wiring boards, is smaller than electromechanical switchboard seen in background*

ADX 7300 is a commercial version of equipment used in the Air Force 465L global communications network. An ADX 7300 is being installed at the American embassy in Paris, France; five or six systems will go into operation this year, ITT says.

The system can handle 3.6 million bits of information a second. Access time to the core storage memory is 5 μsec. The system is expandable to service more than 400 duplex lines.

Portable Seismograph

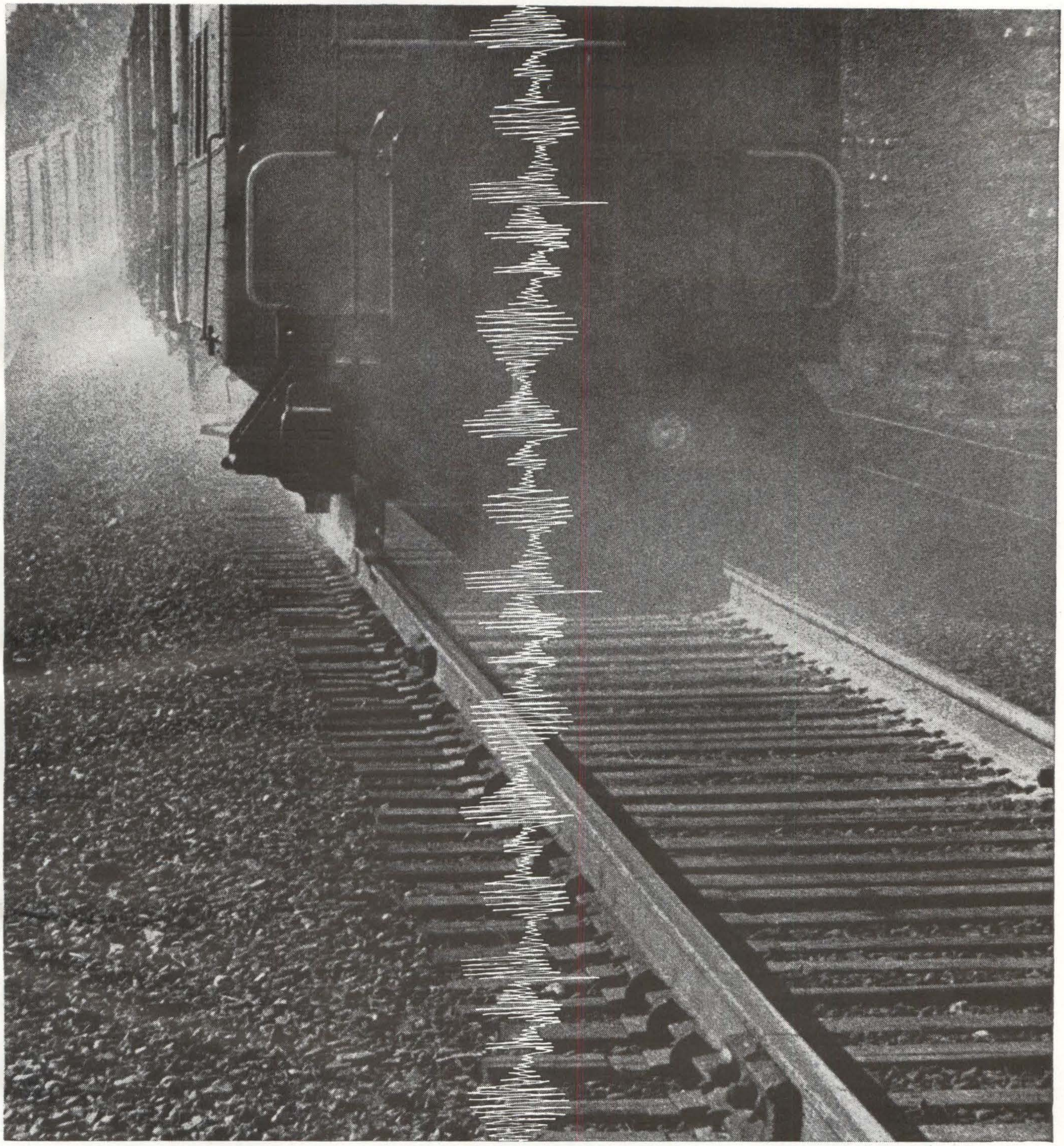


TERRA-SCOUT, *made by Soiltest, Inc., Chicago, indicates on crt time for shock wave to travel from hammer (left) to crt indicator*

50-Kw Klystrons Ordered For Stanford Accelerator

LIGHT-WEIGHT driver klystrons, using periodic permanent magnets for beam focus, will be built by Eitel-McCullough for the two-mile-long linear accelerator at the Stanford Linear Accelerator Center (Project M). The initial contract for $170,000 calls for delivery of the first of the klystrons this year.

The klystrons are designed to deliver 50-Kw peak, 50-w average power at S-band. Final amplifiers, to be driven by the klystrons, will deliver peak power of 24 Mw. The accelerator, being built under an AEC contract, is expected to cost $114 million.



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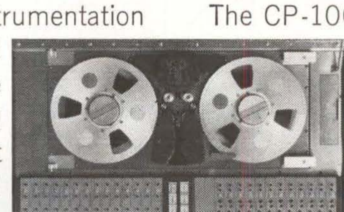


transport assembly lifts up. And it operates on almost any standard source of power, including batteries. The CP-100 is perfect any time, anywhere you need a reliable precise portable. For more data write the only company providing recorders and tape for every application: Ampex Corporation, 934 Charter Street, in Redwood City, California. Sales and service engineers throughout the world.

CIRCLE 25 ON READER SERVICE CARD

MEETINGS AHEAD

METALLURGY OF SEMICONDUCTORS CONFERENCE; American Institute of Mining, et al; Ben Franklin Hotel, Philadelphia, Pa., **Aug. 27-29.**

BALLISTIC MISSILE & SPACE TECHNOLOGY SYMPOSIUM, U.S. Air Force and Aerospace Corp.; Statler-Hilton Hotel, Los Angeles, **August 27-29.**

MAINTAINABILITY OF ELECTRONIC EQUIPMENT, EIA Engineering Dept. & Dept. of Defense; U. of Colorado, Boulder, Colo., **Aug. 28-30.**

INFORMATION PROCESSING, INTERNATIONAL CONFERENCE, IRE-PGEC, IFIPS, AIFPS; Munich, Germany, **Aug. 29-Sept. 1.**

INFORMATION ON THEORY INTERNATIONAL SYMPOSIUM, PGIT and Benelux Section of IRE; Free Univ. of Brussels, Belgium, **Sept. 3-7.**

MICROWAVE TUBES INTERNATIONAL CONFERENCE, URSI; Technological U. of Delft, Netherlands, **Sept. 3-7.**

ADVANCED TECHNOLOGY MANAGEMENT CONFERENCE, IRE-PGEM, AIEE, et al; Opera House on World's Fair Grounds, Seattle, Wash., **Sept. 3-7.**

DATA PROCESSING EXHIBIT, Assoc. for Computing Machinery; Onondaga County War Memorial, Syracuse, N. Y., **Sept. 4-7.**

PETROLEUM INDUSTRY CONFERENCE, AIEE and ISA; Carter Hotel, Cleveland, Ohio, **Sept. 9-14.**

ENGINEERING MANAGEMENT, IRE-PGEM, AIEE et al; Hotel Roosevelt, New Orleans, La., **Sept. 13-14.**

ENGINEERING WRITING AND SPEECH SYMPOSIUM, IRE-PGEWS; Mayflower Hotel, Wash., D. C., **Sept. 13-14.**

ELECTROCHEMICAL SOCIETY MEETING; Statler-Hilton Hotel, Boston, Mass., **Sept. 16-20.**

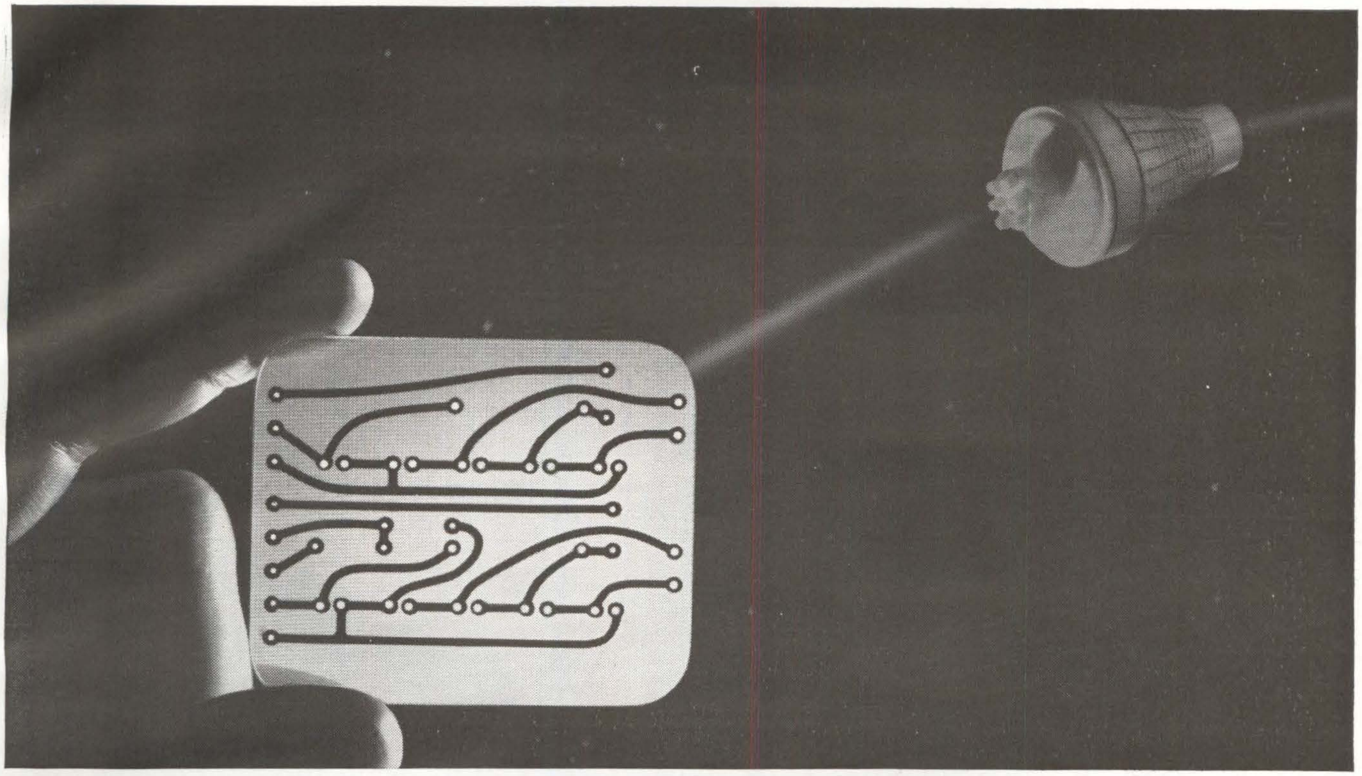
RECTIFIERS IN INDUSTRY MEETING, AIEE; Desher-Hilton Hotel, Columbus, Ohio, **Sept. 18-19.**

ORDNANCE ENVIRONMENTAL SYMPOSIUM (unclassified), Research & Development Div. of the Army Chief of Ordnance, Southwest Research Institute; El Tropicano Hotel, San Antonio, Texas, **Sept. 18-20.**

ADVANCE REPORT

COMMUNICATIONS SYMPOSIUM, IRE-PGCS; *Municipal Auditorium and Hotel Utica, Utica, N. Y., Oct. 1-3. Sept. 7 is the deadline for forwarding CONFIDENTIAL clearances for classified session attendance to: RADC, Griffiss Air Force Base, Rome, N. Y., Attention RAIS. Classified sessions will be accessible to properly cleared U. S. citizens. Also there are many unclassified sessions. Symposium theme is "Communications-Link to Tomorrow". Government as well as industry personnel will present papers.*

Printed circuit by Mutual Electronics Div. of Robinson Technical Products, Inc.



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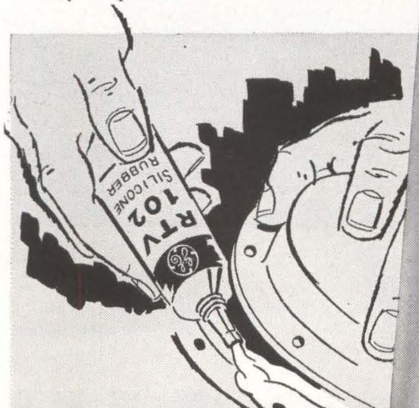

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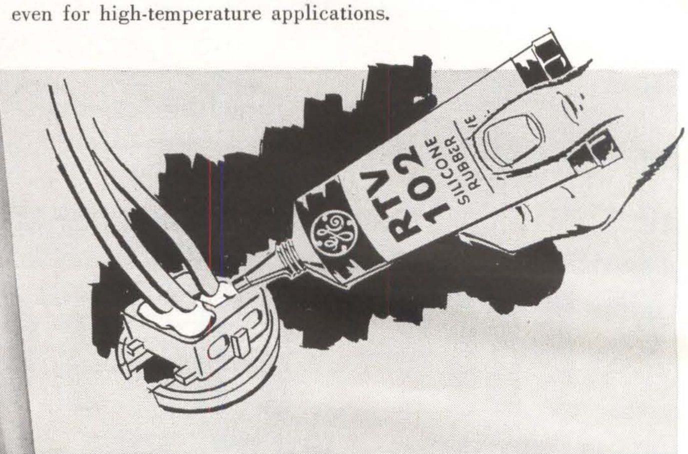

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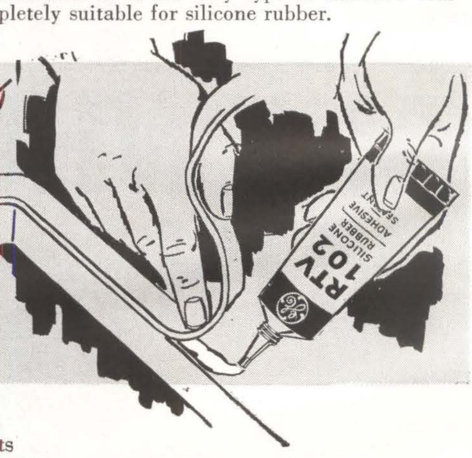

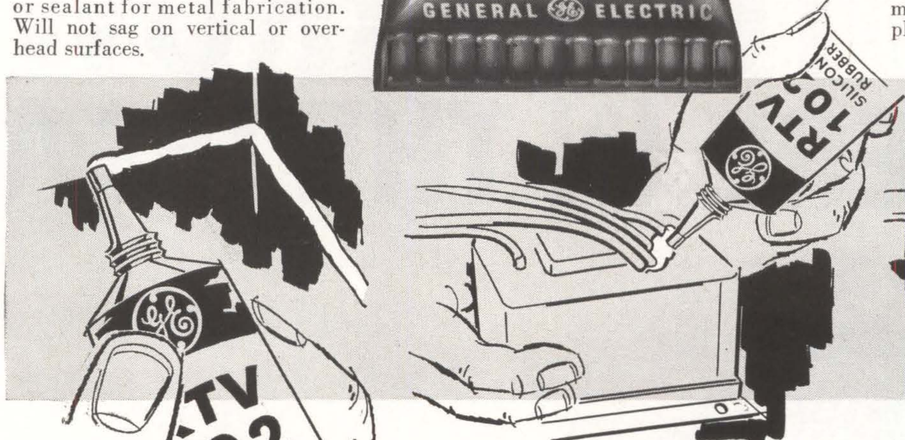

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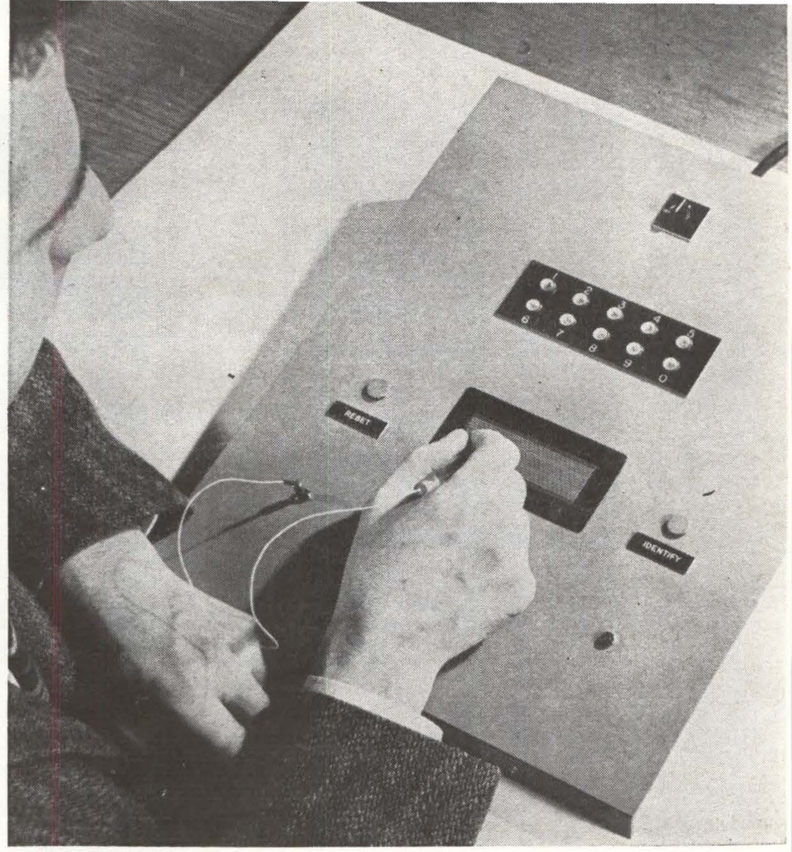
August 24, 1962



WORKING MODEL *of the cursive-script reader contains 12 relays and 8 diodes. Here the author prepares to demonstrate its capabilities*

This simple cursive-script reading machine detects certain readily distinguishable properties of handwritten names of numbers and separates them logically. Its recognition accuracy is about 97 percent

BY LEON D. HARMON
Bell Telephone Laboratories, Inc., Murray Hill, N. J.

HANDWRITING READER Recognizes Whole Words

AUTOMATIC READING of machine- and hand-printed symbols has received considerable attention, while the problem of reading cursive script has been relatively neglected. Two script-reading systems reported recently (see Ref.) evolved from the automatic reader described here.

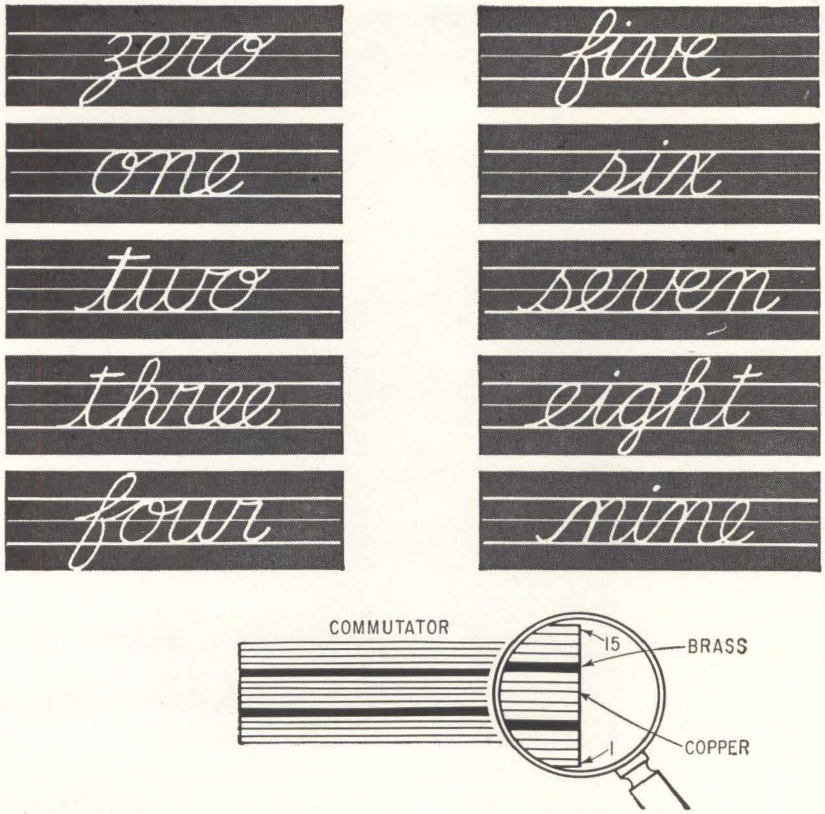
This device automatically recognizes the 10 digits, *zero* through *nine*, when written in continuous (cursive) script. The system operates in real time, processing the writing as it is produced, thus avoiding the necessity for scanning. No attempt is made to detect letters individually; instead, the over-all shape or envelope of a word is inspected. In addition, tests are made for word length and for the presence of special marks such as dots, crosses and slashes.

Obviously, such an approach is suitable only for a very small vocabulary. Much greater sophistication is required for extended recognition. However, some of the tests employed here have proven useful for automatic recognition of an unrestricted ensemble.

OPERATING PRINCIPLES — Real-time signals are derived from a wired stylus which the writer moves over a striated conductive writing surface. This commutator-like surface consists of alternate rows of conductors and insulators. Figure 1 shows the 15 conductors which give crude vertical resolution and none in the horizontal direction.

Two brass bars serve as visual guides for the writing. The writer is asked to consider the bottom one a baseline and to let the *small* letters (e, i, n . . .) occupy the space between the guides, allowing the vertically extended letters (f, h, t . . .) to fall outside these limits.

The 10 numbers as written in Fig. 1 show the differences that can be used in a simple detection system. They are as follows: (1) Numbers 1, 6, 7, 9 are distinct from the others in that they contain only small letters, that is, those lying roughly between the constraining guide lines. (2) Numbers 2, 3, 4, 5, 8 have vertical extensions above the upper guide line while 0, 4, 5, 8 are extended below the baseline. (3) These vertical extensions may occur



STRAIGHTFORWARD ANALYSIS *of these handwritten numbers discloses readily distinguishable properties that can be used in a simple detection system—Fig. 1*

TESTS

DIGITS	A	B	C	D	E	F
0	1	–	0	0	–	–
1	0	0	0	0	0	–
2	0	0	1	–	–	0
3	0	0	1	–	–	1
4	1	–	1	0	–	–
5	1	–	–	1	–	–
6	0	0	0	1	0	–
7	0	0	0	0	1	–
8	–	1	–	–	–	–
9	0	0	0	1	1	–

A = LOWER EXTENSION, LEFT

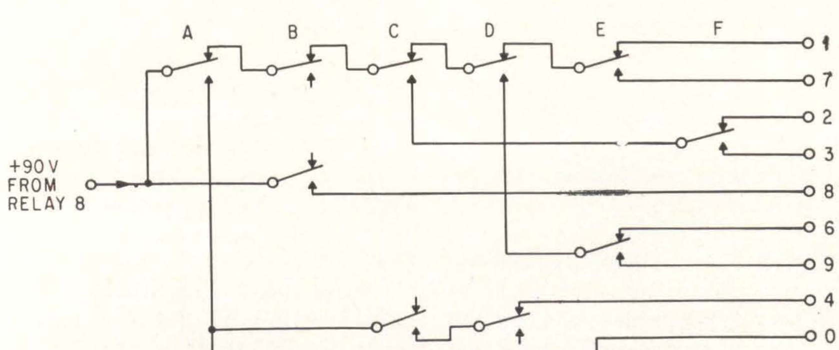
B = LOWER EXTENSION, RIGHT

C = ONE UPPER EXTENSION, LEFT

D = DOT/CROSS

E = ZERO AXIS CROSSING $\Sigma \geq 9$

F = TWO UPPER EXTENSIONS, LEFT



TRUTH TABLE *and its relay contact tree used in the number recognizer, although not minimal, allow wide variation in writing style while tending to minimize relay contacts—Fig. 2*

in the left (0, 2, 3, 4, 5), middle (8), or right (8) portions of the word. (4) Numbers 5, 6, 8, 9 have dotted letters and 2, 3, 6, 8 have crossed (or slashed) letters. (5) Useful distinctions between words are provided by a measure based on word length or letter count. Consider an arbitrarily placed axis, say halfway between the guide lines. A count of the crossings which the script makes with this axis is typically 7 or 8 for the word *one* and 11 or 12 for *seven*. Other typical counts exist for the other digits.

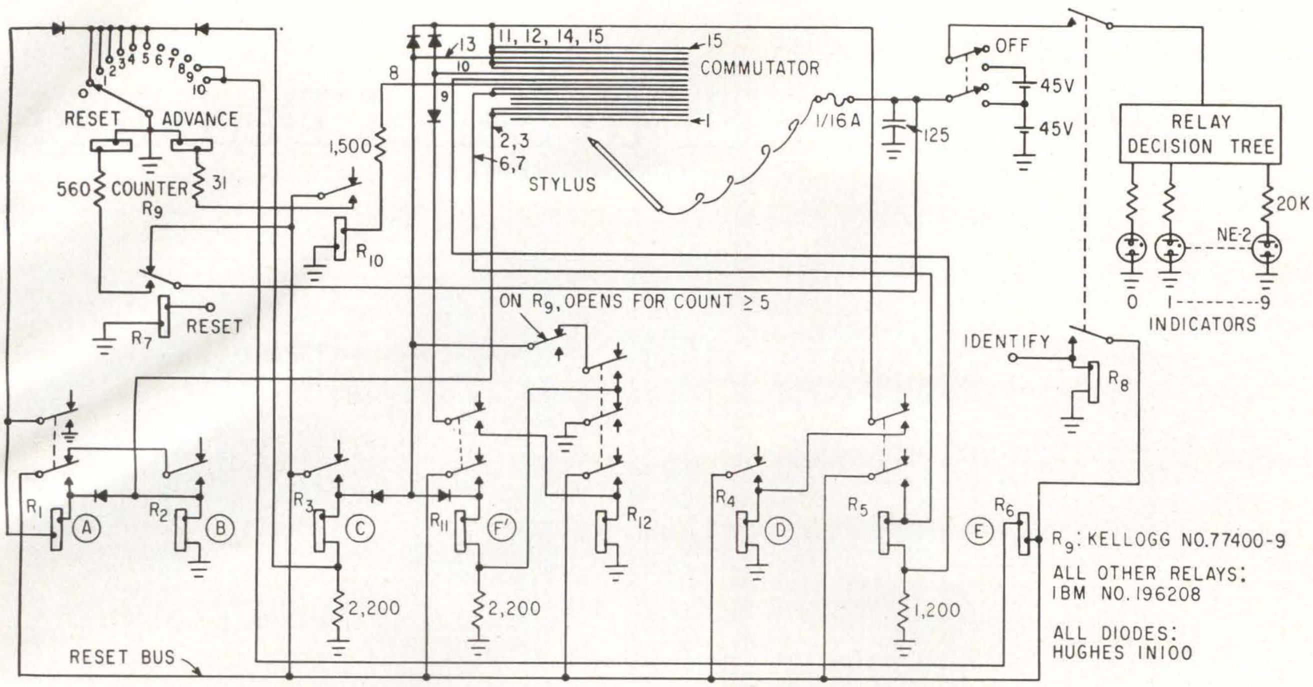
The information obtained from tests based on the properties listed above is sufficient to separate logically the 10 members of the ensemble. For example, *one* can be distinguished from *two* on the basis of vertical extension. *Two* and *three* are separable since *two* has only one vertically-extended letter while *three* has two. *One* and *six* have essentially the same envelope, but the *x* slash or *i* dot are distinguishing features. *One* and *seven* differ considerably in letter count, hence on axis crossings.

For a system that must select one of 10 alternatives, 3.3 binary decisions are the minimum number possible, and 4 binary devices are the fewest that can be used. Because of great variability in writing styles, any practical system will generally profit from some redundancy; in the present case we have adopted a six-bit logic. The truth table used is shown in Fig. 2.

The "don't cares", indicated by dashes, are not arbitrary. Some, like the case where rule C (top extension, left) is applied to the word *five*, allow for careless writing. Here the writer may make a very short upper extension on the *f*, and it will still be acceptable to the machine. This could not be done in the case of a *four*, since a "1" (yes) is required for effective separation from the word *zero*.

The truth table of Fig. 2 and its relay contact tree are by no means minimal; rather they reflect a set of compromises that appears to allow maximum variation in writing habits while tending to minimize relay contacts.

WORKING MODEL—The resultant circuit, containing 12 relays (10 relays for sequential logic, one counting relay and one counter-



ALTHOUGH RELATIVELY SIMPLE, *this script recognition system can read the 10 handwritten numbers with an accuracy of about 97 percent—Fig. 3*

driving relay) and 8 diodes is shown in Fig. 3 and in the photograph.

All relays are initially released by touching the stylus to the RESET button, momentarily energizing relay 7. As the subsequent writing proceeds, the counter (relay 9) steps along once for each separate intersection of the stylus with segment 8 (the chosen axis) of the commutator.

The following sequential logic is employed: (1) If segments 2 or 3 are contacted before a count of 6, relay 1 latches up, indicating a bottom vertical extension in the early (five or fewer axis crossings) or left portion of the word. (2) The only conditions under which relay 2 remains latched up at the end of a word are if a bottom extension occurs in the middle or right part of the word (axis crossings $\geqq 6$) *and* if there has been no bottom extension on the left. Relay 2 thus latched up indicates a middle or right bottom extension. (3) A top left extension is indicated by relay 3 if segment 13 is contacted and the axis crossing count is $\leqq 5$. (4) A dot (or slash or cross) is detected in a rather cheap and dirty way. The logic depends on such a mark being made after the rest of the word has been written. If the stylus hits segment 6 or 7 but fails to contact segment 9 before any of the upper segments (10 or above) are contacted, relays 4 and 5 contrive to latch up 4. This effectively picks up the discontinuity between the tail end of the script (hopefully in the lower half of the writing space) and the subsequent higher dot, slash or cross. (5) Relay 6 is energized for a counter total $\geqq 9$. (6) The presence of two (rather than one) left vertical extensions is detected by the count-of-two circuit formed by relays 11 and 12. Note that relay 11 represents the function F′ (the negation of condition F); a simpler circuit results.

This procedure extracts the required 6 bits of information. After a word is written the stylus is touched to the IDENTIFY contact. This latches up relay 8, applying voltage to the selected one of 10 indicator lamps.

The 45-v supply for the relay and counter circuits requires approximately ½ amp, reasonably well regulated. An alternative output display employs a Nixie 7153 indicator tube which requires a 250-v low-current supply.

READING TESTS — In a controlled test of the device, 20 people wrote five complete sequences of the 10 words. They were asked to write with reasonable care and with their own style and speed. Of these 1,000 trials, there were 96.9 percent correct identifications.

The errors were due to the following causes: *Five, six,* and *nine,* identified respectively as *four, one,* and *seven,* accounted for 2.5 percent of the errors. This is due to failure of the dot detector. If the upswing of the final letter of the word rises above segment 8 of the commutator, the dot detecting circuit (relays 4 and 5) is frustrated.

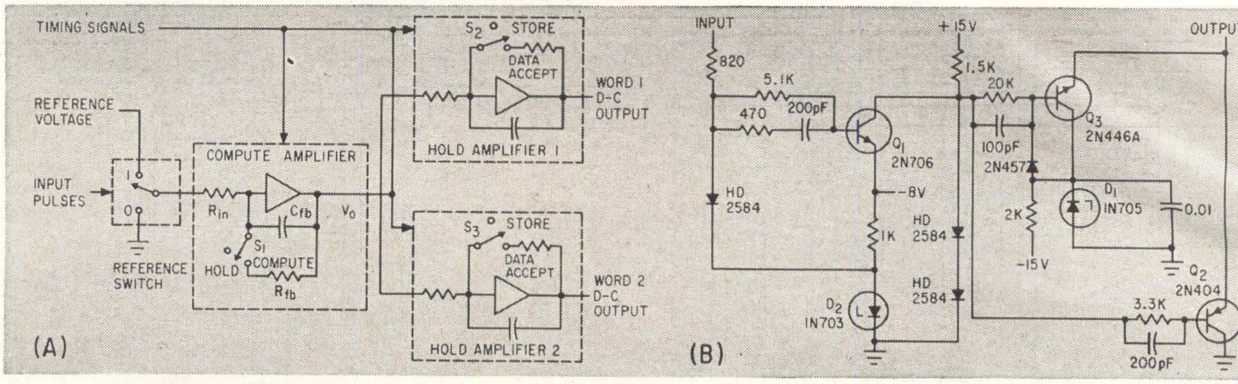
Most of the remaining errors (0.6 percent) were due to writing that was too small to properly operate the detection circuits. For example, in some cases an *h* was made no taller than an *e*.

This is a simple script recognition system that demonstrates a few principles. It can be improved, but the inherent limitations of its detection procedures do not warrant much more refinement. However, the device illustrates that given a few modest constraints, a very simple system can read the 10 digits (when cursively hand-written by reasonably careful writers) with an accuracy of about 97 percent.

REFERENCE

L. S. Frishkopf and L. D. Harmon, Machine Reading of Cursive Script, "Proc. 4th London Symp. on Info. Theory", C. Cherry, ed., p 300, Butterworth: London, 1961.

New Approach to Serial Decoding



SERIAL DECODER *(A) and reference switch (B)—Fig. 1*

Linear summation of charges placed on a capacitor by successive pulses of a binary number yields a voltage proportional to that number

DIGITAL COMPUTING and control systems often use serial data handling techniques and serial storage media such as magnetostrictive delay lines, shift registers and magnetic drums. Often, digital data must be converted to analog, such as in a digital servo controlling a proportional servomotor. The conventional way to do this uses a static storage register and weighted resistor summing. But this decoder converts serial binary data directly to analog d-c voltage without static storage. It can be used whenever moderate (1 to 2-percent) accuracy conversion is acceptable. Binary numbers are presented to the decoder least-significant bit first at a clocked rate in non-return-to-zero form. The decoder output is a d-c voltage directly proportional to the input binary number.

SERIAL DECODER—Consider a group of pulses representing a binary-coded number, least-significant bit leading. Successive pulses of the group represent successively higher powers of 2. To decode this pulse train, a method has been shown[1] in which the 2^0 pulse of an n-bit number contributes $k/2^n$ volts to the final decoder output, the 2^1 pulse contributes $k/2^{n-1}$ volts, the 2^2 pulse $k/2^{n-2}$ volts and so forth. Linear summation of the contributions from each pulse yields a voltage directly proportional to the input binary number.

This concept can be implemented by allowing each input pulse to place a standardized charge on a capacitor, and then allowing decay of that charge by 50% during each succeeding pulse period. Assume the capacitor is initially discharged. A pulse in the 2^0-bit position will place a charge Q on the capacitor. Let the time interval between pulses be the pulse period p. Since the charge decays by one-half each pulse period, the original charge will have decreased to $Q/2^n$ at time T, where $T = np$. A pulse in the 2^1-bit position will also add a charge Q to the capacitor, and since this pulse arrives p seconds after the 2^0 pulse, its contribution to the total charge will be $Q/2^{n-1}$ at time T. In general, a pulse in the 2^j-bit position will contribute a total charge of $Q/2^{n-j}$ at time T. The total charge Q_T on the capacitor at time T is

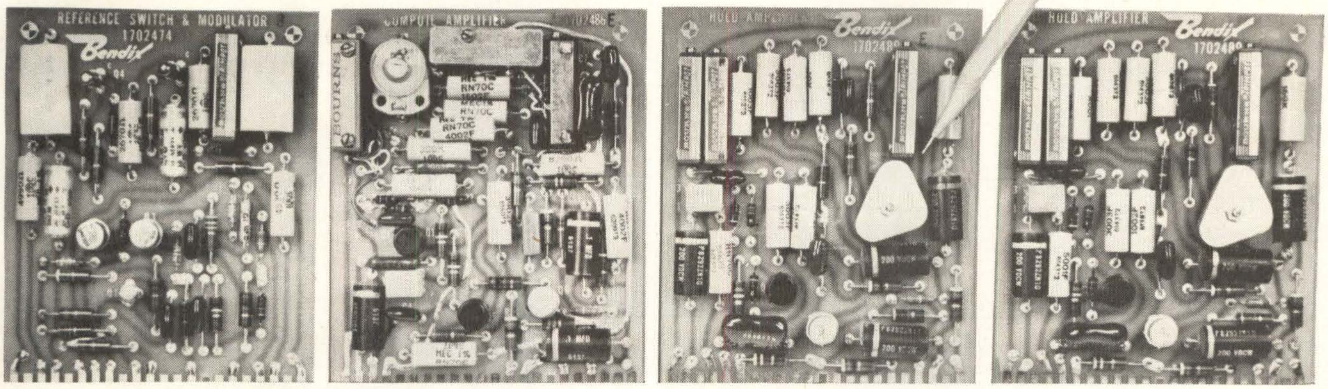
$$Q_T = Q/2^n(A_0 2^0 + A_1 2^1 + A_2 2^2 + \cdots + A_j 2^j + \cdots + A_n 2^n)$$

where $A_0, A_1, A_2 \ldots A_j$ are either ONE or ZERO, depending on the presence or absence of a pulse in the corresponding bit position. Thus Q_T is directly proportional to the magnitude of the input binary number.

PRACTICAL SERIAL DECODER—Figure 1A is a functional diagram of a practical decoder. Input pulses, which represent the input word in binary form, are applied to a reference switch circuit that standardizes the input data by generating pulses of constant amplitude and duration. A ONE input connects the reference switch to a reference voltage, and a ZERO input grounds the switch.

Output pulses from the reference switch are applied to a compute amplifier circuit, which performs the actual decoding of the pulse pattern and then holds the analog voltage for a transfer to another circuit. The amplifier is made up of a d-c operational amplifier, an RC feedback circuit, and a transistor switch. Each pulse from the reference switch applies a fixed current pulse to the amplifier through input resistor R_{in}. Since the pulse width is also constant, a fixed amount of charge is added to C_{fb} for each applied current pulse. Because the operational amplifier maintains its error point at virtual ground, the charge rate is inde-

Eliminates Static Storage



TWO WORD *decoder is packaged on four cards. Common heat sink is used for first three stages of hold amplifiers*

By R. M. CENTNER and J. R. WILKINSON,
Bendix Corp. Research Laboratories, Southfield, Michigan

pendent of the initial charge on C_{fb}. The time constant R_{fb} C_{fb} is set so that the charge on C_{fb} will decay by 50% each pulse period. The time constant is determined by $e^{-p/\tau} = 1/2$ where p is the pulse period and τ is the time constant R_{fb} C_{fb}. For example, if p is 5 μsec, τ must be 7.21 μsec.

Because of the operational amplifier, the contribution of each input current pulse to the output voltage may be calculated independently and the total value may be determined by superposition. If it is assumed that computation begins at t_0 when the least-significant bit enters the system, and concludes at t_x, the end of the most-significant bit, then the final output voltage $V_o(t_x)$ is given by

$$V_o(t_x) = K V_{ref} \left[X_1 + \frac{X_2}{2} + \frac{X_3}{4} + \frac{X_4}{8} + \cdots + \frac{X_n}{2^{n-1}} \right]$$

where V_{ref} is the pulse reference voltage, K is the compute amplifier gain, n is the number of bits, X_1 is the state of the most-significant bit, X_2 is the state of the next bit. Value $V_o(t_x)$ is the correct analog representation of the input binary word.

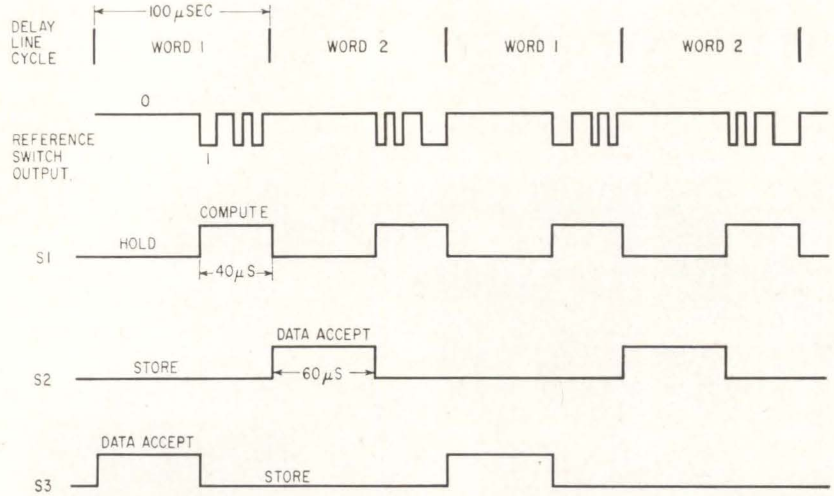
OPERATION—Switch S_1 is in the compute position from t_0 to t_x. At t_x it is switched to the hold position to remove R_{fb} from the circuit. Therefore, the circuit time constant is increased by a large factor and V_o holds its final value.

While S_1 is in the hold position, the decoded analog voltage is transferred to an analog storage, or hold amplifier. This frees the compute amplifier for decoding a new word and thus permits time-sharing of the circuit. The hold amplifier is similar to the compute amplifier, but has a larger feedback capacitor. Thus, it can store the analog voltage for a longer period of time. Any number of words may be multiplexed with the number of hold amplifiers equaling the number of input words. A two-word system is described. Transfer of the data is accomplished by setting the appropriate hold amplifier switch (S_2 or S_3) to the data-accept position while the compute amplifier is in the hold condition. After sufficient time has elapsed for the hold amplifier capacitor to charge, the switch is returned to the store position and the voltage is held until the next cycle of the storage medium.

The system operation may be clarified further by Fig. 2, which illustrates the switching cycle for a two-word system. The input data is obtained from a magnetostrictive delay line containing two serial words. Two iterations of the delay line are indicated. The data is presented in non-return-to-zero form, least-significant bit leading, with −8 volts representing binary ONE and 0 volts representing binary ZERO. Delay line length is 200 μsec, word time 100 μsec, and bit time 5 μsec.

Word length is 20 bits and the required decoder accuracy is 2 percent of full scale.

The decoder is required to examine only the eight most significant bits of each word, since the weight of the ninth bit is 2^{-8}, less than 0.4 percent of full scale. Thus, switch S_1 is placed in the compute position only during the last 40 μsec of each word. During this time, S_2 and S_3 are in the store position. At the end of word 1, S_1 is switched to the hold position and S_2 to the data-accept position. During the 60-μsec period that S_1 is in the hold position, the decoded output of word 1 is being transferred into hold amplifier 1. When the transfer is complete, S_2 is returned to the store position and S_1 to the compute position. At the end of word 2, S_1 is returned to the hold position and



SWITCHING CYCLE *for a two word system. Input data was obtained from a magnetostrictive delay line containing two serial words—Fig. 2*

S_3 is set to the data-accept position. This allows transfer of the decoded output of word 2 to hold amplifier 2. After transfer, the cycle begins again with the decoding of word 1. Residual voltage from the preceding word causes an initial charge on C_{fb} when S_1 is switched to the compute position. However, by the time decoding is complete, the charge due to the residual voltage will have decayed by a factor of 2^8, and will thus cause less than 0.4 percent error in computation.

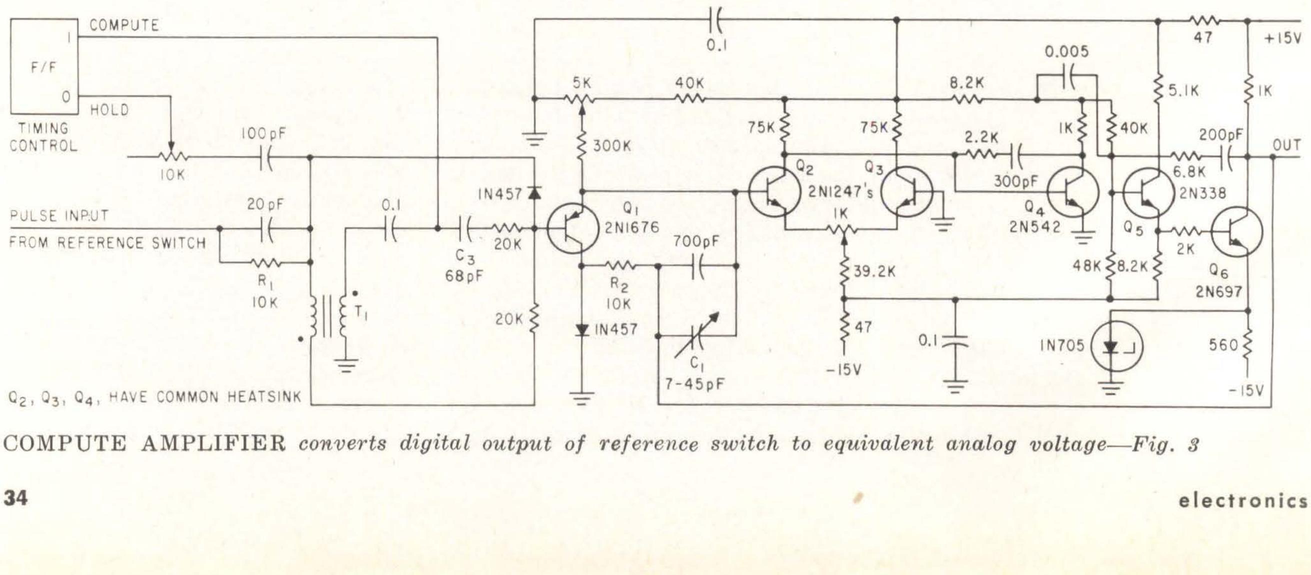
The reference switch is shown in Fig. 1B. This provides low-zero-offset 5-μsec pulses with stabilized amplitude. The input pulses are obtained from a synchronous flip-flop with nominal logic levels of zero and −8 volts. The output pulses switch from zero to −5 volts. The switch uses transistors Q_2 and Q_3, in series-shunt; the leakage current of the off transistor is shunted by the on transistor. Collector and emitter connections are reversed to obtain low transistor offset voltages of approximately 2 mv.

The accurate 5-volt reference level is established by the action of zener diode D_1.

The two switches are driven by Q_1, which shifts the logic levels and inverts the phase. The end of the pulse input is determined by the rapid turn-on of a control flip-flop transistor rather than the slower and less predictable transistor turn-off time. This is important in minimizing timing error when placing the compute amplifier in the hold position at the end of the most-significant bit. The data input is clamped at −3 volts by zener diode D_2 to remove clock noise which would cause an unwanted d-c compute amplifier output at the 0 level. Other small offsets from the reference switch are compensated in the bias adjustments of the compute amplifier. Rise and fall times of the output pulse are approximately 0.05 μsec.

COMPUTE AMPLIFIER — This unit converts the standardized digital output of the reference switch to an equivalent analog voltage and then holds this voltage for transfer to a hold amplifier (see Fig. 3). Transistor switch Q_1 sets the amplifier in the compute or hold position (S_1 in Fig. 1A, R_1 is the input resistor, R_2 the feedback resistor, and C_1 and C_2 make up the feedback capacitor. Trimmer capacitor C_1 is adjusted for optimum decoding linearity. The closed-loop gain of the amplifier is unity, which means the full-scale d-c output is equal to the reference amplitude of 5 volts.

At the end of each word, Q_1 is reverse biased so that only C_1 and C_2 form the amplifier feedback. The amplifier is then on hold and will remain so until computation of the next word begins. During the hold time, the voltage will be transferred to one of the hold amplifiers. The maximum amplifier drift during hold periods must be within approximately $\pm 10^{-7}$ ampere over the temperature range of 5 to 55 C to meet the specified accuracy. This low drift is accomplished by closely matching the temperature coefficients of the transistors in the first three stages. The most significant temperature coefficient is that of V_{be} of Q_2. This is compensated by the V_{be} of the same type transistor Q_3. The beta temperature coefficient



COMPUTE AMPLIFIER *converts digital output of reference switch to equivalent analog voltage—Fig. 3* of Q_2 is matched by the beta coefficient of Q_4. This match establishes the choice of transistor type for Q_4. A common heat sink for Q_2, Q_3 and Q_4 maintains the transistors at the same temperature. Metal film resistors are used at some points to minimize drift due to resistance changes. The discontinuities in the input waveform require an amplifier bandwidth of approximately 170 Kc. This necessitates a higher Q_2 collector current than would be optimum for temperature stability. However, the required equivalent input drift of approximately $\pm 10^{-7}$ ampere was achieved by temperature compensation technique.

Switch Q_1 is turned off by the rise of a flip-flop output. Timing for the turn-off is critical in that it marks the termination of the most-significant bit. Since the rise time of keying transformer T_1 is insufficient to achieve the required fast turn-off of Q_1, C_3 is used to supplement the transformer key. The rise time on the base of Q_1 is 0.1 μsec.

HOLD AMPLIFIER—This is an analog storage device which permits time-sharing of the compute amplifier. At each end-of-word, the output of the compute amplifier is sampled by the hold amplier to provide a decoder d-c output. Hold amplifier outputs are updated each delay line iteration by recomputed values of the digital words. Sampling begins after the most-significant bit of a word and ends just before computation of the next word begins. The amplifier has a closed-loop gain of two and full-scale output is -10 volts d-c.

The amplifier configuration (Fig. 4), temperature compensation, and control switch are the same as in the compute amplifier; R_1 is the input resistor, R_2 the feedback resistor, and C_1 the feedback capacitor. As the bandwidth requirement is relatively low, a first stage collector current optimum for temperature compensation can be used. Drift current during hold of less than $\pm 5 \times 10^{-8}$ ampere was achieved for an ambient temperature range from 5 to 55 C. The switching time to the data-accept position or the store position is approximately 2 μsec.

The two-word decoder has been packaged on four printed circuit cards, as shown in the photograph. For applications involving more input words, one hold amplifier card would be added for each word. The common heat sink used for the first three stages of the hold amplifiers is the triangular-shaped piece of metal. The three transistors are enclosed within this block of aluminum. The heat sink on the compute amplifier is the rectangular shaped piece of aluminum at the top of the card. These heat sinks enabled relatively low drift to be attained without stabilizing circuits.

The two-word decoder was given extensive environmental testing. Over the ambient temperature range 5-55 C, the analog output voltage of the two hold amplifiers, plotted as a function of digital input, corresponded with the best straight line to within 2 percent of reading. The maximum zero offset was less than 0.5 percent of full-scale output, resulting in a dynamic range of 200:1. The zero offset can be decreased by chopper-stabilizing the compute and hold amplifiers. A circuit to accomplish this is now under development. Preliminary results indicate the offset to be less than 0.1-percent of full scale, increasing the dynamic range to 1,000:1. The linearity of the decoder can be improved by decreasing the rise and fall time of the reference switch and compute amplifier input switch.

The serial decoder provides an economical means for converting serial binary digital signals to analog d-c signals with moderate (1-2 percent) accuracy. By eliminating the need for static storage, the serial decoder permits economies to be realized in conversion circuits and thus contributes to more efficient use of hybrid techniques. For example, some control systems having digitized input variables are required to solve complex trigonometric and algebraic equations, which can often be more efficiently handled by analog, rather than digital techniques. Previously, economic trade-off may have favored use of digital computation because of the expense of conversion circuits, the serial decoder now makes the analog approach attractive for certain applications such as automatic checkout equipment, hybrid simulation systems and industrial process control.

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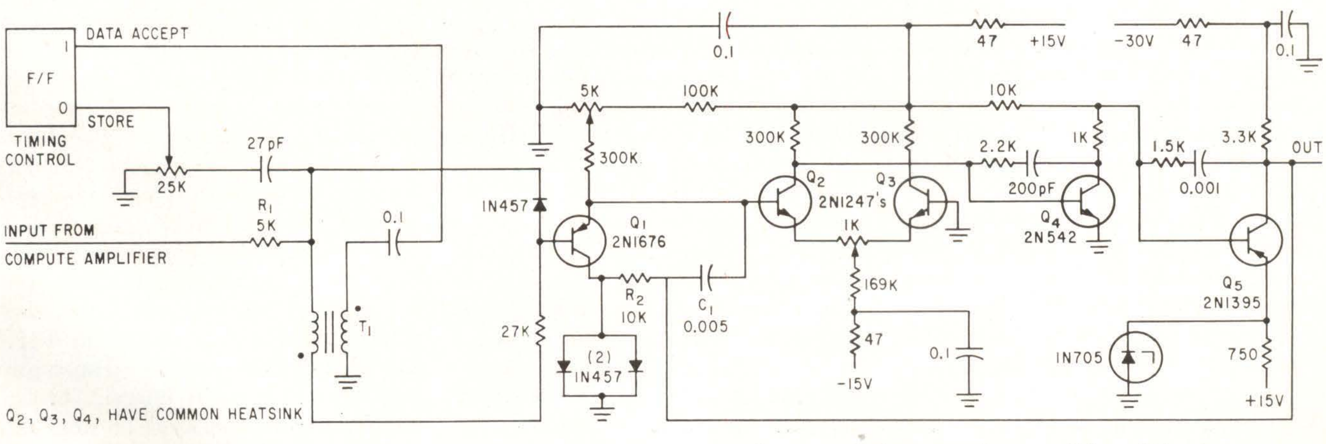

HOLD AMPLIFIER *is analog storage device which permits time sharing of the computer amplifier—Fig. 4*

Simple Curve Tracer

Transistor is driven by sawtooth; beta variation is

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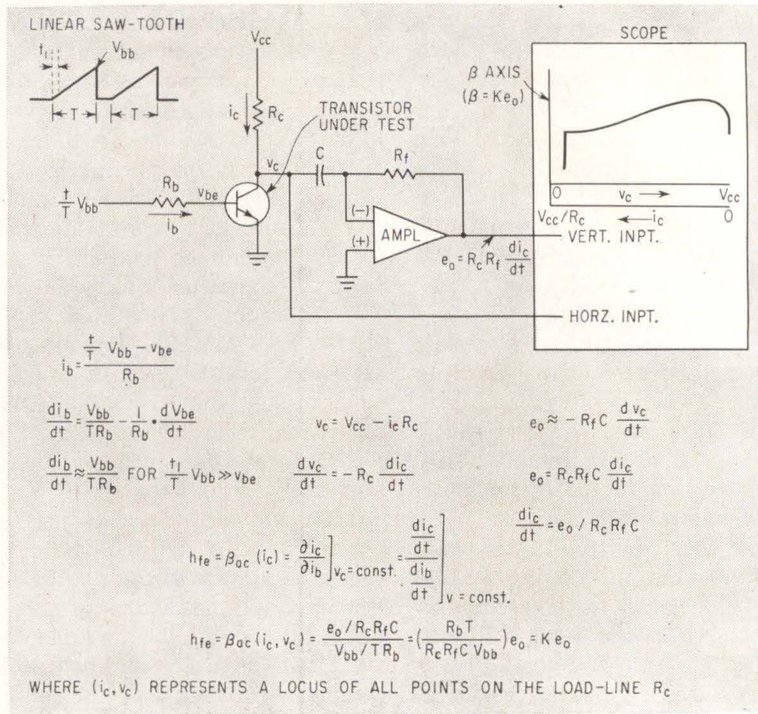


OSCILLOSCOPE *horizontal axis is fed directly from transistor collector to produce time base, vertical axis input is differentiated collector waveform proportional to desired beta—Fig. 1*

TRANSISTOR A-C BETA (h_{fe}) varies both with collector voltage and collector current. Beta is a function of the operating point on the load-line; that is, of $f(v_c,i_c)$. It is frequently desirable in design analysis to determine the exact nature of the function $f(v_c,i_c)$ with respect to load-line operating points. A simple curve-tracing method has been developed to plot low-frequency a-c beta versus load-line operating point.

BETA-TRACE—A diagram of the curve-tracing set-up is shown in Fig. 1. A linear sawtooth of duration T and maximum amplitude V_{bb}, is applied to the base of the test transistor through a current-limiting resistor R_b. A dead-time between the repetitive sawtooth waveforms of 5 to 10 percent of T allows recovery of the differentiating circuit in the collector load. This is illustrated in Fig 1.

The derivative of transistor base current, di_b/dt, is constant for the sweep period T, assuming the peak sweep voltage V_{bb} is much greater than the transistor base-to-emitter voltage drop, V_{be}. (A standing bias applied to the base circuit could make this so.)

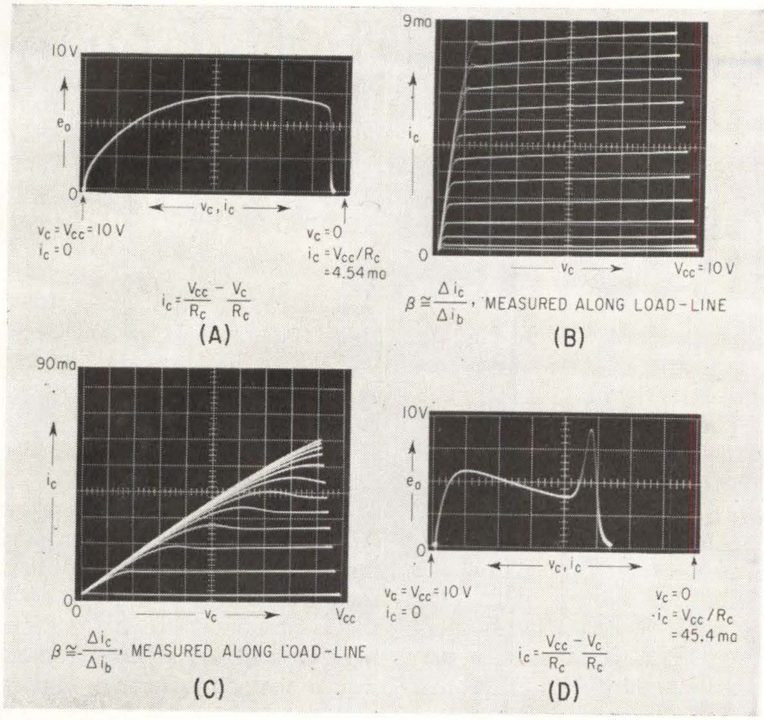
The collector output of the test transistor feeds the horizontal input to an ordinary oscilloscope and the vertical input through a high-gain operational amplifier connected in the differentiating mode. Amplifier output, $e_o = k\, dv_{in}/dt$.

The horizontal scale of the scope represents collector voltage, but may also be calibrated in collector current since these variables are linearly related. Their direction of increase is opposite, however, with the effect that the horizontal scale may be interpreted as a locus of all v_c,i_c load-line operating points.

As shown in Fig. 1, the output voltage of the operational amplifier is proportional to the derivative of the transistor collector current. This derivative, divided by the base-current derivative, which is constant, defines transistor a-c beta h_{fe}. Using these relationships, a-c beta is proportional to the operational amplifier output voltage e_o. The proportionality constant is determined by the value of circuit components and the sweep period T of the sawtooth input.

For each sawtooth sweep cycle a curve is traced on the oscilloscope. The vertical scale is calibrated in beta units and the horizontal scale represents load-line points. Thus an automatic plot of beta versus load-line is obtained. By keeping the ratio of collector resistance to base resistance constant, curves for various load-lines may be obtained without changing the vertical scale factor.

RESULTS—Comparison measurements were performed on various transistors to check the accuracy of the curve tracing method. Beta was calculated directly from i_c and i_b measurements made with milliammeters. Then i_c and i_b data were taken from a set of common-emitter characteristic curves. Finally, audio frequency gain measurements were made at quiescent points on the load-line. The beta values obtained for various transistors by the curve-tracing technique agreed well with these other methods. Figure 2A shows a typical beta curve. A set of common-emitter characteristic curves for the same transistor is shown in Fig. 2B. When the 2N118 transistor was tested at higher current levels, the beta-trace displayed an unusual shape. As is shown in Fig. 2D,



BETA TRACE *for 2N118 transistor with $R_c = 2{,}200$ ohms, $R_b = 680$ ohms and $K = 5.83$ (A); common-emitter characteristic, with base steps of 20 microamp (B). Tests at higher current (C) show common-emitter characteristic for $R_c = 220$ ohms, and 200 microamp base steps; beta display (D) for $K = 8.58$, $R_b = 100{,}000$ ohms and $R_c = 220$ ohms—Fig. 2*

Displays Transistor Beta

shown on oscilloscope for various load values

beta, after falling off with increasing collector current, suddenly peaks to a relatively high value just prior to dropping to zero at the saturation point of maximum current. This apparently anomalous result is correct, however, as is proven by examining the associated set of common-emitter characteristic curves. As is shown in Fig. 2C, the collector curves exhibits a spreading near the collector-voltage saturation line, which would account for a beta increase.

In the test setup, a solid-state operational amplifier was used. In the R_fC differentiating network, C was 0.2 microfarad and R_f was 200,000 ohms. Sometimes it is necessary to shunt R_f with a small value of capacitance to prevent ringing in the differentiating-network/operational-amplifier circuit. A value 1 to 2 percent of C should be sufficient.

During tests V_{bb} was about 143 volts and a sweep period T of 108 milliseconds was selected. The collector supply voltage was arbitrarily set at 10 volts d-c.

Values of R_b and R_c ranged from 3.3 megohm to 22,000 ohms, and from 22,000 ohms to 55 ohms respectively, for the transistor tested. Thus the calculated values of the vertical-scale factor K ($h_{fe} = Ke_o$) ranged approximately from 2.8 up to 8.6.

LIMITATIONS—The upper limit on collector load resistance is determined by the parallel loading effects of the differentiating-network amplifier circuit and the scope horizontal input impedance. It should prove feasible, however, to insert a voltage-following isolation amplifier between the collector output and these input points. This modification could probably extend the beta-trace method into the low microampere collector current region for low leakage silicon transistors.

The lower limit on collector resistance is governed by the driving capability of the saw-tooth source. For a constant collector supply voltage V_{cc}, a lower collector load resistance causes higher collector current levels, which in turn dictate higher base currents; R_b is made lower, or V_{bb} must be increased. Caution must be exercised to avoid nonlinearity distortion in the sawtooth due to excessive loading. Thermal heating and/or power handling capability of the transistor being tested also governs the lower limit. Beta is, of course, a sensitive function of junction temperature; consequently, the beta-trace will be distorted if the junction temperature changes during low-speed sweeps. One way to minimize this effect is to make the sawtooth period T as short as possible and have low repetition rates to take advantage of the thermal lag, or time constant, of the transistor.

The maximum value of the collector supply voltage V_{cc} is limited by the collector breakdown voltage V_{CEO} (worst case, assuming R_b is large) and the maximum input/output voltage level of the operational amplifier before clipping. In general, as V_{cc} is increased, the peak value of dv_c/dt will also increase. This increases the amplifier output voltage, since $e_o = R_f\, dv_c/dt$. Some compensation could be achieved by increasing the sawtooth period T for high collector supply voltages. This would reduce the peak magnitude of dv_c/dt.

The author expresses his appreciation to Rodney A. Mulder of Measurement Research Center for constructing the test set-up, and for recording most of the experimental data.

Testing Space Craft With Induction

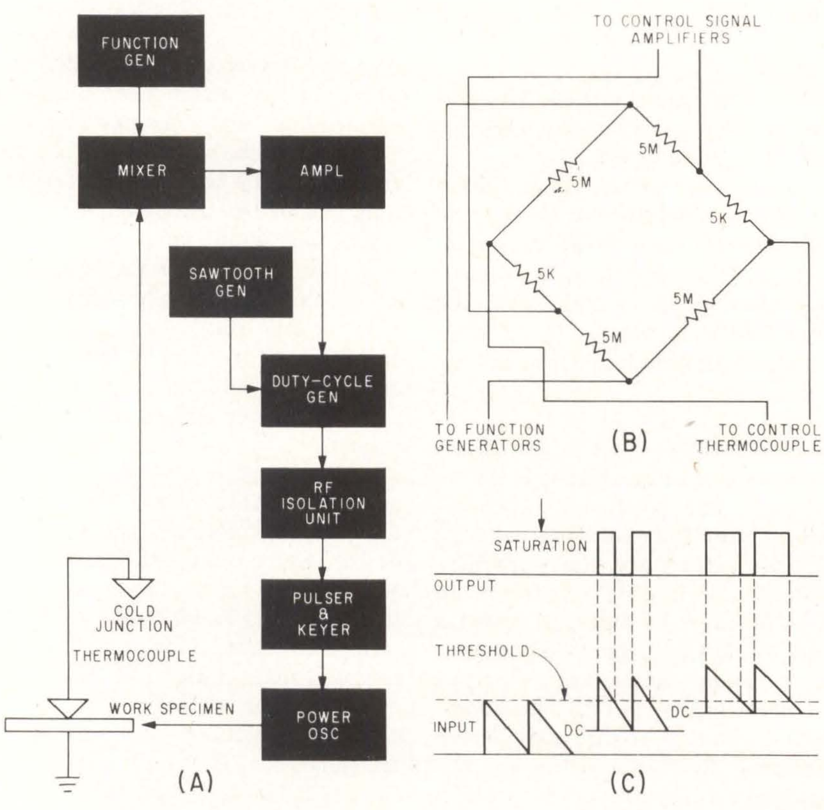
Precise control system using power oscillator handles large amounts of heat. Grid blocking controls power

AT THE HIGH VELOCITIES now attained by aircraft and most missile and space vehicles, aerodynamic heating becomes a design consideration. This heating is caused by compression and friction in the air layer directly adjacent to the surface. Although this phenomenon is always present when there is relative velocity between air and the surface, its effects are unimportant until supersonic velocities are attained. Consequently, aerodynamic heating simulation, often combined with aerodynamic loading simulation, is of primary importance in laboratory structure testing.

In a recent test program at the University of Florida, a full-sized prototype section of a wing leading edge was heated to 3,000 deg F in a simulated re-entry flight lasting two hours. The leading edge was made of molybdenum alloy protected with an oxidation-resistant coating.

The recent achievement of controlled temperatures up to 3,000 deg F on a full-sized specimen was made possible by two new developments. First, a technique for surveying the magnetic field at the test specimen surface permits a desired heat distribution. Second, porcelain copper enamel coated heating coils have permitted operation at high temperatures. The porcelain coating provides an electrical insulation capable of withstanding high temperatures for long periods.

Work in heating aircraft structural shapes by radio-frequency induction was done under sponsorship of the Structural Division, Directorate of Engineering test, Aeronautical Systems Division, Wright Air Development Division. Radio-frequency currents tend to flow on the surface of metal structures and the consequent heating simulates high speed aerodynamic heating where heat flows from a high-temperature boundary layer of air into the surface of the structure. Emphasis has been placed on achieving prescribed heat distributions and following given time-temperature programs.



CONTROL SYSTEM *block diagram, (A); low-level mixer circuit, (B); method of voltage-to-pulse conversion, (C)—Fig. 1*

CONTROL REQUIREMENTS—Aerodynamic heating simulation requires a control system that can vary the heat output from zero to full power within a short time. On re-entry into atmosphere the heat input rises suddenly as the density of the atmosphere increases. To simulate such a flight, heating equipment must provide a rapid and continuously variable power output.

Large amounts of radio-frequency power can be generated by two techniques: (1) the master-oscillator, power amplifier system and (2) the power oscillator. The first method is generally used in radio transmitters. A fixed-frequency signal is generated at low level and amplified to the required power output. Power output control, or modulation, may be accomplished at low power levels. A typical example is grid modulation.

Power amplifiers do not accept a change in load reactance. An induction heater must be capable of operating with a changing load reactance since both the resistivity and the dimensions of a specimen will usually change considerably as

Heaters

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the temperature increases.

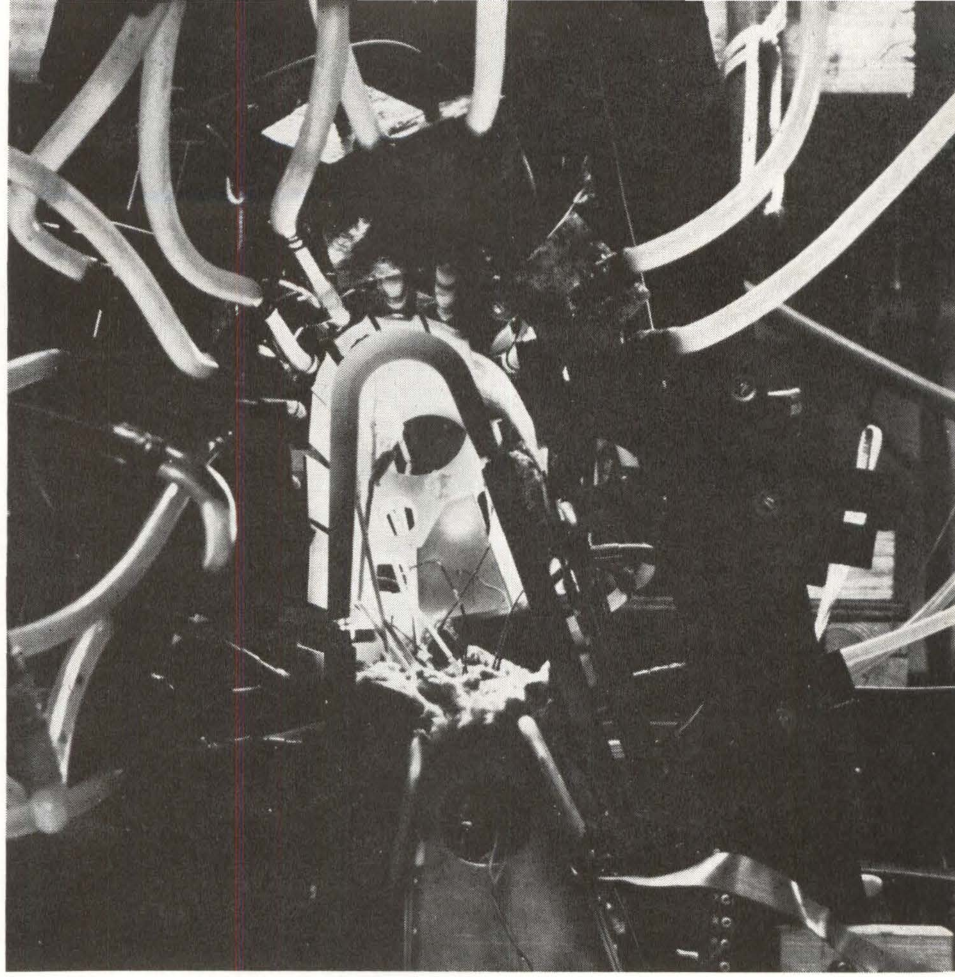
The power oscillator, on the other hand, is self adjusting for load reactance changes. This is one reason why power oscillators are generally used for high-power induction heating.

Power oscillators, however, are not as readily controlled as the power amplifier system. The four conventional methods[2] of control rely on variation of: (1) grid drive, (2) load matching, (3) filament emission and (4) plate voltage. None of these methods is satisfactory for rapid and complete control.

Mathews[3] presents the basic concept of a more satisfactory means of control. This method allows the power oscillator to operate at its optimum point, and permits control of time-average power output by varying the amount of time the circuit oscillates compared to the amount of time the oscillator is off. Since the on- and off-time of the power oscillator may be controlled in the grid circuit, only relatively small amounts of power are handled by the control system. Since the oscillator, when operating, is adjusted to optimum conditions, less instability will develop as power output is varied.

The on-off control is achieved by switching the power oscillator grid-leak resistance and by supplying a high bias through a high resistance to maintain the cutoff condition obtained when the grid-leak resistance is opened during oscillation.

When the grid-leak resistance is open, the high negative bias is maintained and the tube will not oscillate; when the grid-leak resistance is switched in, the bias is shunted and oscillations build up



SECTION *molybdenum alloy wing leading edge is heated to 3,000 deg F during testing to simulate reentry heat flow*

rapidly. Switching of the control circuits is rapid, and full output builds up in a fraction of a millisecond. The time-average power output of the unit depends on the ratio of on-time to off-time.

The ratio of the on-time to the time of one complete on-off cycle is known as the duty cycle. The complete cycle time is so chosen that the pulses of r-f power do not cause individual transient steps in structure temperature. The thermal inertia of structures varies; however, a pulse repetition rate of 360 pulses per second is satisfactory for most conditions.

POWER OUTPUT — Consider a case where the power oscillator has been adjusted to develop a continuous power of 100 kilowatts in the surface of a structure. If the on-time of the oscillator is equal to the off-time, the duty cycle is 50 percent and the average power developed in the specimen is 50 kilowatts.

The average power output of the unit can be represented by the following equation:

$$P_{av} = \theta P_{max}$$

where P_{max} is the power output of the unit while operating continuously and θ, the duty cycle, is represented by $\theta = T_1/(1/360)$ in which T_1 is the on-time and 1/360 is the time of one complete on-off cycle.

A power oscillator whose power output may be varied smoothly from zero to 100 percent is the end component of a complete control system capable of following a prescribed temperature-time history. Figure 1A shows the control system.

Basically, the system is a simple proportional-error servo mechanism where the control signal (or error signal in closed-loop system terminology) is the difference between the output of the control thermocouple attached to the work specimen and a millivolt function-generator output corresponding to the desired temperature program. The control signal corresponding to a small temperature difference is amplified enough to drive a volt-

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age-to-pulse-width converter. The variable-pulsewidth output is amplified by a pulse driver to drive the keyer unit attached to the power oscillator. The keyer unit pulse-modulates power tubes to provide the average power output necessary to maintain the temperature.

On this basic design, several systems have been developed. An early control system incorporated a d-c preamplifier in the control thermocouple circuit ahead of the mixer. Instability in such d-c circuits gave some trouble since the system voltage gain was as high as 5,000,000. Despite this handicap, tests showed the feasibility of a system of this type.

More recent control systems use what is termed low-level mixing. The function generator output, usually of the order of 10-100 volts, is attenuated to the order of magnitude of the thermocouple output. The control function and the thermocouple signal are then compared in a low-level passive mixer to obtain a control (or error) signal. Figure 1B shows such a mixer. The 5-meg and 5-K resistances provide 1,000:1 attenuation of the function generator output to provide voltage levels compatible with the millivolt output of normal thermocouples. A stable chopper d-c amplifier provides the necessary amplification for the control signal to operate the duty-cycle generator.

The duty-cycle generator is a voltage-to-pulse-width converter with low-level pulse output to drive the pulse driver unit. In a recent[4] transistorized design, the duty-cycle generator is driven by a sawtooth generator that may be operated at a fixed frequency between 120 and 1,080 pulses per second. The frequency adjustment permits the choice of a high enough frequency to give a smooth temperature response.

The pulse generator produces a variable-width rectangular pulse. Figure 1C illustrates the technique.

The unit is basically a high-gain amplifier that amplifies the signal considerably when a threshold is exceeded. If the amplifier were linear, a high voltage sawtooth would be obtained; however, due to the high gain of the unit and the low saturation point of the final stages, the sawtooth is clipped so that the effective output is a pulse with width proportional to the small amplitude of the sawtooth that is above the threshold level. Figures 2A and 2B show the circuits used.

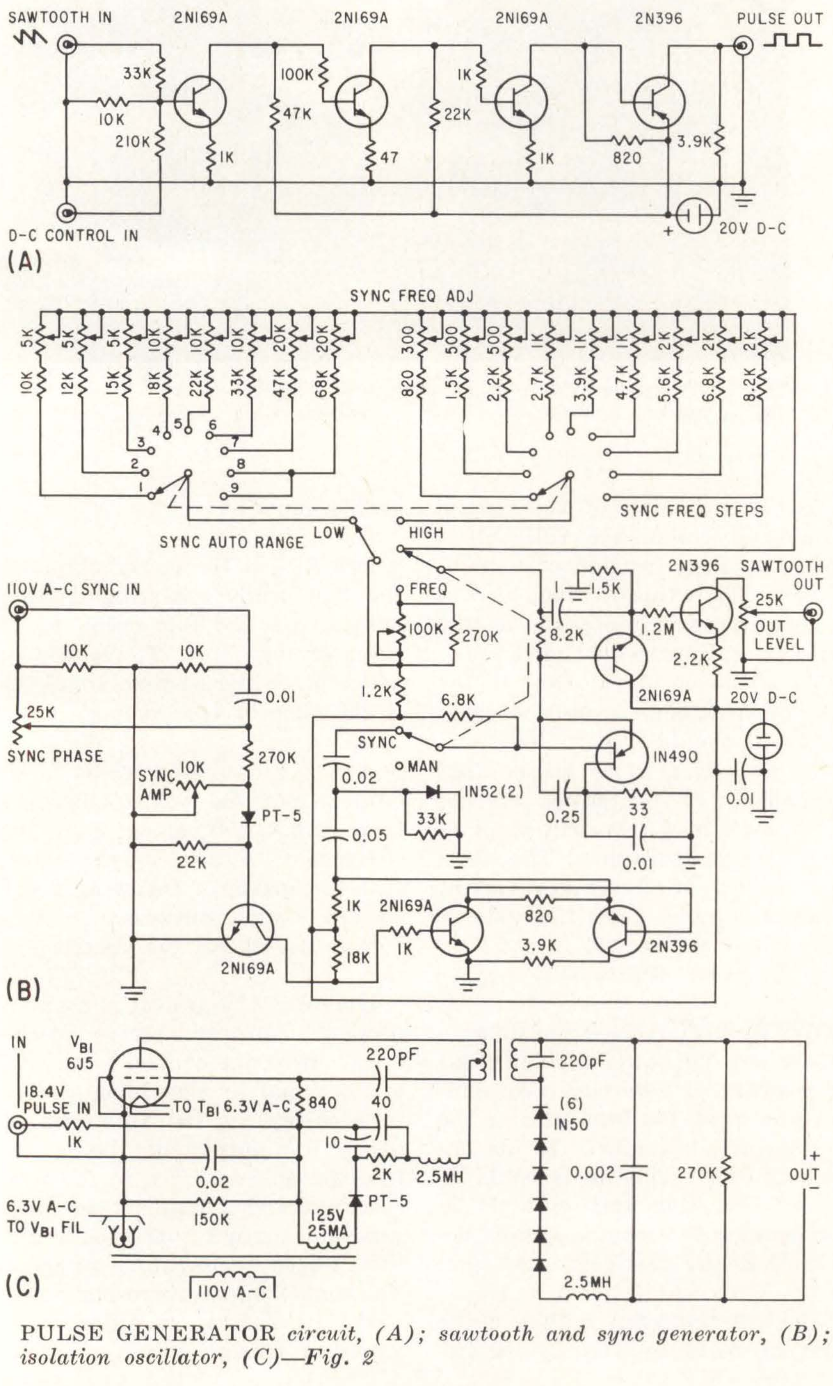
The pulse driver amplifies the output of the isolation unit to a power level sufficient to control the keyer tubes of the power oscillator (see Fig. 3).

Figure 4 shows the pulse driver unit and the keyer circuits.

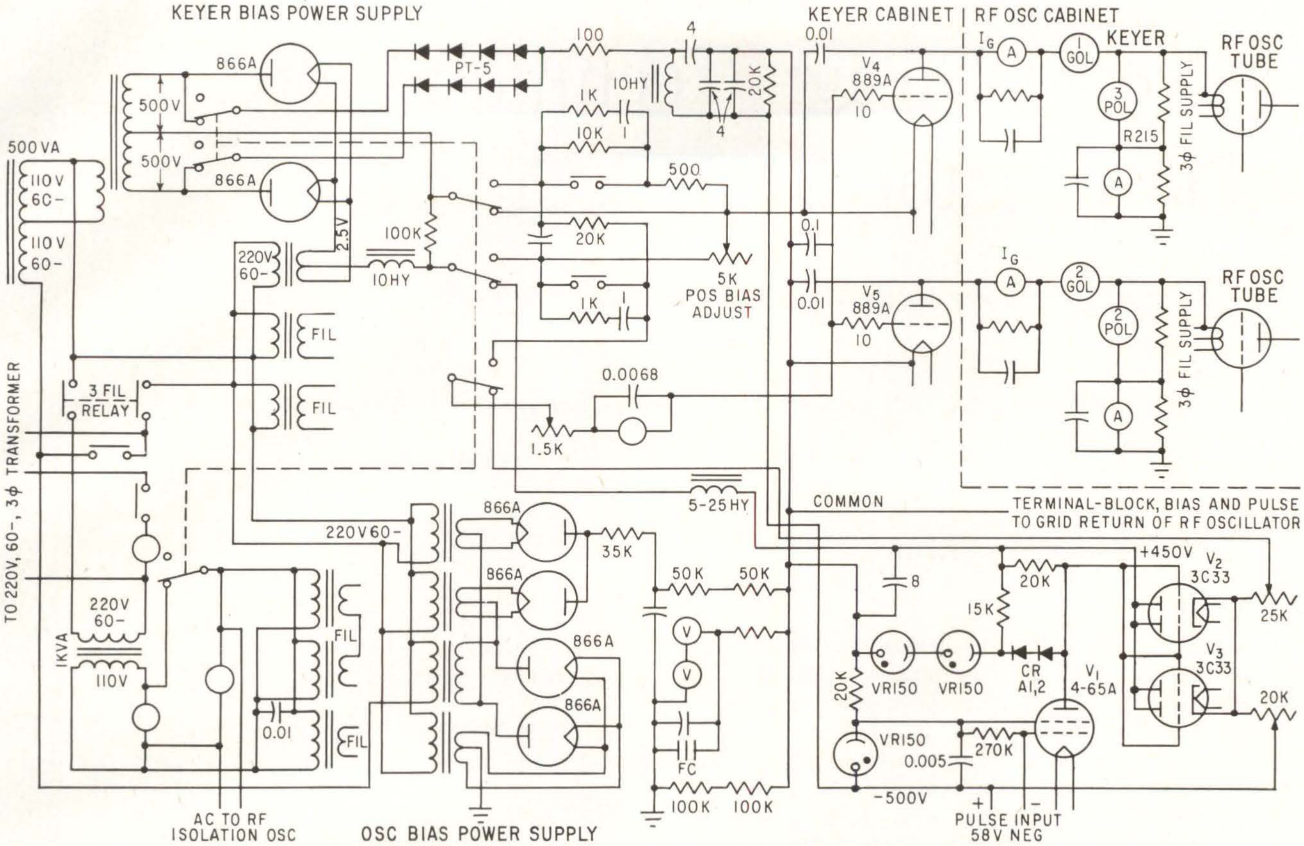
SYSTEM PERFORMANCE—Since several of the variables are a function of the test specimen, no categorical statement can be made concerning overall system response, accuracy and stability; only characteristics of the control elements alone can be considered.

Three time constants are significant in the control circuit of this system. These may be classified as follows: (1) keyer and power oscillator build-up time; (2) error-channel response; and (3) function generator rise time.

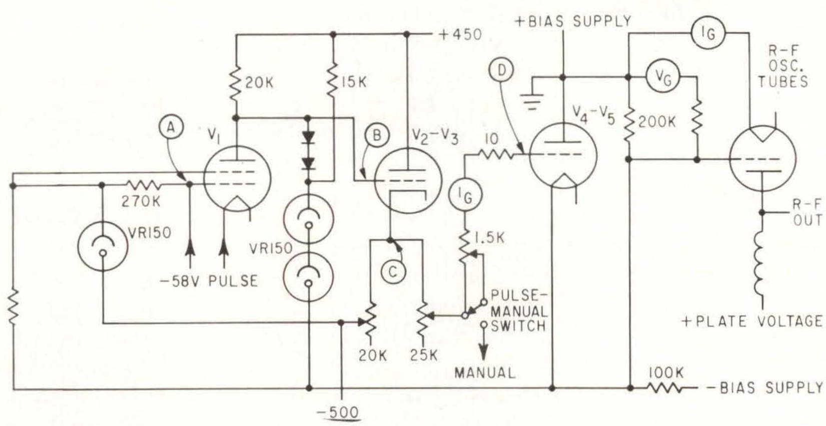
The power oscillator can be pulsed at up to 800 pulses per second before keyer and oscillator time constants cause erratic be-



PULSE GENERATOR *circuit, (A); sawtooth and sync generator, (B); isolation oscillator, (C)—Fig. 2*



OSCILLATOR, KEYER *and pulse driver circuit—Fig. 3*



PULSER AND KEYER *simplified circuits—Fig. 4*

havior. Since both turn-on and turn-off time constants are involved in repetitive pulse operation, the power oscillator and keyer response time to a step function is better than 1 millisecond.

The control signal (or error channel) amplifier is a chopper amplifier utilizing a 440-cps carrier frequency. Published drift stability is $\pm 5 \mu V$ equivalent drift for 1,000 hours. Response to a step function is better than 3 milliseconds.

The maximum controllable temperature rise depends on the function generator. The function generator used with one system permits a 0.5 percent accuracy function if the rise rate doesn't exceed 330 millivolts per second. The full-scale range is 70 millivolts so the most rapid controlled time rise permitted by this function generator is about 20 milliseconds. Using chromel-alumel thermocouples such a function rise rate corresponds to a temperature rise rate of 14,000 deg F per second.

While high temperatures have been achieved in the past, the tests at the University of Florida were the first in which induction heating methods were used to duplicate the distribution of heating intensity over the surface of a full-sized section of leading edge and to follow a prescribed timewise variation of temperature. The leading edge tested was not intended for any specific aircraft, but was produced for a hypothetical typical manned controllable glider as a result of a research project jointly sponsored by the Metals and Ceramics Laboratory and the Flight Dynamics Laboratory of the Aeronautical Systems Division, AFSC.

This work was performed under a subcontract from the Bell Aerosystems Company.

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Novel Design Technique for Transistor Digital Circuits

Permits designers to derive equations for cutoff and saturation conditions of a transistor logic circuit. Equations will provide circuit values for worst-case variations of parameters. By plotting these equations, the designer can then see how to optimize the circuit values

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ALTHOUGH most transistor-logic-circuit design methods take into account the temperature-stabilization problem, few allow for parameter variations. Rather, they design to nominal values and rely upon moderate-to-large safety factors[1] to compensate for circuit-component tolerances and variations in load requirements. This often results in circuits that are either too critical or have unrecognized capabilities.

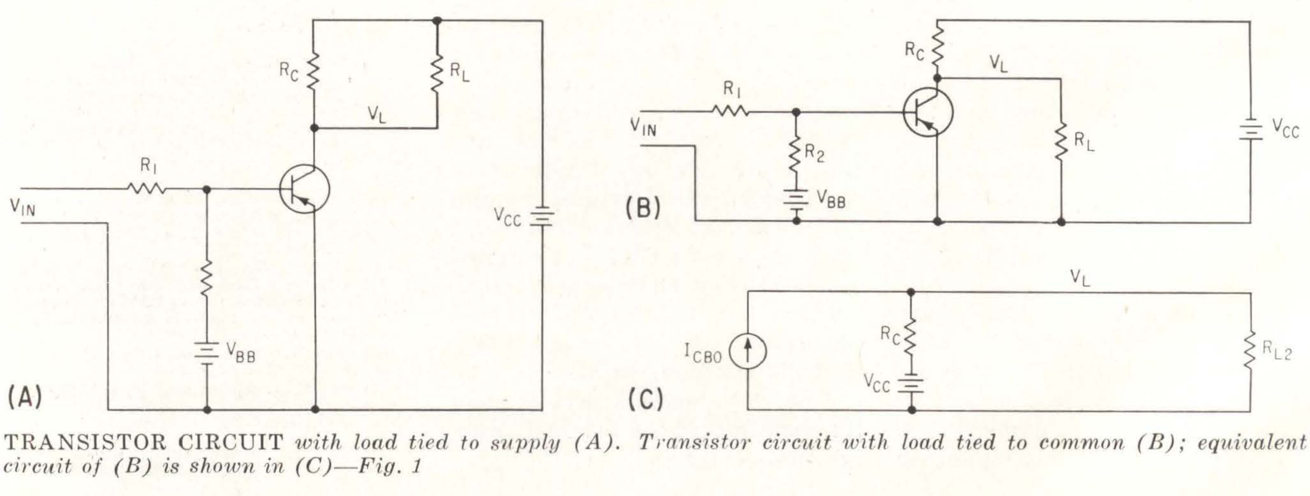
This circuit-design method uses fewer safety factors but shows the deviations in performance due to parameter variations graphically. This design method shows there are different combinations of nominal parameter values that will allow the circuits to operate at an optimum. By plotting the circuit cut-off and saturation equations, choices can be based on the graphs, allowing reliable circuits to be designed to meet tighter specifications.

In a single digital system, it is normal to expect the system requirements of each circuit to remain constant. Therefore, the design procedures for each of the logic circuits can be combined, thus minimizing design time as well as the number of different component values for all circuits. It is found often that use of one type of transistor enables one set of design calculations to govern the choice of parameters for several circuits, thus saving time, effort and money.

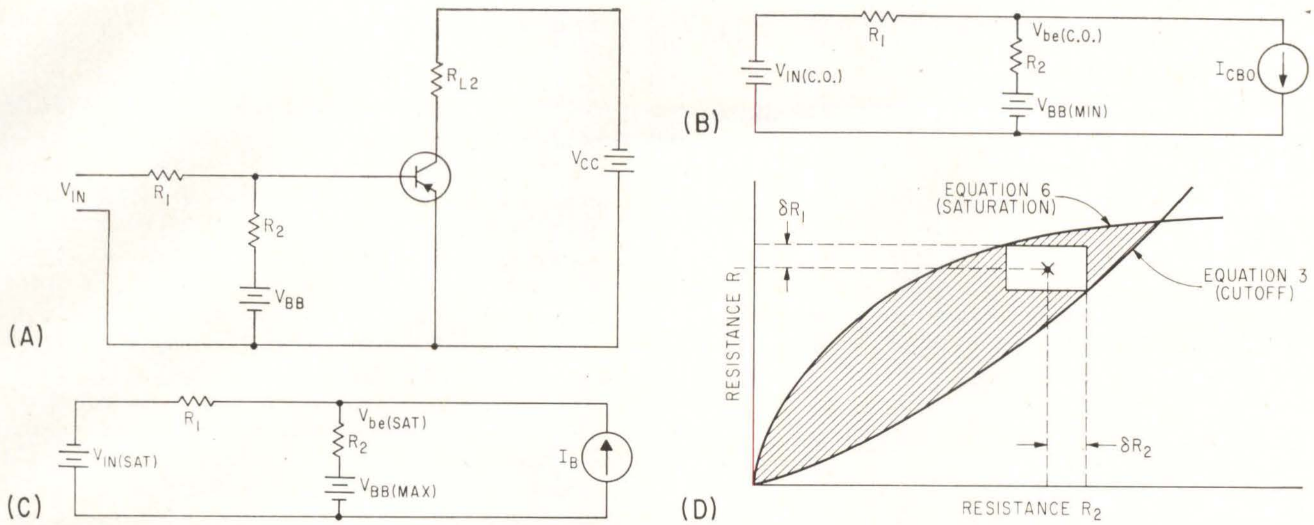
DESIGN STEPS—The first step is to determine the input and output conditions. Normally, the input conditions will have been determined by either previous designs or system logic rules.

The most important factor in determining output conditions is the type of loading. Only d-c loading will be considered. This type of loading may be either a resistor connected to a supply voltage or to a common potential. Each type of loading requires different treatment. A *pnp* common emitter (c.e.) configuration is assumed. Although the derivations involve different-polarity transistor parameters, the equations also hold true for *npn* types.

Where a load is connected to a supply voltage (R_L, Fig. 1A), the internal load of the circuit, that is, the collector resistor (R_C) in the c. e. configuration should be as large as possible to ease collector current requirements. The maximum value of R_C is then determined by the maximum rise or fall times. The minimum load expected, therefore, determines the maximum value of R_C. If 10 RC is kept smaller than t_r, the allowable rise or fall time, the degradation of



TRANSISTOR CIRCUIT *with load tied to supply (A). Transistor circuit with load tied to common (B); equivalent circuit of (B) is shown in (C)—Fig. 1*



INVERTER AMPLIFIER *(A) and its equivalent circuit for cutoff condition (B) and its equivalent circuit for saturated condition (C). Graph (D) plots saturation and cutoff values of* R_1 *and* R_2*—Fig. 2*

the waveshape because of these components will be negligible

$$R = \frac{R_C R_{L1}}{(R_C + R_{L1})}$$

where R_c is the collector resistor, R_{L1} represents the maximum value of external load resistor R_L and C is the sum of the wiring and stray capacitance and any bypass capacitors; thus

$$RC \leqq t_r/10 \qquad (1)$$

Where the load is connected to a common potential, as in Fig. 1B, R_C must be selected so that the voltage appearing at the load meets system specifications. From the equivalent circuit shown in Fig. 1C

$$R_C \leqq R_{L2} \frac{|V_{CC(\min)}| - |V_L|}{|V_L| + I_{CBO}R_{L2}} \qquad (2)$$

where $|V_{CC(\min)}|$ is the minimum value of collector supply voltage, $|V_L|$ is the minimum allowable voltage at the load, R_{L2} represents the minimum value of the load resistance, I_{CBO} is the maximum leakage current of the output transistor, and absolute values of voltages are used to prevent confusion in writing about maximum and minimum values of negative voltages.

If R_C, as determined above, can be large (that is, if the collector current is small compared to the transistor ratings), then the value for R_C may be selected from the collector current versus current amplification factor curves for the transistor. Resistor R_C should be selected so that the variations in I_C due to supply fluctuations and resistor variations have a minimum effect on beta.

To insure operation at high temperatures, the maximum power dissipated at the junction must fall within the manufacturer's specifications. Also in the computations, I_{CBO} at the maximum operating temperature is used. To insure operation at low temperatures, a minimum beta is used in all equations.

INVERTER OR BUFFER AMPLIFIER—Having determined the maximum load on the amplifier, the supply voltages and fluctuations and the type of transistor to be used, the circuit in Fig. 2A will now be designed. In Fig. 2A, R_{L2} represents the maximum total load on the transistor when saturated and thus would include the parallel resistance of a R_C and R_L combination such as that shown in Fig. 1A. If needed, speed-up or delay capacitors may be added in parallel with R_1 or R_2.

The equivalent circuit for cut-off is shown in Fig. 2B. Here

$$R_1 = R_2 \frac{V_{be(c.o.)} + V_{\text{in}(c.o.)}}{V_{BB(\min)} - V_{be(c.o.)} - I_{CBO}R_2} \qquad (3)$$

where $V_{be(c.o.)}$ is taken to be positive.

After a design has been made, a calculation of $V_{be(c.o.)}$ will provide a check on design accuracy. Rearranging Eq. 3

$$V_{be(c.o.)} = V_{BB(\min)} \frac{R_1}{R_1 + R_2} - V_{\text{in}(c.o.)} \frac{R_2}{R_1 + R_2} - I_{CBO} \frac{R_1 R_2}{R_1 + R_2} \qquad (4)$$

To insure the stage being cut-off, $V_{be(c.o.)}$ must be greater than zero volts when I_{CBO} is maximum, R_2 is maximum, V_{BB} is on the low side, R_1 is minimum, and $V_{\text{in}(c.o.)}$ is in the most critical condition for the cut-off state, that is, when $V_{\text{in}(c.o.)}$ is on the high side of its tolerance. The use of $I_{CBO(\max)}$ insures the stage being cut off. As I_{CBO} decreases, $V_{be(c.o.)}$ will become more positive.

The equivalent circuit for the saturated state is shown in Fig. 2C.

To insure saturation, I_B is selected slightly greater than necessary. Hence

$$I_B > V_{CC(\max)}/\beta_{\min}R_{L2} \qquad (5)$$

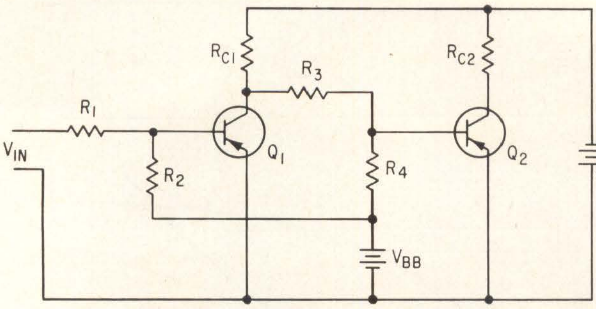
From Fig. 2C

$$R_1 = R_2 \frac{V_{\text{in(sat)}} - V_{be(\text{sat})}}{V_{BB(\max)} + V_{be(\text{sat})} + I_B R_2} \qquad (6)$$

where $V_{be(\text{sat})}$ is taken to be negative and $|V_{\text{in(sat)}}|$ is the minimum value for the ON condition.

Knowing the load current, the maximum value of $V_{be(\text{sat})}$ may be found from the manufacturer's specification sheet.

The curves of Eq. 3 and 6 are plotted on Fig. 2D. Any combination of nominal values of R_1 and R_2 are



NONINVERTING *transistor amplifier—Fig. 3*

permissible which allow the maximum variations of these parameters to remain within the cross-hatched area.

It is best, because of power supply and triggering requirements, to choose a value of R_2 as large as possible.

The maximum value of R_2 that enables the allowable resistor variations to remain in the cross-hatched area may be determined analytically. If the allowable deviations (δ) of R_1 and R_2 are the same, for the cutoff condition

$$R_{1(\min)} = R_2 \frac{(1+\delta)}{(1-\delta)} \frac{V_{be(c\cdot o\cdot)} + V_{in(c\cdot o\cdot)}}{V_{BB(\min)} - V_{be(c\cdot o\cdot)} - I_{CBO}R_2(1+\delta)} \qquad (7)$$

and for the saturated state condition

$$R_{1(\max)} = R_2 \frac{(1-\delta)}{(1+\delta)} \frac{V_{in(sat)} - V_{be(sat)}}{V_{BB(\max)} + V_{be(sat)} + I_B R_2(1-\delta)} \qquad (8)$$

Here δ represents the maximum fractional variation in R_1 and R_2. Since Eq. 8 must be greater than Eq. 7, combining the two equations

$$\left(\frac{1-\delta}{1+\delta}\right)^2 \frac{V_{in(sat)} - V_{be(sat)}}{V_{BB(\max)} + V_{be(sat)} + I_B R_2(1-\delta)} \geqq \frac{V_{be(c\cdot o\cdot)} - V_{in(c\cdot o\cdot)}}{V_{BB(\min)} - V_{be(c\cdot o\cdot)} - I_{CBO}R_2(1+\delta)} \qquad (9)$$

Since $V_{be(c.o.)}$ must be only slightly greater than zero, setting this equal to zero has no effect on the stability of the design, providing the parametric variations remain in the cross-hatched area.

After algebraic manipulations

$$R_{2\max} = \frac{\left(\frac{1-\delta}{1+\delta}\right)^2 (V_{in(s)} - V_{be(s)}) V_{BB\min} - (V_{BB\max} + V_{be(s)}) V_{in(c\cdot o\cdot)}}{[1-\delta]\left[V_{in(c\cdot o\cdot)} I_B + \frac{1-\delta}{1+\delta}(V_{in(s)} - V_{be(s)}) I_{CBO}\right]} \qquad (10)$$

Also from power considerations

$$R_{2(\min)} = (V_{BB(\max)} + V_{be(sat)})/I_{BB} \qquad (11)$$

where I_{BB} is the total allowable current drain per stage from the bias supply. Thus

$$R_{2(\min)} \leqq R_2 \leqq R_{2(\max)} \qquad (12)$$

If R_2 is chosen from Eq. 12, then R_1 may be calculated from

$$R_{1(\min)} \leqq R_1 \leqq R_{1(\max)} \qquad (13)$$

where $R_{1(\min)}$ is given by Eq. 7 and $R_{1(\max)}$ is given by Eq. 8.

Thus, the need to plot Eq. 3 and 6 occurs only in critical design specifications. Then, the graphical solution enables the designer to see the effects of parameter variations and, if necessary, to make the best compromises.

NONINVERTING AMPLIFIER—A noninverting amplifier (Fig. 3) can be designed using the same methods and often the same value components as the buffer amplifier. If the same transistors and power supplies are used throughout, the difference in this design and that of the buffer amplifier lies in the selection of R_{C1}, R_3 and R_4. As in the inverter, speed up or delay capacitors may be added according to the designer's needs. Resistor R_{C2} is dependent upon the type of load (the load resistance of Q_2 is not shown) and may be calculated from either equations 1 or 2. The saturation base current may be calculated from Eq. 5; if the load resistance is connected to the supply, as in Fig. 1A, R_{L2} is the parallel resistance of R_{C2} and the load resistance. Normally, the output requirements of this circuit will be identical to that of the inverter. Hence, R_{C2} will be the same as the R_C of the inverter and the base currents will be identical.

To find R_3 and R_4, proceed as in the design method to find R_1 and R_2 of the buffer amplifier. The input to stage Q_2 is the V_{ce} of Q_1. Providing system rules be followed for internal connections, $V_{ce(c.o.)}$ will represent the same level as $V_{in(sat)}$ of the buffer amplifier. Thus, the saturation equation for the second stage is identical with Eq. 6 of the inverter amplifier, with $V_{in(sat)}$ replaced by $V_{ce(c.o.)}$ of Q_1, R_1 with R_3 and R_2 with R_4. The magnitude of the $V_{ce(c.o.)}$ of Q_1 determines the value of R_{C1}.

The cut-off conditions for these parameters are defined by Eq. 3 with $V_{ce(sat)}$ of Q_1 replacing $V_{in(c.o.)}$, R_3 replacing R_1 and R_4 replacing R_2.

BISTABLE MULTIVIBRATOR—The design of this circuit (Fig. 4A) is similar to the inverter amplifier. Resistor R_C is determined by the use of either Eq. 1 or Eq. 2 as in the inverter amplifier. Figure 4B shows the equivalent circuit of the cut-off stage.

Usually $V_{ce(sat)}$ is known from the manufacturer's specifications. Choosing a value for $V_{ce(sat)}$ that is slightly more negative than the specifications will insure the cut-off condition. If $V_{ce(sat)}$ is known or assumed, then Fig. 4B becomes identical to Fig. 2B, with $V_{ce(sat)}$ replacing $V_{in(c.o.)}$. Thus,

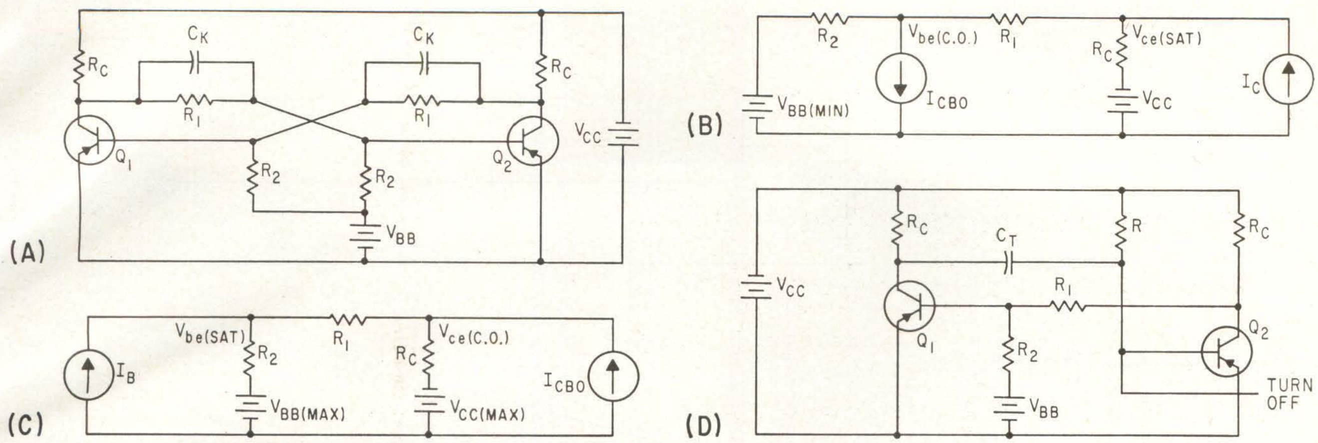
$$R_1 = R_2 \frac{V_{ce(sat)} + V_{be(c\cdot o\cdot)}}{V_{BB(\min)} - V_{be(c\cdot o\cdot)} - I_{CBO}R_2} \qquad (14)$$

The equivalent circuit for the saturated case shown in Fig. 4C. To insure saturation, the base current

---

SYSTEM SPECIFICATIONS

Operating Temperature: -20 to $+60$ C
Transistor: 2N404 (*pnp*)
V_{CC} -12 ± 0.50 volts
V_{BB} $+12 \pm 0.50$ volts
Negative logic used; rise and fall times to be 2.0 μsec
Max False input: 2.0 volts
Minimum True input: 8.0 volts
Resistors: to have 5% tolerance



BISTABLE MULTIVIBRATOR *(A) and its equivalent circuits for (B) the cutoff and (C) the saturated conditions. A monostable multivibrator is shown in (D)—Fig. 4*

is selected by Eq. 5. Then

$$R_1 = R_2 \frac{V_{ce(c\text{-}o\text{-})} - V_{be(sat)}}{V_{BB(max)} + V_{be(sat)} + I_B R_2} \qquad (15)$$

where

$$V_{ce(c\text{-}o\text{-})} = \left(\frac{V_{be(sat)}}{R_1} + \frac{V_{CC(max)}}{R_C} - I_{CBO}\right)\frac{R_1 R_C}{R_1 + R_C} \qquad (16)$$

and where $V_{be(sat)}$ and $V_{ce(c.o.)}$ are negative.

Notice that the equations for the multivibrator can be interchanged with those of the inverting amplifier, with V_{ce} replacing V_{in}. Therefore, once V_{ce} is calculated, the design procedures are identical.

The C_K capacitors speed switching and are usually determined by the allowable fall or rise time of the multivibrator output waveshape. The larger the capacitor, the easier it becomes to switch the circuit. However

$$R_C C_K < T_R/10 \qquad (17)$$

to prevent distortion of the waveshape.

MONOSTABLE MULTIVIBRATOR—The method of determining R_c, R_1 and R_2 in Fig. 4D is identical to that of the bistable multivibrator. The value of R is determined by the collector current of Q_2 which in turn is determined by R_C and the load resistance, which is not shown in the drawing. Thus

$$R \leqq \beta_{(min)} \frac{(V_{CC(min)} - V_{be(sat)})}{I_{C(max)}} \qquad (18)$$

Then C_T is determined by the desired timing of the multivibrator and the selected value of R. Thus

$$C_T \approx T_d/0.693R \qquad (19)$$

where T_d is the pulse width of the multivibrator.

DESIGN EXAMPLE—Design a noninverting amplifier that can drive six OR gates and produce a complementary output capable of the same power. The Table lists system specifications. Figure 5A shows the OR gate configuration that is driven by the amplifier (Fig. 5B). In Fig. 5B, R_L represents the OR-gate load of a transistor.

The maximum collecter dissipation at an ambient temperature of 55 C is 35 mw. Assuming a 2.5 mw per degree derating curve

$$P_{C(60C)} = 35 - 5 \times 2.5 = 22.5 \text{ mw}$$

The maximum current required by any OR gate is

$$I_g = 26.4/5.04 \times 10^{-3} = 5.25 \text{ ma}$$

Therefore, the maximum total load which Q_2 must supply is

$$5.25 \times 6 + 12.5/R_C = I_{C2}$$

Assuming the wiring capacitance to be about 100 $\mu\mu$f, then from Eq. 1,

$$R_{C2} \leqq 2.0 \times 10^{-6}/10 \times 100 \times 10^{-12} = 2{,}000 \text{ ohms}$$

Allowing for a 10-percent deviation from a 5-percent tolerance resistor, choose R_{C2} = 1,800 ohms. Then

$$I_{C2} = 31.5 + 12.5/1.62 = 39.2 \text{ ma}$$

From the manufacturer's specifications, at a collector current of 50 ma, $V_{ce(sat)}$ is at most 0.35 volt. Therefore, the maximum dissipation across the junction is 0.35 × 40 = 14 mw, which falls within the allowable limits.

To insure saturation

$$I_B \geqq V_{CC(max)}/\beta_{min} R_{L(min)} = I_{C(max)}/\beta_{min}$$

Choosing a minimum β of 20 (5 units below the manufacturer's guaranteed saturation beta of 25) then

$$I_B \geqq 40/20 = 2 \text{ ma}$$

From the transistor specifications $V_{be(sat)}$ is at most −0.5 volts with I_c = 48 ma and I_B = 2.9 ma. Then for saturation, Eq. 6 becomes

$$R_3 = R_4(V_{in(sat)} - 0.5)/13 + 2R_4$$

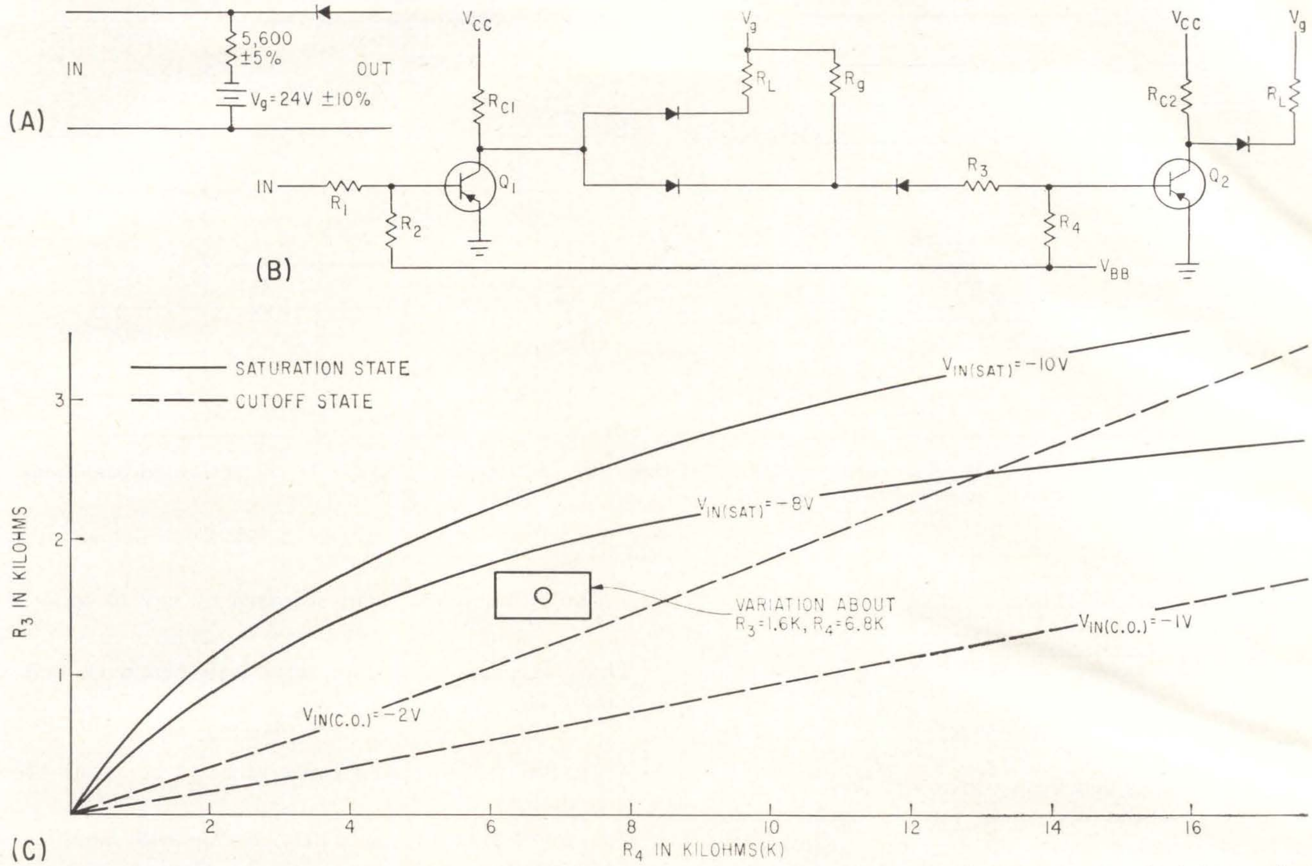
For cutoff, I_{CBO} must be calculated. The manufacturer specifies a maximum I_{CBO} = 90 microamps at a 80-C junction temperature. At 25 C, I_{CBO} is 5 microamp maximum. Assuming a straight line increase in leakage current, 20-milliwatt collector dissipation and 0.35 C/mw junction temperature rise, $I_{CBO(max)}$ at 60 C ambient is 70 microamp.

From Eq. 3, with the resistances in kilohms and $V_{be(c.o.)} \approx 0$

$$R_3 = R_4[V_{in(c\text{-}o\text{-})}/(11.5 - 0.07R_4)]$$

Figure 5 C shows a family of curves for R_3 and R_4. Different values of input voltage conditions are used to obtain the curves. However, any or all of the parameters could be varied to obtain several graphs, thereby gaining insight about circuit operation.

If $V_{in(sat)}$ = 8.0 volts and $V_{in(c.o.)}$ 2.0 volts, as the



EXAMPLE *uses basic* OR *gate shown in (A) in the noninverting amplifier (B). Graph (C) provides insight on final choice of resistance values—Fig. 5*

system specifications require, and $\delta = 0.10$, then from Eq. 10

$$R_{4(max)} = \frac{(0.67)(7.5)(11.5) - (13)(2)}{[0.9][(2)(2) + (0.82)(7.5)(0.07)]} = 7.95 \text{ kilohms}$$

Choosing nominal values, let R_4 be 6.8 kilohms. Then R_3 is calculated from Eq. 7 and 8 according to Eq. 13. Thus

$$R_3 \geqq \frac{(2.0)(1.22)(6.8)}{11.5 - (0.07)(1.1)(6.8)} \geqq 1.52 \text{ kilohms}$$

$$R_3 \leqq \frac{(0.82)(6.8)8.0 - 0.5}{12.5 + 0.5 + (2.0)(6.8)(0.9)} \leqq 1.66 \text{ kilohms}$$

Therefore, let $R_3 = 1.6$ kilohms.

This choice, as shown in Fig. 5C, allows a 10-percent variation of parameters to have no noticeable effect on circuit operation. Note that as the input and output conditions become more critical, the area of permissible design values becomes smaller.

The first stage has loads connected to the common as well as to a supply. Thus, the stage must supply the base current of the second stage through R_3 to essentially a ground potential.

Therefore, from Eq. 2

$$R_{C1} \leqq 1.44 \frac{11.5 - 8.0}{8.0 + .07 \times 1.44} \leqq 0.622 \text{ kilohms}$$

where 1.44 (kilohms) is the minimum resistance of R_3 (Fig. 5B), where R_3 corresponds to R_{L2} of Fig. 1C. Then let $R_{C1} = 560$ ohms.

Also, Q_1 must supply a total load current

$$I_C = 31.5 + 12.5/R_{C1} = 56.3 \text{ ma}$$

where the 31.5 ma go through the OR gate load designated by the R_L-R_g combination in Fig. 5B (R_g denotes one OR gate and R_L denotes 5 OR gates. To supply this current with a minimum β of 20, $I_B \geqq 2.82$ ma. Therefore, let $I_B = 3.0$ ma.

At $I_C = 60$ ma and $I_B = 3.0$ ma, $V_{ce(sat)} = 0.35$ volts maximum. Thus, junction power dissipation will be

$$P_C = 56.3 \times 0.35 = 19.7 \text{ milliwatts}$$

This could be near the power capacity of the transistor. If a greater safety margin is wanted, a redesign of the second stage using a lower value for $V_{in(sat)}$ would ease the current requirements of Q_1. (This raises the allowable maximum value of R_C in the first stage.) The design of R_1 and R_2 can be carried out by utilizing Eq. 10 and 13. The results are such that $R_2 \leqq 5.5$ kilohms. By choosing $R_2 = 5.1$ kilohms, 1.15 kilohms $\leqq R_1 \leqq 3.14$ kilohms. The choice of R_1 would probably be made dependent on availability and/or quantity of other resistor design values in the same range.

Any circuit using d-c parameters for cut-off and saturation biasing may be designed in this manner. By allowing for realistic variations, circuits designed by this method will operate in all specified environments. Sometimes it is impossible to incorporate every safety factor. Here, engineering judgment must be used to determine which condition must be improved or held to tighter specifications.

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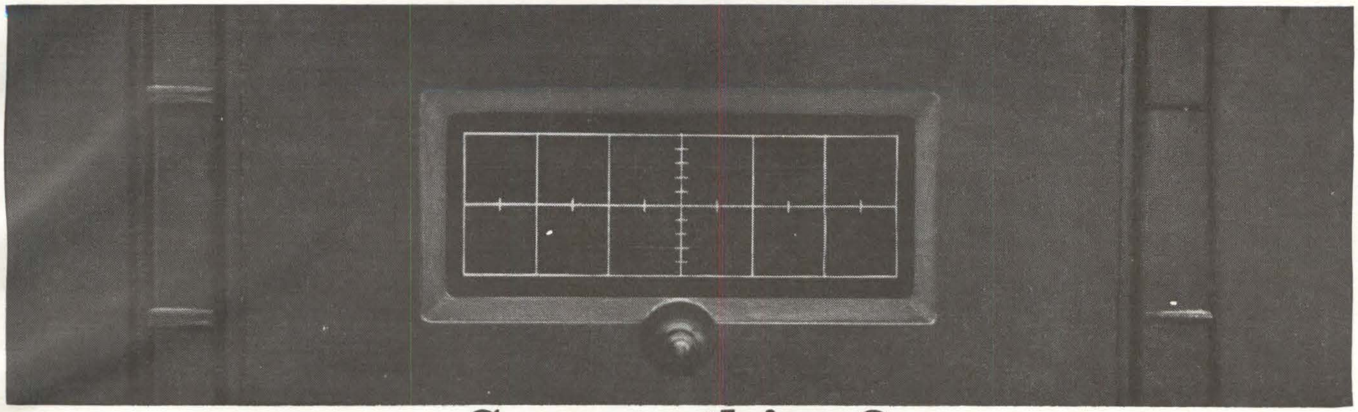

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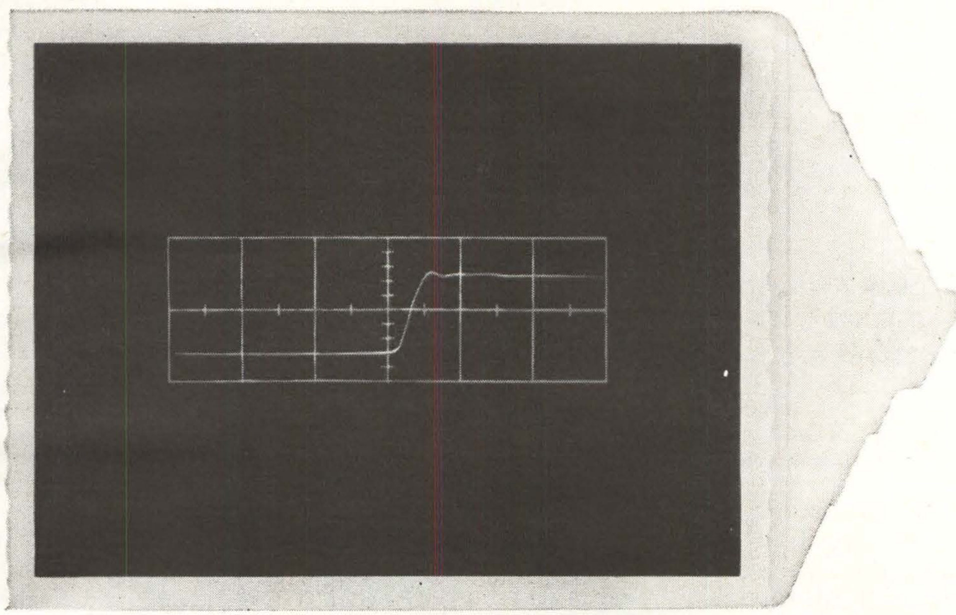

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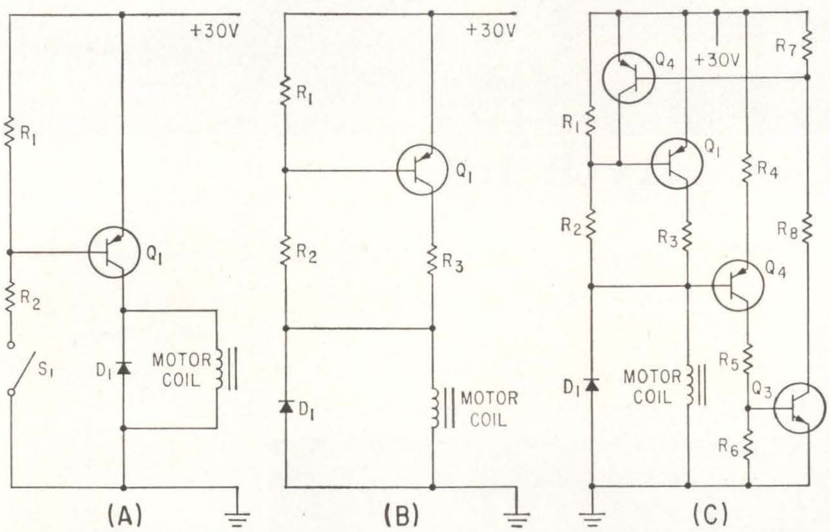
Transistor Circuits Control Small D-C Motors



TRANSISTOR *circuits for on-off control (A), load compensation (B) and protection from motor overload (C)—Fig. 1*

On-off, load compensation, overload protection and speed control are provided

By FRED W. KEAR
Lytle Corp., Albuquerque, N. M.

TRANSISTOR circuits offer an accurate and dependable means for controlling small d-c motors. Their use enables a relatively small signal to apply, remove or otherwise regulate electrical power to the motor.

D-c motors have become widely accepted in military systems and industrial control applications. In many applications, such as timing, control, programming and data recording, the control of power to the motor determines the accuracy and efficiency of the system.

A typical requirement of a d-c motor control circuit is simply the application and removal of power to start and stop the motor. The circuit in Fig. 1A is one of many control circuits that could be used for this function. Transistor Q_1 is in series with the motor coil and controls power to it. Damage to the transistor is prevented by D_1, which removes inverse voltage spikes. When S_1 is closed, the base-bias network consisting of R_1 and R_2 applies forward bias to Q_1, applying power to the motor. When S_1 is opened, R_1 applies reverse bias to Q_1, and power is removed from the motor. This type circuit has remote control applications where motor power may not be switched directly by a switch.

LOAD COMPENSATION—When motor current must be varied to compensate motor loading, the circuit in Fig. 1B may be used. Reverse bias applied to Q_1 is series with the motor coil removes motor power. The low resistance of R_3 develops emitter bias at high values of motor coil current. Diode D_1 protects the transistor by removing inverse voltage spikes from the circuit. Relatively high values of resistance are chosen for R_1 and R_2 to maintain forward bias on the transistor. When mechanical loading of the motor causes more current to flow through it, the added current through R_1 and R_2 increases forward bias on the base of Q_1 Thus the transistor provides more current through the motor to compensate the overload.

In applications where equipment must be protected from damage caused by overloading of d-c motors, a circuit like that in Fig. 1C can be used. Transistor Q_1 is in series with the motor coil so that reverse biasing of the transistor removes power from the motor coil. Diode D_1 again removes inverse voltage spikes resulting from motor inductance.

The bias necessary to provide motor current under normal load conditions is provided by resistors R_1 and R_3 shown in diagram.

A low value of resistance is chosen for bias resistor R_3 so that

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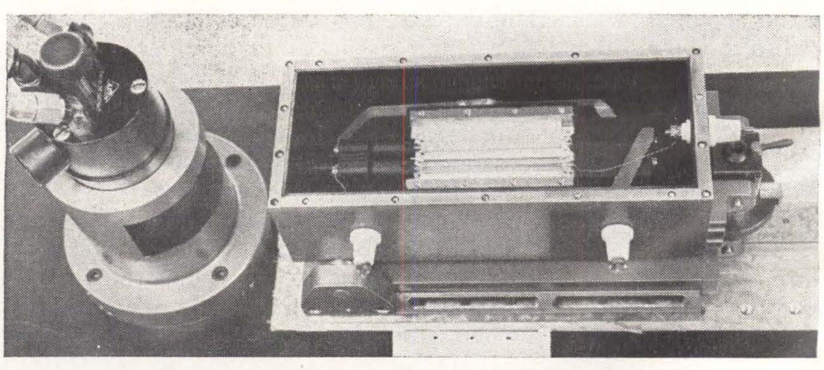

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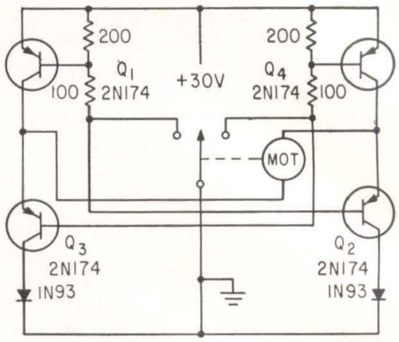
OTHER OFFICES AND REPRESENTATIVES IN PRINCIPAL U.S. AND CANADIAN CITIES appreciable increases in motor coil current produce a useful voltage drop. The base circuit of Q_2 which is connected to the junction of R_3 and the motor coil, is provided with emitter bias from Q_1. This bias is adjusted so that motor current exceeding a nominal value will cause Q_2 to conduct. As a result, current through R_5 and R_6 will increase and forward bias will be applied to Q_3.

Conduction in Q_3 causes drop in voltage at the junction of R_7 and R_8, applying forward bias to Q_4. When transistor Q_4 is switched on, it clamps the base of Q_1 to the positive bus and this reverse bias removes power from the motor. After an overload, the motor must be started again by shorting the positive motor lead to the positive bus, grounding the base of Q_3 or connecting the base of Q_4 to the positive bus. This switching can be accomplished by a time-delay mechanism or directly or remotely by switches.

REGULATING SPEED—Speed of a d-c motor can be controlled through the contacts of a inertial governor using the circuit in Fig. 2.

Closure of the normally open governor contacts provides a surge of reverse current through the motor that rapidly overcomes its



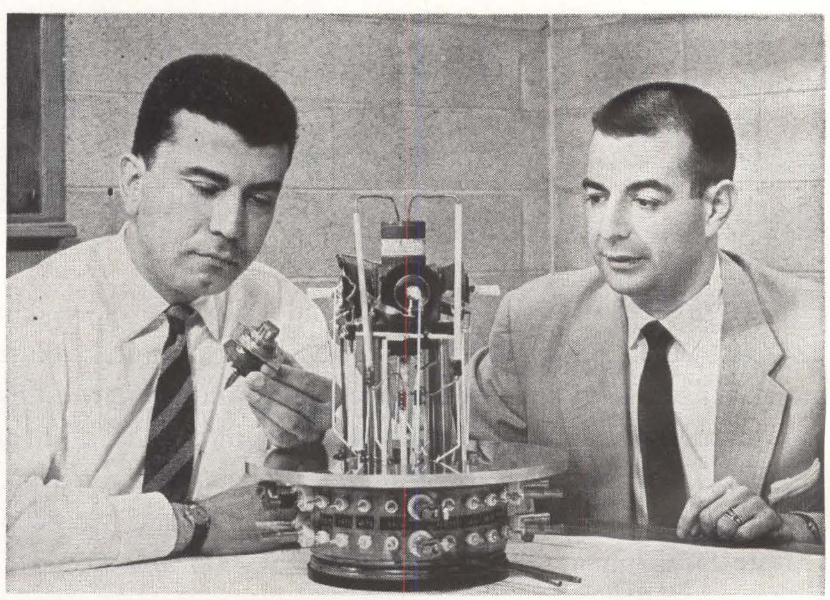
INERTIAL *governor with transistor circuit regulates tendency toward motor overshoot—Fig. 2*

tendency to overshoot. When the arm of the governor closes the circuit to the base of Q_2, transistors Q_1 and Q_2 conduct. Thus a current path is provided from ground through Q_2, the motor coil and Q_1 to the 30-volt bus. When the governor arm closes the circuit to the base of Q_3, transistors Q_3 and Q_4 conduct and provide current to the motor.

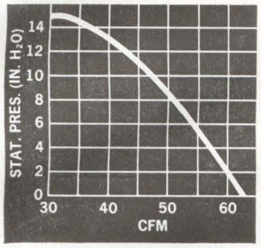
The current path is from ground through Q_3 the motor coil and Q_4 to the positive bus. Thus the motor can be made to rotate normally in either direction using this circuit by alter the normally closed governor contacts.

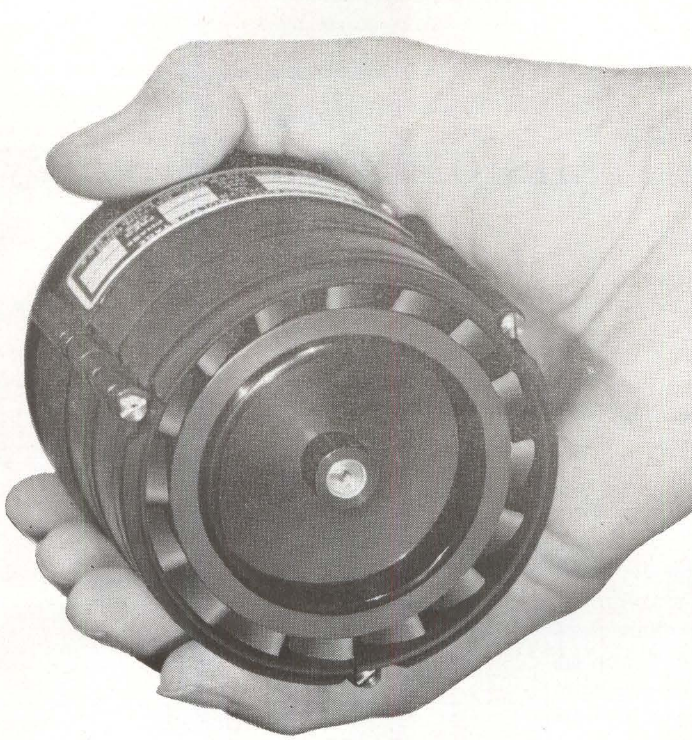
These circuits are representative of many techniques for using transistors to control d-c motors.

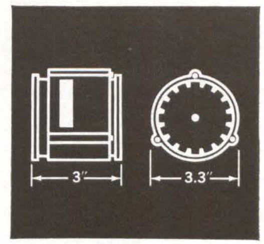
Solar Generator for Satellites



CESIUM *diodes in series deliver 100 watts in Thermo Electron Engineering solar thermionic generator. Satellite power source was developed under USAF Aeronautical Systems Division sponsorship for Thomson Ramo Wooldridge*







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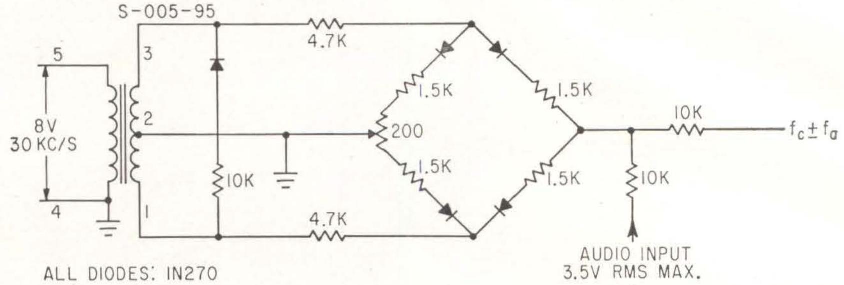
NEW MATERIALS combined with more sophisticated core windings are responsible for the development of ultrasonic frequency transformers that have desirable characteristics useful in digital and analog applications. These units are now receiving attention by circuit designers for applications in balanced modulators, phase inverters and in power output stages.

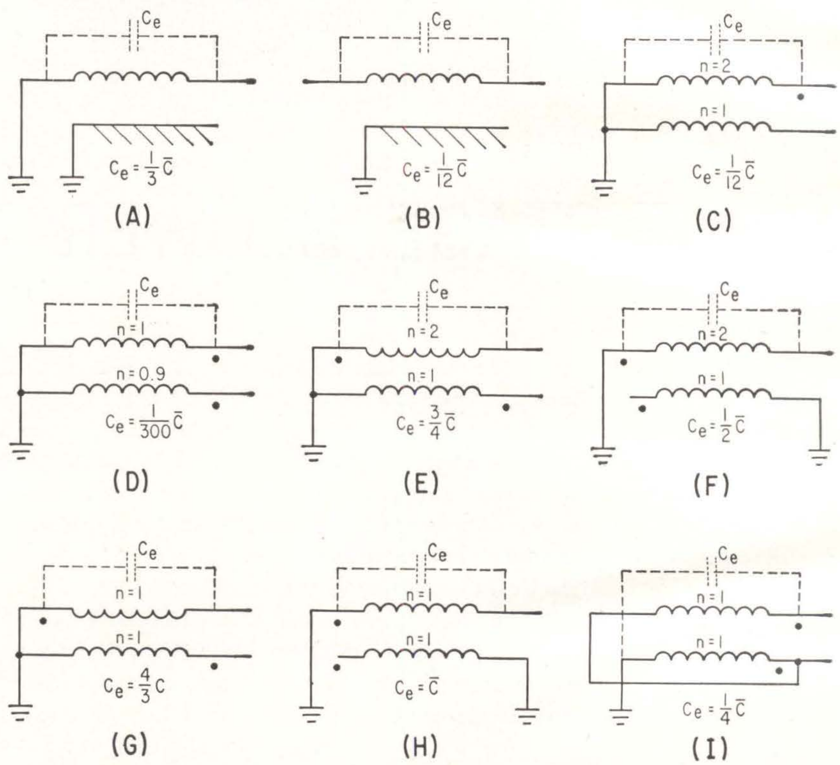
Originally designed to accommodate magnetostrictive rod resonators (see ELECTRONICS, July 13, 1962, p 62), wideband ultrasonic-frequency signal transformers operate from a few kilocycles to a few megacycles per second.

Prior to 1961, ultrasonic transformers were limited to power-coupling types for industrial cleaning and mixing equipment, and handled up to two kilowatts with frequency response typically 10 Kc to 100 Kc. Transformers now developed are signal types having low power, but with frequency response extended both in terms of octaves and absolute cycles per second. Flat response falls off at 3 db at 3 Kc and 22 Mc without compensation, when the new units are properly wound and terminated.

Improved phase characteristics go along with improved response, and amplifiers and other circuits equal to their lower frequency audio counterparts can be constructed. These transformers are now being used in circuits other than those involving magnetostrictive rods because their range of operation is adapted to perform a wide variety of circuit functions.



BOYNTON-SCHOLT *modulator gives a 60 db suppression of 30 Kc carrier without adjustment over a wide range of ambient temperature and frequency—Fig. 1*



MONOLAYER WINDING *configurations and the magnitude of equivalent capacitance in terms of physical capacitance—Fig. 2*

CIRCUIT APPLICATIONS—Examples of u-f signal transformers which have been developed for use with magnetostrictive rod devices includes a transformer used in 480-element spectrum analyzer to couple push-pull 6CA7/EL-34 pentodes to a 30-ohm filter bank. If the secondary is terminated into 15 ohms, this transformer delivers more than 100 watts from four 6CA7 or 6550 pentodes. Frequency response is ±2 db between 4 Kc and 1.5 Mc.

A small transformer, was developed for balanced modulator applications which require the highest possible symetry and balance in a centertapped winding. One of many balanced modulator circuits[1] which can be used with this transformer is shown in Fig. 1.

An incidental result of the pursuit for balance in this transformer is an unusually wide frequency response which is remarkable both

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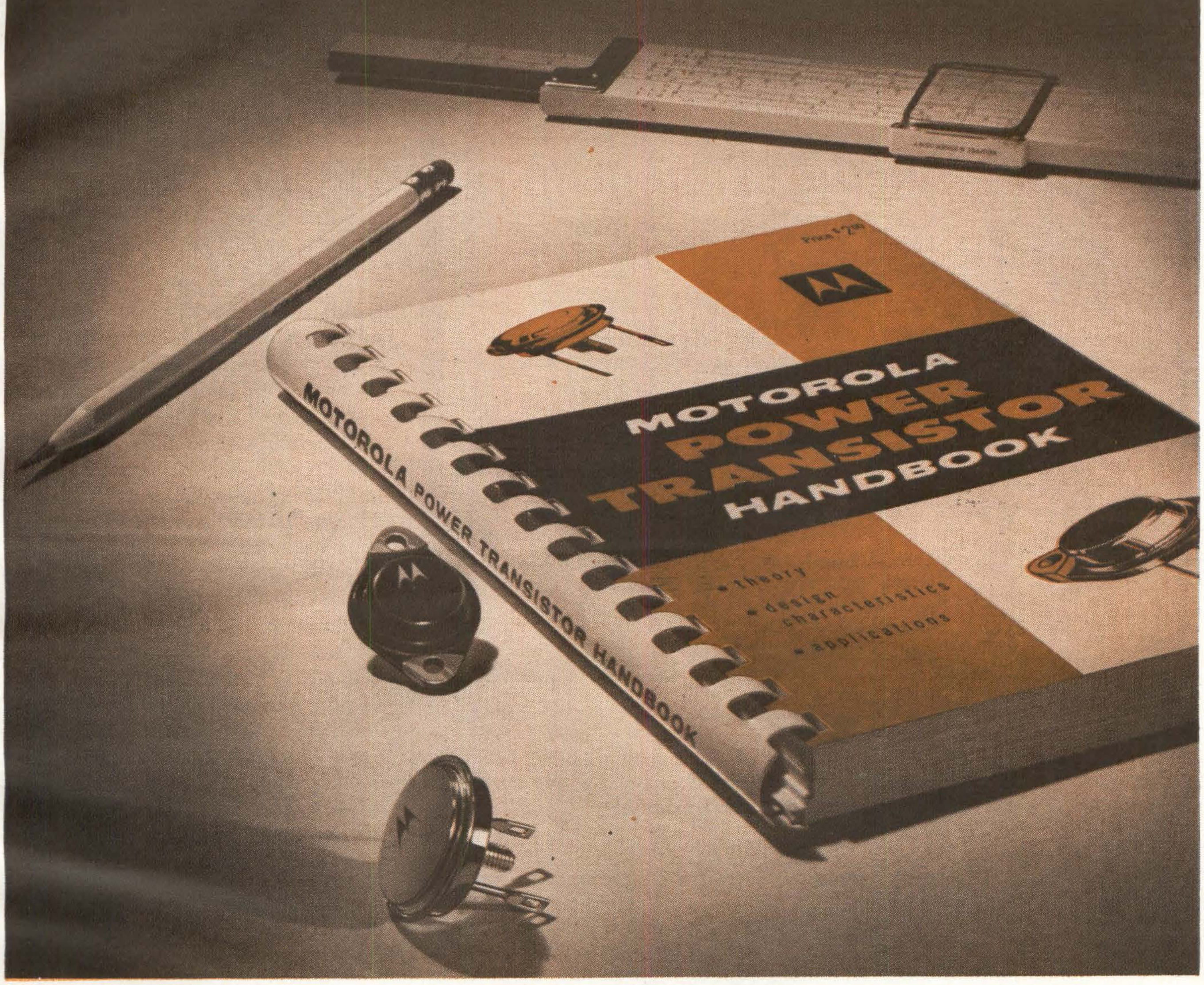

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CIRCLE 53 ON READER SERVICE CARD

in terms of octaves and absolute cycles per second. A flat response falling off 3 db at 3 Kc and 22 Mc is obtained without compensation when primary (terminals 4 and 5) is driven from a 50-ohm source and terminals 1 and 3 are terminated into 200 ohms.

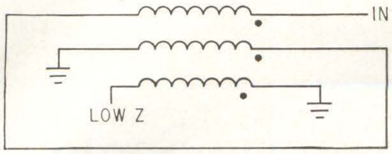
An intermediate sized general purpose transformer[2], also developed, is a modern version of the TF2A35YY tube base blocking oscillator transformer of the 1940's. New materials and winding geometry described in the next section give a two orders of magnitude improvement in coupling and in balance over its 20 year old prototype.

HIGH COUPLING—An objective in design of wide-band transformers is to attain high coupling between windings without the large capacitance that usually comes with closely-spaced coils.

High coupling is obtained by minimizing the flux linking one winding but not another. Berg and Howland,[3] working with r-f transformers describe an interesting method of forcing the flux of one coil to encircle another even though located on an opposite side of the magnetic circuit. They place a conducting shield over the core to prevent the escape of flux. This technique is satisfactory for radio frequencies above one megacycle but effective shields at low frequencies are to thick to be practicable.

Windings can be placed over one another without serious effective capacitance if care is used to arrange windings and their connections so that the signal voltage differences across planes of high capacitance are minimized.

The effective capacitance which appears across a winding has a value such that the signal energy it stores is equal to the signal energy stored by all the capacitance in the transformer. Since the energy stored is proportional to the square of the voltage it is obvious that the bandwidth of a transformer can often be extended more easily by reducing voltage differences than by reducing capacitance. Figure 2 illustrates some monolayer winding configurations and the magnitude of Ce in terms of $\overline{C}$ (the capacitance between the



WINDING CONFIGURATION *capable of large bandwidth with a phase reversal and high impedance transformation—Fig. 3*

joined leads of the coil and the adjacent surface). In Fig. 2, *Ce* is the equivalent capacitance which determines the upper frequency response, and *C* is the physical capacitance. These are not necessarily the same.

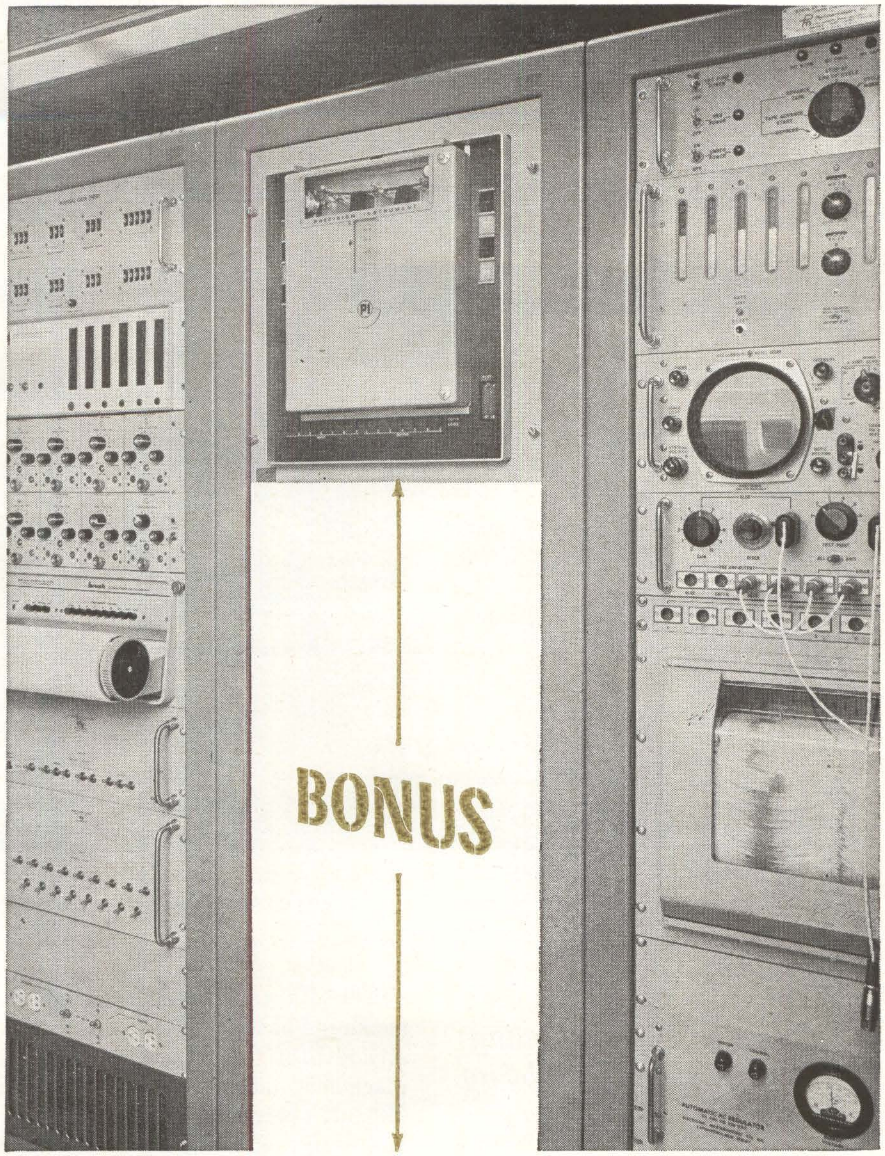
We learn from Figure 2D that the effective capacitance can be made very small when small impedance ratios without phase inversion is all that is required of transformer. Figures 2E through 2H show that capacitance is minimized when all layers are wound in the same direction. This is a happy circumstance for the insulation stresses are minimized at the same time. Figures 2E and 2G represent a "wrong" method for phase inversion.

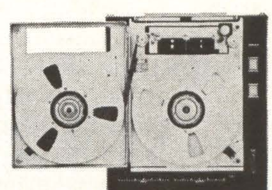
WIDE RESPONSE — Monolayer autotransformers can give very wide frequency response even with substantial impedance ratios. The configuration of 2I has low capacitance together with only one-fourth the leakage inductance of the equivalent isotransformer.[4] A two-stage phase reversing transformer, shown in Fig. 3, performs the inversion at a low impedance to reduce capacitance and uses two auto-former connected layers to change impedance.[5]

Multifilar windings are frequently used in u-f transformers to achieve unity coupling between sections. For examples, the modern version of the TF2A35YY is a double bifilar not to be confused with quadrifilars which have four identical sections.[6]

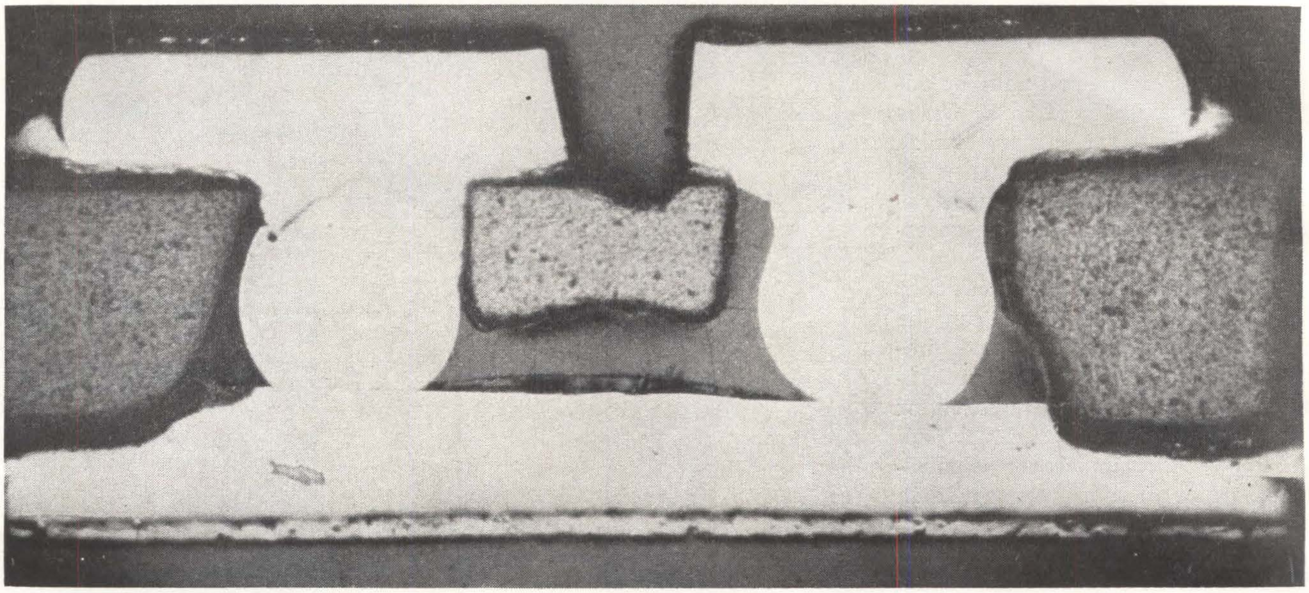
REFERENCES

(1) Richard Boynton, M. B. Co., unpublished communication May 14, 1962
(2) Spectran Electronics Corp., Data Sheet S-005-35
(3) R. S. Berg and B. Howland, *Rev of Sci Instr*, 32, No. 7; July, 1961
(4) T. A. O. Gross, U. S. Patent 2,448,028
(5) T. A. O. Gross, U. S. Patent 2,475,611
(6) Spectran Electronics Corp. Data Sheet S-005-30
(7) Spectran Electronics Corp. Data Sheet S-005-95 (see Fig. 1)





Transistor's Leads Are Its Hermetic Seals



CROSS SECTION *of transistor shows base and emitter plates at top, connecting alloy spheres, silicon die and collector plate. Active element is hermetically sealed, can be used as is or can be assembled into various conventional cases*

Conducting alloy spheres replace fine wires; brazing replaces soldering, welding

By HERBERT S. EVANDER
Hughes Aircraft Co.
Semiconductor Div.,
Newport Beach, Calif.

IN MANUFACTURING diffused planar transistors, as much as 80 percent of the total cost can be in assembling the device into a package. This is mainly because each device must be assembled individually into its own package. In contrast, device processing in the slice area, which establishes electrical parameters, involves processes such as gaseous diffusion and evaporations, where as many as 1,000 devices are formed on a slice of silicon, with up to 100 slices processed at one time. High assembly cost is due to the high labor content in handling and the loss of some units at various assembly operations.

The most costly assembly operation is attaching fine gold wires to the emitter and base regions on the silicon die and to the leads of the package header. Low mechanical strength of the fine wires plus the placement accuracy make this a difficult operation to mechanize. In addition, fast changing device characteristics and packages militate against mechanized assembly.

In the automatically assembled Microseal transistor, however, the design is such that the parts virtually fall together. Instead of fine wires, small alloy spheres are used in a ceramic housing to make connections both to base and emitter areas and to the leads. The sketch indicates the design concept.

Although the machine used for assembly (see cover) is a prototype, it can produce production line volumn. Composed essentially of an indexing turntable and a brazing heater, it requires two operators to hand load the component parts into the alignment jigs; clamping is automatic and the brazing gas heater is timed into the machine and comes on automatically long enough to make the brazed hermetic closure.

There are 12 stations on the lazy susan turntable, all exactly the same and consisting of a nest that receives the component parts and two spring loaded, cam-operated clamps to hold the assembly.

The nest is made of ceramic and is shaped to control the flow of heating gas around the unit. It has slots and pins to align the parts and a stainless steel platform to steady the two long leads of the emitter and base top plates. A stirrup clamp is used to hold the two long leads and a finger clamp to hold the complete assembly.

Each set of clamps can be moved out of the way independently, giving easy access to the alignment nest. The clamps can be seen in various positions in the photograph on the cover.

MACHINE OPERATION — Machine loading is simple and straightforward. At the first loading station, the alignment fixture stops with both clamps up and off to the side. The operator removes the previously completed assembly, then places the emitter and base plates into the nest, then the ceramic body; the holes in the ceramic body fit over cylinderical pins on

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Front panel mount Microfuse holder (with the hexagon nut rear of panel). Rugged aluminum body and knurled cap; both can be anodized in color. Fungus and shock resistant. Sealing "O" rings in cap and on body. "Eye" type terminals specially designed for easy soldering.

282002

Rear panel mount Microfuse holder (with the round nut mounted from front of panel). Rugged aluminum body and knurled cap; both can be anodized in color. Fungus and shock resistant. Sealing "O" rings in cap and on body. "Eye" type terminals specially designed for easy soldering.

281002

Front panel mount Microfuse holder (with the hexagon nut rear of panel). Molded from high strength, high dielectric material. Knurled cap for easy grip, with skirt for positive "O" ring seal. Rugged "Eye" type plated brass terminals separated by molded barrier to provide complete insulation.

284000 Series

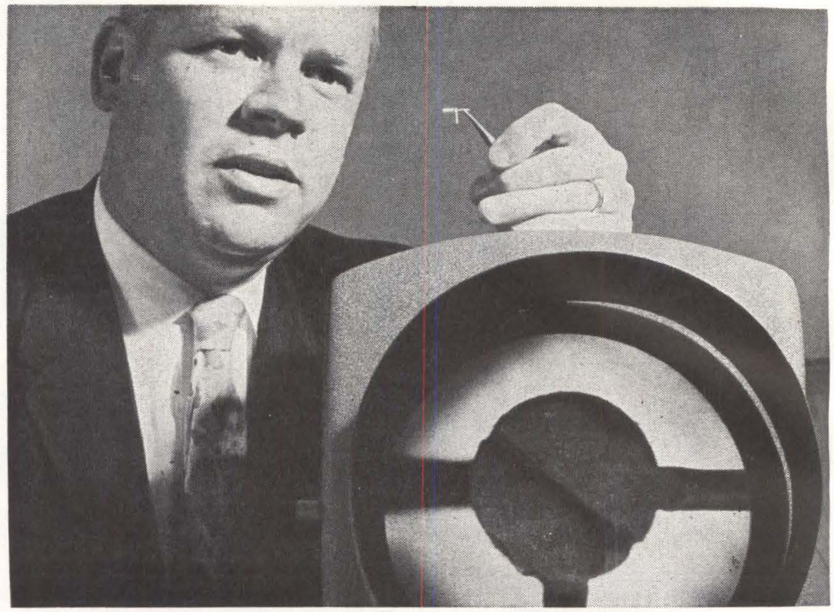
Indicating Microfuse holder—when the fuse blows indicating bulb glows. Knob molded from transparent material with serrations for easy gripping. Skirt of knob for positive "O" ring seal. Body from high strength, high dielectric material. Indicating holders available in wide voltage ranges from 2½ to 125 volts.

PRODUCTS SHOWN ACTUAL SIZE

Microfuses achieve low fuse resistance values with high reliability in ultra-fast blowing characteristics. Microfuses can be hermetically sealed, suitable for potting applications. Glass enclosed visible filament. Microfuses available in 1/500 through 5 amps at 125 V. Short circuit interrupting capacity 125 V—10,000 amps DC.

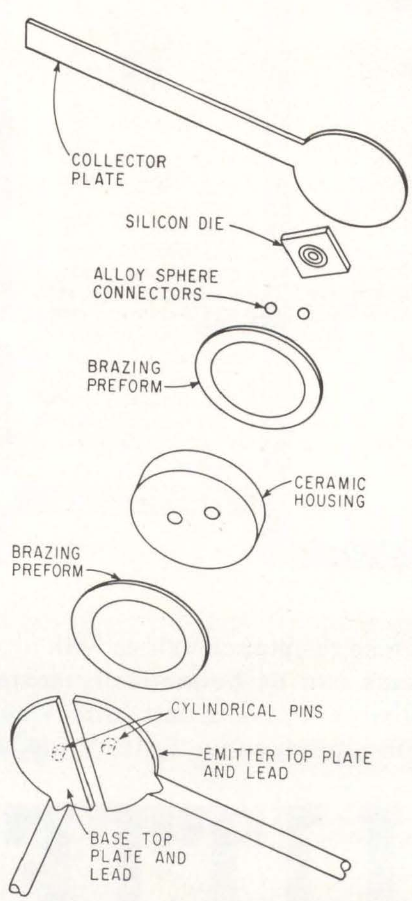
LITTELFUSE

Des Plaines, Illinois



BASE AND EMITTER *plates are visible in comparator scope. Inventory control of transistors is improved because of flexibility in adding cases of various types after basic transistor unit is completed*

the leads. As the turntable indexes to the next loading position, the stirrup clamp swings over and



TRANSISTOR *is assembled by letting parts essentially fall together and then brazing to obtain hermetic sealing*

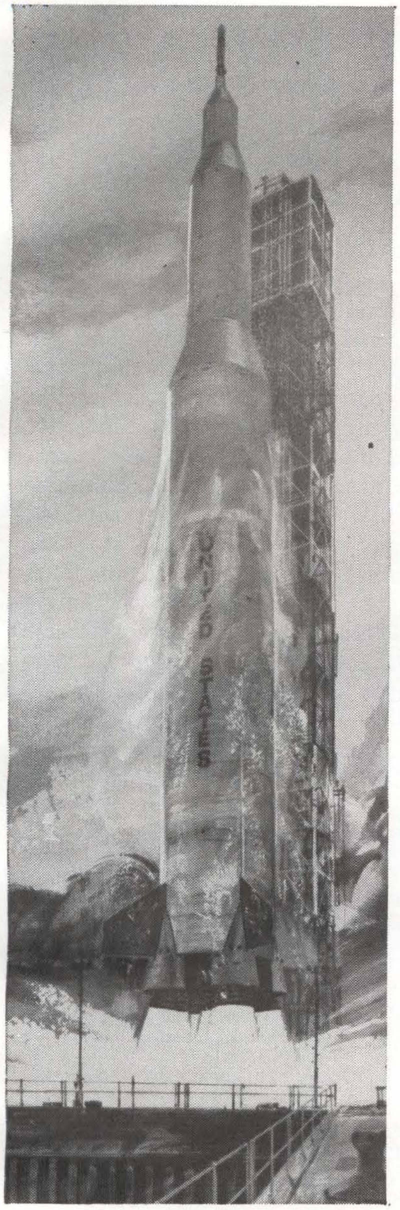
straight down, holding the two long leads firmly in place.

At the second loading position the two alloy spheres and the collector plate with silicon die are added. As the turntable again indexes, the finger clamp swings over and moves down to clamp the sandwiched parts.

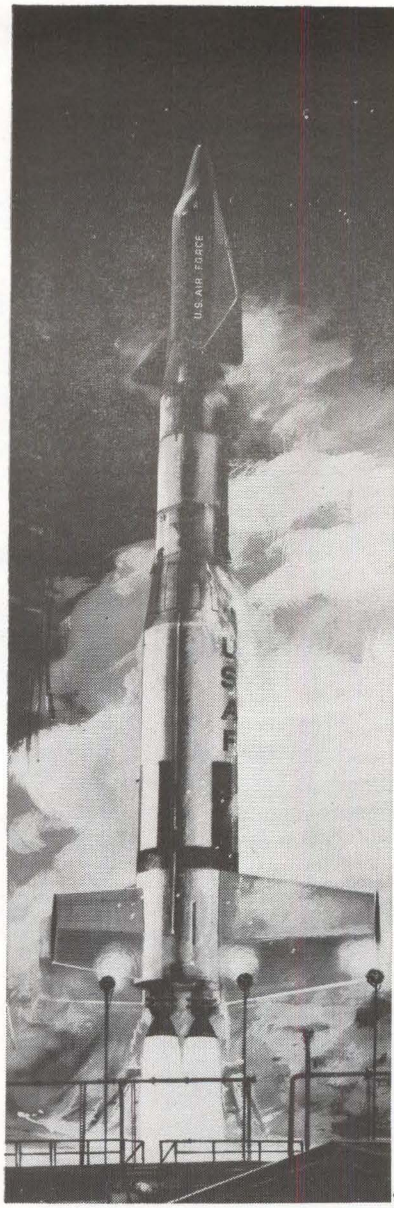
Finally, the assembled transistor stops at the brazing station where gas, heated electrically by an element at the nozzle, and surrounded by a shroud of nitrogen gas to prevent oxidation, complete the seal. The completed transistor is 0.08 inch in diameter and 0.03 inch thick, and has three integral leads.

The cross section photomicrograph shows how the connecting spheres have fused with the silicon die and with the base and emitter leads. The hermetic seal at base and emitter results from the fusion of the cylinders to the ceramic body, producing, in effect, a ceramic-to-metal header assembly. The spheres play no part in producing hermeticity.

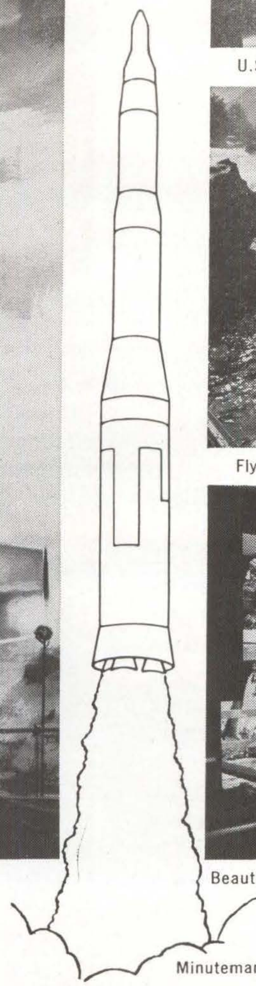
Once the basic hermetically sealed transistor has been fabricated, it can be used as is or it can be assembled into various types of cases to suit customer requirements. As a result of the flexibility in using various case styles, much greater control over excess inventory is possible.



Saturn Launch Vehicle

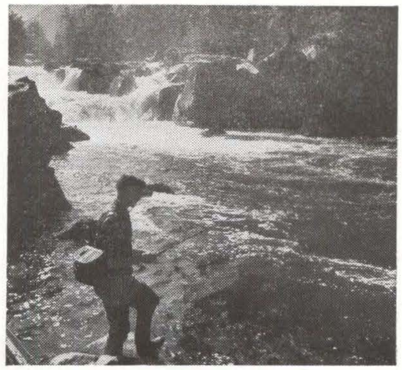


Dyna-Soar Space Glider

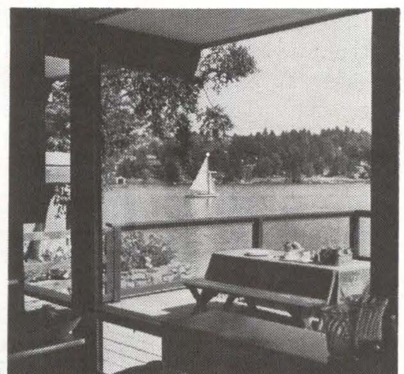


Minuteman ICBM

U.S. Science Pavilion at Seattle World's Fair



Fly-casting on Skykomish River near Seattle



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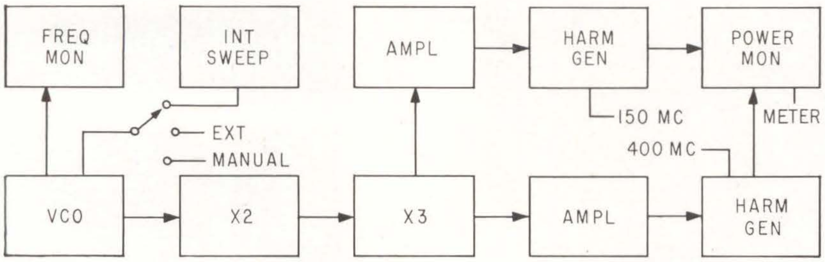
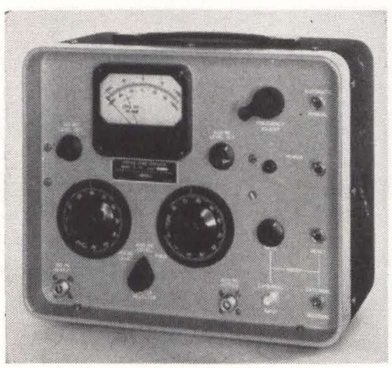
DESIGN AND APPLICATION



Signal Generator Tests Doppler Receivers

Sweep adjustable between 50 cps and 1Kc modulates the r-f carrier

NEW from General Dynamics/Electronics, 1400 N. Goodman St., Rochester 1, N. Y., the model SC-741 transistorized doppler signal generator comes with outputs at 150 and 400 Mc but other frequency pairs are available between 30 Mc and 1 Gc with maximum tuning range of 0.1 percent of center frequency. Frequency calibration accuracy is 0.002 percent, drift is less than 0.00002 percent per hour after warmup and short-term jitter is less than 0.1 radian rms. Output range is -60 to -160 dbm within 2 db, internal f-m modulation is a linear one shot sweep over the entire frequency range at a rate adjustable from 50 cps to 1 Kc. Manual frequency control is also available. An external sweep may be applied between d-c and 1 Kc with a sensitivity of 24 Kc per volt. External p-m is adjustable between 0 and ± 90 degrees with sensitivity of 45 degrees per volt. Modulating frequency is read directly on a front panel meter. A precision voltage-controlled crystal oscillator is

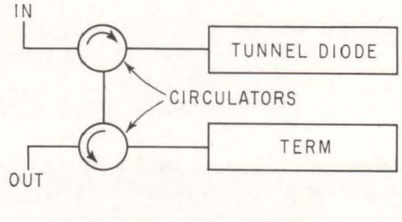


the r-f source and is multiplied to provide output frequencies. In manual operation, a vernier 10-turn control sets output to 400 Mc $\pm$ 60 Kc or 150 Mc $\pm$ 22 Kc. Operation is either 106-125 v, 50 to 400 cps or an internal battery supply.

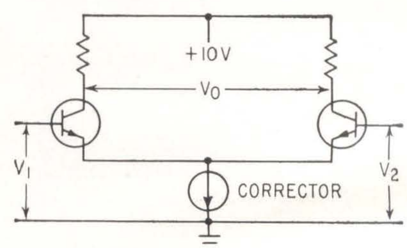
CIRCLE **301** READER SERVICE CARD

Tunnel Diode Amplifier Has 17 Db Gain at 1.7 Gc

IN production at Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N. J., the model NC-1601 low noise tunnel diode amplifier was designed for radio theodolite use. This model has an operating bandwidth from 1.6 to 1.7 Gc with 17 db gain. With gallium-antimonide



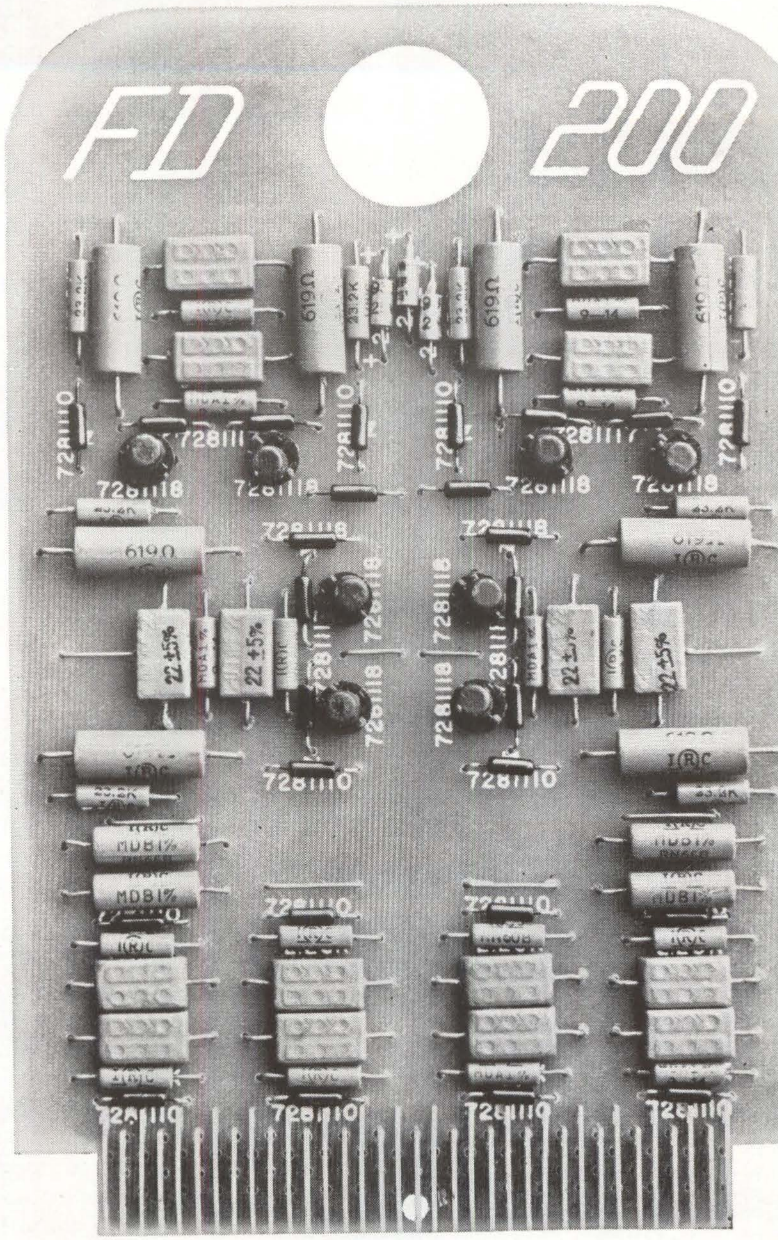
tunnel diodes, noise figure is 3.5 db and with germanium diodes noise figure is 4.5 db. Power supply is from an internal battery source. When biased, the tunnel diode will amplify all signals up to its cutoff frequency. The microwave mount determines frequency of interest. Circulators are used to separate incoming and amplified signals. The circulator provides nearly constant match to amplifier while isolating changes in antenna swr from affecting the amplifier. Any portion of the amplified signal reflected from the receiver is terminated. The unit is insensitive to reactive termination at all frequencies in and out of band. The amplifier is then fail-safe and should either amplifier or power supply fail, the signal will still pass through. The mtbf is calculated at 35,000 hours. As no r-f pumps are required for operation, no spurious signals can be generated. **(302)**

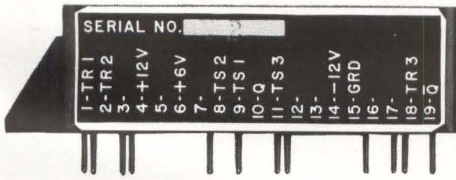


Current Regulator Operates Over Wide Voltage Range

INTRODUCED by CircuitDyne Corp., 480 Mermaid St., Laguna Beach, California, the Currector series of solid-state, two-terminal devices regulate current to a constant value analogous to the voltage limiting action of a zener diode. These devices come in a variety of current values in polar and non-polar versions. The sketch shows typical operation in an improved differential amplifier. In this circuit, the Currector acts as a common emitter impedance. Since the common-mode rejection ratio is directly proportional to this impedance value, it is desirable to select the largest

both 10mc





ONE FOR THE BIRD ONE FOR THE BLOCKHOUSE

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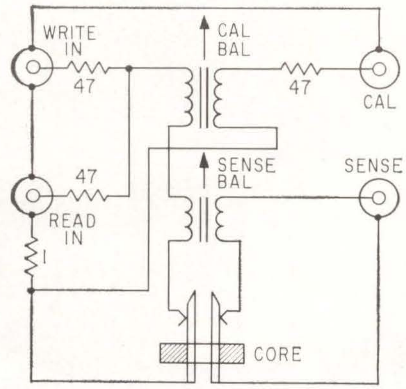
DELCO RADIO
DEPENDABILITY RELIABILITY

Division of General Motors • Kokomo, Indiana value that the magnitude of the available bias supply will permit. Assume that the emitter impedance must supply 2 ma to the transistor pair and a 500,000-ohm impedance is required by stability and common-mode rejection specifications. A 500,000-ohm resistor and 1 Kv bias will prove awkward. Same performance can be achieved using a 2 ma Currector and bias of 10 v. CIRCLE 303, READER SERVICE CARD

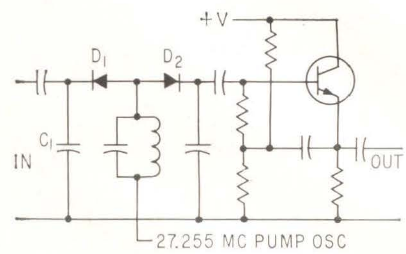


Simple Method of Testing Miniature Ferrite Cores

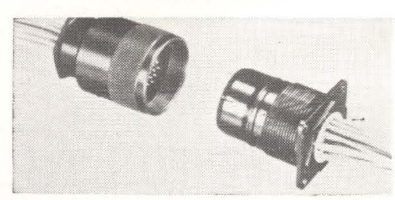
MANUFACTURED by Computer Instrumentation Corp., Rt 38 and Lonwood Ave., Cherry Hill, N. J., the model 4021-B core test jig is a manually operated instrument for easy and rapid analysis of miniature ferrite cores or metal tape wound cores. Cores between 0.015 inside diameter and 1.0 inch outside diameter can be inserted into the jig which has a two conductor probe, one for driving and the other for sensing. Core voltage response is observed on a cro connected to the output. Current amplitude is monitored through non-inductive 1-ohm, 1-percent calibration resistor. Two adjustable coupling bucking transformers are used to eliminate common-mode noise voltages caused by airflux pickup and capacitance between input and output pins. **(304)**

Parametric Amplifier With Ultra High Input Impedance

ANNOUNCED by Denro Labs, 2801 15th St., N.W., Washington 9, D. C., the model 514A amplifier has 20,000 megohm input resistance, 3 cps to 300 Kc bandwidth and a rise time of 2.5 μsec. Broadband noise level with input open is under 100 μv rms, power gain is up to 50 db, dynamic range is 100 μv to 0.1 v,



voltage gain is unity, output impedance is under 500,000 ohms, detectable signal power is 10^{-18} watts and the phase is adjustable either 0 or 180 degrees. A 27 Mc crystal-controlled oscillator is used as pump source and is fed to a parallel-tuned circuit aligned 100 Kc above pump source frequency. As shown in the sketch, the tank coil is connected to two diodes. Diode D_1 is a high Q silicon with very low reverse leakage and capacitance. Diode D_2 has low Q but high rectification efficiency and low noise. Both diodes will be space charged. Input signal sees reverse biased junction resistance and capacitance of D_1 and swamping capacitor C_1. Signal varies junction capacitance of D_1 which affects tuned circuit impedance proportionately. Diode D_2 linearly reproduces the r-f level change into a bootstrapped emitter follower amplifier which also acts as an isolation stage to prevent reflection and output impedance loading. Phase reversal is by inverting the diodes. **(305)**



Multipin Connector Withstands Vibration

MICRODOT INC., 220 Pasadena Ave., S. Pasadena, Calif. Microminiature multipin connecter features a threaded coupling ring mated to a threaded receptacle that furnishes positive holding for installations subjected to vibration. It can provide 61 power contacts or 19 coaxial contacts within a shell of 1⅛ in. in diameter. Smallest connector contains up to 19 power contacts in a ¾-in. shell. **(306)**

PRODUCT BRIEFS

ONE-SHOT MULTIVIBRATOR, a 10 Mc module. It operates from −55 C to +125 C. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. **(307)**

MICROMINIATURE RELAYS have welded header-to-can. The BR-11 series is capable of switching dry circuit to 2 amp loads at 28 v d-c. Babcock Relays, 1645 Babcock Ave., Costa Mesa, Calif. **(308)**

NON-POSITION SENSITIVE RELAYS for single-phase motors. Dependable life is over 1,000,000 cycles. Metals & Controls Inc., a corporate division of Texas Instruments Inc., 34 Forest St., Attleboro, Mass. **(309)**

MINIATURE CONNECTORS are hermetically sealed. They are available in flangeless, square flange, bulkhead and socket types. Hermetic Industries, 4232 Temple City Blvd., Rosemead, Calif. **(310)**

SINGLE-ARM PLOTTING BOARD for analog, digital application. It utilizes an electroluminescent panel to backlight the plotting area. Computer Systems, Inc., Monmouth Junction, N. J. **(311)**

MAGNETRON TEST SET for all-purpose use. All tests are in accordance with MIL-E-1D. Electronics for Education, Inc., Horsham, Pa. **(312)**

BROADBAND ISOLATOR covers 18.0 to 26.5 Gc. Isolation is 25 db minimum, insertion loss 1.0 db maximum. E&M Laboratories, 15145 Califa St., Van Nuys, Calif. **(313)**

SOLID STATE COUNTER with five digit in-line readout. Input range is 0 to 20,000 cps. Cox Instruments Corp., 15300 Fullerton, Detroit 27, Mich. **(314)**

SAMPLING SCOPE PLUG-IN has 3,500 Mc bandpass. Risetime is 0.1×10^{-9} sec (0.1 nsec). Tektronix, Inc., P. O. Box 500, Beaverton, Ore. **(315)**

PRECISION RESISTANCE CARDS for microwaves. Standard sizes are 6 in. by 12 in. Metavac Inc., 45-63 162nd St., Flushing 58, N. Y. **(316)**

D-C SUPPLY has 10 v output at 0-250 ma. Ripple is 1 mv peak to peak max. Atlas Controls Inc., 9 Erie Drive, Natick, Mass. **(317)**

DIGITALLY PROGRAMMABLE SCALER offers manual or electrical control. Accuracy is ±0.05 percent. Trio Laboratories, Inc., Dupont St., Plainview, L. I., N. Y. **(318)**

TRANSFORMERS & REACTORS meet MIL-T-27. They are in custom production. Nothelfer Winding Laboratories, Inc., P. O. Box 455, Trenton 3, N. J. **(319)**

INSTRUMENT CART transports oscilloscopes. The aluminum cart measures 41 in. high, 18 in. wide and 26 in. deep. Lavoie Laboratories, Inc., Morganville, N. J. **(320)**

INTEGRAL LEVER ACTUATORS with low force-high overtravel. Two models are available. Cherry Electrical Products Corp., P. O. Box 438-7, Highland Park, Ill. **(321)**

THERMOELECTRIC MODULES are miniaturized. Units cool temperature sensitive components. Semitronics, Inc., 63 Swanton St., Winchester, Mass. **(322)**

TEMPERATURE RECORDER features low-cost. Unit has high resolution. Rustrak Instrument Co., Inc., 130 Silver St., Manchester, N. H. **(323)**

DUCT PANEL ADAPTERS for cooling electronic equipment. They are quiet and reliable. McLean Engineering Laboratories, P. O. Box 288, Princeton, N. J. **(324)**

SOLID STATE A-C CONTACTOR replaces bulky electromechanical type. Load circuit can be from 10 cps to 25 kc. LJ Products, 7450 Girard Ave., La Jolla, Calif. **(325)**

MOTOR TIE CORD made of waxed Nylon. It ties smoothly and flat. Gudebrod Bros. Silk Co., Inc., 225 W. 34th St., New York 1, N. Y. **(326)**

L-V POWER SUPPLY has 1 percent regulation NL to FL. Price is $87.50. Trelcom Engineering Co., P. O. Box 6209, Baltimore 6, Md. **(327)**

BERYLLIUM COPPER POWDER is moldable, sinterable. It is made in a standard-100 mesh particle size range. The Brush Beryllium Co., 5209 Euclid Ave., Cleveland 3, O. **(328)**

HEAVY DUTY TOWER for microwave installation. It is constructed in an equilateral triangular pattern. Rohn Mfg. Co., Peoria, Ill. **(329)**

VOLTAGE VARIABLE CAPACITORS range from 7 to 120 pf at -4 v. Prices range from $1.85 to $7.75 in 100 quantities. Eastron Corp., 25 Locust St., Haverhill, Mass. **(330)**

C-C TV SYSTEM with high picture clarity. It is fully automatic. GPL Div., General Precision, Inc., 63 Bedford Rd., Pleasantville, N. Y. **(331)**

DELAY LINES are molded in epoxy. Temperature stability is 50 parts per million per deg C. Allen Avionics, Inc., Mineola, N. Y. **(332)**

SOLID STATE DECODER with in-line readout. It uses plug-in p-c construction. Burroughs Corp., P. O. Box 1226, Plainfield, N. J. **(333)**

TIME TOTALIZER for the data processing industry. It automatically records computer usage time. Advance Data Systems Corp., 2037 Granville Ave., Los Angeles 25, Calif. **(334)**

INDUSTRIAL VOLTAGE SCANNING SYSTEM measures 50 channels. Information is presented in digital display and as permanent printed record. Dymec, a division of Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif. **(335)**

Literature of the Week

VIBRATION METER Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif. Capabilities of the type 1-117 vibration meter are described in a four-page bulletin. **(336)**

ULTRAMICROWAVE EQUIPMENT DeMornay-Bonardi Corp., 780 S. Arroyo Parkway, Pasadena, Calif. Catalog contains photos, specifications and dimensional drawings on millimeter wave equipment for the W size, 90 to 140 Gc. **(337)**

H-V TEST EQUIPMENT Peschel Instruments Inc., Route 216, Towners, Patterson, N. Y. Short-form catalog No. 62 covers h-v test sets and h-v power supplies. **(338)**

MIL SYNCHROS Vernitron Corp., 602 Old Country Road, Garden City, L. I., N. Y. Detailed specifications to aid in rapid selection of size 23, 60 cycle Thru-Bore synchros for servo applications are given in a data sheet. **(339)**

UNIVERSAL CONTACT FEEDER Fansteel Metallurgical Corp., North Chicago, Ill., has issued a bulletin on a universal contact feeder that increases production rates up to 35 percent. **(340)**

IN-BAND SIGNALING SYSTEM Lenkurt Electric Co., Inc., 1105 County Road, San Carlos, Calif., offers a pamphlet on the type 927A in-band signaling system that converts d-c signaling pulses to 2,600-cycle tone pulses for transmission. **(341)**

NARROW-HEIGHT COMPONENTS Microwave Development Laboratories, Inc., 15 Strathmore Road, Natick Industrial Centre, Natick, Mass. Bulletin O-1 lists narrow-height microwave components. **(342)**

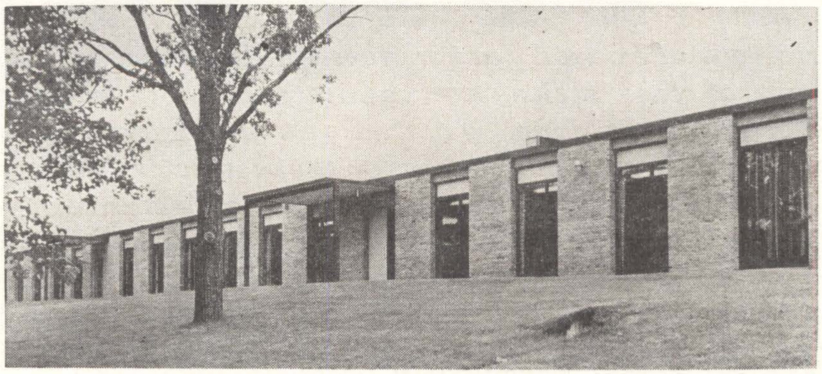
SHAFT POSITION ENCODER Datex Corp., 1307 S. Myrtle Ave., Monrovia, Calif. Bulletin contains information on a self-selecting brush U-Scan shaft position encoder. **(343)**

TRANSPARENT WELDED CIRCUIT RG Circuits Co., 15216 Mansel Ave., Lawndale, Calif., offers a catalog sheet on the nonresonant, rigid, heat-cold-humidity-resistant welded circuit. **(344)**

ROTARY SWITCH Oak Mfg. Co., Crystal Lake, Ill. Four-page brochure highlights a subminiature, 12-position, ½-in. rotary switch. **(345)**

COOLING EQUIPMENT McLean Engineering Laboratories, P.O. Box 228, Princeton, N.J., has published a catalog presenting its packaged Mil-Spec blower line. **(346)**

ACOUSTIC CALIBRATOR Engineering Dynamics Associates, Inc., 6651 S. Wellington Ct., Littleton, Colo. Four-page technical brochure describes a portable high-intensity acoustic calibrator. **(347)**



Fabri-Tek Doubles Plant Space

FABRI-TEK, INC., magnetic memory manufacturer, has more than doubled its production space with an addition to its plant at Amery, Wisc.

The firm, with headquarters in the Minneapolis suburb of Hopkins, Minn., has been manufacturing core memory planes and stacks at Amery since 1959. It moved into a new 12,000-square foot building there in 1960. This year's addition brings Amery plant space to 25,000 square feet.

Most of the company's 400 employees now work in this installation. Two plants in Hopkins house the headquarters staff and R&D.

The firm was founded in 1957 by M. F. (Mike) Michelson to manufacture high quality magnetic core memory planes and stacks for the growing electronic computer industry. Core memory components are still the mainstay of the business, but Fabri-Tek has expanded its line to include a broader variety of types and sizes, plus a line of complete memory systems.

The expanding Fabri-Tek R&D department is doing advanced research on thin film memory components and on new systems using core and film elements.

Leonard Kent Takes ARRA Executive Post

ANTENNA & RADOME RESEARCH ASSOCIATES, Westbury, L. I., N. Y., announces the appointment of Leonard I. Kent to the position of vice president for engineering. In this capacity he will be responsible for the company's design, research and development efforts which will include those in the fields of solid state and ferrite devices.

Kent was president of Consolidated Microwave Corp. whose assets were acquired by Antenna & Radome Research Associates.

Measurement Systems Hires Rhyins

RICHARD W. RHYINS has joined the staff of Measurement Systems, Inc., Norwalk, Conn. as manager of advanced development engineering.

He was formerly with the Barnes Engineering Co. in Stamford, Conn.

TI Realigns Components Activity

MARK SHEPHERD, JR., executive vice president of Texas Instruments Inc., Dallas, Texas, has announced that TI's Transistor Products and Components divisions have been combined into one division to be known as the Semiconductor Components division.

The new division will be under the direction of TI vice president Cecil Dotson. He formerly headed the Transistor Products division and International division.

TI vice president Jay Rodney Reese, who has headed the Components division, becomes manager of the International division.

Elect F. A. Lindsay Itek President

FRANKLIN A. LINDSAY has been elected president of Itek Corp., Lexington, Mass., replacing Richard S. Leghorn who recently resigned. Leghorn will retain a part-time relationship with the company.

Lindsay has been executive vice president of the firm which specializes in information handling equipment for military and civilian uses.

Lionel Corporation Elects Raney

MELVIN A. RANEY has been elected president and chief executive officer of The Lionel Corp., Hillside, N. J.

Raney joined Lionel in 1961 as general manager of Induction Heating Corp., Brooklyn, N. Y., a wholly

The "HH" series is Hitachi's new superior line of television receiver tubes, the ultimate in far-reaching reception of television waves.

For RF amplifier of VHF television tuners, specify the 4R-HH2 and 6R-HH2 which feature very high transconductance, high sensitivity and low noise. These twin triode tubes replace the 4BQ7A and 6BQ7A without change of circuit.

For frequency convertor and local oscillator of VHF television tuners, specify 5M-HH3 and 6M-HH3 twin triodes which replace the 5J6 and 6J6 without change of circuit.

The "HH" series is another fine quality line from Hitachi, one of the most completely integrated electrical manufacturers in the world.

INTERNATIONAL IMPORTER INC.
2242 South Western Avenue,
Chicago 8, Illinois, U.S.A.

Hitachi, Ltd.
Tokyo Japan

owned Lionel subsidiary. He was then elected president of the subsidiary.

Sylvania's EDL Promotes Smith

APPOINTMENTS of C. A. (Kip) Smith as manager of technical liaison for the Electronic Defense Laboratories of Sylvania Electric Products Inc., Mountain View, Calif., is announced.

With Sylvania since 1932, Smith joined liaison at EDL in 1957.

SDS Appoints J. M. Mitchell

SCIENTIFIC DATA SYSTEMS, INC., Santa Monica, Calif., has appointed Jack M. Mitchell associate manager of digital computers.

Mitchell was computer engineering manager at Packard-Bell Computer prior to joining SDS.

LFE Electronics Names Anderstrom

EDWARD A. ANDERSTROM has been promoted to director of manufacturing for LFE Electronics, the major operating group of Laboratory For Electronics, Inc., Boston, Mass. Included in his new assignment is responsibility for produc-

Are you a COMPLETELY INFORMED electronics engineer?

Today you may be working in microwaves. But on what project will you be working tomorrow? You *could* have read **electronics** this past year and kept abreast of, say, microwave technology. *There were 96 individual microwave articles between July, 1961 and June, 1962!*

But suppose tomorrow you work in some area of standard electronic components, in semiconductors, in systems? Would you be up-to-date in these technologies? Did you read the more than 3,000 editorial pages that **electronics'** 28-man editorial staff prepared last year?

electronics is edited to keep you current *wherever* you work in the industry, *whatever* your job function(s). If you do not have your own copy of **electronics**, subscribe today via the Reader Service Card in this issue. Only 7½ cents a copy at the 3 year rate.

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MITSUMI PARTS

MITSUMI ELECTRIC CO., LTD.
Komae, Kitatama, Tokyo

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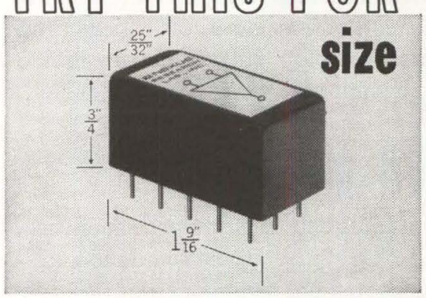

Our new silicon transistor operational amplifiers for analog instrumentation offer:

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RESEARCH LABORATORY, INC.
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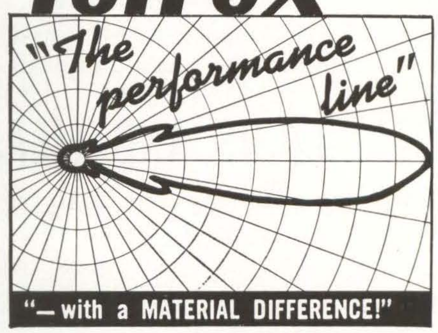

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Provide optimum performance and reliability per element, per dollar. Antennas from 500 Kc to 1500 Mc. Free PL88 condensed data and pricing catalog, describes military and commercial antennas, systems, accessories, Towers, Masts, Rotators, "Baluns" and transmission line data.

ANTENNAS SINCE 1921 — Communication and TV Antennas

Telrex LABORATORIES
Asbury Park 41, New Jersey, U.S.A.

CIRCLE 69 ON READER SERVICE CARD

tion of Doppler navigation systems, ground controlled approach radars and ground support equipment being made by LFE Electronics for the military.

Anderstrom succeeds Richard C. Sorensen, now president of Tracerlab, LFE's nucleonics division, and the Keleket X-Ray Corp., a wholly-owned LFE subsidiary.

PEOPLE IN BRIEF

Col. Albert R. Shiely, Jr. of the Air Force's Electronic Systems div. appointed program director of BMEWS. **B. Richard Climie,** ex-Collins Radio, named technical staff assistant at Aeronautical Radio, Inc. **Lawrence C. Murdock** from Bissett-Berman, to its Hytech, San Diego, div. as chief engineer. **Melvin A. Goldberg,** formerly with Westinghouse Broadcasting Co., now v-p and director of research of NAB. **James Sanders** moves up at Electronic Associates, Inc., to group mgr. of the process control engineering group. **Franklin E. Jutton,** previously with GE, named production mgr. of the Systems div. of Electro-Mechanical Research, Inc. **Robert T. McTigue,** v-p and director of Oak Mfg. Co., elected president of its subsidiary, Hart Mfg. Co. **Robert W. Lambdin** leaves Kollsman Instrument Corp. to join Airtron, a div. of Litton Industries, as a senior staff scientist for solid state materials. **Bruce A. Highstrete** promoted to asst. mgr. of the research dept. of Hughes Aircraft Co.'s microwave tube div. Corning Electronic Components advances **Glenn A. Blackmon** to supervisor of capacitor market development, and **A. J. Hotte** to supervisor of capacitor product engineering. **George W. Spencer,** previously with Erie-Pacific, appointed mgr. of the military data systems dept. of the System Sciences div. of Control Data Corp. **Z. K. Geanes,** ex-Quantatron, Inc., now marketing director, western region, for GPI's Librascope div. **O. Dexter Covell Jr.,** ex-AMF Corp., named exec v-p of Detectron, Inc. **Joseph Baumoel** has left Liquidometer Corp. to form an engineering consultation firm in Jericho, N. Y.

electronics

WEEKLY QUALIFICATION FORM FOR POSITIONS AVAILABLE

ATTENTION: ENGINEERS, SCIENTISTS, PHYSICISTS

This Qualification Form is designed to help you advance in the electronics industry. It is unique and compact. Designed with the assistance of professional personnel management, it isolates specific experience in electronics and deals only in essential background information.

The advertisers listed here are seeking professional experience. Fill in the Qualification Form below.

STRICTLY CONFIDENTIAL

Your Qualification form will be handled as "Strictly Confidential" by ELECTRONICS. Our processing system is such that your form will be forwarded within 24 hours to the proper executives in the companies you select. You will be contacted at your home by the interested companies.

WHAT TO DO

1. Review the positions in the advertisements.
2. Select those for which you qualify.
3. Notice the key numbers.
4. Circle the corresponding key number below the Qualification Form.
5. Fill out the form completely. *Please print clearly.*
6. Mail to: D. Hawksby, Classified Advertising Div., ELECTRONICS, Box 12, New York 36, N. Y. (No charge, of course).

COMPANY	SEE PAGE	KEY #
ATLANTIC RESEARCH CORPORATION Jansky & Bailey Div. Alexandria, Va.	75	1
ATOMIC PERSONNEL INC. Philadelphia, Pennsylvania	73	2
AVCO RESEARCH AND ADVANCED DEVELOPMENT Division of Avco Corporation Wilmington, Massachusetts	74	3
DELCO RADIO Div. of General Motors Corp. Kokomo, Indiana	62*	4
ESQUIRE PERSONNEL SERVICE INC. Chicago, Illinois	74	5
F & M SCIENTIFIC CORP. Avondale, Penna.	74	6
HOUSTON INSTRUMENT CORPORATION Bellaire, Texas	108*	7
JET PROPULSION LABORATORY Pasadena, California	73	8
LOCKHEED AIRCRAFT CO. Burbank, California	24*	9
McDONNELL St. Louis, Mo.	73	10
MICROWAVE SERVICES INTERNATIONAL INC. Denville, New Jersey	74	11
REPUBLIC AVIATION CORPORATION Farmingdale, Long Island, New York	75	12

Continued on page 74

(cut here) **electronics WEEKLY QUALIFICATION FORM FOR POSITIONS AVAILABLE** (cut here)

(Please type or print clearly. Necessary for reproduction.)

Personal Background

NAME ....

HOME ADDRESS ....

CITY .... ZONE ...... STATE ....

HOME TELEPHONE ....

Education

PROFESSIONAL DEGREE(S) ....

MAJOR(S) ....

UNIVERSITY ....

DATE(S) ....

FIELDS OF EXPERIENCE (Please Check) 82462

☐ Aerospace	☐ Fire Control	☐ Radar
☐ Antennas	☐ Human Factors	☐ Radio—TV
☐ ASW	☐ Infrared	☐ Simulators
☐ Circuits	☐ Instrumentation	☐ Solid State
☐ Communications	☐ Medicine	☐ Telemetry
☐ Components	☐ Microwave	☐ Transformers
☐ Computers	☐ Navigation	☐ Other ....
☐ ECM	☐ Operations Research	☐ ....
☐ Electron Tubes	☐ Optics	☐ ....
☐ Engineering Writing	☐ Packaging	☐ ....

CATEGORY OF SPECIALIZATION

Please indicate number of months experience on proper lines.

	Technical Experience (Months)	Supervisory Experience (Months)
RESEARCH (pure, fundamental, basic)	......	......
RESEARCH (Applied)	......	......
SYSTEMS (New Concepts)	......	......
DEVELOPMENT (Model)	......	......
DESIGN (Product)	......	......
MANUFACTURING (Product)	......	......
FIELD (Service)	......	......
SALES (Proposals & Products)	......	......

CIRCLE KEY NUMBERS OF ABOVE COMPANIES' POSITIONS THAT INTEREST YOU

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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jpl needs

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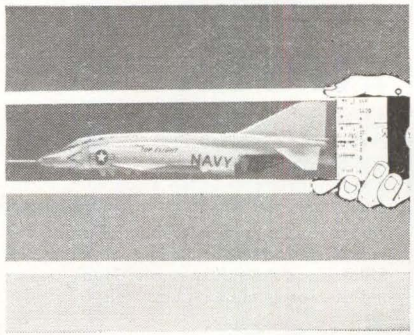

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Mr. D. F. Waters,
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Analysis of advanced electronic communication systems including radio, carrier, telephone, microwave:
Must have design and marketing experience with commercial and military users.
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Graduate IE or Metallurgist with 5 years experience in the manufacture of refractory metals or high temp. alloys. Exp. in Powder Metallurgy, Product Scheduling and Manufacture. Company client assumes all expenses.
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electronics

WEEKLY QUALIFICATIONS FORM FOR POSITIONS AVAILABLE

(Continued from page 72)

REPUBLIC AVIATION CORPORATION Missile Systems Division Mineola, Long Island, NY	73	13
SYLVANIA ELECTRONIC SYSTEMS • WEST Mountain View, California	107*	14
UNION CARBIDE NUCLEAR CO. Oak Ridge, Tennessee	108*	15
P 9428	75	16

*These advertisements appeared in the 8/17/62 issue.

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UNDISPLAYED RATE

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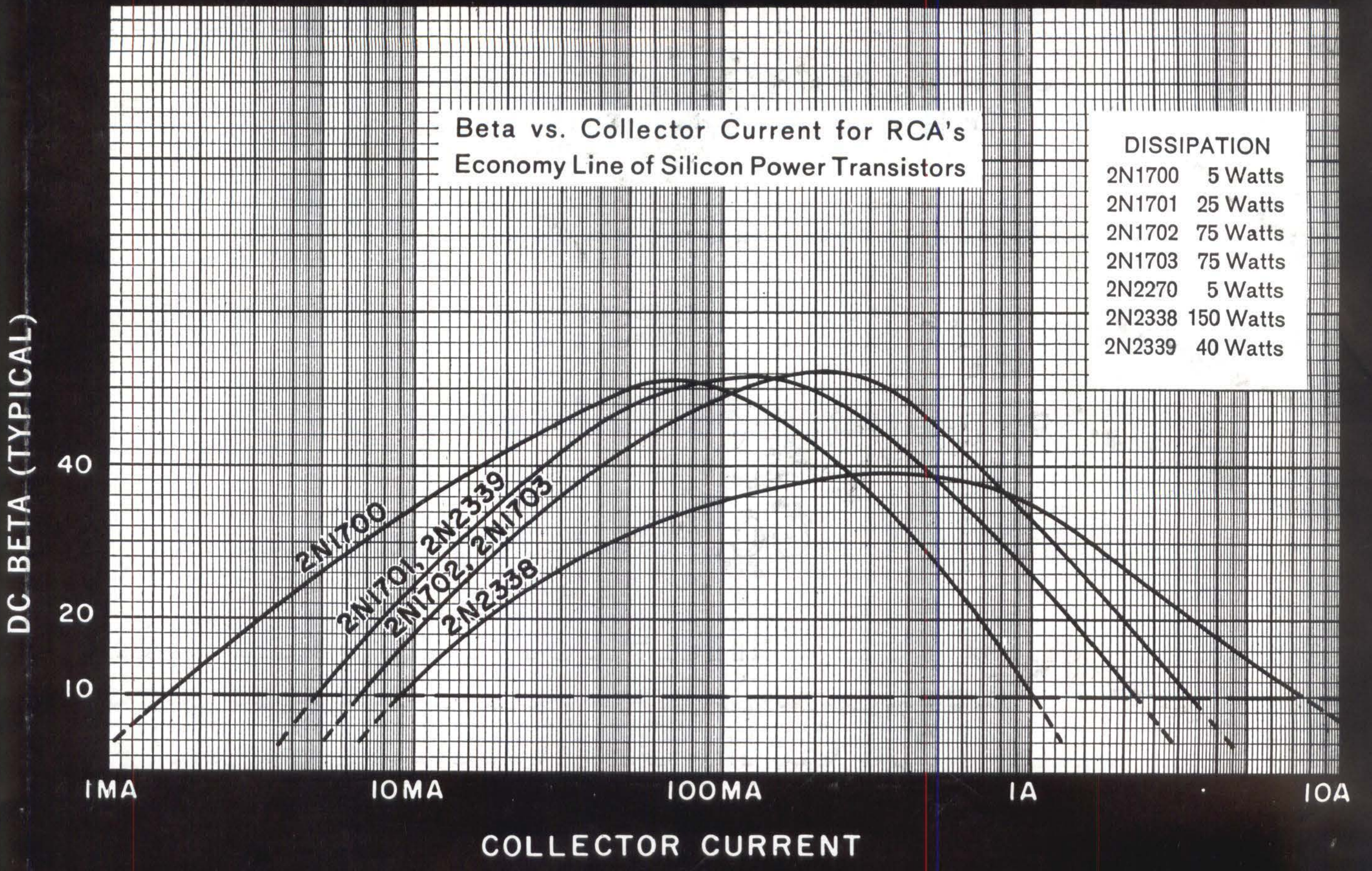

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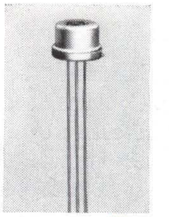

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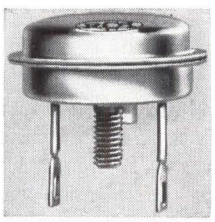

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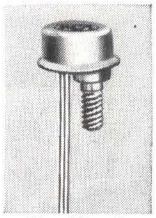

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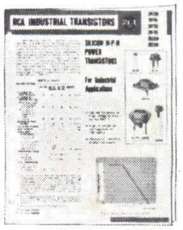

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