Electronics®

Direct digital control runs the process: page 49
Relays that challenge transistors: page 56
Integrated circuits shrink a radar set: page 74

March 23, 1964
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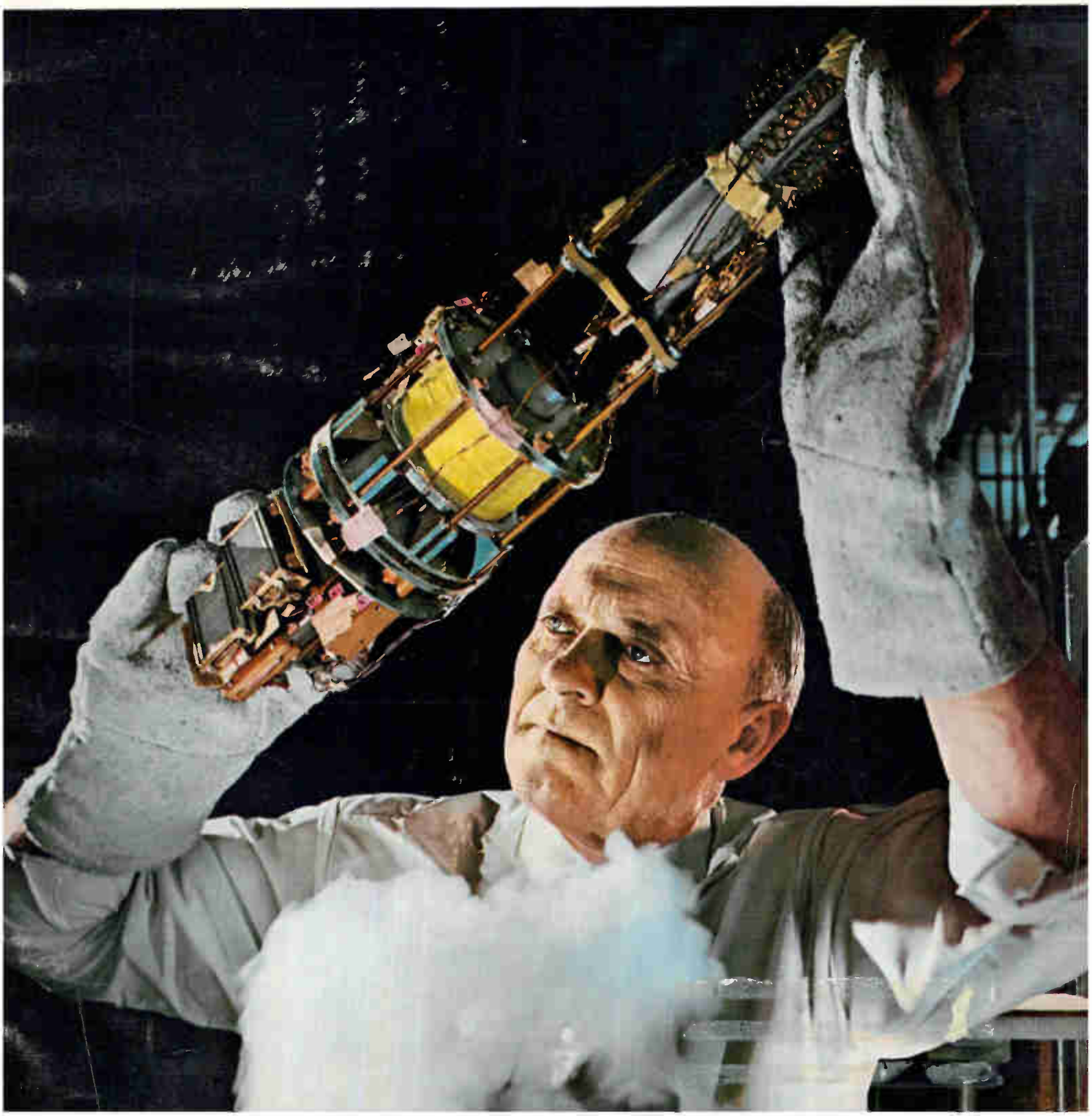
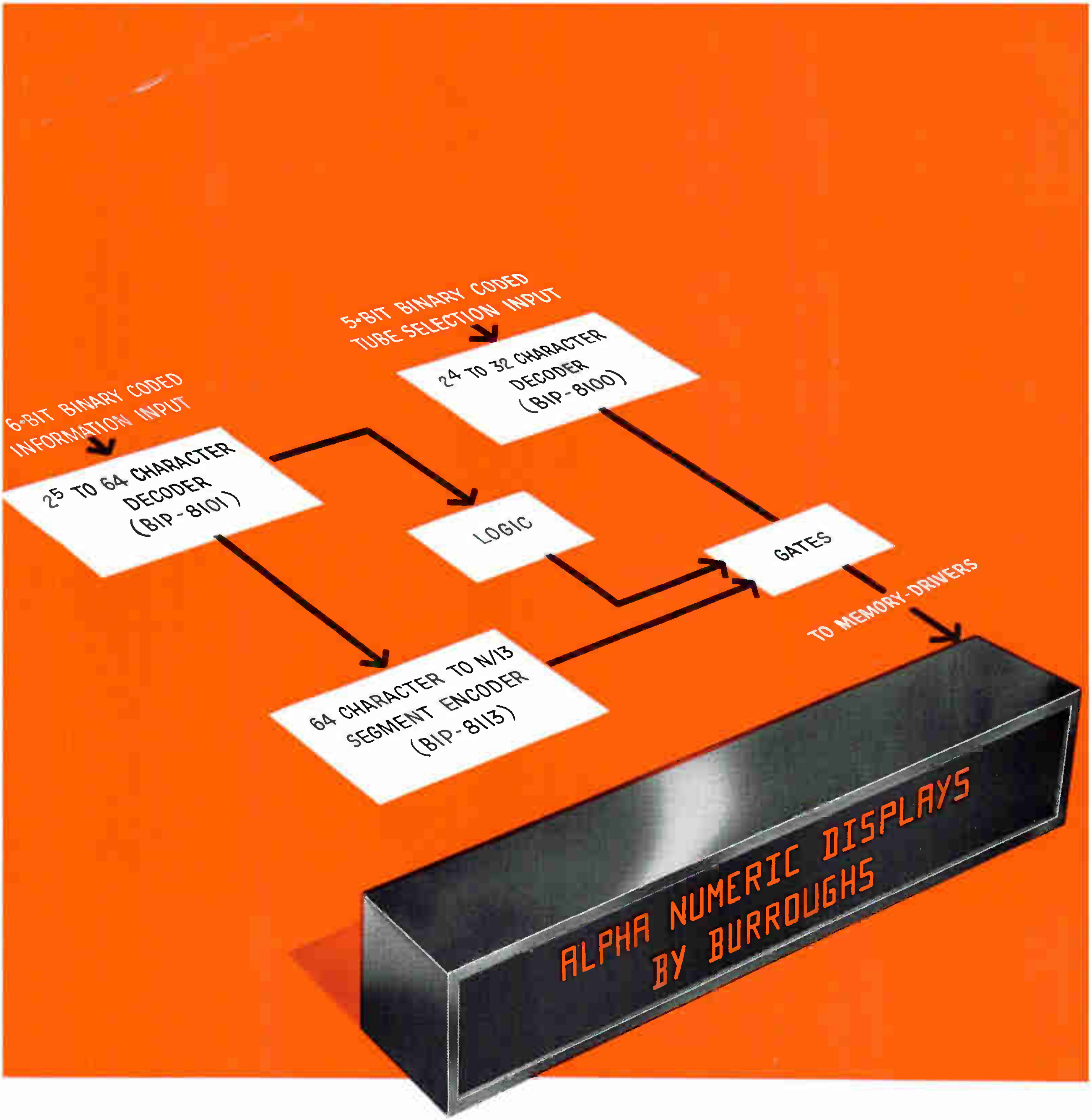
A McGraw-Hill Publication

Below: new d-c power supply, the cryogenic flux pump





everything from the input . . . out

Alpha Numeric Display Systems by Burroughs, designed around new Alpha Numeric Nixie® Tubes, give you everything from the input . . . out. These systems are adaptable to any kind of electronic information display requirements. System flexibility is enhanced by the use of standard highly reliable semi-conductor modules. Standard packages include memory-driver modules, decoding and encoding devices, and associated control circuitry. The modular concept facilitates custom design of display systems to meet individual functional and physical specifications. Visual display is made particularly effective by unique tube characteristics . . . unexcelled brightness and continuous line characters . . . which provide exceptional readability. In addition, any one of a number of available character sizes may be incorporated in a system to provide the best display for a given situation or application.

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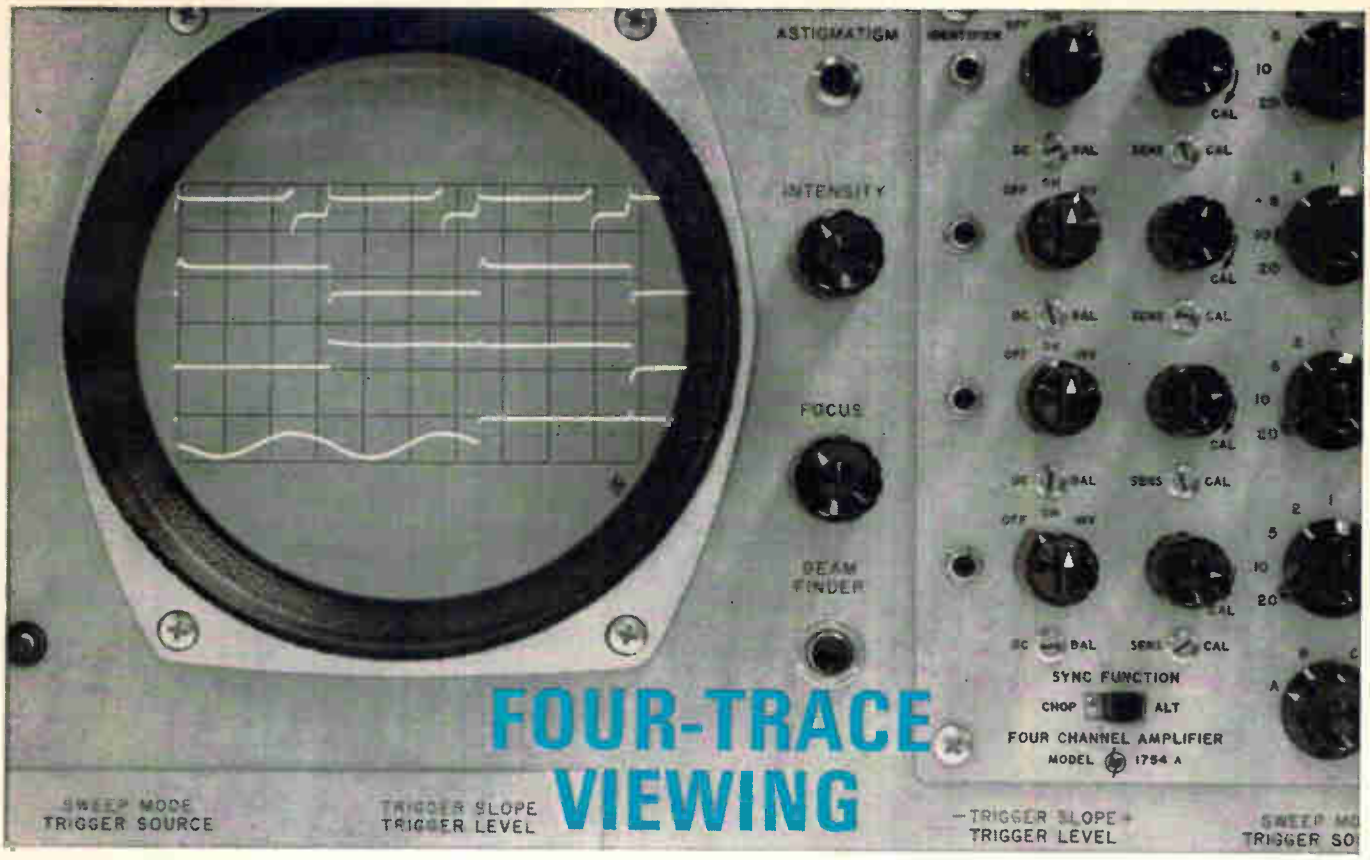

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- **1 mc switching rate for bright traces**

Now view and compare four signals simultaneously on your hp 175A Oscilloscope with the new 1754A Four-Channel Amplifier plug-in. Each channel has a bandwidth of 40 mc and a sensitivity of 50 mv/cm. Independent position controls allow you to superimpose waveforms for easy comparison on the large 6 x 10 crt of the 175A. The fast 9 nsec rise time and multi-channel capability are ideal for measurements in logic circuits.

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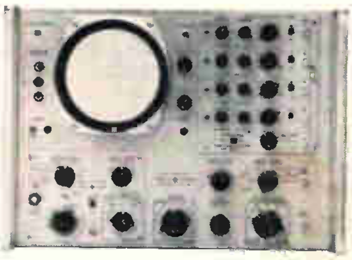

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New Universal Counters Tailored to Your Measurements:

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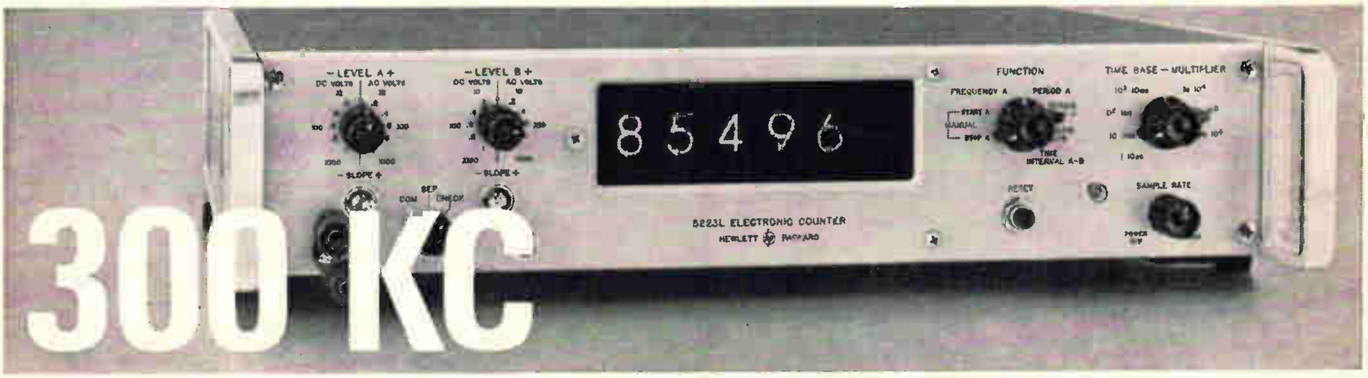

March 23, 1964
Volume 37, Number 12

Electronics

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Technical articles

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II. Application

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Readers Comment

Process control

Perhaps you have directed your "Help Wanted" editorial of Feb. 21 [p 5] to the wrong department. Important as a customer relations department is, if one is to prosper, it is the engineers who must produce something better than the other fellows.

The electronics consultant can provide a better control system than the in-plant process engineer if he expands his know-how in a demonstrable manner. One of the most likely areas for such improvement is in power supply.

I refer to the frequent failure to design the process control system to be compatible with the available power supply. Rather than divulge the process secrets to the local power company, many process companies go it alone. As a result, the supply voltage dips and momentary outages, which are barely discernable to the majority of the utility's customers, can cause a complete plant shut-down.

After one of these events, it is so obvious that the process got in trouble that seldom is the process control system reappraised. A frequent solution is for the process company to increase its investments in some form of standby or no-break power supply. This may be considerably more expensive that a few minor control revisions which can go a long way to making the process needs compatible with the available local utility power system.

John R. Linders
The Cleveland Electric
Illuminating Company
Cleveland, Ohio

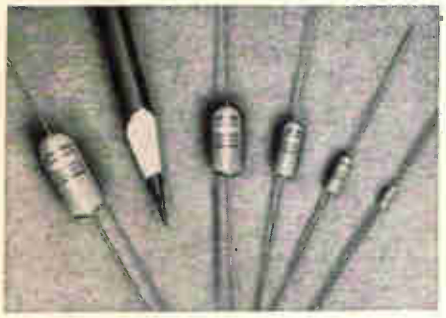
Dolphin intelligence

I read with interest your Crosstalk article, Voice of the Dolphins [p 5, Nov. 22, 1963]. However, the assignment of an intelligence quotient of 190 "on a human scale" by one of the scientists engaged on the project, establishes Tursios Truncatus among the sublime of the mammalian class.

A typical human population

(Advertisement)

Fully-Molded Bullet-Nose Solid Tantalex® Capacitors Available in Five Case Sizes



Developed by the Sprague Electric Company to help designers of digital computing equipment and other industrial electronic devices reduce their costs, Type 154D solid-electrolyte Tantalex Capacitors have performance characteristics which are comparable to those of higher-priced metal-clad capacitors from other sources.

Particularly practicable for applications which demand good electrical characteristics without necessarily requiring the superior moisture resistance of more expensive metal-encased units, Type 154D Capacitors are available in five case sizes, giving circuit designers a broader range of capacitance values and voltage ratings from which to choose.

The five cases include two tiny sizes ideally suited for high-density "cordwood" packaging. In the smallest case (.090" diameter x .250" long), maximum capacitance ranges from 1.5 μF at 6 volts to .1 μF at 75 volts. In the next smallest case (.138" diameter x .390" long), maximum capacitance ranges from 15 μF at 6 volts to 0.68 μF at 75 volts. The largest of the three remaining case sizes offers capacitance values up to 330 μF.

Ideal for Machine Installation

Because of the uniformity of their molded cases, these bullet-shaped capacitors are well-suited for machine installation on printed wiring boards. They can be furnished on lead tapes to meet customer specifications and needs of automatic insertion equipment.

The rounded end or "nose" of the bullet-shaped body identifies the positive terminal lead.

For application engineering assistance write to Tantalum Capacitor Section, Field Engineering Department. For complete technical data, write for Engineering Bulletin 3530A to Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Mass.

4SC-103-64

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6 Reasons Why SPRAGUE is a Major Resistor Supplier

FILMISTOR® PRECISION FILM RESISTORS

metal-film, molded case

Distinct limited temperature coefficients and low tolerances to meet exacting application requirements. Rugged end cap construction for long-term stability and reliability. Superior resistance to humidity and mechanical damage. Surpass MIL-R-10509D requirements. Send for Bulletin 7025B.

deposited-carbon, molded case

Approach precision wirewounds in reliability and stability, yet are smaller in size and have lower self-inductance. Low, controlled temperature coefficient. Dense molded case provides outstanding humidity protection. Send for Bulletin 7000A.

deposited-carbon, conformal coated

Full rated load operation at 70 C with no wattage derating. Assured uprated loads at lower operating temperatures. Ideal for circuitry where small size, humidity resistance, and close tolerance (±1%) are required. Send for Bulletin 7005A.

CIRCLE 270 ON READER SERVICE CARD

ACRASIL® PRECISION/POWER WIREWOUND RESISTORS

silicone-encapsulated

Combine the best features of both precision and power wirewound types. Resistance tolerances to ±0.05%. Unusually tough encapsulation protects against shock, vibration, moisture, fungus. Meet MIL-R-26C requirements. Smaller than conventional wirewounds, yet greater in stability. Send for Bulletin 7450.

CIRCLE 271 ON READER SERVICE CARD

BLUE JACKET® VITREOUS ENAMEL POWER WIREWOUND RESISTORS

All-welded end cap construction with special vitreous coating for long-term dependability. Axial-lead style for conventional wiring or on printed boards. Tab terminals for higher wattage applications. Meet MIL-R-26C requirements. Send for Bulletins 7400B, 7410D, 7411A.

CIRCLE 272 ON READER SERVICE CARD

KOOLOHM® CERAMIC-SHELL POWER WIREWOUND RESISTORS

Exclusive ceramic-insulated resistance wire permits "short-proof" multilayer windings for higher resistance values. Standard and non-inductive designs. Non-porous ceramic shell for moisture protection and electrical insulation. Axial-lead, axial-tab, and radial-tab styles. Send for Bulletins 7300B, 7305, 7310.

CIRCLE 273 ON READER SERVICE CARD

GLASS-JACKETED POWER WIREWOUND RESISTORS

Ferrule terminals soldered to metallized ends of glass casing for true hermetic seal. Virtually failure-proof, even in extremely corrosive industrial and salt atmosphere. Standard and non-inductive windings. External meter-multiplier types also available. Send for Bulletins 7350, 7420, 7421.

CIRCLE 274 ON READER SERVICE CARD

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Flat silhouette permits stacking of resistor banks in close quarters. Aluminum thru-bar simplifies mounting and conducts heat from resistance element. Vitreous enamel protective coating. Meet MIL-R-26C performance requirements. Send for Bulletin 7430.

CIRCLE 275 ON READER SERVICE CARD

For complete technical data, write for engineering bulletins on the resistors in which you are interested to: Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Massachusetts.

4SR-166-63

SPRAGUE®
THE MARK OF RELIABILITY

Get The Full Story at IEEE Booths 2416 Thru 2426 (such as that of the U. S.) has a Gaussian distribution of intelligence with the norm arbitrarily set at 100 (for example, Stanford-Binet, Wechsler-Bellevue, Tests), 65% of the population having an I.Q. between 85 and 115. Reference to tables of normal distribution then shows that less than 0.01% of the population has an I.Q. of 160 or over. There has probably never existed more than a handful of men with an I.Q. of 190. Thus Tursios Truncatus far outweighs the intellect of Charles Darwin (about 135) though it might fall a little short of Goethe (I.Q. between 185 and 200).

We may expect an early report from the dolphins on the interesting behaviour of the Sperry scientists, as soon as they have solved the trivial problem of communicating with that inferior upstart of the animal kingdom, Homo Sapiens.

Stephen Blow
Atomic Energy Commission
Roskilde, Denmark

▪ The I.Q. figure used is not one measured on the human scale, but rather an equivalent, in terms of how well the dolphins manage in their own environment. It does not mean that if they could learn German, dolphins would start writing Goethe-like poetry. Just means they're damned clever beasts.

Impoverishment

Mr. John Joss refers to a possible impoverishment of the language [p 6, Feb. 21]. This has already occurred!

Alibi is used where excuse is intended. Alternate has become synonymous with alternative.

There is surely no excuse for using the wrong word when a correct alternative exists.

Dewi L. Williams
Chateauguay Centre
Quebec, Canada

Mixer harmonics

In your Jan. 10 issue I found some figures which puzzle me. In the Reference Sheet article, Linear Scales Show Mixer Harmonics, author Roger T. Stevens states on page 37 that the ratio between F_L/F_H varies between 0.893 and 0.911. Using the figures in the article, I arrive at a variation between 0.891 and 0.909.

Could you tell me if there is a specific reason for the difference in my figures and those of Mr. Stevens, such as an understood quantity not listed in the article, or whether the division was wrong?

John G. Giovino
Quality Control
Applied Physics Corp.
Monrovia, California

▪ Author Stevens says he used a slide rule. With a desk calculator, the ratios come out to 0.89159 and 0.90985, which round off to 0.892 and 0.910.

Microwave tubes

We read with much interest on page 52 of the Dec. 13, 1963, issue about the conference on Design and Use of Microwave Tubes, held in London on October 16-18, 1963.

We should appreciate very much your informing us how we could get the papers on that conference.

G.F. Cirri
Fabbrica Italiana Valvole
Radio Elettriche
Florence, Italy

▪ The 250-page book containing all the papers presented at the conference may be obtained by sending four and a half dollars (or equivalent) to the publications department of the Institution of Electrical Engineers, Savoy Place, London.

Principle

For all the fancy footwork concerning the use of the word "data" (singular and plural), the Feb. 28 issue was tripped up by another of those banes to the proofreader: principal slipped in in the place of principle in the article about the lens antenna [p 25].

I cannot, simply cannot understand why people who are otherwise discrete, continue to make this kind of error; the spelling and meanings of the two words are certainly indicative that they are discreet entities.

Very semantically,
A.W. Edwards
Century Electronics
& Instruments
Tulsa, Oklahoma

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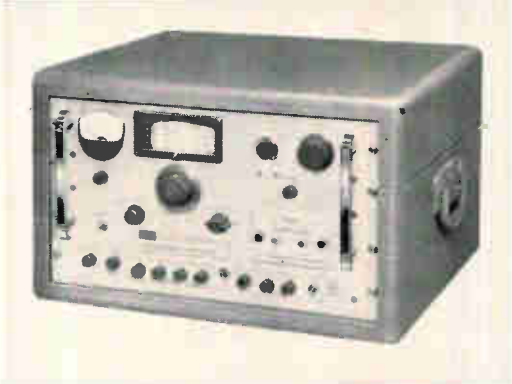
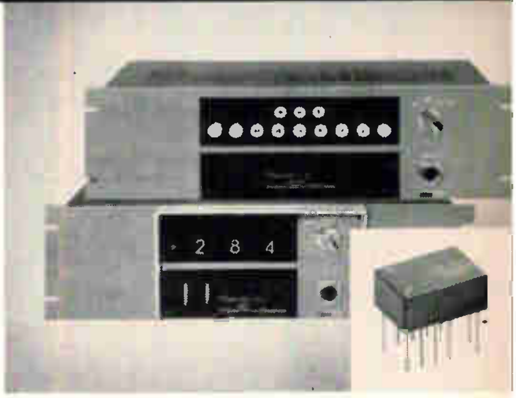
* In Jerrold products, the common denominator is quality plus creative engineering

TACO, leader in design and manufacture of satellite-tracking antennas, offers a complete range of telemetering and microwave arrays embodying the most modern antenna technology.



JERROLD ELECTRONICS rf sweep generators, such as the famous wide-plus-narrow-band Model 900-B, are trusted by discerning engineers for all their if, vhf, and uhf testing needs.



HARMAN-KARDON, through its Data Systems Division, offers a series of basic digital logic modules, digital voltmeters, and analog/digital converters which are enjoying ever-increasing usage.

Embracing the diverse industrial fields of rf test instrumentation, microwave transmission and reception, telemetry communications, and EDP data systems, the manufacturing subsidiaries of The Jerrold Corporation build uncompromising quality into the creative products bearing the names JERROLD, HARMAN-KARDON, TACO, and ANALAB. A few are shown here.

For detailed information on hundreds of specialized products that can fill your needs in electronic communications, control, and display, write

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Philadelphia, Pa. 19132
Subsidiaries: Jerrold Electronics • Harman-Kardon
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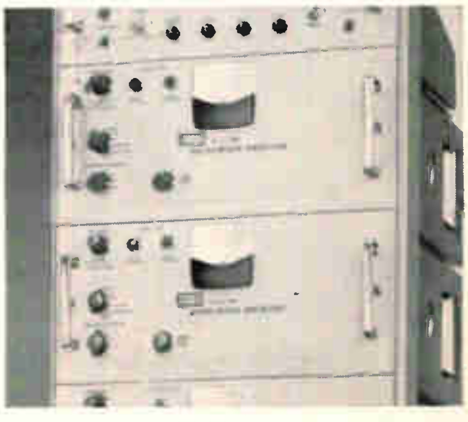
ANALAB precision oscilloscopes and scope-camera systems are being used more and more where accuracy is a must. Frequencies up to the 5-kmc range can be electronically sampled or stored on Analab scopes.



JERROLD ELECTRONICS microwave receiving and transmitting equipment answers the need for highly reliable, easy-to-maintain gear for video, voice, and data-communications applications.

See these products in Booths 3904 to 3914 at the IEEE Show.

People

Shepherding TRW Semiconductors Company's insulated-gate field-effect transistor into production—its initial outing is at the IEEE show this week—will be George Luettgenau, director of the group that developed it and operated it at up to 500 Mc as an oscillator and to 100 Mc as an amplifier.

Luettgenau's reputation in high-frequency circuit devices goes back to 1960 when he discussed his success at extending power transistor range in a paper presented at the Western Electronics Show and Conference. "It created quite a flash," he says. In 1962, Luettgenau's group got permission to develop prototype circuit designs for outside customers; the field effect transistor represents the group's latest effort.

Luettgenau was pushed into electronics by the Nazi government in 1944, when he was one of 400 German high school students selected to attend an air-force-sponsored research institute. He worked in Germany for the U. S. Army and Air Force before coming to the U. S. in 1959.

C. Gordon Little, after doing the job for a year, recently got the title —director of the Central Radio Propagation Laboratory of the National Bureau of Standards at Boulder, Colo. The laboratory is the U. S.'s final authority on radiowaves at all frequencies. Little joined NBS in 1958. His science career was precipitated by the school system in England, where he lived as a child. The system required each student to choose either science or liberal arts. Little, with no previous attachment to either, chose science.

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Meetings

Radio Technical Commission for Marine Services Meeting, RTCMS, Somerset Hotel, Boston, Mass., **March 31-April 2.**

Joint Computer Conference, British Computer Society, IRE, IEE; Edinburgh, Scotland, **March 31-April 3.**

Symposium on Engineering Aspects of Magnetohydrodynamics, IEEE, MIT; Massachusetts Institute of Technology, Cambridge, Mass., **April 1-2.**

Symposium on Microminiaturization of Electronic Equipment, British Institute of Electrical Engineers; Edinburgh, Scotland, **April 3-5.**

NAB Annual Convention, National Association of Broadcasters; Conrad Hilton Hotel, Chicago, **April 5-8.**

Nonlinear Magnetics International Conference, IEEE; Shoreham Hotel, Washington, D. C., **April 6-8.**

Protective Relay Annual Conference, Texas A&M University; College Station, Texas, **April 6-8.**

Cleveland Electronics Conference, IEEE, ISA, Cleveland Physics Society, Western Reserve University, Case Institute of Technology; Public Hall, Cleveland, Ohio, **April 7-9.**

Dielectrics and Insulating Materials Conference, IEE (Br.); London, England, **April 8-10.**

Measurement and Control Instrumentation Symposium, ISA; Hotel Floridian, Tampa, Fla., **April 8-10.**

SMPTE Technical Conference, Society of Motion Picture and Television Engineers; Ambassador Hotel, Los Angeles, **April 12-17.**

Microelectronics Symposium, IEEE; Chase Park Plaza Hotel, St. Louis, Mo., **April 13-15.**

Flight Test Instrumentation International Symposium, College of Aeronautics, Cranfield, Bedfordshire, England, **April 13-16.**

URSI Spring Meeting, National Committee of URSI, Professional Technical Groups of IEEE; National Academy of Sciences, Wash., D. C., **April 15-18.**

Aerospace Electro-Technology International Conference & Exhibit, IEEE; Phoenix, Arizona, **April 19-25.**

Rotating and Static Precision Components International Symposium, Bureau of Naval Weapons; Washington, D. C., **April 21-22.**

Spring Joint Computer Conference, American Federation of Information Processing Societies; Sheraton-Park Hotel, Washington, D. C., **April 21-23.**

Southwestern IEEE Show, Southwestern IEEE; Dallas Memorial Auditorium, Dallas, Texas, **April 22-24.**

Photographic Science and Engineering International Conference, Society of Photographic Scientists & Engineers; Hotel Americana, New York, N. Y., **April 27-May 1.**

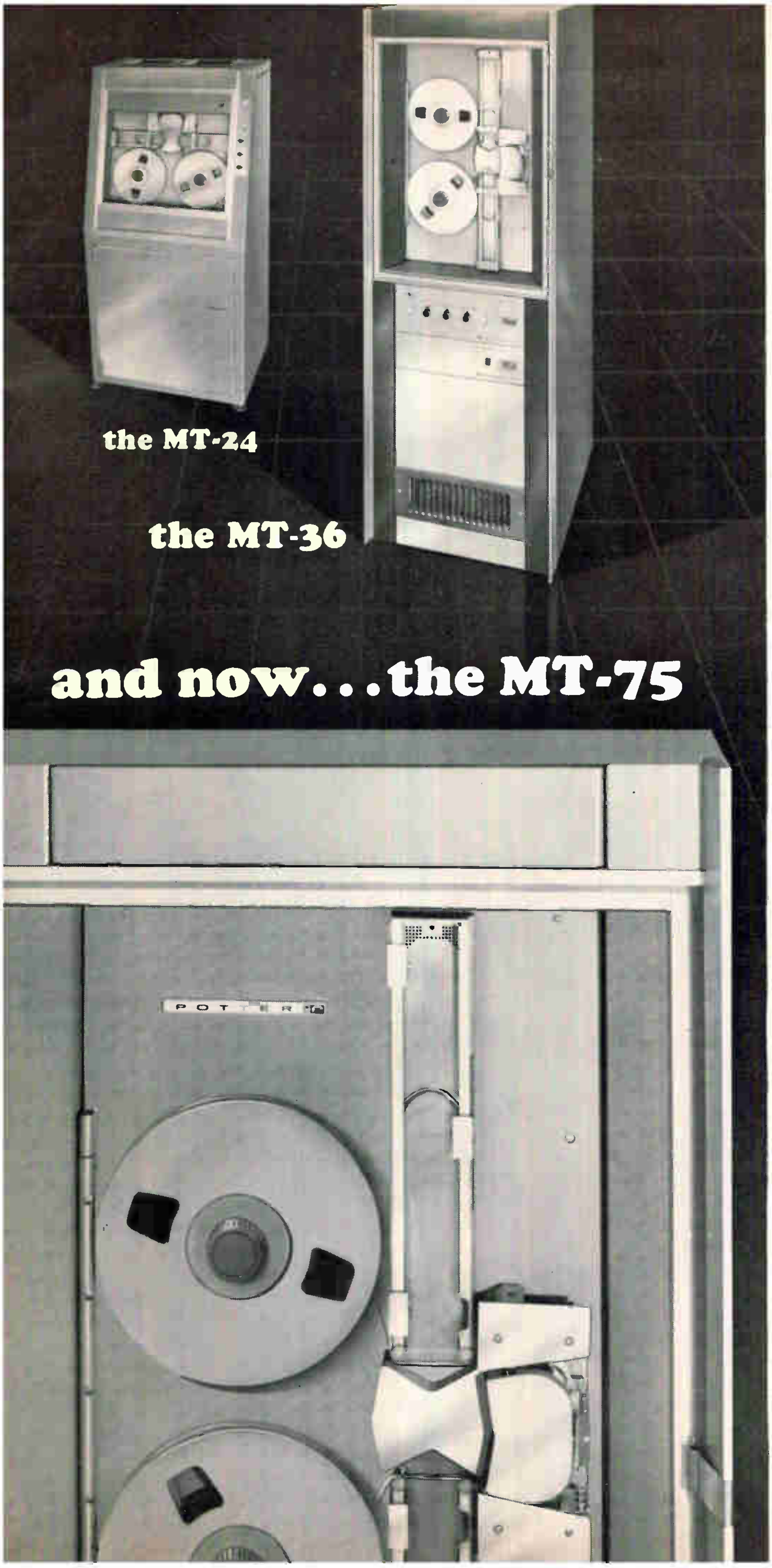
Magnetic Inductance Core Conference, Magnetic Powder Core Association of the Metal Power Industries Federation; Chicago, Ill., **April 28, 1964.**

Call for papers

Rochester Conference on Data Acquisition and Processing in Medicine & Biology; University of Rochester, Rochester, N. Y., July 13-15. April 15 is the deadline for submitting original fundamental and applied papers to Kurt Enslein, 42 East Avenue, Rochester, N. Y. 14604. Subjects covered will include medical literature, experimental data, methods of dealing with all aspects of the communications problems, and systems now in operation.

WESCON (Western Electronics Show and Convention), Los Angeles District and San Francisco Section, representing the 6th Region, IEEE, and Western Electronic Manufacturers Association; Los Angeles Sports Arena and Hollywood Park, August 25-28. April 15 is deadline for submitting: 1) three copies of a 100 to 200 word abstract; 2) three copies of a 500 to 1,000 word summary of the paper which identifies the related work and extent of new contributions in the field, and 3) indication of technical field in which paper falls. Submit to Robert R. Bennett, Technical Chairman, 1964 WESCON, Suite 1920, 3600 Wilshire Boulevard, Los Angeles, Calif. 90005. Papers in all electrical and electronics fields will be considered.

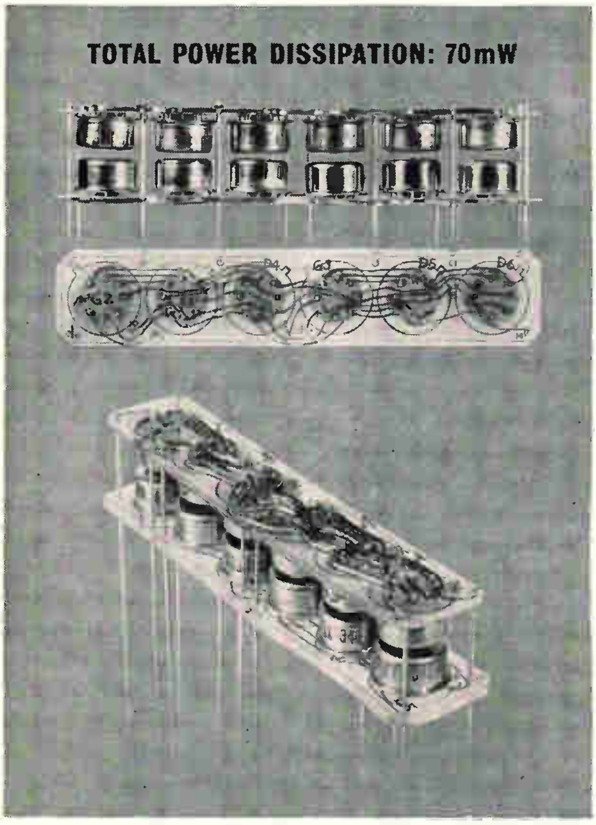
Microwaves, Circuit Theory and Information Theory International Conference, The Institute of Electrical Communication Engineers of Japan; Akasaka Prince Hotel, Tokyo, Japan, September 7-11. Deadline is May 31 for submitting a 100-word abstract plus a two-page summary of 800 to 1,200 words to Kiyoshi Morita, c/o The Institute of Electrical Communication Engineers of Japan, 2-8, Fujimicho, Chiyoda-ku, Tokyo, Japan. Some topics include microwaves, circuit theory, information theory.


the MT-24
the MT-36
and now...the MT-75
POTTER

Silicon Planar Epitaxial

NEW: LOW POWER

with 2.5 mW / node power dissipation



Three views (actual size) show high density assembly of circuits in TO-5 type packages.

This assembly of 12 low power Micrologic integrated circuits functions as a triply redundant majority voter in a space flight control system. Each module incorporates six Double Gates, three Buffers and three 4-Input Gates and has a total power dissipation of **70 milliwatts.** It is one of 80 such modules in the system.

LOW POWER This family of Micrologic circuits (MWμL™) is specifically designed for applications where milliwatt or low power dissipation is essential. Power dissipation is 80% less than standard Micrologic, while typical propagation delay is 40 nsec per stage.

RELIABILITY These low power Micrologic circuits are manufactured using the same process steps and masking techniques used with standard Micrologic, thus assuring the same high reliability proven in over 29 million hours of operating life tests.

AVAILABILITY Although its general availability is announced now, Fairchild has been manufacturing and shipping low power Micrologic to a government agency since November of 1962. These devices are now offered as standard products available directly from Fairchild distributor stocks.

SPECIFICATIONS Complete specifications on the six devices shown (at right) are now available. Data sheet also includes specifications on the 921 Gate Expander low power Micrologic element which is grouped with this family.

PLANAR: A PATENTED FAIRCHILD PROCESS

F/P-2164-B

MICROLOGIC!

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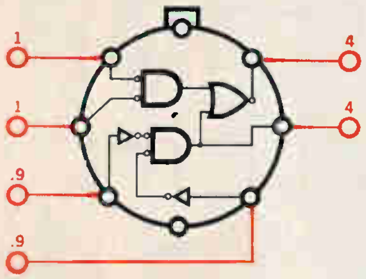

908 MODULO 2 ADDER

Generates the Mod. 2 addition or exclusive OR function. Average power dissipation: 10 mW.

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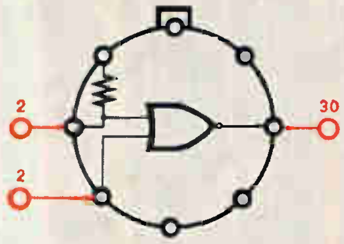

909 OATED BUFFER

A low impedance inverting driver circuit. Used typically as a line driver, in multivibrators, or for pulse differentiation. Average power dissipation: 10 mW @ 50% duty cycle.

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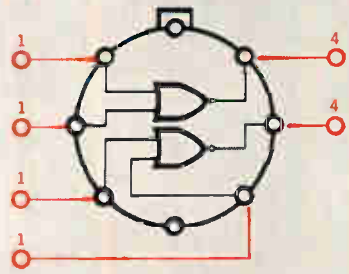

910 DOUBLE GATE

Used as a pair of NOR gates R-S Flip-Flop, pair of inverters, or double inverter. Average power dissipation: 4 mW.

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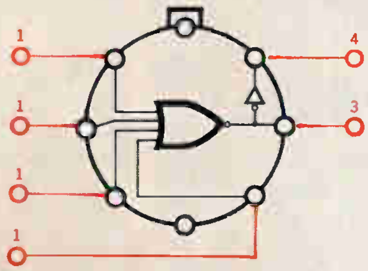

911 4-INPUT GATE

Used as an OR gate by applying true inputs. Average power diss: 4 mW.

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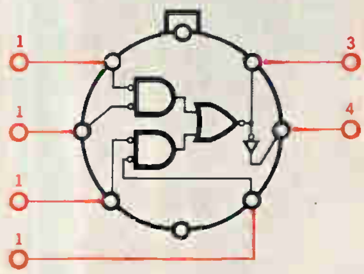
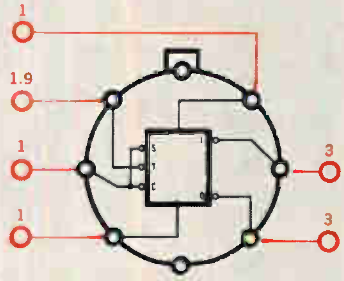


912 HALF ADDER

A multipurpose combination of three basic RTL circuits for a complete half adder or an exclusive OR gate. Average power diss: 8 mW.

LOAD FACTOR | DRIVE FACTOR



913 TYPE D FLIP-FLOP

This element is a gated Flip-Flop for use as a binary in registers and counters. Average power dissipation: 12 mW.

Logic symbols drawn in accordance with Military Standard 806B as follows: = NAND, = NOR, = INVERTER.

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SEMICONDUCTOR

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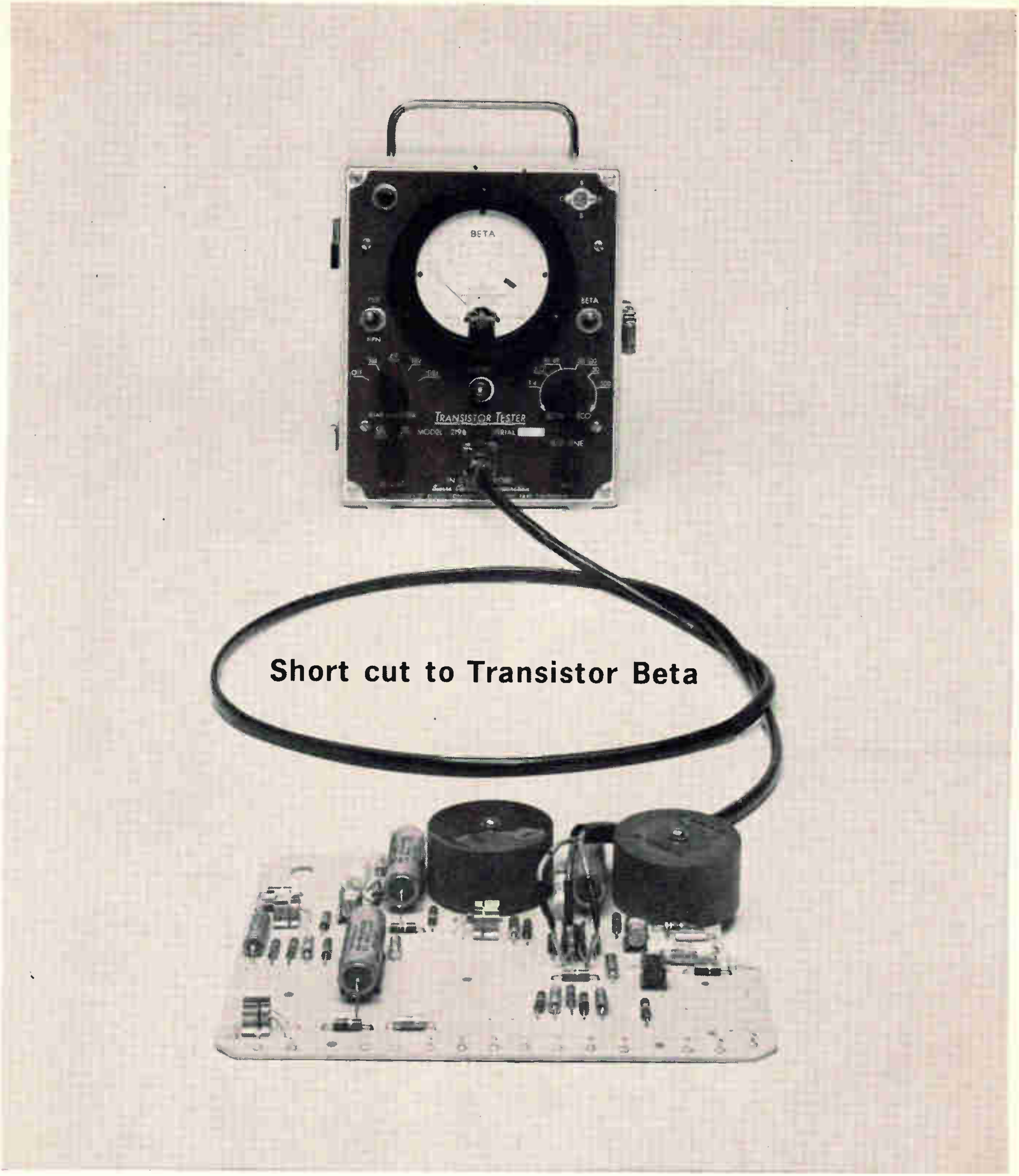

The quickest path to a transistor's Beta lies through the line that leads to a Sierra Model 219B Transistor Tester. It cuts straight through the soldered and lead-bestrewn byways of out-of-circuit testing. Takes you directly to transistor Beta in-the-circuit ☐ Model 219B reads Beta directly in-the-circuit in four overlapping ranges (1-3, 3-12, 10-40, 30-120). In out-of-circuit testing, it will measure leakage current (I_{co}) as well from 0-50 and 0-500 ma ☐ This 12-pound pathfinder carries test prods, a handbook of trenchant transistor test data, and seven small batteries for self-powered operation in its pack. You'll rediscover all these facts and more in the product bulletin available now from Sierra. Or, you can see for yourself by lining up a product demonstration with your Sierra sales representative.

SIERRA ELECTRONIC DIV.
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Sierra Electronic Division / 3885 Bohannon Drive / Menlo Park, California

Editorial

A new package for you

On this issue's cover, you will see Electronics' new signature, spelled with a capital E for the first time in the magazine's 34 years.

This departure from tradition symbolizes several changes in the magazine. We are trying to make Electronics more useful, more informative and more interesting.

Beginning with this issue, we will publish Electronics every other week instead of weekly, and on Monday instead of Friday. The reason is simple. We publish Electronics for subscribers, and enough of them told us that once a week is just too often for a technical magazine.

One improvement involves the table of contents on page 3. It is redesigned so you can quickly find articles of prime interest.

News stories are listed at the top of the table-of-contents page. They report more than just developments in electronics. They describe why these developments are important, what's really behind them, and how they fit into the fast-growing electronics field. Other articles report on technical and non-technical developments in fields such as marketing, management and personnel.

News of this kind will be found in four separate places:

1) Electronics Newsletter on page 17—a rundown of trends and last-minute developments.

2) Electronics Review on page 25—short stories interpreting the major news of the past two weeks in six fast-reading pages.

3) Washington Newsletter—intensive behind-the-scenes reporting on government activities affecting the industry (page 39).

4) Probing the News—depth studies of timely subjects. This issue's lead story (page 95), for example, digs into the status of Negroes in the electronics industry and explains why companies have difficulty finding trained Negro engineers.

Technical articles, of course, continue to be the heart of every issue of Electronics. We will publish more of these than ever before. Starting on page 49 of this issue you will find 42 pages of broader, easier-to-read feature articles.

Each article is labeled at the top so you can quickly see its area of technology. Background information explains the kinds of problems solved by each development, its applications, advantages and limitations. You will not have to be a specialist to understand and use any article. Yet each article will have enough important new information to help even the most specialized engineer.

A good example is the article, "Direct Digital Control," on page 49. It describes an important new approach to designing industrial control systems. Similarly, the article describing the application of the gate turn-off switch discusses a subject of interest to engineers from every part of the industry.

An editor is assigned to cover every major sector of the electronics field. This enables us to cover the industry broadly, yet intensively.

These assignments are outlined on page 4, where we list Electronics' staff. "Floating Departments," which may be handled by different editors, include such subjects as medical electronics, bionics and air traffic control.

We are continuing the typographic streamlining of Electronics that was started last year. Art director Howard Berry, with the help of magazine designer Bradbury Thompson, has given our pages a cleaner look designed to make them easier to read.

A lot of changes have been incorporated into this issue, and there will be more editorial changes reflecting this fast-changing industry. One thing that isn't changed, incidentally, is the subscription price.

We would like to know what you think of our efforts. Won't you take a minute to write to the editor?

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- **Operating Temperature:** -20° C to +55°C
- **Temperature Coefficient:** <0.01% per °C
- **Recovery Time:** 50 microseconds
- **Isolation:** 400 volts (except HB 2050)
- **Meters:** Voltmeter and Ammeter
- Convection Cooling
- For Relay Rack or Bench Use
- Multiple output and high voltages
- Plate, Grid and Heater Voltages
- Continuously Variable, Zero to full output

See our Complete Catalog in eem Sec. 4000, eBG PAGES 321-352

MODEL	DC OUTPUT RANGE VOLTS	DC OUTPUT RANGE MA.	REGULATION LOAD O-MAX %	REGULATION LOAD O-MAX ΔV	REGULATION LINE %	REGULATION LINE ΔV	RIPPLE RMS MV	AUX. OUTPUT 6.3VAC Unregulated	PRICE
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#3	0–400	0–150	0.025	0.1	0.1	0.4	3	10 AMP	
400 B	0–400	0–150	0.025	0.1	0.1	0.4	3	10 AMP	270.00
	0–150	0–5	*	*	*	*	1		
430 D - #1	0–450	0–300	0.025	0.1	0.1	0.4	3	10 AMP	675.00
#2	0–450	0–300	0.025	0.1	0.1	0.4	3	10 AMP	
800 B - #1	0–600	0–200	0.02	0.1	0.1	0.4	3	10 AMP	575.00
#2	0–600	0–200	0.02	0.1	0.1	0.4	3	10 AMP	
605	0–600	0–500	0.02	0.1	0.1	0.4	3	20 AMP	425.00
	0–150	0–5	*	*	*	*	1		
615B	0–600	0–300	0.02	0.1	0.1	0.4	3	10 AMP	355.00
	0–150	0–5	*	*	*	*	1		
1250 B	0–1000	0–500	0.01	0.1	0.05	0.4	3		650.00
1220 C	0–1200	0–50	0.01	0.1	0.05	0.4	3	10 AMP	465.00
1520 B	0–1500	0–200	0.01	0.1	0.05	0.4	3		695.00
HB 2050	0–2000	0–500	0.005	0.1	0.02	0.4	3		1565.00
HB 2500	0–2500	0–50	0.005	0.1	0.02	0.4	5		975.00

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CIRCLE 16 ON READER SERVICE CARD

Electronics Newsletter

March 23, 1964

NC making inroads in auto industry

The auto industry is beginning to rival the aircraft industry in use of numerically controlled (NC) machines. Detroit's Big Three auto makers are reported to have well over 100 such machines in use, but they won't talk about them. **NC is a hot issue between unions and management.** One manufacturer is already in litigation over NC use.

Die-making is one of the latest applications of NC's ability to automatically shape metal in three dimensions. First, probes "feel" a plastic model to gather the 3-D data needed for the punched tape that controls the cutting machine. Then, any quantity of identical, precision metal dies can be made. **Some tool and die makers are said to be watching this development with horror.** If the machine proves out, 40 tool and die shops that are NC equipped could handle the work that 400 now get.

An NC computer-drafting machine draws three-dimensional views of proposed auto models so the designers can tell what the car would look like from a tall building, or a mile down the road.

EIA frets over foreign markets

The upsurge in foreign nationalism and self-sufficiency is creating industrial as well as political headaches, according to the delegates to last week's spring conference of the Electronic Industries Association. They agree that the U. S. electronics industry should expand overseas sales—to its own as well as foreign governments' advantage—but they are aware that **obtaining new international markets gets tougher every year.**

To ease the way, Harold M. Landau, marketing director for Raytheon Co.'s European operations, called for **establishment of an international market research center** to help boost sales of U. S. defense-developed technology throughout the free world. He said the quasi government-industry center would "determine who we are in terms of national, industrial and technical strength; where we are in world competition; where we want to go in terms of national, economic, political, technical and military objectives; and how to get there in regard to alternate routes possible."

1964 to be colorful year

Japan is about to let down its trade barriers on U. S. color-tv sets but it is unlikely that U. S. manufacturers will rush into that market. They are much too busy trying to satisfy the expected demand here.

Japan's Ministry of International Trade confirms that the government will remove restrictions on the use of foreign exchange for color-tv imports "sometime this year"—probably in April. Japanese manufacturers aren't too concerned. For one thing, the price of a **U. S. 21-inch color set would be about $840 in Japan—far too costly for the average Japanese.** Besides, the manufacturers remember that restrictions were removed from black-and-white sets some time ago and the number of sets imported has been negligible.

Meanwhile, U. S. color picture tube manufacturers are gleefully anticipating—and frantically tooling up for—**a 1964 market of 1.5 million tubes for new sets, plus replacements for the 1.5 million sets already in existence.** Radio Corp. of America last year kicked off an $11.6 million expansion program and estimates it will produce 1.3 million color tubes in 1964—far below expected demand. Motorola Inc.'s $5 million investment in National Video Corp. is paying off with a build-up in the tube production. Sylvania, running its reopened color-tube production, lives on a 24-hour, 6-day week after doubling its labor force to 720. (Sylvania just joined the rectangular color tube makers.) Zenith Radio Corp. has Rauland Corp. working at top speed. It's full color ahead.

Radiation falls as satellite rises

There is new evidence that radiation may not be as serious a hazard in space travel as was thought. It may be relatively mild in outer space compared with the intensity of radiation belts closer to earth.

Preliminary reports based on findings from NASA's Interplanetary Monitoring Platform indicate that **astronauts may find smooth sailing after they get beyond the intense radiation** trapped in the earth's magnetic field. Temporary electrical shielding might protect the space traveler on the first leg of his journey.

The reports were given March 12 by scientists who have radiation-gauging equipment onboard the space platform. The reports were not conclusive because the data covered only the first 19 orbits, extending 122,800 miles into space, and because the sun, a prime source of radiation, is throwing out relatively little radiation now.

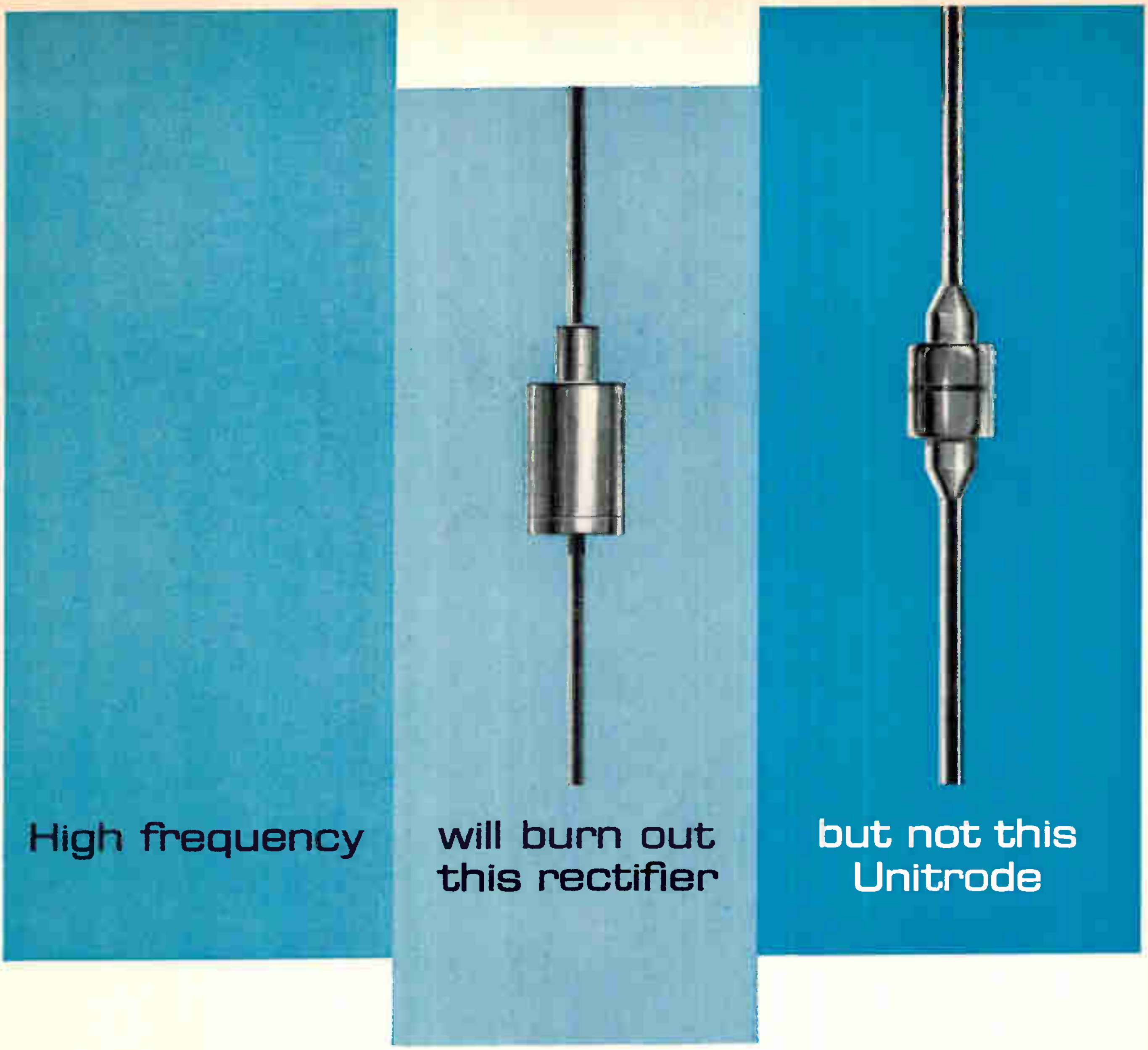
The NASA satellite found that **the earth's magnetosphere extends out about 40,000 miles.** The magnetosphere moves against the solar wind like a missile nose-cone in a supersonic wind tunnel. Where the solar wind hits the megnetosphere, a shock front creates a turbulent wake. On the sun side of the shock front, practically no high-energy radiation particles were detected. But the wake is filled with them, indicating that the particles accelerate and gain energy in the shock wave. About half the particles apparently get trapped in the Van Allen belts.

Programed hamburgers

Now that American Machine & Foundry Corp. has made pin boys passe in bowling alleys, it is trying to automate another bit of Americana—the drive-in hamburger stand. **But so far, the system isn't threatening those long-legged carhops.** The carhop still takes the order. Then she turns the slip over to a girl behind a key-punch console. Hitting the right keys orders the kitchen to fill the order automatically or manually. The food comes out on a conveyor belt and the system prints out the check. Developed by Shepard Labs, Inc., of Summit, N. J., the system has already been field-tested at a Long Island drive-in.

Neurotic Computers

Those who complain of the progressive dehumanization of life as a result of machines may be heartened by news of the progressive humanization of computers. A psychiatrist at Stanford University, working with an IBM 7090, **has programed the computer to simulate a woman patient's anxieties** and indecisions about men, so that the psychiatrist can ask the computer questions and explore its answers without having to worry about mistakes. The "patient's" vocabulary contains 257 words and its "mind" holds 105 beliefs. Certain arrangements of words form beliefs, and certain groups of beliefs form "complexes." What happens if the 7090 is told something that conflicts with its beliefs? It develops a simulated anxiety attack, of course.



Now Unitrode eliminates excessive reverse power dissipated in the diode during turn-off. This means you can reduce ripple and the size of transformers and filters by increasing operating frequency.

At 100 KC, the rectification efficiency of the Unitrode® fast-recovery rectifier is only 1% less than at 60 cps. Reverse recovery time is typically 75 nanoseconds . . . and continuous average rectified current ratings are 2 amps even with PIV's of 600 volts!

Unitrode makes this possible by a novel silicon diffusion process that nearly eliminates the reverse current spike during turn-off — and considerably shortens turn-off time. Further, the new fast-switching series has the unique one-piece Unitrode construction that survives long term overloads without damage and is immune to aging effects.

With a hard glass sleeve fused to all exposed silicon surface, the resulting void-free junction cannot be contaminated. And they're no bigger than . . .

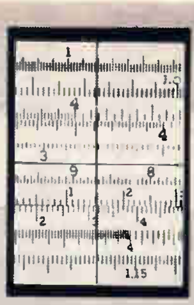
. . . this

Individually inspected, 100% tested, Unitrode fast-recovery rectifiers have to cost more than ordinary rectifiers. But if performance is more important to you than pennies, compare all the remarkable devices based on the Unitrode principle: 3-amp silicon diodes, 3-watt zeners, high-voltage stacks and bridge assemblies. They're stocked by Unitrode representatives nation-wide.

For information, product demonstration and samples, contact UNITRODE TRANSISTOR PRODUCTS, INC., 214 Calvary Street, Waltham, Mass. 02154. Tel. (617) 899-8988, TWX (617) 894-9876.

UNITRODE

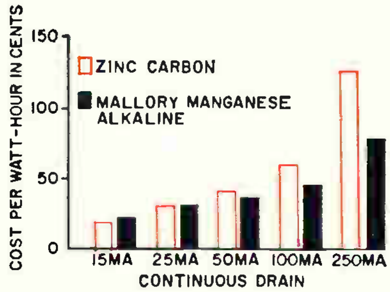
IEEE Booth 1102



MALLORY

P. R. MALLORY & CO. INC., INDIANAPOLIS 6, INDIANA

Manganese Alkaline Batteries Give Long Life on High Drain Service



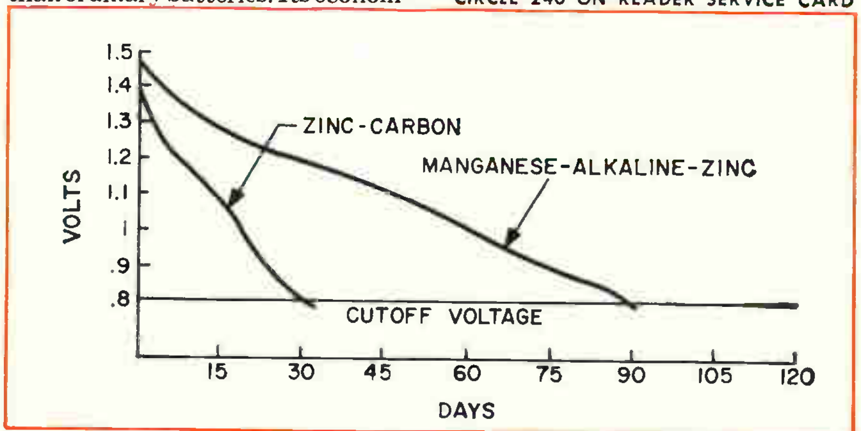
There are numerous applications requiring a dry battery capable of delivering relatively high currents, continuously or intermittently. Among these are motor drives for cameras and tape recorders; lighting; photoflash, including strobe lights. For this type of use, the Mallory Manganese Alkaline system offers superior performance and economy. It is a high energy system, with qualities of stability, service life and storage life approaching those of Mallory Mercury Batteries . . . and especially applicable to heavy duty service.

The manganese system delivers 25 to 35 watt-hours per pound, or two to four times that of zinc carbon batteries. At current drains of 50 MA and higher, it has considerably lower cost per watt-hour than ordinary batteries. Its economical advantage increases as drains go higher (see chart).

The voltage of the manganese system, although not as stable as that of Mallory Mercury Batteries, stays far more constant throughout service life than with conventional batteries. The system, moreover, has low impedance (less than 1 ohm per cell) and can often be used to a lower cut-off point than zinc carbon cells.

Through the use of internal construction comparable to the mercury system, Mallory Manganese Alkaline batteries have exceptionally long storage life. Capacity loss after three years of storage at 70°F is in the order of 20% or less. Double steel case effectively prevents leakage. A complete line of standard cell sizes is available.

CIRCLE 240 ON READER SERVICE CARD



Life span of cells discharged into 60-ohm loads for 8 hours per day at 70°F.

Mallory Film Resistors pass flame resistance test

If you're concerned with ability of components to survive severe overloads safely, here's a report on Mallory MOL metal oxide film resistors that should interest you.

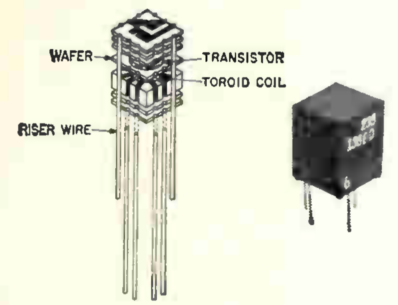
The first part was easy. The MOL resistors were subjected to 1.1 times rated voltage for nominal wattage for 3 minutes. There was no smoke or odor. Then came the tough part. For 1 minute, an overload of 2.25 times rated voltage for nominal wattages was applied—increasing to 3.15 times rated voltage, until the resistors reached maximum temperature. In spite of this abuse, there was no flame or emission of molten material.

Flame resistance is just one of the "extras" you get with MOL resistors. They are exceptionally stable: resistance changes less than 1% in 10,000 hours of life test at rated voltage, and holds steady even under long exposure of 95% relative humidity. Ratings of 2, 3, 4, 5 and 7 watts are available, with resistance values ranging from 30 ohms minimum on the 2 watt to a maximum of 125 K ohms for the 7 watt unit.

CIRCLE 241 ON READER SERVICE CARD

DESIGNER'S FILE

Highly Reliable Micromodules Produced in Quantity

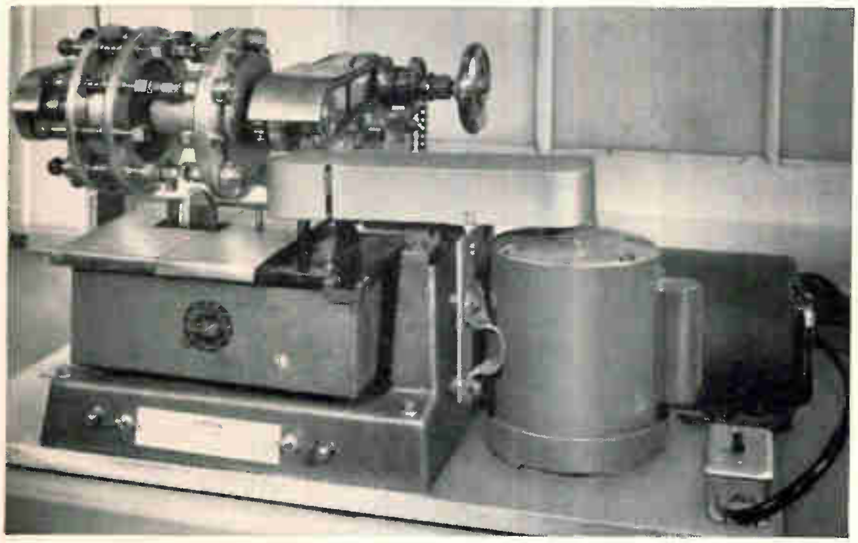


Typical micromodule assembly. Diagram at left shows method of assembly. At right is completed module, shown actual size.

For manufacturers who are planning miniaturized circuitry using the micromodule design concept, Mallory has developed techniques and facilities for assembly of micromodule packages. These facilities constitute a complete, integrated system capable of producing packaged wafer circuitry on economical production basis, either for pilot production or for volume manufacturing. Using the tooling which we have developed, we have produced thousands of micromodules of many types during the past few months. We have capacity for production at rates exceeding 1000 modules per week, including mechanized methods for testing of individual wafers, handling, orientation, soldering, encapsulation and final tests of complete modules.

Micromodules offer one of the few approaches to microminiaturization applications with well documented reliability. Our engineers can work with you to modularize your circuit, applying this method of disciplined geometry to both digital and analog circuitry.

CIRCLE 242 ON READER SERVICE CARD



Special soldering fixture is typical of Mallory production tooling.

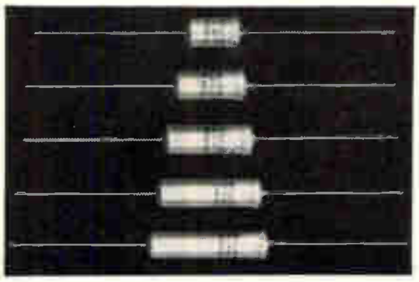
Elkonite® parts add stability to high-power vacuum tubes

Inside of high-power klystrons, magnetrons and other big electronic tubes, there are some unusual materials problems which are being solved by Mallory Elkonite materials. For structural elements, designers often need a combination of high conductivity and good strength at elevated temperatures. If you use different metals in combination — one for conductivity, one for strength, you're apt to run into unequal expansion which causes changes in geometry, and thus makes frequency drift.

Elkonite materials can give you combination of properties which you can't find in natural materials or alloys. They are powder metallurgy products in which a refractory material such as tungsten or molybdenum is merged with a conductive material such as silver or copper. Elkonite materials have good strength at elevated temperatures, coupled with good electrical and thermal conductivity. By varying composition, we may be able to tailor-make the exact properties you need.

CIRCLE 243 ON READER SERVICE CARD

Miniature TCW electrolytics for transistor circuits



You can get a lot of capacitance . . . and a lot of quality . . . in this compact-size line of aluminum case electrolytics. Designed especially for transistorized equipment, the TCW series has a combination of excellent stability and economical price which makes them a leading choice in industrial and entertainment equipment. Long service life is assured by all welded construction, with positive end seal. Leakage current and ESR are uniformly low and stable.

TCW's are rated for ambients from −40°C to +85°C. Standard case size is 3/8" diameter, in lengths from 5/8" to 1 5/8". Ratings range from 545 mfd., 3 volts to 20 mfd., 150 volts. Available with or without Mylar* insulating sleeve. Case sizes up to 1" diameter and voltages up to 350 WVDC available on request.

*Registered trademark, E. I. du Pont de Nemours

CIRCLE 244 ON READER SERVICE CARD

ABRIDGED DATA

Cathode	IH
Heater	6·0 V 1·0 A
μ	100
r_a	4·0 KΩ
g_m	25 mA/V
P_a (max.)	100 W
V_a (max.)	1 000 V 3 500 V (pulsed)

Typical Class C Output

20 W at 2 500 Mc/s
1 600 W at 3 000 Mc/s
(peak)

HIGH SLOPE UHF TRIODE

This forced-air-cooled high slope triode, which conforms to the USA JAN-7289 specification, is the latest STC addition to the 2C39A family. Its construction, which includes a ceramic/metal envelope, is more rugged than that of the 2C39A. Also, the distributed inductance and capacitance of the grid/cathode and grid/anode configurations are more tightly controlled. In most cases this valve can be used as a unilateral direct replacement for the 2C39A. The 7289 is for use as a power amplifier, oscillator or frequency multiplier up to 3 000 Mc/s. Write, 'phone or Telex for Data Sheets to STC, Valve Division, Brixham Road, Paignton, Devon, England. USA enquiries for price and delivery to ITT Electron Tube Division, Box 104, Clifton, New Jersey.

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COMPONENTS GROUP

64/10MS

TICOR II

ON-LINE DATA REDUCTION...IN THE LABORATORY

Mincom's TICOR II 1.5-mc Recorder/Reproducer expands your existing data reduction capability to standards previously considered impossible. Radar recording, single sideband, serial PCM and other time-base-sensitive systems are now handled easily and dependably by TICOR II—fixed-head longitudinal recording of as many as fourteen channels. Flutter components below 200 cps are essentially removed. Time base correlation between events is held below ± 0.5 μsec anywhere on the tape. TICOR II's installation in your data reduction center enhances the value of all your current field and lab recording systems. Rapidly convertible from 1/2-inch to 1-inch tape operation. All solid state, one equipment rack, completely RFI-shielded. Write for specifications.

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Electronics Review

Volume 37
Number 12

Military Electronics

International shakedown

In July of this year, 24 British sailors and two officers will board the guided missile destroyer USS Biddle to replace an equal number of U.S. Navy personnel. Thus begins a test run of the projected multilateral force (MLF)—a fleet of harmless-looking merchant ships manned by a mixed crew of NATO personnel, with Polaris-type missiles tucked away below deck.

Other nations will follow the British and, by December, 1964, of the crew of 18 officers and 315 men 54% will be American and 46% allied. Nations that have agreed to put men on the Biddle so far are West Germany, Greece, Turkey, Italy, the Netherlands.

Togetherness. Although the equipment on the Biddle will not be the same as that being considered for the MLF, it will provide operational experience with complex weapon systems such as the Asroc antisubmarine rocket and the Tartar surface-to-air guided missile; it will also provide a test for how well the different nationalities can live together—can Greeks eat Italian spaghetti? can anyone eat canned American spaghetti?; and probably most important, it will keep the MLF concept alive while the Atlantic Alliance is going through this current period of stress and strain.

Plans for the MLF call for 25 merchant-type ships, each carrying eight ballistic missiles. Cost of the fleet would be close to $2.2 billion—40% of which the U.S. would pay. The ships would probably be built in NATO countries and the weapon system in the U.S.

There's no official decision yet on what weapon system the ships will use. Of the two main contenders—an advanced Polaris (A-3) missile and the USAF-sponsored Mobile Mid-Range Ballistic Missile (MMRBM)—the Polaris seems to be winning by default. Congress has cut the MMRBM program back severely, and only its stellar-inertial guidance seems sure to survive.

Ideal for wanderers. The guidance system, which actually was a going project before the missile was even begun, could be used on any missile chosen for the MLF—even the Polaris A-3—if it is operational in time. A stellar system is ideal for a wandering fleet such as the MLF, and could eliminate the need for expensive shipboard navigation such as the Ships Inertial Navigation System (SINS) used on Polaris submarines. With a stellar-inertial system in the missile, the ship would not need to know its own position so precisely. Right after launch, the missile would take a fix on the stars, determine its own position, and calculate a trajectory to the target.

While the MLF is a panacea for some, it is an absurdity to others. The reactions to the concept are so widely divergent that it may never come into being. More than being controversial, it is a seaborne Rorschach test. Everyone sees in it his own hopes or fears.

How they see it. Admiral Claude Ricketts, Vice Chief of Naval Operations, sees the MLF as a logical extension of NATO. The Johnson administration sees it as a way to discourage proliferation of nuclear weapons—which it failed to accomplish with France. Germany sees it as a way to share nuclear power. Britain dislikes it, and Labor Party leader Harold Wilson says he would agree to it only if it were the sole way to keep Germany from becoming a nuclear power (which Germany could be by going in with France).

Polaris missile contractors may one day get brand new business from this $2.2 billion plan. On the other hand, they may not.

The decks of the USS Biddle will be the proving ground for a proposed multilateral—and multilingual—force.

The 30-mile zone

The Navy has found a way to double the range of its electronic "eyes." A sonar "alert ring" now can be extended to a radius of about 30 nautical miles around a transmitting ship. The previous limit was 15 miles. When a surface ship or submarine crosses the circle, the transmitting ship detects it and can launch a weapon against it.

The widened range is a result of the Navy's conquest of the convergence zone—a sound channel deep in the sea. The Navy has learned to bounce a signal off the channel to the surface. The technique is like over-the-horizon radar turned upside-down and used under water.

The phenomenon is a result of action by two conflicting forces—temperature and pressure—on the sonar signal in water. Increasing cold deflects a signal downward, while increasing pressure bends it upward. Both cold and pressure increase with depth, so both forces act on the signal. For the first 2,500 feet, however, the force exerted by the increasing cold is stronger than that caused by the pressure; hence the signal keeps going down. Below 2,500 feet, where the sound channel begins—it ends at 15,000 feet—the temperature is quite constant but the pressure continues to increase.

Consequently, the upward force predominates and sends the signal to the surface. Because of the near-horizontal angle at which the initial sonar signal is transmitted, the signal ends up on the surface again approximately 30 nautical miles from the transmitting ship. If it meets a reflecting surface, the signal will bounce back along the same route, down to the sound channel and then up to the sending ship's receiver.

The AN/SQS-26 sonar also can bounce signals off the ocean bottom when operated at a steeper angle. Although the Navy won't say, it seems logical that if one-bounce convergence-zone sonar is good, two bounces would be better. If the Navy does come up with a sonar that works at 60 miles, a follow-on weapon would be needed.

Business at sea

Navy's new Instrumentation Ship Project Office has made two important innovations in contracting.

- For the first time, Navy will name an electronics company as prime contractor for a ship-conversion program. The contract will be in the $100-million range.
- Bidders will not have to submit costly technical proposals—a thankless task for the losers. 18 Navy engineers are preparing the specs.

Capt. Alex F. Hancock heads the new office which is under the Chief of Naval Materiel, and is administratively located in and supported by the Bureau of Ships. The project office will equip and check out all instrumentation ships in support of all Defense Department and civilian space agency (NASA) tracking needs.

In the new missile-range chain of command, users of the Atlantic Missile Range and parts of the Pacific Missile Range will submit program requirements for ships, aircraft and land equipment to the National Range Division (NRD) of the Air Force Systems Command. If ship equipment is needed, and NRD doesn't have it, NRD will ask Capt. Hancock's office to get it and install it. The Military Sea Transport Service will man and operate the ships. The range agencies will schedule them and be responsible for their instrumentation.

Good customer. The project office will be a big buyer for a long time. There are now 17 instrumentation ships, and NRD wants three more. They will be used for tracking and data acquisition in the Project Apollo lunar-landing program. Two of the existing ships will be extensively modified for Apollo. On all the ships, old equipment will continually give way to new gear. New programs will undoubtedly call for new ships and new gear in the future. (The project office wasn't formed in time to handle the big uhf modification on the second Atlantic Instrumentation Range Ship, ARIS. Air Force bought the equipment and BuShips will install it. But there will be more work in fiscal 1965 on the ARIS ships and sizeable upgrading on the American Mariner.)

Sliced ships. The three new ships for Apollo will be converted T-2 tankers (the ships will be sliced in two and a new midbody 374 feet long will be inserted). One electronics prime contractor will design, fabricate, install and check out the instrumentation and electronic systems for all three ships.

To save time and money for both Navy and industry, Navy isn't asking for technical proposals. Industry will submit only methods and management proposals, without prices. Proposals, due April 6, should tell how the bidder will handle and coordinate electronic and shipyard portions of the work.

Microelectronics

Minuteman by products

Makers of civilian equipment can now buy the microcircuits that guide the Minuteman missiles.

Last year the Autonetics division of North American Aviation, Inc., ordered 140,000 microcircuits, and this mass production was expected to encourage a swing to microcircuits for military and civilian use.

Now that expectation is being put to the test. Texas Instruments Incorporated of Dallas, which got the lion's share of that order, said last week it would sell 18 types of the circuits on the open market.

Autonetics is building the guidance, control and checkout system for the Air Force's improved Minuteman, the first major military system to go microelectronic. Autonetics is buying 23 kinds of semiconductor integrated circuits from Texas Instruments, Westinghouse Electric Corp. and the Radio Corporation of America, mostly for the missile's airborne computer.

When the computers began coming off Autonetics' production line last fall [Electronics, Nov. 1, 1963, p 14], a big problem was the small number of satisfactory circuits that the suppliers could make.

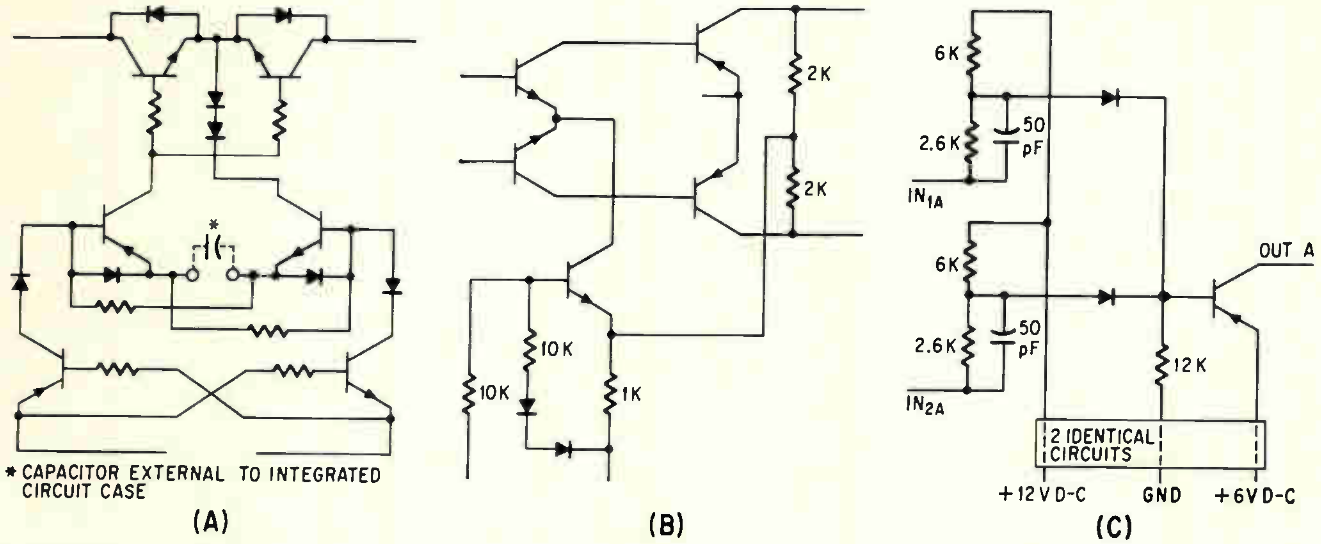
Now Texas Instruments says it has improved its yield, is meeting Minuteman delivery requirements, and can produce extra circuits on the same lines to the same specifications. Autonetics gave Texas Instruments the OK and Air Force didn't object.

TI stole a march on Westinghouse and RCA. Westinghouse is now charging along the same path. It is also producing a surplus of Minuteman circuits—the surplus may soon be 50%. The open market would be a good outlet for slightly modified circuits that don't meet Minuteman's rigid requirements. Westinghouse makes 17 circuits.

RCA recently slipped several Minuteman-type devices into its catalog.

Texas Instruments expects most of its sales to be to military-equipment companies. The circuits now cost $22 to $165, steep for most commercial applications. Even so, a lot of customers have been making inquiries. With the new line, 75% or more of a military-type, general-purpose computer can be built. Autonetics is using them in its own Monica J aerospace computer.

The specifications, incidentally, are Autonetics', too. The Air Force hasn't any specs for integrated cir-



Minuteman units. These are the demodulator-chopper (A), a general-purpose amplifier (b) and matrix switch (c) that Autonetics designed for the improved Minuteman missile

cuits. That will be remedied soon. Autonetics is drafting military specs under an Air Force contract.

Texas Instruments' new line is based on diode-transistor logic. There are input and output gates, memory reading and writing units, a flip-flop and four NAND gates as the logic circuits. The linear circuits are a demodulator chopper, driver switch and four units that can be used as operational amplifiers.

Industrial electronics

Automation vs. antitrust

The United Mine Workers plan to appeal to the U. S. Supreme Court a lower court's ruling that is bound to have a profound effect on the $400 million controls market.

The issue goes back to the 1950's when John L. Lewis, the union's president at the time, agreed to let the coal-mine owners automate. The owners eliminated 70% of the mining jobs and the remaining UMW men received higher pay and benefits. But the small mines could afford neither the automatically controlled equipment nor the higher pay scale. One company, Phillips Brothers, brought an antitrust suit against the UMW in a U. S. District Court in Knoxville, Tenn., and won in 1961.

The court held that the union and the big companies could not "conspire" to spur automation and thus squeeze the smaller coal companies out of the industry. On Dec. 18, the U. S. Sixth Circuit Court of Appeals in Cincinnati again decided (Pennington vs. United Mine Workers) in favor of Phillips.

Whatever the Supreme Court decides, there's trouble ahead. Most industries today—steel, glass, chemicals and shipping, to mention a few—face what coal did in the 1950's. They are in highly competitive markets and look hopefully to automation for some solutions. But Pennington vs. UMW will make them stop and reexamine their plans.

Little interest aroused. Despite its implications, the case has received remarkably little attention. Only the unions seem to be following it closely.

Several questions immediately arise. At what point is it a conspiracy to bargain collectively over new machines and methods? Does the trend to continuous union-employer study groups lay both sides open to charges of monopoly or restraint of trade? Must unions always object to automation just to prove they are not conspiring? Is automation making antitrust laws obsolete?

The government has a big stake in the outcome, too. If Phillips is upheld, the Justice Department may find it impractical to try to stem automation by intervening in the execution of a labor contract. But if the agency refuses to do so, its decision will be an invitation for a political charge that big government always sides with big companies and big unions.

Exit computers

One of the most backward industries, when it comes to automatic process control, has just greased a couple of skids for computer process control. And computer firms on both coasts are worried.

The New England-based Fitchburg Paper Co. has discontinued operation of its IBM 1710 process system. That makes the third such discard in less than a year. (Two systems have been discontinued and delivery of another is reportedly deferred.)

The main reason, said to be one plaguing the entire industry, is inability to program the papermaking process.

The Fitchburg system was installed in August, 1962. After 18 months, the system was thought ready to go on-line, closed-loop, to measure basis weight (the weight of a sheet of paper 3,000 ft. long, the basis of all paper selling and buying), but the axe fell first.

Feeling their way. Robert Walker of Fitchburg's engineering team says it was programming trouble. "It [the paper process] is a more complex problem than we had hoped it to be. The mathematical model of our process is extremely complex. We haven't been able to program all the actions of the people working on the machines. There are too many variables controlled by feel, a sense of touch resulting from years of experience." And, he added, "papermaking is far from a pure science, still mainly an art, depending to a large extent on the skills of experienced operators."

Programming difficulty (which an IBM spokesman says is no problem at all) seems to be only one of many. Economics, company politics and, of all things, the cost of controlling air pollution are reported to be large factors.

What good is it? Last year, just about the time the Health, Education and Welfare Department concluded a report blaming Potlatch Forest Industries, Inc. of Lewiston, Idaho, for the highly corrosive air over that city, the paper mill stopped using its 1710 system. But William Gray, Potlatch's executive vice president, said the reason for scrapping the process computer was the lack of accurate, reliable instrumentation.

"For us, using a process computer now, at a time when our facilities and instrumentation need so much updating is like giving a three-year-old a chronometer—what good is it to him, what good does it do for him?" says Gray.

Potlatch is reported to be spending over $1 million in extensive modernization and instrumentation—and say they plan to use an IBM system again in about a year, open loop, to gather data on the efficiency of their modernized process. Then, according to Gray, the company will "resume pulp and papermaking under control of IBM's equipment."

Fitchburg, which was recently acquired by Litton Industries, is another case. George R. Wallace, III, Fitchburg's new president, wrote in an interdepartment memo that ". . . a review of the installation reveals that it does not now, nor can it be expected in the near future, to provide a return on our investment. Management therefore concludes that further use of a process control computer must await a higher state of development in the computer art. We are therefore discontinuing use of our process computer."

No comments. For some time IBM has been operating a pilot paper mill at its Yorktown Heights, N.Y. research center, using it to find solutions to the problem of instrumenting the papermaking process. The company has refused to comment on the action of the paper mills except to say that "removal of the 1710 is not due to failure of the machine to perform but for other considerations."

Whatever the other considerations, process computer manufacturers on both coasts are depressed. They have expressed off-the-record apprehension that the Fitchburg development may push the paper industry back five or more years in its acceptance of the computer as a useful tool.

Components

Big hopes, small diodes

The Hughes Aircraft Co. is so sure that its new microglass diode will be the ultimate in microminiature components that the company is boosting its production capacity to a million a week and hoping for further increases.

The diodes—there are 10 types with ratings up to 100 volts and 300 milliamperes—are being shown for the first time today at the IEEE Show. Dr. Dietrich A. Jenny, manager of Hughes' Semiconductor division, thinks the diodes (photo) are the last word in discrete components—the most sophisticated of the conventional diodes.

Each diode is a chunk of glass and metal only 60 mils in diameter and 30 mils high. A diffused-junction silicon die 20 mils square is sealed hermetically inside. The die is bonded to a wide-area silver contact. The diode is sealed twice, once by a glass-to-silicon seal, then into the glass pellet.

Discrete move

The Westinghouse Electric Corp. is betting on a glass capacitor to help the company grab a chunk of the market in high-reliability discrete components.

Despite the threat of competition from microcircuit technology, Westinghouse has been quietly acquiring know-how in these discrete components designed for use in missile and airborne computers, guidance systems and communications gear. Its researchers have long since solved the problem of hermetically sealing plates, leads and contacts into glass.

It may be significant that Westinghouse has hired at least two former employees of the Corning Glass Works, which, with Vitramon, Inc., of Bridgeport, Conn., dominates the field of high-priced, high-reliability glass capacitors.

J. Peter Hegg, who came to Westinghouse last year after three years at Corning, is product manager of the capacitor division. Robert Randell, who worked on capacitors for five years at Corning, insists that he has had only the slightest connection with the Westinghouse glass capacitor.

The quality capacitors made by Corning and Vitramon are produced to military specification MIL-C 11-272B, which lists both companies' products on its "qualified" list. But in practice Corning is the sole source for capacitors of the CY10, CY15, CY20 and CY30 types. At least two big manufacturers of original equipment want

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Ammeter	8	0.51110 μa to 5.1110 amperes	10 picoamperes
Resistance Bridge (4 terminal, guarded)	10	0.51110 ohms to 511.10 megohms	10 microhms
Comparison Bridge (4 terminal, guarded)	To 5.1110 times reference standard	1.0000	0.01%
Ratiometer (Direct reading)	3	0 to 1.00000 0 to 0.051110 0 to 0.0051110	1 part in 10^{-5} 1 part in 10^{-6} 1 part in 10^{-7}
Null Detector	Sensitivity—5 microvolts; Input impedance—approximately 1 megohm; AC rejection 60 cps and up; 80 db, Guarded, battery operated.		
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a second source of the capacitors. And that seems to be the role Westinghouse intends to fill.

Microwave

Self-pointing antenna

An experimental X-band antenna at the research facility of Electronic Communications, Inc. in Timonium, Md., may point the way to more efficient and versatile tracking and communications systems. It reverses an incoming signal so it goes back to exactly where it came from, despite disturbances in the atmosphere.

ECI's Merrill I. Skolnik and Donald D. King, who are developing the array, think it may make feasible the wireless transmission of r-f power from, say, earth to an orbiting space platform. The system would work like this: once a low-power pilot signal has linked the ground transmitter and the space vehicle, the signal is amplified and retransmitted as coherent r-f power to the receiver in the space vehicle.

The antenna is a self-phasing array of 64 horn elements that react to a received signal from a communications transmitter, radar beacon or radar target. If the target is moving, the array doesn't need the usual tracking information to follow it—the beam that it transmits follows the target's position automatically. Conventional phased-array radars require external phase control of the antenna elements to move the beam.

In some respects, the self-phasing array is like the antennas that adapt to changes in the troposphere. However, those antennas only receive signals, while the new array can both send and receive.

The array is arranged as a large aperture, divided into 64 subapertures, or horn antennas, arranged to allow any desired array configuration. To each subaperture is connected a network that reverses the phase of any signal received, by performing a conjugate operation. Each of the 64 subapertures then retransmits the reversed signals, which add coherently to one reversed signal.

Putting bigger horns on the little horn radiators improves concentration of the radiated r-f power

Analysis of the array shows that the signal from each subaperture is independent of the transit time between target and receiver. As a result, perturbations of the propagation medium, which affect microwave and troposcatter systems, do not affect this system.

Development work on the antenna has been sponsored by the Air Force's Rome Air Development Center, Rome, N. Y.

Employment

Shifting patterns

Despite some curtailment of military orders, electronics continues to be a growth industry and a good job market.

Government business is spread thinner and, in some cases, shifted back and forth between companies and between areas of the country.

Many defense contracts ended last year in Southern California. Since then, one big new order after another has gone East or down to Texas, raising complaints of political favoritism. With some 360,000 workers around Los Angeles depending on government aircraft, missile and electronics work, the pinching off of big contracts hurts. Companies are wary of stockpiling employees in anticipation of contracts, and some concerns have now begun to break up their research-and-development teams.

Yet few experienced engineers are out of work, especially those willing to go where the contracts are. But more often than before, an engineer—particularly a junior engineer—must settle for less than he hoped for in a new job. A drifting of engineers to the Southwest has reduced some of the pressure on the West Coast.

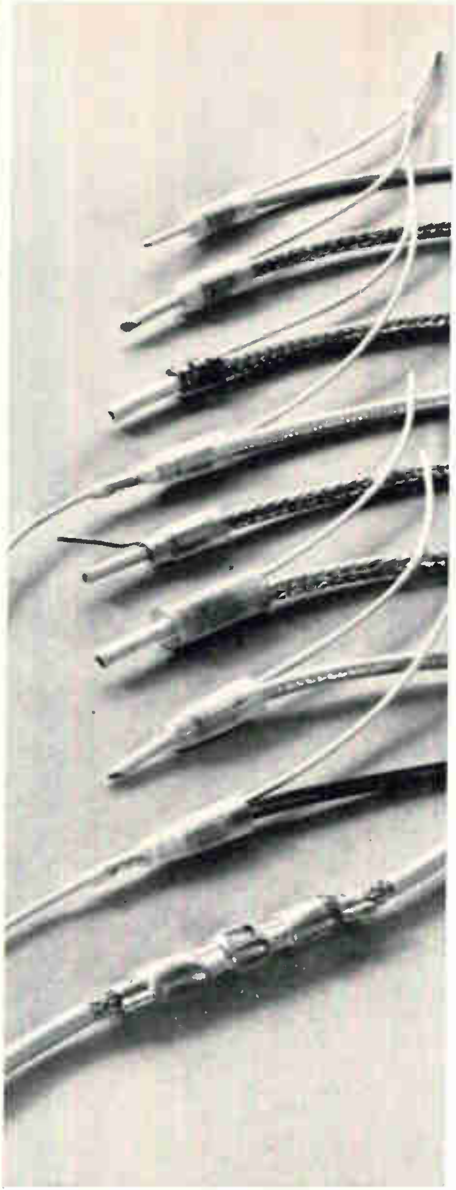
Up the coast from Los Angeles, the situation is less critical. The majority of contractors around San Francisco are trying to do their paring back by attrition—by not filling vacancies as they occur. On the plus side, the western plants of the Electronic Systems division of Sylvania Electric Products, Inc., are going so strong on the Minuteman missile and on other military equipment that they have increased their employment by 60% to 4,500. Semiconductor companies, especially a group of makers of integrated circuits, are also hiring strongly.

At the Boeing Aircraft Co. in Seattle, cancellation of the Dyna-Soar space project cost 105 out of 1,404 electronics engineers their jobs last December. Most seem to have gotten jobs out of the area.

A surplus of average-ability engineers is reported in New England, where the electronics industry has had troubles for the past few years. The largest employer, the Raytheon Co., had 43,000 employees in 1962, but that figure has dwindled to 32,000. Some companies have been hiring, but employment is generally down.

New England has not been getting big contracts, nor has it been getting enough of the subcontracts that are so important to its companies that specialize in research and development. Some NASA subcontracts are starting to trickle in, and an upswing in this business is anticipated when the new NASA Electronics Research Center goes into operation.

Business remains good in the Southwest and in Florida. Both areas have been doing well. Texas aircraft companies have won two huge military aircraft contracts, the TFX (F-111) and VAL. NASA's



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Manned Space Center in Houston and the Kennedy Space Center in Florida are both sources of employment. Cape Kennedy, in fact, is recruiting across the country to fill about 150 engineering positions.

The Midwest and the Mid-Atlantic regions are in pretty good shape. The industry is well diversified in these areas, and the general upturn in electronics business offsets the slowdown in government orders—except for a few pockets like Long Island. Mid-west companies in particular are no longer so chagrined at being left out of many of the government's advanced R&D projects. Their main military stock in trade is conventional, tactical equipment, and this kind of gear in demand today.

Computers

Whistle while you work

Among the strange sounds at the national political conventions this summer may be two-tone whistles emanating from telephone booths in the press section. They'd be coming from a new electronic device designed to speed stories from the reporter to a typesetting machine many miles away.

The producer, the Digitronics Corp. of Albertson, N.Y., calls the system Data-Verter. It enables the reporter to write his story on a typewriter with special innards, then transmit it by telephone to a computer that punches a tape which runs a typesetting machine.

The typewriter's keys open shutters. Each shutter is flanked by a permanent magnet and magnetic tape. As each key is released, the magnet sweeps across the shutters and, through those that are open, the letters are recorded as magnetized spots on the tape. Closed shutters shield the tape from magnetism.

The taped story is then taken to a transmitter that converts the spots to audible whistles—one tone where there is a spot on the tape, another tone for no spot. The transmitter whistles its tune through a loudspeaker into a standard telephone. At the newspaper office, the incoming whistles are translated back into machine language.

The missing link. Digitronics expects a reporter for at least one newspaper to use the Data-Verter at the conventions. The company calls the development "the last link in data-process applications," a simple, portable field input. Five models will soon be field-tested. Production and deliveries are scheduled this fall.

Other customers include food companies, trading-stamp concerns and a railroad.

A model for salesmen contains a roll of nonmagnetic material on which are printed the items for sale. These items are also represented by coded perforations on the roll. By turning a knob, the salesman can bring the printed information into a viewing slot, in line with its punch-code counterpart. He can adjust the knob to print, with eight type-wheels, variable information such as order size.

At the end of the day, the salesman takes his portable transmitter to a telephone, where the transmitter "reads" the tape into the phone at 400 to 500 words a minute.

Some applications require battery power. In recording work time and attendance from employee badges or time cards, for example, the cards' thickness prevents the permanent magnet from getting close enough to the tape. A more powerful electromagnet is needed.

Inventory-taking. Viewing slots show what is being recorded by the Data-Verter.

Solid-State

Junction problem solved

Texas Instruments Incorporated is all set to produce planar germanium transistors. Their one-gigacycle "prototype" unit, the G-3032, will be shown at the IEEE show this week and visitors will learn that 4-Gc units have been produced successfully and that high frequency "custom" units can be ordered.

The development is seen as a major technological breakthrough; one that could expand existing transistor frequency barriers and help open up the consumer market for germanium devices.

Advantages. Germanium is inherently capable of higher frequency operation than silicon and the ability to manufacture transistors in planar form enhances this high-frequency capability. It allows using photographic techniques which permit more precisely controlled junction areas than can be made with germanium mesa transistors.

K. B. Landress, project engineer at Texas Instruments, isn't talking much about the new technique which calls for depositing a silicon dioxide film on germanium; this is combined with various processing to produce a planar collector-base junction with good reverse characteristics. "We got lucky in a few places," he says, "and we figured a way out of problems in others."

Longer Life. Landress heads a 14-man group at Texas Instruments that has been studying the problem of producing planar germanium for two years. "When we started, people were saying silicon was going to run germanium out of the semiconductor business. I think we have something now that will extend germanium's life for no telling how many years."

Right now Landress' group is handling orders. On a "crash" basis it can turn out several hundred a week. "Somebody would have to make a decision if we got any big orders," said one Texas Instruments spokesman.

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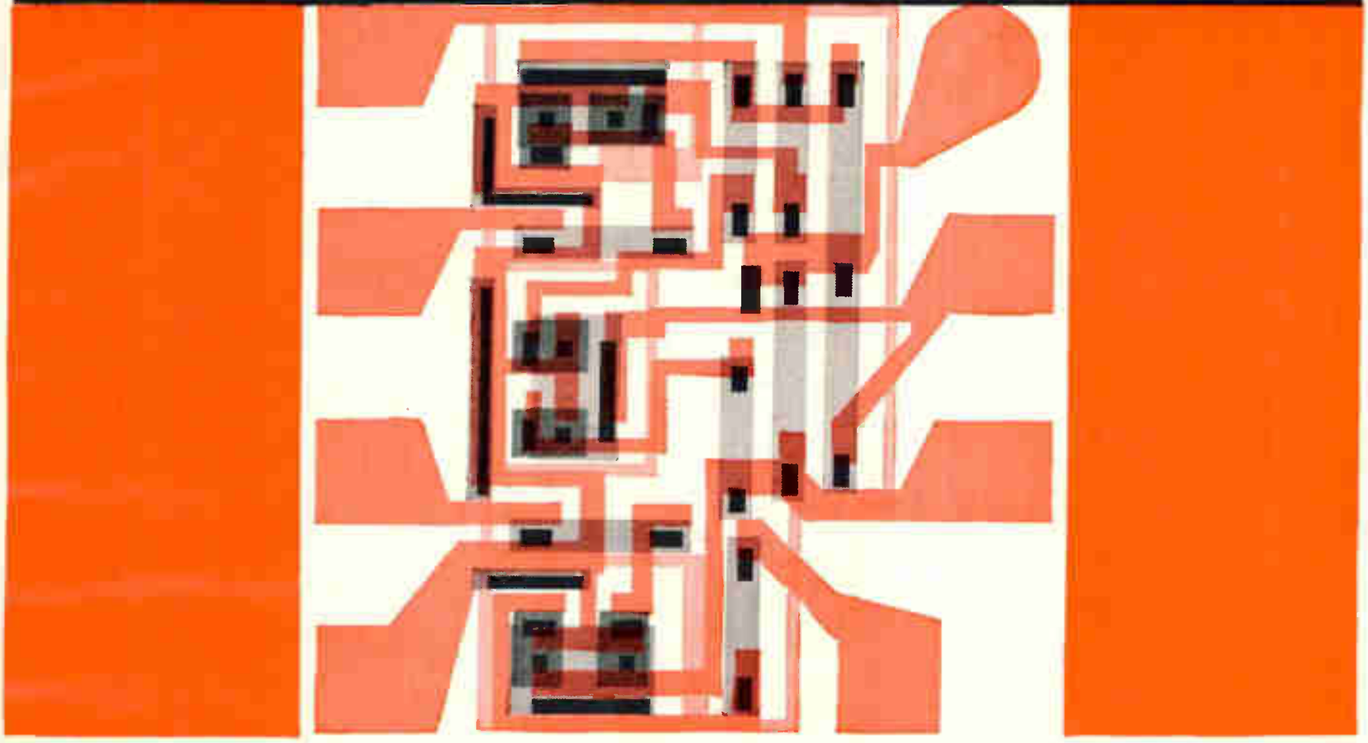

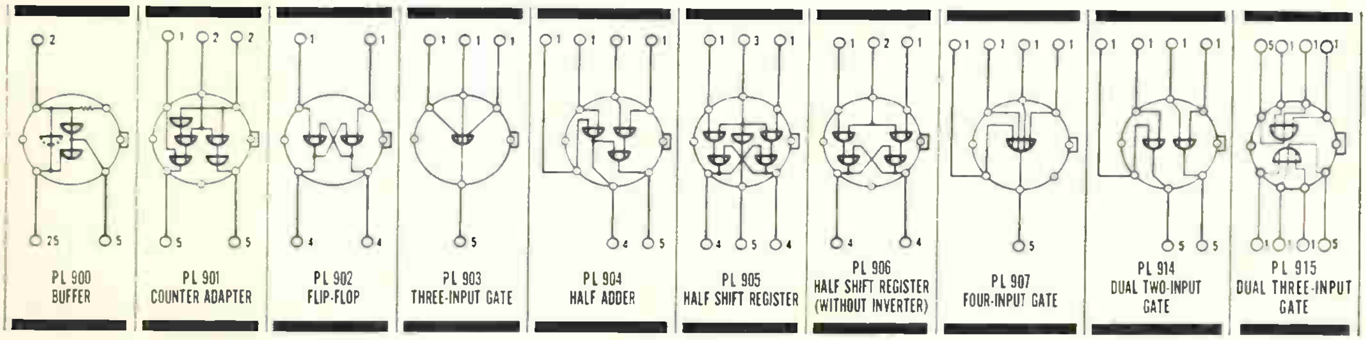

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HOW TO MAKE A "COMPACT" INSTRUMENTATION CABLE

To any engineer who has ever tried to design a 1¼″ instrumentation cable into a 1″ space, Rome-Alcoa dedicates this new, "compact" component insulation.

The material that makes this new insulation possible is colored Heat Sealable Mylar* polyester film.

We wrap two spiral layers directly over the shielding braid of the individual component...thus replacing thicker, extruded insulations of polyethylene or polyvinyl chloride.

Besides the obvious advantages of significantly smaller cable diameters and lighter weight, this new material offers the additional advantages of high dielectric strength, moisture resistance and excellent mechanical protection. Because of the reduced build-up of a cable component, longer, continuous, unspliced lengths of finished cable may be possible.

HOW IT'S MADE Each of the Mylar layers is coated on one side with polyethylene. The first layer is spiral-wound over the shielding braid with the polyethylene side facing outward. The second layer is spiral-wound over the first with the polyethylene side facing inward.

The component is then heated to a temperature high enough to fuse the adjacent coatings into one homogeneous polyethylene layer. This bonds both Mylar layers into one tough, flexible, waterproof lamination to give mechanical protection inside and out.

INSULATION QUALITIES The Mylar insulation is at least as reliable as extruded plastics, with these added benefits—it reduces the chances of "pinholes"—it is lighter—it gives the finished cable a smaller diameter – it is more flexible than extruded insulations and is therefore easier to work with.

Mylar-wound insulation has electrical properties superior to nylon and approximately equal to PVC and polyethylene. It has greater resistance to electrical breakdown than any of the extruded plastics. For example, typical tests have shown dielectric strength breakdown voltages of 4000 volts/mil as compared to 800 volts/mil for polyethylene.

*DU PONT REGISTERED TRADEMARK

One of the most significant characteristics of Heat Sealable Mylar polyester film is its excellent resistance to cut-through and abrasion. Mylar has been shown to resist cut-through better than PVC extrusions having three to four times the Mylar thickness.

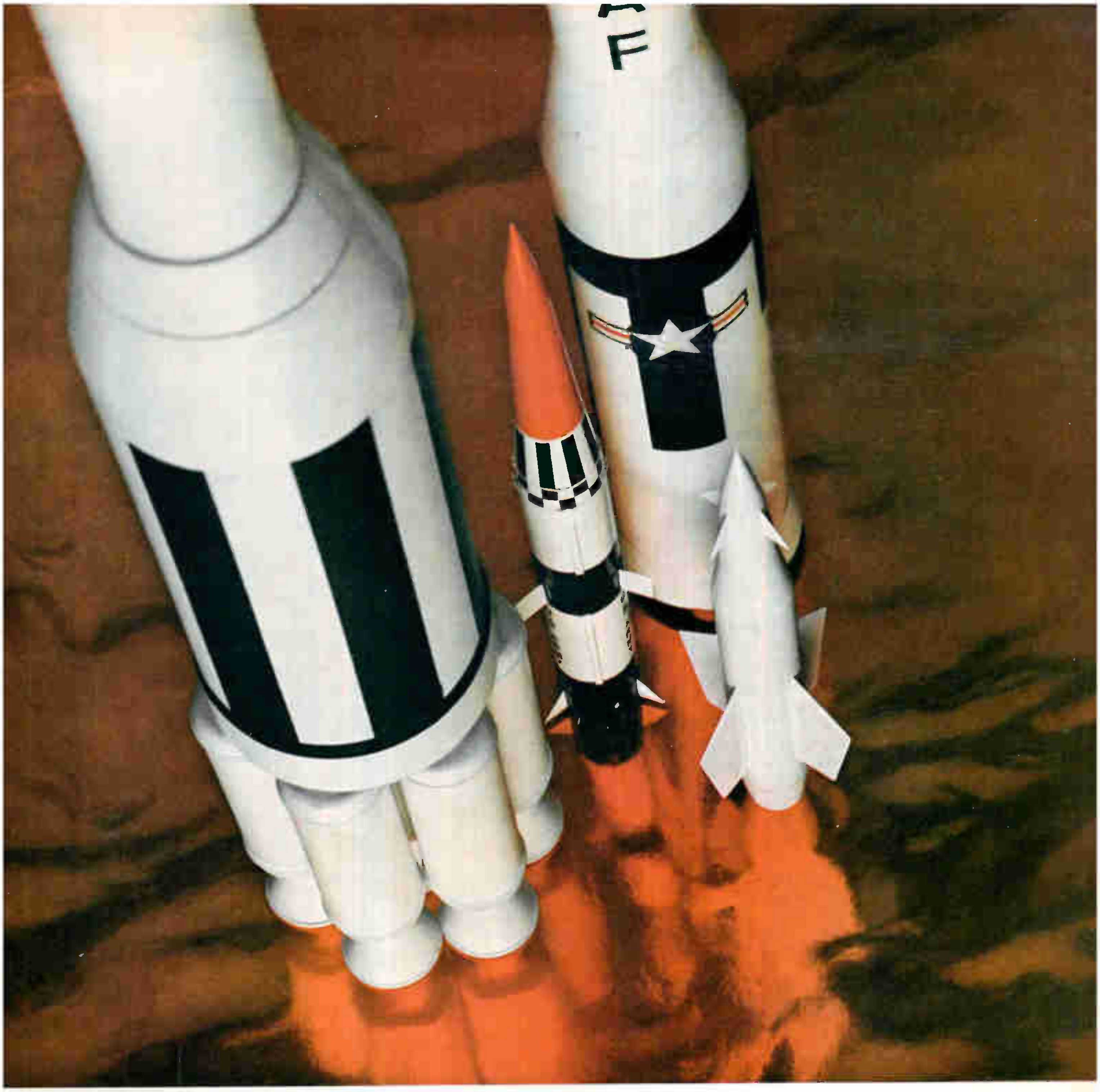
WHERE TO APPLY IT To the user of instrumentation cable, this new Rome-Alcoa product means a wider range of component insulating materials available for selecting the precise cable construction you need.

In some cases—notably where either small diameter, lighter weight or longer lengths of unspliced cable are vital—we recommend Mylar-wound shield isolation. In others, we may recommend other standard materials.

ASK THE EXPERTS The increasing complexity of instrumentation cable and the choice of insulation materials available to you make it more necessary than ever to go to an authority on instrumentation cable. You can help protect the functioning of your system by having instrumentation cable designed and constructed by experts.

Rome-Alcoa is, frankly, one of the few companies that qualify. We've been designing and constructing these cables since their conception. If you're going to need instrumentation cable soon, call us. As a starter, send for our 24-page booklet entitled, "Instrumentation Cables, Cable Assemblies and Hook-up Wires." In it, we describe instrumentation cable constructions, cable production, military specifications, and our qualifications. For your copy, write **Rome Cable Division of Alcoa**, Dept. 27-34 Rome, N. Y.

ALCOA



Who has the power at Thiokol?

Thiokol solid fuels power the nation's top missiles. Thiokol motors power manned aircraft from the X-1 to the X-15. Thiokol is also a power in synthetic rubber, sealants, metal-working, and many other fields.

When you're selling a product or service to a company where diversification is a way of life—how do you know where the *buying* power lies?

"Diversification at Thiokol," says President J. W. Crosby, "also means diversification of responsibilities, including purchasing. To solve problems in these areas, we rely on the experience and advice of our management executives."

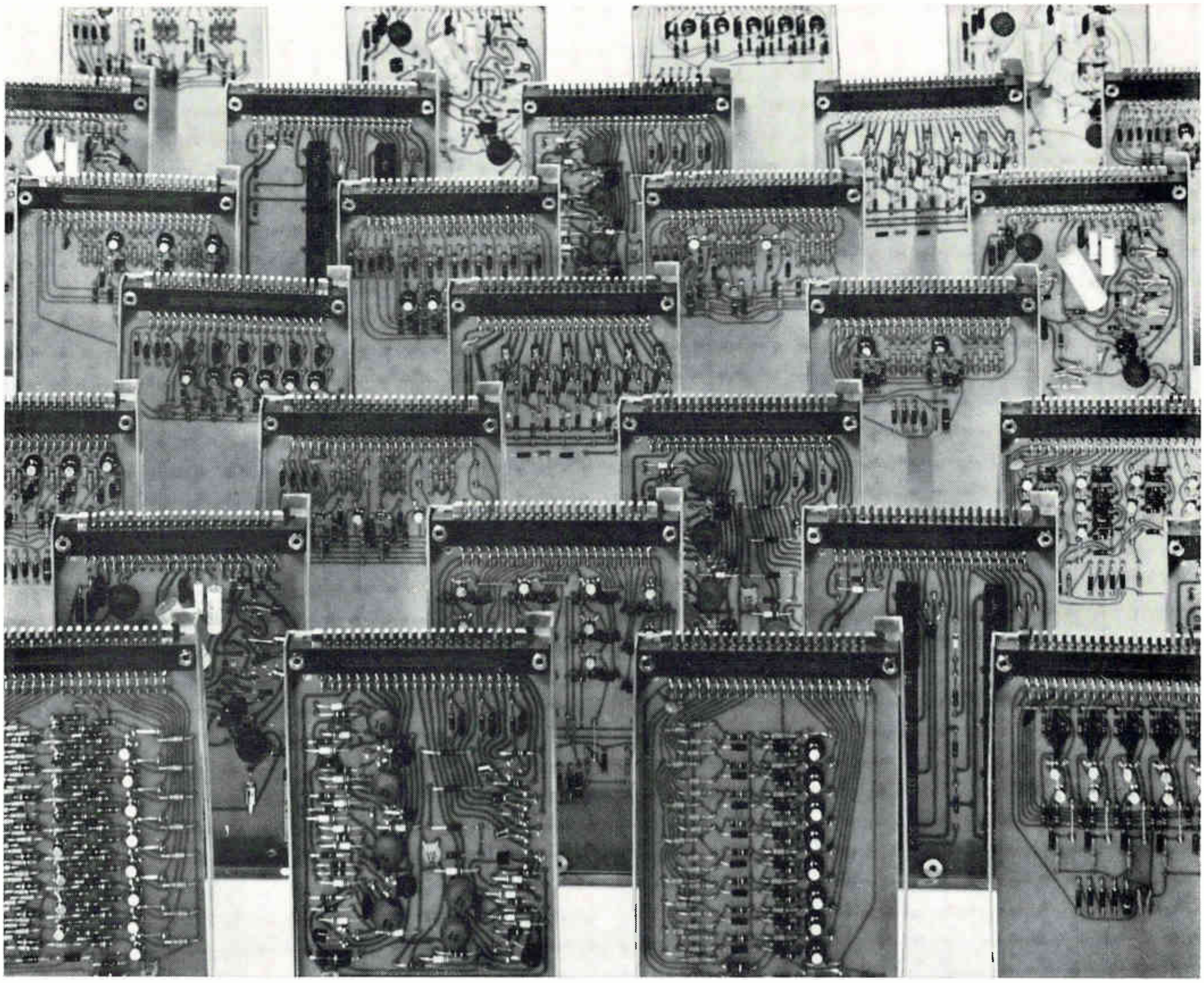
But few salesmen have the power to see busy top executives. So how do you get your selling story told?

Try this: the pages of Business Week. It goes directly to many of the most powerful decision-makers in business and industry. It's read at all the *decision levels.*

An example? At Thiokol Chemical Corporation, Business Week subscribers include the President, District Managers, Project Managers, Operations Managers, Sales Managers, Engineers, Supervisors. 140 management subscribers in all.

Throughout the business world, there are over 400,000 Business Week subscribers, who feel the way Mr. Crosby does: "We have to be intimately aware of new developments in engineering, design, material, and services. We need information on what's new and what's best." That's the function of this magazine:

Sell at the decision level



Fairchild Controls' Industrial Potentiometers Can Save You 20%

FAIRCON

FAIRCHILD'S NEW LINE GUARANTEES HIGHEST QUALITY
AND CUTS THE HIGH COST OF POTENTIOMETERS

Faced with the problem of high cost for high performance? The FAIRCON line offers a new high level of precision for industry—bridging the gap between low quality commercial grades and ultra sophisticated MIL spec potentiometers.

Top Performance Plus Substantial Savings Too

Check the FAIRCON LIN-Chart below. The white band in the chart indicates the standard high linearity available in the FAIRCON F200 two-inch, single-turn potentiometer. If your requirements fall within this broad range, you can save UP TO 20% over the complete MIL spec unit you may now be using. Similar savings (and precision) are available throughout the entire FAIRCON line of single-turn and multi-turn potentiometers.

You save money with Fairchild GUARANTEED quality and performance—and with quality potentiometers especially engineered and manufactured for large volume industrial applications. Whatever your control problems... computing...instrumentation...process control...communications...involving potentiometers, send us your requirements, blueprints and specifications for prompt appraisal and quotations. FAIRCON for quality...*at a price commensurate with overall system cost.*

LIN-CHART FOR FAIRCON F200 POTENTIOMETER

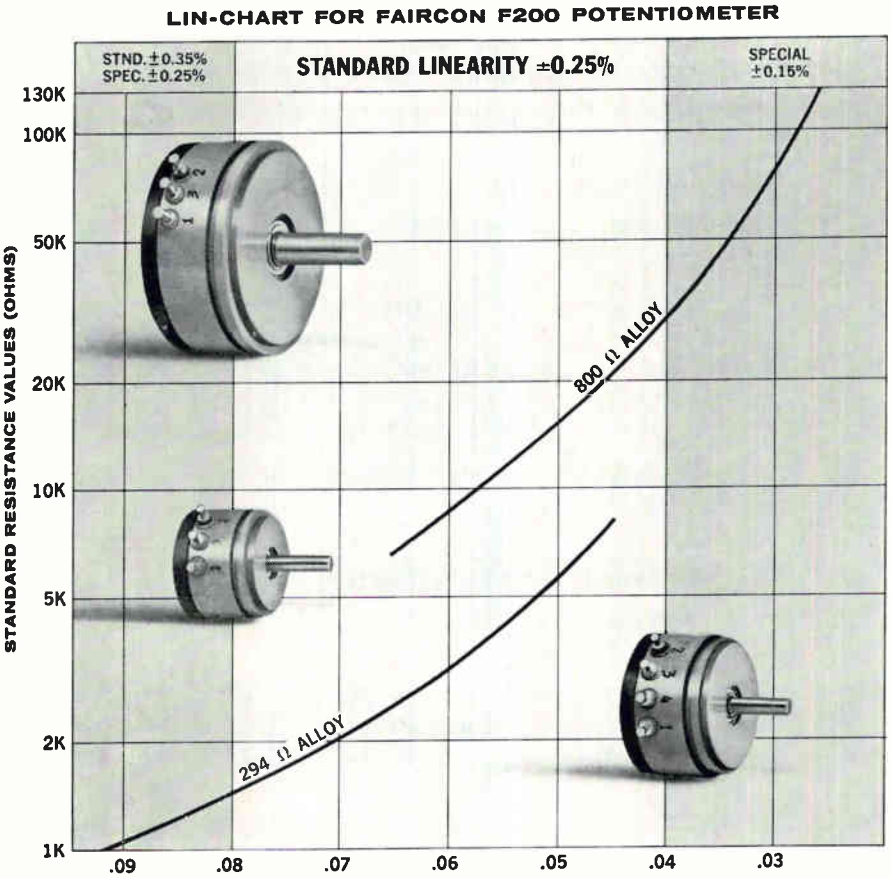


Chart and specifications for complete FAIRCON line available on request.

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Washington Newsletter

March 23, 1964

Electronics tariffs face axe at Geneva

After nearly four months, the Tariff Commission and the Trade Information Committee (TIC), are winding up the hearings they have held in preparation for the so-called Kennedy round of trade negotiations, to open May 4 in Geneva. The trade talks will be in the 57-nation General Agreement on Tariffs and Trade (GATT).

Next step is a crucial decision by President Johnson on what items, if any, the U.S. wishes to except from the bargaining. (Aim of the bargaining is tariff cuts up to 50 percent on industrial goods.) Sometime in June, the nations will exchange these "exceptions lists." Last week, the Electronic Industries Association, one of the final industry groups to testify, urged the Commission to recommend the exception of electronic consumer products, tubes, and basic parts for consumer, commercial and industrial electronic products. The Commission has heard hundreds of such pleas for a place on the exception list. Basically, **the Administration is determined to make as few exceptions as possible,** in order to bargain at Geneva over the widest possible range.

At this stage, chemicals, woolens and cotton textiles, shoes and steel appear to have the best chance of making the exceptions list, if Johnson agrees to any exceptions at all. The President will make the determinations on the basis of a complex of political, economic and diplomatic considerations. **It is likely that he will want U.S. negotiators prepared to go to Geneva to talk tariff cuts in electronics,** despite the forceful arguments of EIA that imports of Japanese consumer electronics items have badly hurt U.S. companies already.

Nike X decision due after tests

Construction of a wide range of communication, navigation and command and control facilities is authorized in a new military construction bill, expected to pass the House of Representatives this week. The bill, already passed by the House Armed Services Committee, calls for $1.6 billion in new construction for the fiscal year starting July 1—$200 million less than the Administration wanted.

Included is $32-million for development, test, operation and support facilities at Kwajalein Island in the Pacific for the Nike X antimissile missile system. On the basis of upcoming tests and evaluation the **Defense Department will decide late this year whether to order the Nike X into production.**

NASA looks past Apollo

Space officials are starting to pick projects beyond the manned-lunar-landing Apollo program, even though the first astronaut won't set foot on the moon before 1970—if by then. The reason is that the National Aeronautics and Space Administration has been reasonably assured by Administration and Congressional leaders that **the space budget from now on will hold somewhere around the $5-billion to $5.5-billion level.**

This means that NASA soon will have funds to start new projects. Spending on the current manned-lunar-landing program that has been running from $3 billion to $3.4 billion over the past year will begin to taper off. Spending on current projects will begin to decline in fiscal 1966. Spending will be down to about $3 billion by fiscal 1970.

NASA now wants to start an **input of three new programs next year** to take over when present programs begin to phase out. One is a lunar exploration program to follow the Apollo program. It calls for multiple lunar landing with astronauts extending their time on the moon from hours to weeks.

Next, NASA wants to get a manned orbiting space station in the near-earth space environment. Since the Air Force has won the nod to develop the initial manned orbiting laboratory (MOL), NASA officials are highly sensitive about the possibility of being forced into a secondary role and **intend to push hard for its own manned space laboratory program.**

The third major area that NASA is eyeing is earth-orbiting satellites that would perform a variety of duties—data collectors from multiple ground stations, beacons for navigation systems, and even as aids to air traffic control. **The interplanetary space exploration program won't be increased much above its present annual level** of about $150 million, at least for several years. A Mars expedition is still uncertain.

Hands off notice to scientists

A House Armed Services Subcommittee is demanding that the Air Force **tighten up procurement regulations which govern research contract awards.** The subcommittee's insistence grows out of an investigation into a contract for basic research in energy conversion awarded to TYCO Laboratories, Inc., of Waltham, Mass., by the Electronic Systems Division (ESD) of the Air Force. The subcommittee charges that a scientist who drew up the contract requirements for Cambridge Research Laboratories succeeded in limiting negotiations so as to unduly favor TYCO over two competitors.

The subcommittee recommends that the Air Force **limit laboratory personnel participation in contract negotiations to scientific matters** and instruct ESD procurement officers to exercise their full authority over contract awards. It also says technical evaluations of research procurements should be handled so as to "dispel the climate of favoritism . . . created by the practice of laboratory personnel evaluating proposals responsive to requirements they themselves generate."

Clear disclosure of the possible expansion of a contract and its ultimate estimated cost should be made to all bidders, and Washington approval should be required where the contract wil leventually cost more than authorized, the subcommittee thinks.

Senate hunts ways offset defense cuts

Creation of a government-industry commission to recommend ways **to facilitate transfer of defense technology to civilian needs** will probably be urged upon Congress by the Senate Manpower Subcommittee. The subcommittee has held lengthy hearings on the problem of industry adjustment to declines in military spending. Its report to the Senate will be made soon. Other likely recommendations include a new look at patent policy to make sure that optimum use is being made commercially of government-financed technology, and legislation to make sure that areas hit by abrupt defense shifts can qualify for federal economic and training assistance available under programs like Area Redevelopment.

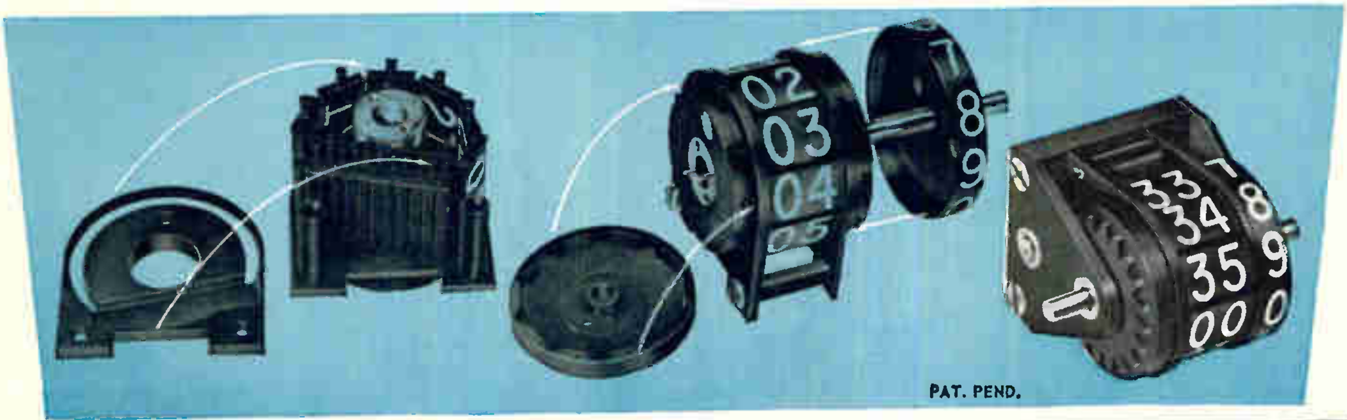
ComSat award

As expected, Hughes Aircraft Co. won the contract—worth $4 million to $8 million—for the Communications Satellite Corp.'s "early bird" satellite. It will go up in early 1965.

The Simplified Angle Counter

cppc with one Geneva VS. multiple gears, springs and shutters

—means trouble free operation



The New Clifton Precision Angle Counters are extremely *simple* (hence reliable), *small* (1.85 cu. in.) *lightweight* (1.5 oz.) and display 1/4" *numerals* —in addition they are *tested and proven!*

The CPPC Counter uses an extremely simple mechanism as compared to the nested drums and complex gearing of other 360° counters.

The major contributing factor to simplicity and smaller size is the totally new concept used in presenting the 10's and 100's of degrees. Further details of this concept are available upon request.

Due to the elimination of complex gearing, the Clifton counter has a more normal spacing between numbers than other counters— thus requiring a smaller instrument panel opening and providing easier reading.

In the CPPC Counter, the drive shaft is coupled directly to the units counting wheel—hence backlash is eliminated. Shaft extension may be right, left or both.

Rotation is reversible and continuous with clockwise rotation of the input shaft extending right resulting in an increasing readout value.

Because the message units are captively supported and forcibly driven, these angle counters operate in any attitude and are highly resistant to shock and vibration.

SMALL QUANTITIES IMMEDIATELY AVAILABLE

For further information: Sales Dept. 5050 State Road, Drexel Hill, Pennsylvania, 215 MA 2-1000, TWX 215 623-6068—or our Representatives.

SPECIFICATIONS
TYPE AWH-170-006

Numeral Size	.250" high, white on black drums and plates
Torque	1 oz-in max. at 20°C
Input Shaft Speed	500 RPM Continuous 1800 RPM Intermittent
Life	5 million revolutions min.
Operating Temperature	+125°C to —55°C
Weight	1.5 oz.
Mil Spec.	Designed to meet Mil-E-5272 "C"

CLIFTON PRECISION PRODUCTS
DIVISION OF LITTON PRECISION PRODUCTS, INC.

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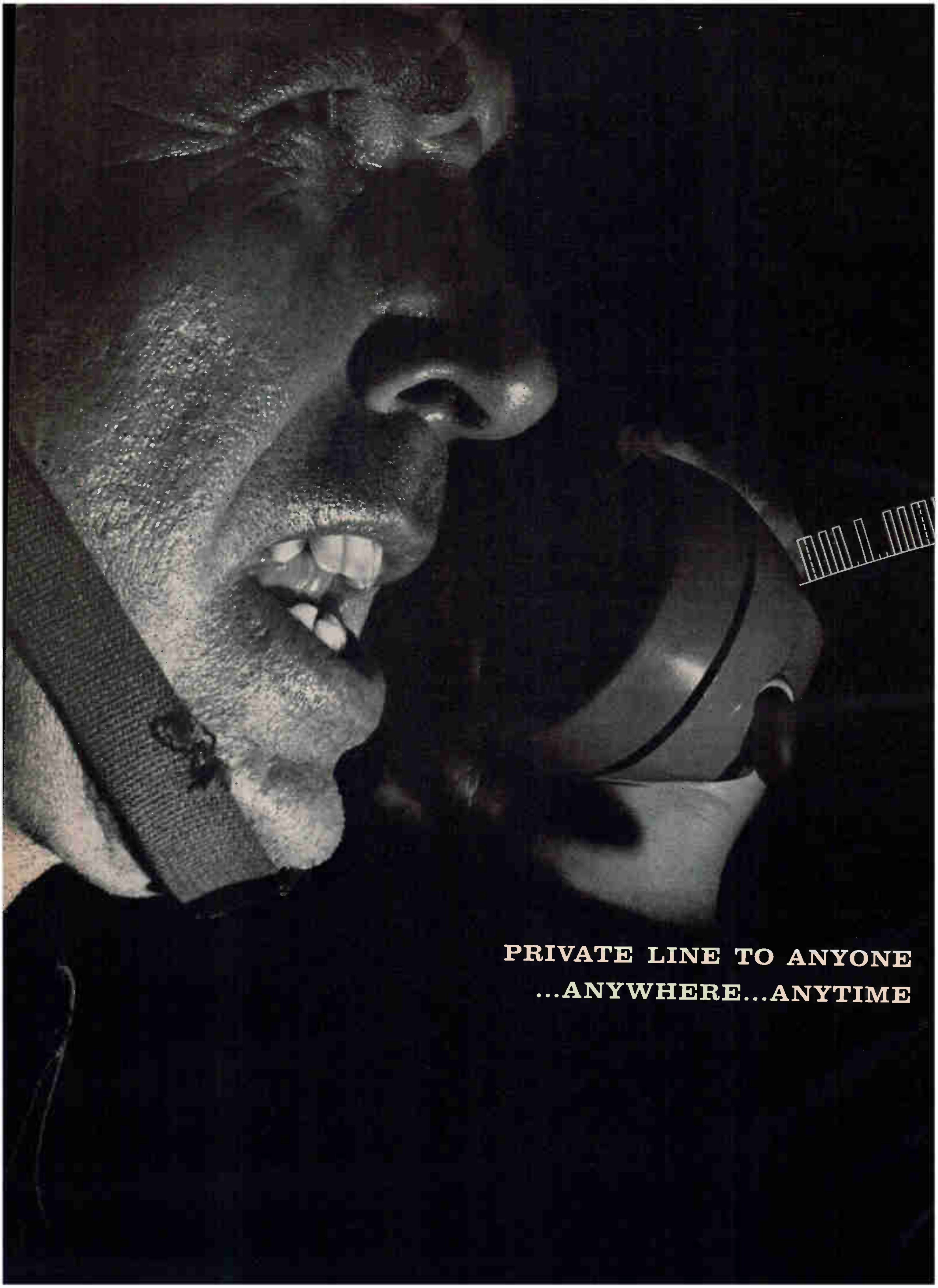
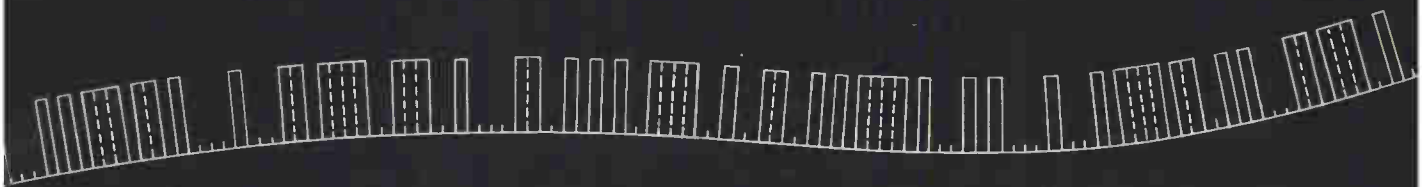

PRIVATE LINE TO ANYONE
...ANYWHERE...ANYTIME



OTOROLA'S RADEM* concepts, being applied to the most important recent vance in military communication systems...will carry many high-priority radio mes- ges simultaneously in a single wideband frequency channel; maintain private-line ect dialing without central exchanges or fixed nets; do this without interference tween concurrent messages transmitted from different locations within the system; d perform these tasks with designs that lend themselves to the application of advanced, tegrated electronic circuitry. RADEM is one of the many major military and space ctronic programs in progress at Motorola. Scientists and engineers interested in join- g the men who are making basic contributions to both research and applications in vanced electronics write today describing your background and experience in:

ystems Design • operational and functional systems analysis, economic analysis, optimum me-bandwidth utilization, digital, voice and data communications, secure communications.

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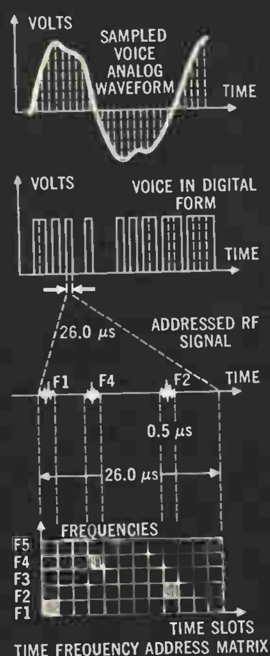

*__RADEM__ *(Random Access Delta Modulation) principle diagramed above is the result of 5 years of independent Motorola research.*

MOTOROLA **Military Electronics Division**

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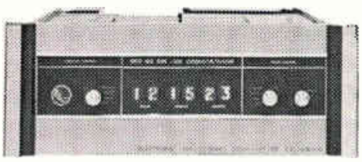
Are you ready for the best news about digital timing equipment prices since the day Oog & Goog

lowered prices on their original model notched stick? Price reductions of 8 to 30% have been announced by the world's most experienced developer of precision time-code generators and related equipment. Engineering advances during 1963 and production economies made possible by customer acceptance have resulted in substantial price reductions in the following precision products...

EECO 858 TIME CODE GENERATOR/READER

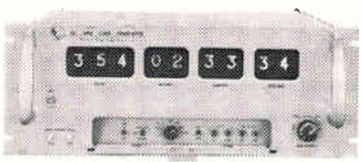


In recording mode, generates IRIG B format (modified to omit days) to mark analog data on mag tape for future reference. In reproduce mode, reads out hours, minutes and seconds on Nixie Tube display, provides slow code for strip-chart recorder, etc. Add-on 859 Automatic Search Unit converts 858 into complete automatic search system for time-coded mag tape. Send for the new low price.

EECO 807 ATLANTIC MISSILE RANGE TIME CODE GENERATOR

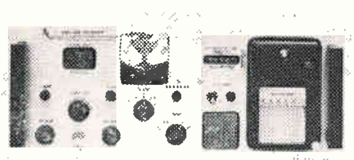
All three AMR codes produced simultaneously. Both level-shift and modulated plus auxiliary pulse rates. Send for the new low price.

EECO 811 TIME CODE GENERATOR



Generates all four IRIG codes simultaneously, or NASA or AMR codes, or combination. Extremely rugged, less than 40 pounds, Nixie-tube display, frequency stability 5 x 10^{9}. Send for the new low price.

EECO 880 VLF RECEIVER/COMPARATOR



All 181 channels at the flick of a thumbwheel switch. Digitally selects any frequency from 12.0 to 30.0 kc in 0.1 kc steps. Optional 60 kc channel. New narrower servo bandwidth. Includes strip-chart recorder. Send for the new low price.

...and many other reductions resulting from advanced design in standard lines. Check the types of items you are interested in...

- ☐ TIME CODE GENERATORS
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- ☐ NEON DISTRIBUTION AMPLIFIER

...and send this ad to EECO, Mail Station 1220, Box 58, Santa Ana, California 92702.

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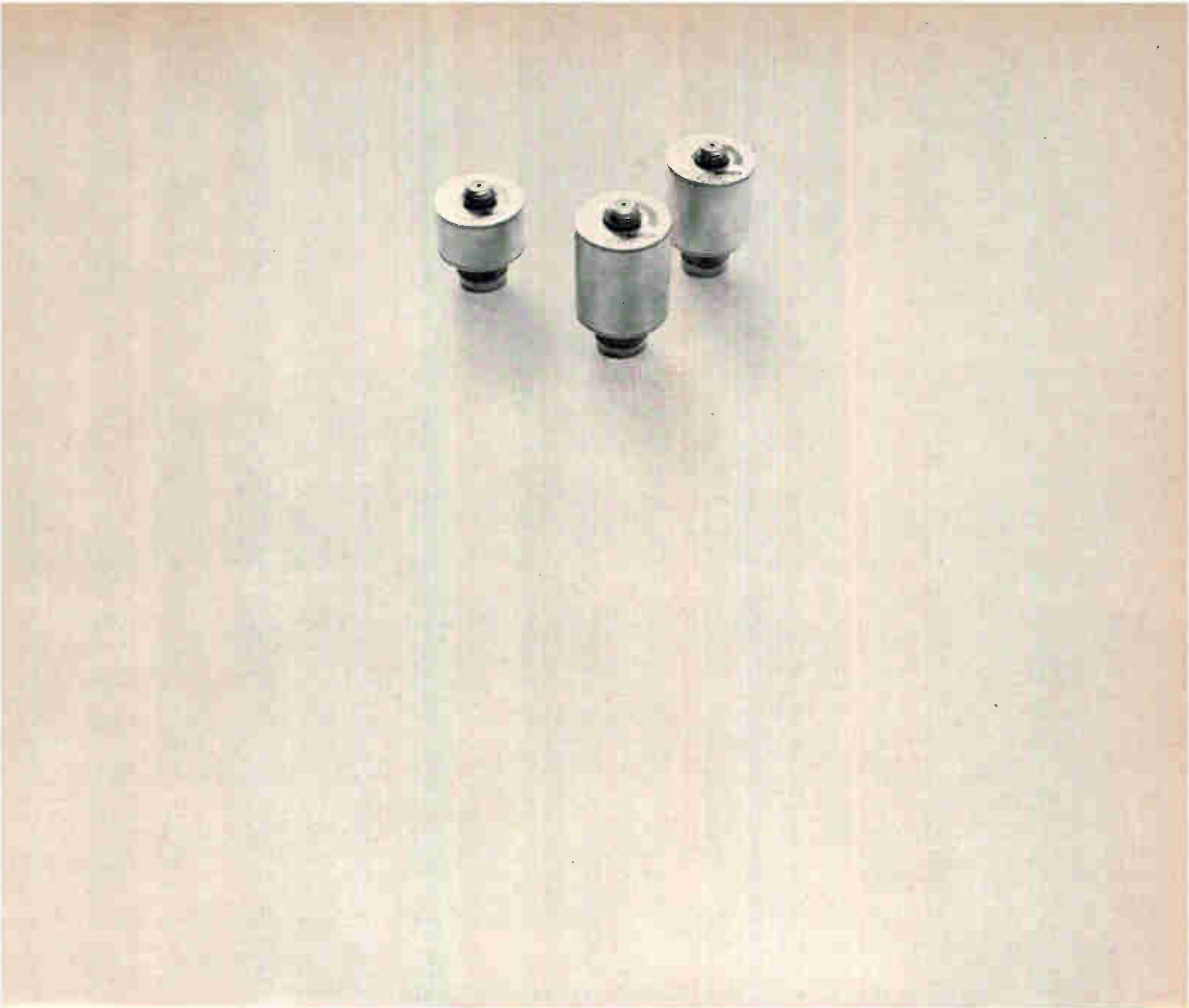

SHOWN ACTUAL SIZE

Consider the source...

and you'll consider these advanced new source followers

CEC's Type 1-304 Source Followers represent a major breakthrough in the field of signal conditioning for piezo-electric accelerometers.

These miniature, solid-state impedance matching devices measure only ¼ cubic inch, weigh less than 16 grams, and consume power at a rate as low as 1.2 ma nominal at 22v. Yet their reliability and operational characteristics are truly outstanding. High input impedance is over 500 megohms, output impedance is as low as 15 ohms, near-unity gain is 0.98 nominal, and frequency response spans 0.65 to 10,000 cps.

Other advantages include...

- Lowest noise level yet achieved.
- No ringing from overload or other causes.
- Only 0.3 seconds to warmup.
- Completely stable, even under extreme environmental conditions.
- Readily available from inventory.

The 1-304 family is composed of three distinctly different source followers, thus meeting the needs of virtually every application.

1-304-0001 is a basic source follower capable of readout directly into a frequency counter or oscilloscope. Primarily intended for rocket test stands, it replaces more costly emitter-followers—at ½ their noise level.

1-304-0002 is a source follower *combined* with an augmenter for use where extremely long output cables are required.

1-304-0003 is a source follower incorporating a +2.5 volt bias and voltage limiter for telemetry use. The limiter assures that the signal will remain within limits by squaring off peaks beyond the range of the readout.

For full information, call CEC or write for Bulletin CEC 1304-X1.

Transducer Division CEC

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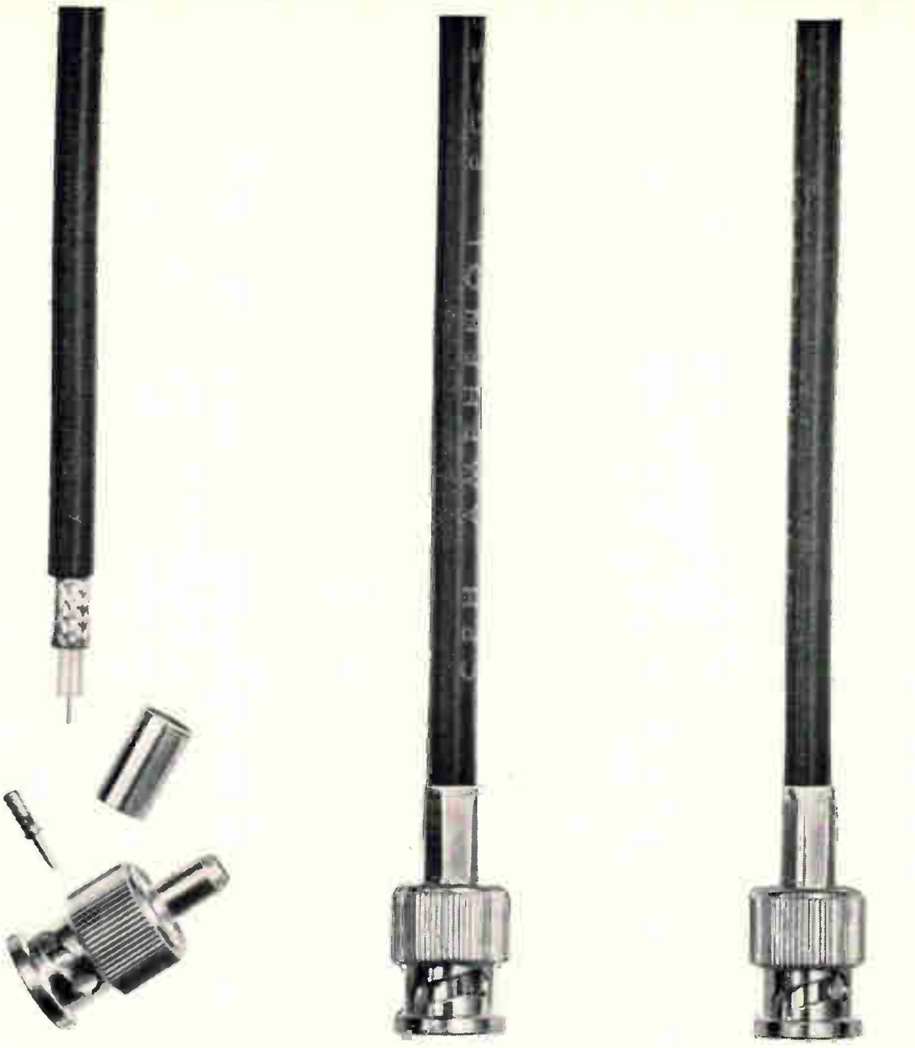
CIRCLE 45 ON READER SERVICE CARD



Assembly
(less than 30 seconds)

Performance
(up to 10Gc.)

Cost
(save up to $1.20)

These are FXR's revolutionary new Amphenol/ipc "quick-crimp" BNC coaxial connectors.

Assembly: Simplicity itself. No hypercritical tolerances, no tiny washers or inserts. Just three pieces that even a butterfingers can assemble in 15 to 30 seconds. And of course no braid comb-out or anything like that.

Cost: Less, much less. ($0.60 each in quantities of 250.) That's 60 cents to $1.20 less than other crimp-type connectors. And it's seven cents less than its UG 260 B/U counterpart. Plus the much-reduced assembly labor costs of quick-crimps over UGs.

Performance: Positive electrical and mechanical uniformity. Increased cable retention. 500 volts rating. VSWR is uniformly excellent to 10 Gc. Connectors are impedance matched to all 50 ohm RG cables normally associated with the BNC Series, but may also be used with 75 and 95 ohm RG cables when VSWR is not critical.

Test them yourself. Order a few (or a lot—we're in mass-production now) from FXR or your local Amphenol-Borg distributor. FXR, 33 East Franklin St., Danbury, Conn.

FXR™ THE RF PRODUCTS AND MICROWAVE DIVISION OF AMPHENOL-BORG ELECTRONICS CORPORATION

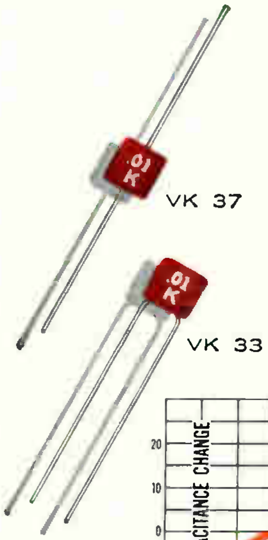
NOW!

VITRAMON* QUALITY

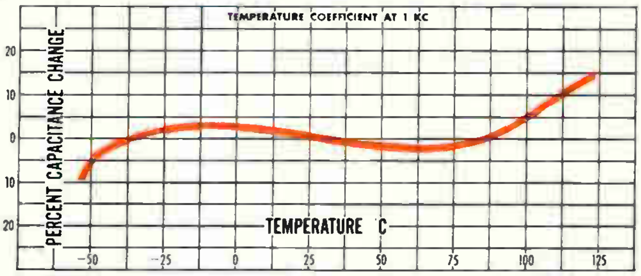
-NEW LOW PRICES!

DIPPED CERAMIC

Vk microminiature capacitors



* Conforms to MIL-C-11015
* 10 to 10,000 pf
* −55°C to 125° operation
* 200 vdc
* 10% and 20% tolerances



These new dipped ceramic capacitors have all the exceptional electrical and physical characteristics of the famous "VK" Capacitor, but are made to sell **for as low as ⅓ the cost** — a price made possible through the use of new materials and new production techniques.

High quality, "high K" units, they're designed for both industrial and military applications. Ideal for computer use, they have a guaranteed temperature coefficient of no greater than ±7% within a range of 0°C to 85°C and no greater than ±15% over a temperature range of −55°C to 125°C. Dissipation Factor is 1.5% for values through 680 pf; 2.5% through 10,000 pf.

Four case sizes available in either axial or radial lead configuration.

Write for complete information on prices and technical data.

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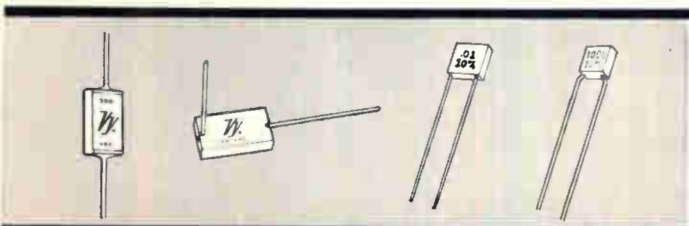

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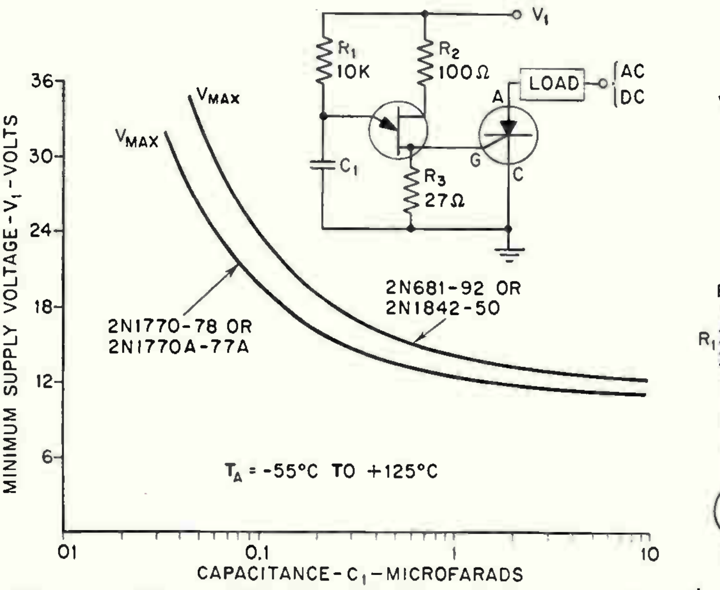
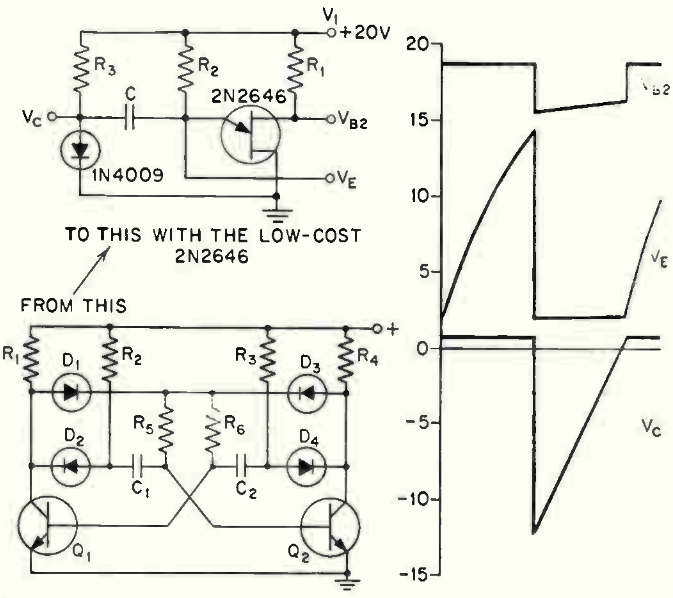
CIRCLE 47 ON READER SERVICE CARD

This new unijunction transistor will reduce overall circuit cost, simplify circuitry.

For 60¢, how can you go wrong?



2N2646 FIRING CIRCUIT FOR LOW AND MEDIUM CURRENT SCR'S



LOW-COST MULTIVIBRATOR WITH OUTPUT WAVEFORMS

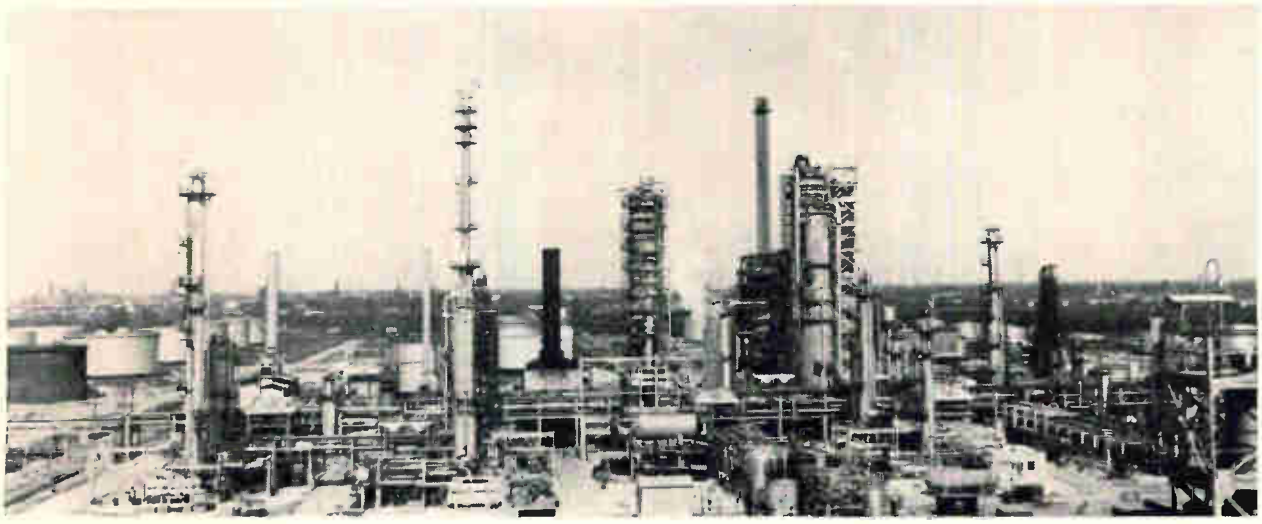
The economical 2N2646 in the small TO-18 package offers a guaranteed minimum output pulse amplitude, making it ideal for firing Silicon Controlled Rectifiers with forward current ratings of 35 amperes. (The 2N2649 offers minimum output pulses capable of firing SCR's with ratings of 235 amperes.) The curves of minimum supply voltage vs. capacitance shown are for two representative SCR types. The circuit shown will operate reliably over a temperature range from −55°C to +125°C.

The 2N2646 in this circuit provides the ultimate in simplicity and low cost (note that you eliminate 3 resistors, 1 capacitor, 3 diodes and a transistor). Choosing the proper capacitance and resistance values you get a wide range of frequencies and duty cycles. The output can drive an NPN transistor or a gate-turnoff SCR, provides good isolation between the load and the timing circuit. You can also get selected versions of the 2N2646 (5E35 and 5E36) with guaranteed frequency and duty cycle in a standard oscillator circuit.

Only 60¢ in 1,000 and up quantities, the new 2N2646 silicon unijunction transistor features an entirely new structure which results in low saturation voltage, peak-point current and valley current, as well as a high base-one peak pulse voltage. And it is a much faster switch. The unijunction has always been able to simplify circuitry and reduce cost. Now it saves you even more. Write for complete details to Section 16C158, Semiconductor Products Department, General Electric Company, Electronics Park, Syracuse, New York. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: International General Electric, 159 Madison Avenue, New York 16, N.Y.

Available through your G-E semiconductor distributor

GENERAL ELECTRIC



Process industries, typified by this petroleum refinery operated by Standard Oil of Ohio at Toledo, will benefit most from Direct Digital Control. These industries have long experience in multi-loop, although conventional, process control

Direct digital control at the threshold

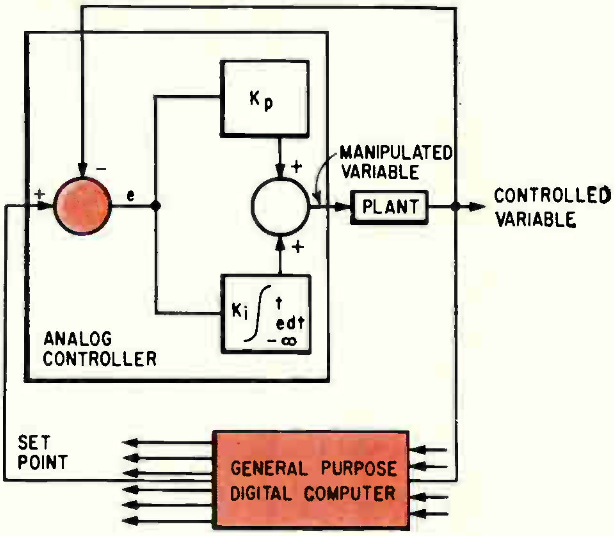
A new concept of control, with a centralized special purpose digital computer instead of separate analog devices, may finally win widespread acceptance for electronic process control. The direct digital controller is simpler than a process control computer and needs no complex programming

By H.F. Kloch and J.D. Schoeffler

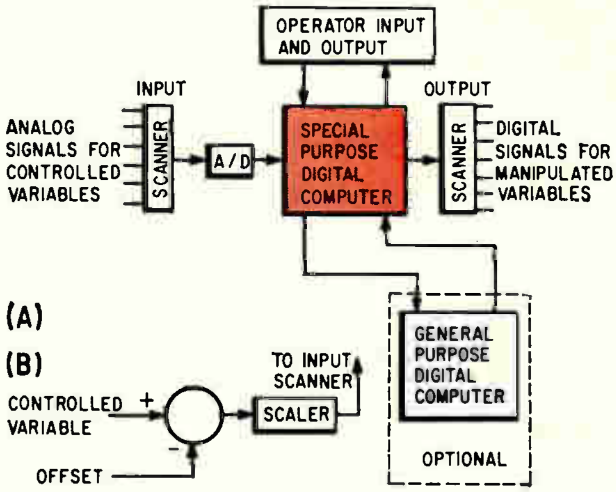
Systems Research Center, Case Institute of Technology, Cleveland, Ohio

Traditionally, industrial process control has used pneumatic instruments and controls. Only within the past seven years have electronic devices made a dent and what they have done has been disappointing. Although electronic instruments and controls have worked satisfactorily, they have not proven out economically in many applications. Now a new concept, Direct Digital Control (DDC), may change all this. Direct digital control of processes will allow tighter operation, regulated by simple, relatively inexpensive, special purpose digital computers. It does not require a large investment of time and money for computer programming.

Most often, process control means regulating or maintaining several hundred variables at predeter-



Computer process control at present is complex. Diagrammed is one control loop of a general purpose digital computer controlled process



Direct digital control replaces conventional analog controllers with one time-shared special purpose digital computer, using an optional general purpose computer for process optimization as in A. Inset B shows signal offset and scaling relationships

mined values. Each parameter is regulated with a conventional analog controller, or many may be controlled by a single process control computer. Both approaches work but are either inadequate or too expensive when an engineer wants to optimize the process rather than just control it.

In a conventional (using an analog controller) control system, the variables (pressure, temperature, flow, speed, rate, liquid-level and the like) are continuously sensed and subtracted from a set-point (or reference) to produce an error signal. This signal is amplified and used to manipulate the variable to decrease the error.

To this conventional control system, designer's are adding a general purpose, high-speed digital computer with analog-to-digital (A/D) and digital-to-analog) (D/A) converters as shown above, on the left. Process variables are sampled, quantized, and fed to the computer which monitors the variables and prints out records of process performance. In addition, the digital computer often uses a mathematical model of the process, together with analytic performance criteria, to determine optimal operating conditions (set-points). These set-points are converted to analog signals and transmitted to the analog controllers, either automatically or through an operator.

DDC of processes

Direct Digital Control is an intermediate step replacing a group of analog controllers with a single, time-shared, special purpose digital computer. This DDC computer duplicates the analog controller's actions while providing easy communication with an operator and/or a general purpose digital computer.

The function of the DDC computer is shown in the simplified diagram above right. At the left of the diagram are shown some controlled variables. Transducers sense each, producing an electrical signal which is offset and scaled (that is, zero-reference set at a convenient level for the range of signals expected and the resulting signal scaled in magnitude as indicated in insert B). The scanner samples each input channel in turn and applies the signal to an A/D converter which quantizes the signal and transmits the result to the DDC computer. Stored within this computer are the set-points, previous error for each variable and allowable limits. The variable is first checked to determine if it exceeds allowable limits; if it does an alarm is sounded and control is returned to the operator. If the variable is within limits, the DDC computer subtracts the variable from the set-point to determine the present variable error and using the previous value of error, computes a new value of the manipulated variable from an appropriate algorithm.

Parameters for each control loop are stored in the computer memory and used in the algorithm for computing manipulated variables. Because these are stored as numbers (not limited, as in an analog device, by the physical limits of a potentiometer or capacitive device) the parameters of the controllers may be varied over a much wider range than in actual analog controllers. Moreover, the parameters can be changed individually (because they are separate numbers) without the interaction problems often encountered in analog controllers with their input dials. The new value of the manipulated variable is transmitted to a digital actuator which drives the variable to the new value. The output scanner connects the DDC computer output to the proper actuator.

Input-output devices

Two other input-output devices are available, a manual station controlled by an operator and a general purpose digital computer. The manual station allows the operator to call for special print-outs of selected variables, to supply new set-points, or to change the DDC computer parameters, that is, the constants used in the algorithm for a particular variable. In addition, the operator may over-ride the DDC computer assuming control when conditions warrant.

The other input-output device is a general purpose digital computer. Its normal function may be the processing of payroll records, engineering calculations, etc., but it is also used to communicate with the DDC computer for starting up the process, shutting it down, controlling the system during alarm situations, or for process optimization.

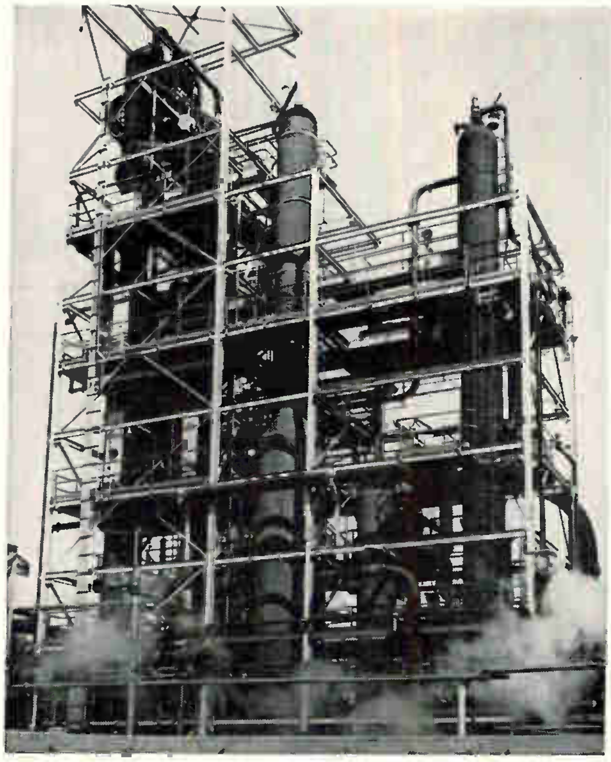
Actual application

Direct digital control has been simulated by several companies and at least one has tried it on an actual process[1, 3, 4, 5]. Involved in these simulations were Corning Glass, Conoflow Corporation, Monsanto Chemical, Leeds and Northrup, Westinghouse Electric, TRW (Bunker-Ramo), Foxboro and others. In these studies, single loop processes with various types of elements were simulated on either a digital or hybrid computer and DDC evaluated using signal rise time, overshoot, and other criteria.

The result was general agreement on minimum sampling intervals for typical process variables of 1 second for flow, 5 seconds for pressure, and 10 seconds for temperature variables. Thus for a process of approximately 200 loops, the required scanning rate is well within the state of the art, being approximately 150 points per second for a 200 loop controller with a typical distribution of the variables among flow, pressure, etc.

One of these experiments by Monsanto Chemical Company and Bunker-Ramo, applied DDC to an operating plant in the separations section of Monsanto's ethylene facility at Texas City, Texas.[1] Since a DDC computer was not available, it was simulated on a more conventional (RW 300) process control computer. The distillation column (pictured right) had 10 control loops including temperature, pressure, and flow variables. The 10 variables were each sampled once per second and the data transmitted to the computer. The corresponding manipulated variables were calculated using a discrete version (error values sampled at equal intervals of time rather than on a continuous basis) of the proportional-plus-integral (P-I) control algorithm.

Results indicate that all ten loops responded at least as well as with conventional analog controllers and in most cases gave a smoother and faster response. This improvement was traced to the noninteracting parameters of the digital controller, and the fact that these parameters could be adjusted much more exactly than in the analog controller. As a result of this study, it was estimated that the saving in capital investment for a 200 loop direct digital control system would lie between \$500 and \$1000 per loop. (One industry spokesman has stated that, concerning cost, possibly 50 loops can be the breakeven point—Ed.)



Experimental DDC was tried in Monsanto Chemical's Texas City, Texas, ethylene plant, controlling 10 loops on this distillation column. Savings for a similar 200 loop system were estimated at 500 to 1,000 dollars per loop less than for conventionally equipped loops

Benefits to industry

Industries benefiting most from DDC will be those which are already experienced in multi-loop conventional process control. These include steel, petroleum, glass, chemical processing, food, and electrical utilities. Other processing industries which have much to gain from better control, such as paper, are retarded by the lack of adequate automatic measuring instruments for critical process variables.

The principal benefits of DDC are both immediate and potential. They include: lower capital investment by replacing many analog controllers and recorders with one time-shared DDC computer; better control because each controller parameter can be changed over a wider range than can the corresponding parameter of an analog controller, and in addition, the controller parameters are noninteracting (can be changed independently) and can be varied in a much smoother manner; straightforward data logging because the desired data is present in a single location, in digital form, and may easily be printed out for a permanent record or displayed for an operator; ease of communication with a general purpose digital computer which need not be tied up 100% of the time on the process, but used only as needed by the operator; ease of automatic start-up and shut-down by a general purpose computer communicating with the DDC computer; and, potentially improved control algorithms such as non-interacting control, non-linear control, and the like.

Experience with the present generation of digital process computers indicates most of the cost of implementing computer control lies in determining an adequate mathematical model of the process and in the programming of the computer, rather than in the hardware itself. This is mainly because those processes which can best profit from computer control are mathematically the most complex and least understood. Consequently, a computer is often added to a process initially for data gathering and model building purposes even before it can be economically justified.

DDC allows economical data gathering for model building purposes. Then, when the process is well understood, a general purpose computer (either on or off line) can communicate with the DDC computer to optimize set-points, controller settings, and even dynamic response.

Hardware requirements

Potential users of DDC are essentially in agreement as to the requirements for a DDC computer. Monsanto Chemical, Corning Glass, and the DuPont Company at a recent conference listed their requirements. These include a reliability or availability of 99.95% (4 hours down time per year). Several types of outputs are also needed including dc for driving conventional pneumatic actuators, pulses for devices such as stepping motors, and a pulse whose width is proportional to the output signal and which can then be integrated by an output advice such as a motor.

Many companies are readying equipment for DDC but details are still proprietary. In recent months, two companies have announced equipment for direct digital control. The first, Minnesota Mining and Manufacturing, displayed a controller at the September ISA show in Chicago. This controller will be available for use with 8 to 32 loops. Claims are that it will be economically competitive at 20-30 loops. Outputs of this unit are low current signals for driving conventional actuators. The other user desired outputs are not available.

The Westinghouse Electric Corporation is going to install DDC at a unit of Commonwealth Edison in Chicago for control of all boiler loops.[9] A control computer is used as the DDC computer to scan the inputs, convert them to digital signals and process them. The algorithm for each control loop is programmed and can be either simple or complex depending upon need. This is in contrast to the 3M special purpose DDC computer discussed above which does not permit programming of the individual loop algorithms. The Westinghouse system will also provide all of the types of outputs discussed above. Their more complex computer allows a pre-programmed operation which will depend upon operating level. Computer control parameters in the DDC algorithms will be changed as the operating conditions of the boilers change. (The program for this installation resulted from a detailed IBM 7090 computer study of Commonwealth Edison's boiler system).

Problems

One point of unanimity among potential users of DDC is that the computer must be at least as reliable as existing analog controllers. This poses the problem that failure of the computer can cause the shut-down of the entire process together with the production of much off-quality product. (This is in contrast to only one loop going out if an analog controller is downed.) To achieve the required 99.95% availability demanded by users, reliability of presently available computers must be increased by an order of magnitude. This is within the state of the art.

A second problem is the digital actuator on the output side of the DDC computer. Conventional analog pneumatic valve actuators are very reliable and economic but they require the computer to supply a dc signal. This signal is first converted by a current-to-pneumatic transducer to an air signal which is then applied to the actuator. This requires each such channel have an analog memory which stores the signal between successive outputs.

Output actuators which are actually digital would not need this analog memory. For example, some development has been achieved on actuators which accept a binary-coded signal, each bit entering on a single line.[6] This binary signal drives the digital actuator directly without converting the signal to analog form. At the recent IFAC (International Federation on Automatic Control) Congress in Basle, Switzerland, a digital valve was demonstrated by the Lignes Télégraphiques and Téléphoniques of Paris, France. It was actuated by digital signals, each bit of which controlled a single solenoid. American companies judged this particular valve too expensive for general use, but it is indicative of the direction in which actuator research is headed.

Another attractive output actuator is the stepping motor, which is capable of stepping to any one of a large number of discrete angular positions and remaining there until further input signals are received. The motor steps one position for each pulse received, the direction being determined by which of two lines received the pulse as shown at the top of p 53. Stepping motors are available from several manufacturers in a variety of sizes.

An example: the SLO-SYN motor made by Superior Electric Company. It is capable of rotating at about 200 steps per second maximum or approximately 72 RPM. With such a motor as the output device, the DDC computer supplies the correct number of pulses during each sampling interval to change the manipulated variable by the desired amount. One way is to run the motor at maximum velocity over a portion of the interval; another is to run at minimum velocity over the entire interval. The former seems to be simpler to implement.

The stepping motor can also be used in a variety of applications other than opening and closing valves. For example, it may rotate the shaft of a potentiometer or rheostat thereby controlling voltage or current flow. This can alter the firing angle of a bank of silicon controlled rectifiers or the bias of a magnetic amplifier to control the speed of a motor. The rotary motion can also be converted to linear motion by conventional devices.

DDC computer structure

A study of DDC was initiated at Case Institute of Technology several years ago. Out of this initial study has come one design for a DDC computer using stepping motors as actuators. This system's design illustrates the general principles governing a DDC computer with this type of actuator.

Conventional analog controllers produce an output signal which is a linear combination of the input error (proportional control), the derivative of the error (rate control) and the integral of the error (reset control) which is

$$m(t) = K_p e(t) + K_d \frac{de(t)}{dt} + K_i \int_0^t e(t)dt \qquad (1)$$

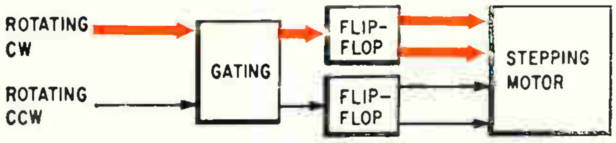
where m(t) is the manipulated variable, the output of the controller. Simulation of direct digital control indicates that adequate control can be achieved using only the proportional and integral control functions. In fact, the addition of the derivative function in digital form makes the control unduly sensitive to noise and quantization errors. Using standard sampled-data theory, a digital approximation to Eq. 1 with $K_d = 0$ is found to be

$$\Delta m_n = Ae_{n-1} + Be_n \qquad (2)$$

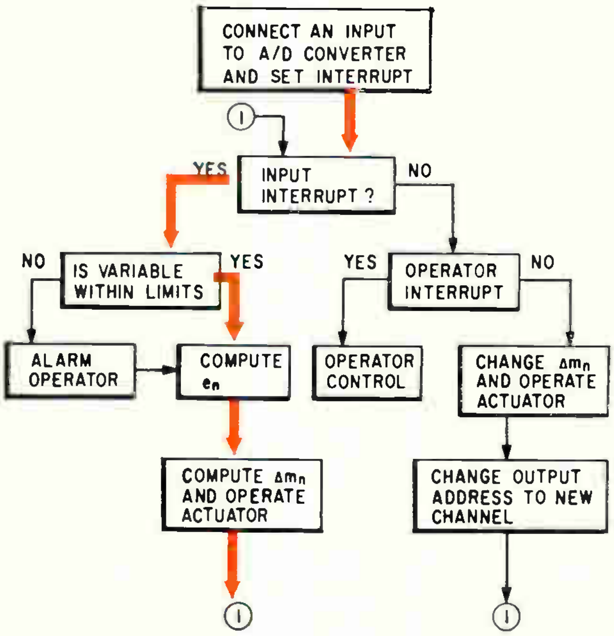
where Δm_n is the change in the manipulated variable, e_{n-1} is the previous value of error, e_n is the present value of error in the controlled variable, and the constants A and B are functions of the controller parameters K_p, and K_i and the sampling interval.

The function of the DDC computer is to evaluate changes in the variables using Eq. 2 repeatedly for each controlled variable. Thus, the same simple computations are repeated over and over, the only differences between calculations for successive channels are the constants and error signal. As a consequence, no programming of the computer is necessary to use it to control a process. Because of this, the internal structure of the DDC computer can be much simpler and less costly than for a general purpose machine.

When stepping motors are used as the digital actuators, the number of pulses required to effect a change in the variable is linearly related to Δm_n and hence can be incorporated into the constants A and B. That is, the quantity calculated in Eq. 2 can be the number of pulses needed with no conversion required. If the input to a digital actuator



Output actuators which are actually digital, such as this stepping motor control, need no memories as do analog pneumatic valve actuators



DDC computer operation is shown in this flow chart. Improved process control results from wider adjustment range and non-interacting parameters of signals

The authors

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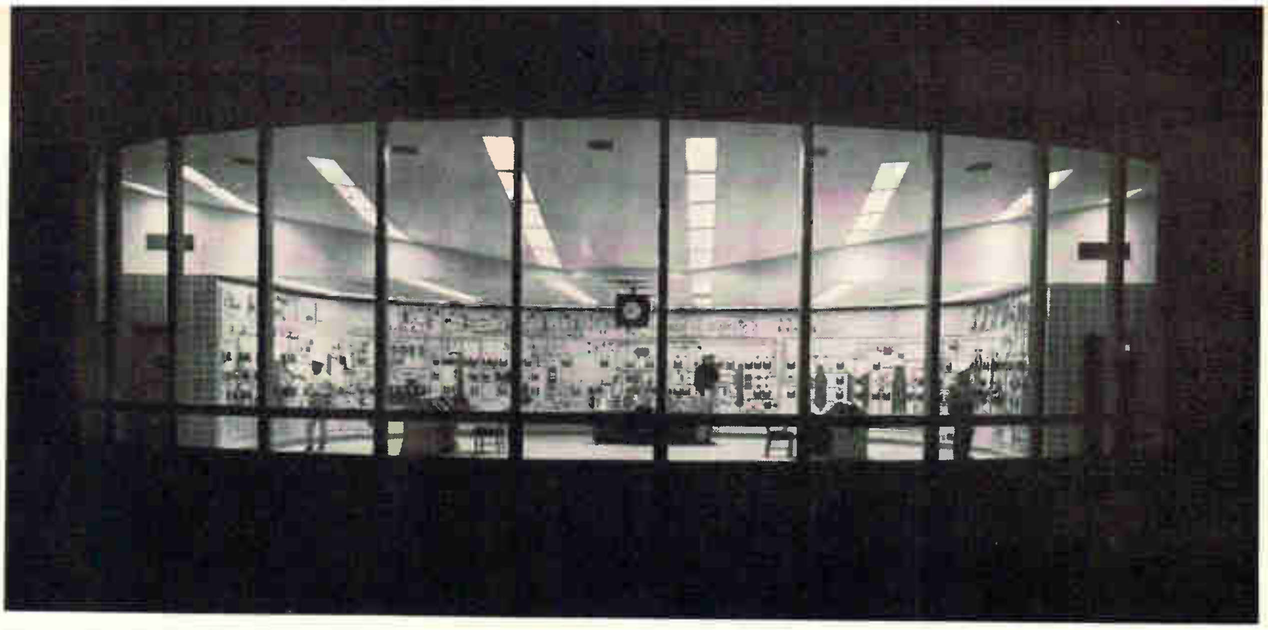


Compactness of DDC will replace such massive nerve centers as this **Central Control House at Sohio's Toledo Refinery. Instrumented 96-foot curved panel controls processing loops and catalytic cracking and steam generation**

is the actual digitally coded variable, then m_n is calculated from Δm_n by adding the previous value of the variable to it before transmission to the output.

With the DDC computer shown on page 50 the information entering the registers of the computer from the input scanner is a digitized representation of the measured variable.

The drawing also shows an A/D converter, but there is considerable research and development under way towards producing a digital signal directly at the measuring instrument. From the viewpoint of transmitting information by wire for distances of possibly up to a mile, in a situation where the chances for interference pick-up are good, the digitized version is superior to the analog. Because it is uneconomical to have an electronic A/D converter at each measuring instrument, development is being pressed for a family of digital sensors for pressure, temperature, flow and the rest.

The scanner generally scans in an interlaced pattern under control of the computer. The computer keeps track of the variable being scanned so that it may be entered correctly into the computer memory.

The input scanner is usually a relay switching matrix. Its switching time is long, compared to the time required for the computer to perform the arithmetic calculations. There is also a time delay required for the transients in the A/D converter to decay. The net result is that the computer can do other operations while waiting for the next read-in operation to occur.

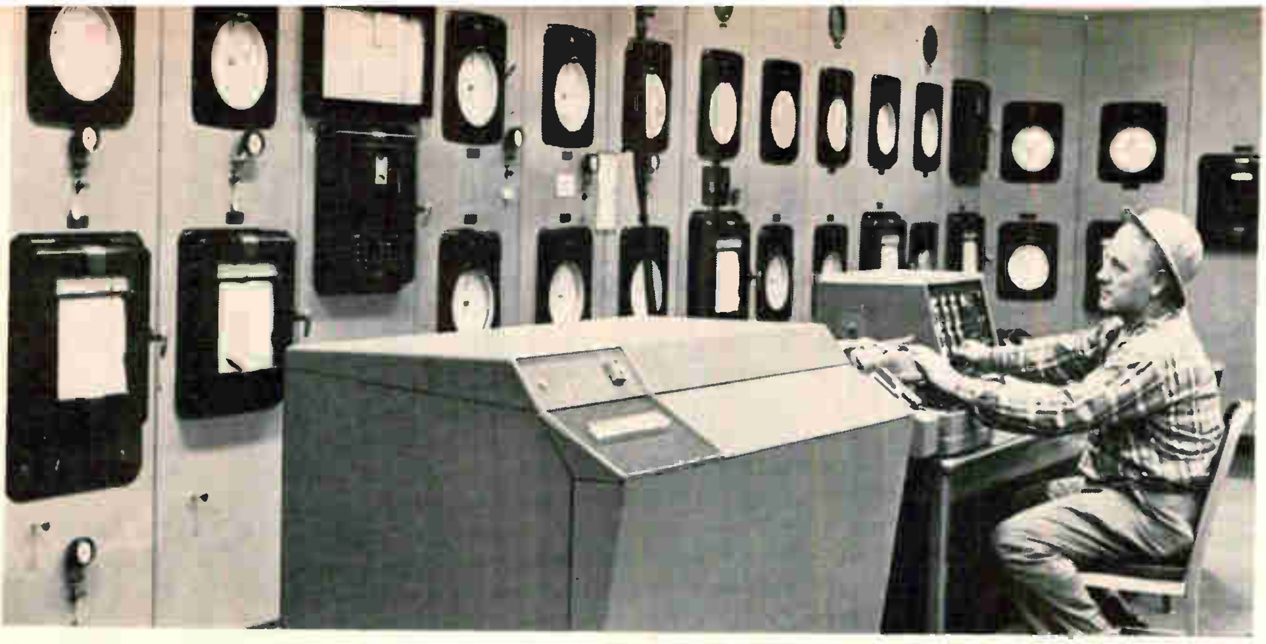
Operation of the computer can be summarized by the flow chart on page 53. During each one second interval, the computer rapidly scans the output channels. When an input channel has been sampled, quantized, and the transient in the A/D converter has disappeared, an interrupt signal causes the machine to stop scanning the output lines and to take the input signal and process it. This involves calling the appropriate data for that channel out of memory, checking the variable to insure that it is within allowable limits, and signaling an alarm if it is not. Assuming it is within limits, the variable is substracted from the set-point (stored in memory) to form the present error. This error and the constants in memory are used with the digital approximation of the proportional-plus-integral algorithm to calculate a new count-down word. This word together with the present error are then stored again in memory and the computer returns to output scanning until interrupted again by the next input channel.

The DDC computer calculates the number of pulses which must be supplied to each stepping motor to effect the required change in the variable and stores these numbers in its memory. Each time a pulse is transmitted to a stepping motor, the number stored in the memory is counted down by one until it is zero (when the change desired in the variable is completed).

During each one-second sampling interval the computer continually scans the output channels, checking count-down words in the memory. If a word is non-zero, a pulse of the proper polarity is sent to the corresponding stepping motor and the count-down word decreased by one. The computer proceeds to the next channel doing the same operation and when all channels have been scanned, begins again with the first one. Assuming that the computer must be capable of driving any motor at its maximum speed, each output channel must be scanned approximately 150 times per second.

If the operator wishes to insert new set-points or controller settings or request certain output data, he signals the computer from the typewriter input. Such an input is of lower priority than the input scanner.

Besides supplying pulses for stepping motor type actuators, this DDC computer design is capable of supplying the other two required types of outputs.



Simulated at Texas City were those instruments at the left next to the air gages. Tests using an RW-300 computer proved DDC'd loops responded at least as well as conventional loops but in most cases both smoother and faster

A low-power motor can be used to rotate the wiper of a rheostat to provide a current for the current-to-pneumatic conversion needed to operate pneumatic actuators. The stepping motor provides the memory required for this analog output. The pulse-width type of output is obtained by replacing the stepping motor with a flip-flop. The flip-flop is set when a new Δm is calculated for the channel and is reset when the count-down word is zero. For a constant count-down rate the flip-flop is set for a time proportional to Δm.

Further research and development

From recent simulations and studies it appears that some form of Direct Digital Control for processes will, as one DDC manufacturer has stated, find a budding market in about two to three years. But, in order to make DDC completely practical (one computer manufacturer says this will be in a minimum of five years—Ed.), further development of input sensors (providing digital outputs economically) is necessary. Digital output devices must also be perfected with particular attention paid to speed of response, economics, and reliability.

The introduction of fluid logic with its low cost, low volume, and freedom from environmental limitations (which makes possible DDC computers which are not entirely electronic) will be a challenging factor.[7] The slower operating speed of fluid devices would limit the number of loops that could be controlled by a single machine to 10 or 15, but this would be compensated for by the decrease in cost. An increase in reliability would also be obtained by having 5 or 10 DDC computers, rather than one, controlling a large plant.

Since the cost of any computer is tied closely to the number of bits carried through calculations and the sampling rate, it may be desirable (strictly from a marketing viewpoint) to take advantage of the difference in quantization level required for transient versus steady-state operation.[8] That is, during an upset of the process, the level of quantization of the controlled and manipulated variables could be decreased and the sampling rate increased. The machine would be designed to control the process during transients or upsets using a given sampling rate and a low level of quantization (3 or 4 bits). When steady-state is approached and resolution of control becomes important, the sampling rate could be decreased and the level of quantization increased. In this way, it would not be necessary to build a computer capable of operating simultaneously at the maximum sampling rate with the maximum quantization levels, and this might result in significant reductions in computer cost.

Certain non-linear control algorithms could also be easily implemented by a DDC computer, which would be too expensive to add to analog controllers. For example, a bang-bang type of control (full-on or full-off) is often effective when errors are large. A combination of this type of non-linear control for large errors and conventional control (P-I) for small errors may result in distinctly improved control at no additional cost, since it involves only a minor modification of the DDC computer described.

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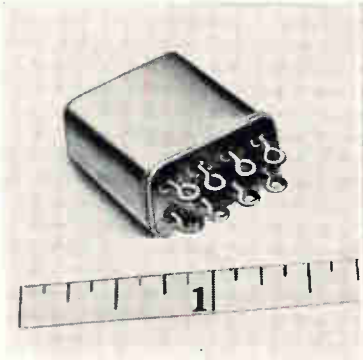
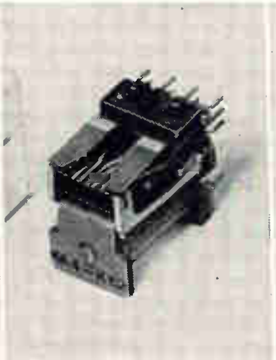
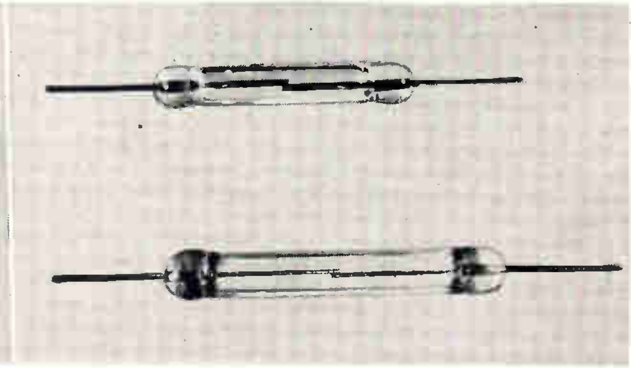


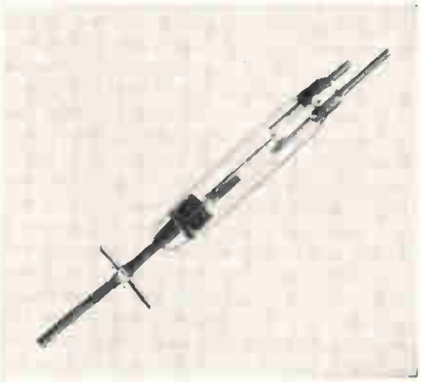
Rotary armature, GS 57668



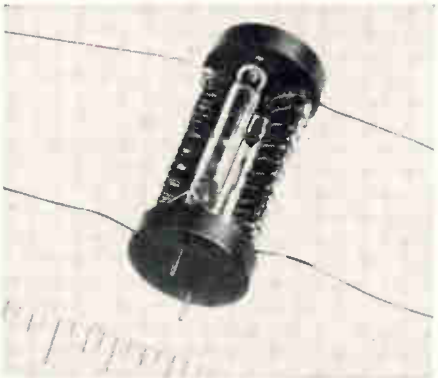
Miniaturized MA type



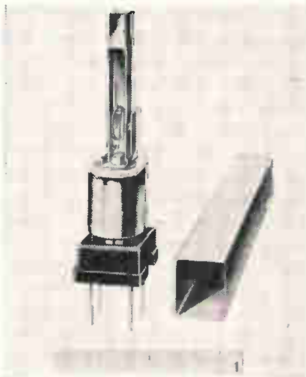
Dry reed sealed contacts



Mercury wetted type 218



High speed Ferreed relay



Tuned Reed Selector type 215

Relays that challenge semiconductors

New devices make springs and coils look even more attractive in power and control applications that don't require very high speed operation

By Waldo Holcombe
Manager, Applications Engineering, Sigma Instruments, Braintree, Mass.

When semiconductor devices were sweeping the electronics industry a few years back, many designers put them into almost every kind of circuit whether they really belonged or not. Sometimes they swept out electromechanical relays on a psychological basis rather than technical. Engineers decided that only transistorized equipment was up to date; relay equipment was not. True, the relays had some serious limitations: most were slow speed devices and contacts pitted and burned reducing the life of the switch.

Since those salad days, manufacturers have developed new relays (see photographs) that are faster than those of five year ago and have longer life. Some, for military missile systems, have expected lifetimes of one billion operations—an unheard of figure in 1959. A lot of designers have swung back to electromechanical relays and design procedures based on technical and economic considerations rather than psychological reasons (Table, shown below).

When comparing the electromechanical relay to a semiconductor switch, a designer has to consider the mechanical limitations of the springs, pivots, coils and contacts. Similarly, he has to remember that a transistor alone is usually not a switch. A semiconductor switch has a transistor plus other components and wiring.

In general if very high speed operation is required, the electromechanical relay is out. Most relays still operate at speeds of milliseconds or slower while semiconductor circuits operate at speeds of microsec. If high power must be switched or cost is critical the semiconductor circuit is usually unsatisfactory. A semiconductor switch can be ten times as expensive as an electromechanical relay; in some applications, 25 times as costly.

The most important design considerations are size, reliability, lifetime, circuit isolation and speed of operation. Probably the most significant new developments in relays are miniaturization, packaging (hermetically sealing in glass enclosures) and new applications.

Squeezing in a switch

If a designer has to "squeeze in" a switch, he usually has to go to an electromechanical device unless a single transistor or silicon-controlled rectifier can serve as the switch. Other solid-state switches require associated circuitry and heat sinks that make the complete switch so bulky it isn't tiny at all.

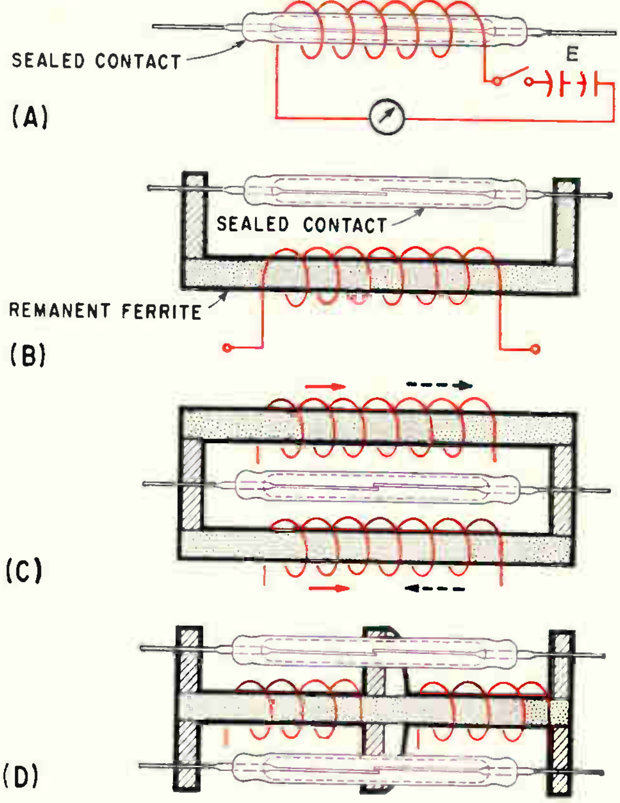
If multiple circuits are involved and multiple functions have to be performed semiconductor switches are at an added disadvantage, particularly in applications where weight is a limitation. The physical size of a solid-state switch in excess of a 3-pole relay can be the size of a shoebox.

A typical new miniaturized relay is the GS 57668 rotary armature device used in military designs. Even though it is no bigger than a crystal can, it has a rotary armature operating two transfer contacts which are arranged symmetrically. The relay has longer life than older switches because its contacts are made of precious metal and are sealed in a contact chamber that is kept free of plastic materials. As a result, the brown powder of organic

The relay versus semiconductors

Factors	Semiconductor Relay	Electromagnetic Relay
Sensitivity	10–100 ma at 1–10V	0.1–1.0 W at 0.1–10^4 ohm
Speed of response	microsecond range	1–25 milliseconds
Versatility	Single Purpose	Excellent
Life	Excellent	Fair
Circuit Isolation	Poor	Excellent
Reliability	Varies	Varies
Vibration	Excellent	Fair
Temperature	Poor	Good
Humidity	Good	Fair
Contamination	Good	Poor
Size	Poor	Fair
Quantity production	Favors large quantities	Favors small quantities
Overload characteristics:		
Signal circuit	Usually good	Fair
Load circuit	Usually poor	Good
Cost		
Development	High	Low
Manufacturing	High	Low
Maintenance	Excellent	Low

Bell Telephone Laboratories



Four ways to operate a high speed miniaturized reed relay

polymers cannot form and coat the contacts, increasing their resistance. The GS 57668 is designed to operate at 100 milliwatts at 25 c. Switching speed is 2.5 milliseconds.

Another example of real miniaturization: the new MA and MB relays developed by Bell Telephone Laboratories for space projects. The MA relay has a maximum contact capacity of 4 transfer contacts; the MB has a minimum capacity of 6 transfer contacts. Both are small enough to be mounted on printed circuit boards.

Through thick and thin

In almost every application, reliability, life or both have to be serious considerations. In many ways the electromechanical relay is more reliable than the semiconductor circuit. A transistor used within its rating is a very reliable device, but it is extremely sensitive to current and voltage transients that exceed its ratings. A transistor can be protected against transient surges—generally by placing a diode across any load inductance or installing bypass capacitors by adding components, but this reduces overall reliability. The minimum complexity for a circuit like the Schmitt trigger used as a switch turns out to be: 2 transistors, 4 resistors, 1 capacitor, 1 diode, and at least 18 solder connections or joints.

A relay to do the same job is probably not as reliable as a transistor alone. But relays can withstand transient surges that would be catastrophic to a transistor.

Operating characteristics of sealed contacts in air core coils

Sealed contact	Operate amp. turns	Release amp. turns	Approx. minimum operate time
224A.......	90 ± 12	34 ± 8	About 1 m.s.
237A (G29).	34 ± 12	18 ± 8	" .5 m.s.
237B.......	30.5 ± 5.5	15 ± 4	" .5 m.s.

Relay contacts used to be vulnerable to contamination from volatile silicon, hydrocarbon or sulphide products and subject to clogging from dust and lint. Sealed relays, which are more expensive, have almost ended this restriction. To improve reliability, relays are sealed in glass and the two main types of glass enclosed devices are the dry reed type and the mercury wetted type.

The reed relay has been available for years, however, it has been miniaturized so its scope of application has increased. It is operated by a magnetic field in several different ways (figures above). In A, the current passes through a winding surrounding the sealed contact. In B, pulse operation magnetizes a square-loop ferrite element which is the reed. The sealed contact remains closed without holding power because it is magnetically latched. A pulse, smaller in magnitude and of opposite polarity, releases it. Minimum operating time varies from 1½ millisec to 1 millisec depending on ampere turns (see table above).

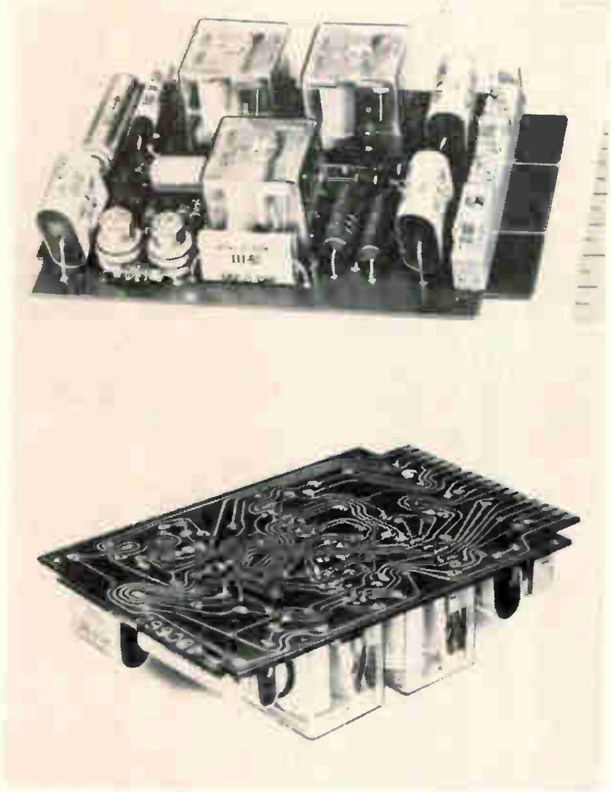
Another kind of dry reed relay, developed for missile applications, can have 2 or 3 normally opened contacts. These relays make use of permanent magnets to bias the break contacts closed in the unenergized condition. Other new developments include cobalt and cobalt-zinc ferrite cores which increase the capability of relays by adding memory without holding power, coincident selection, and high speed operation close to the microsecond range. These are the ferreeds.

Sealed relays with mercury wetted contacts have

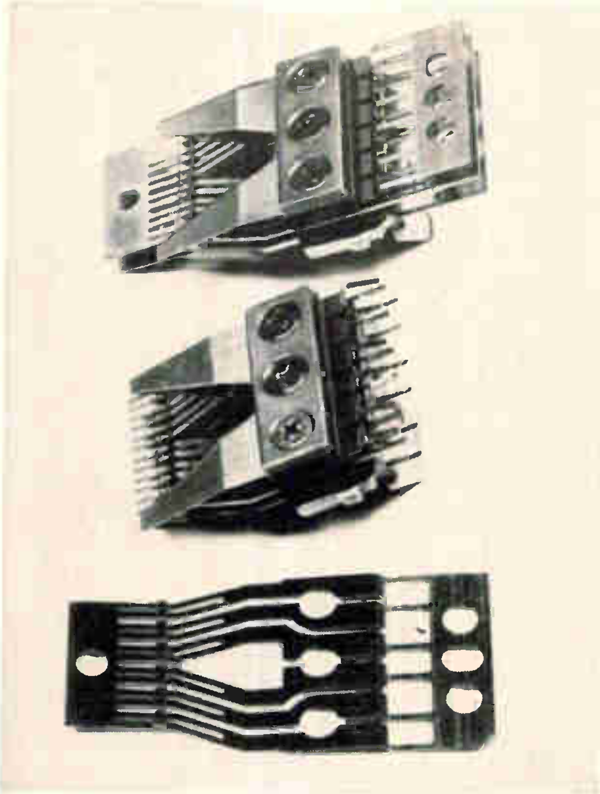
The author

Waldo Holcombe joined Sigma Instruments, Inc. in 1942. In 1944 he was in charge of Research and Development.
He attended Harvard, where he majored in Physics. He took post-graduate work in astrophysics at the University of California.
Prior to joining Sigma, he taught science for a number of years at the Brooks School in North Andover, Massachusetts, and returned to Brooks during 1945-51. He is now a trustee of that school.
He went back to Sigma in 1951, and in 1958 was transferred from Engineering to Sales. At that time he was appointed Applications Engineering Manager within the Sales Department, the position he now holds

Bell Telephone Laboratories



Plug-in printed wiring board with MB type relays



Contact springs for MB type relay

the least contact chatter, sometimes none, and the longest operating life. The 226 D type is one of the newest and smallest, so small it can be packaged in a small size relay can.

In another new mercury wetted relay, long life has been sacrificed to make it more resistant to shock and vibration. Changing armature design and reducing the amount of mercury cut life almost 10 times to several million operations.

Circuit isolation

Still another advantage the electromechanical relay has over its semiconductor rival is circuit isolation. When you turn off a relay, it is totally off and the impedance will be about 1,200 megohms. A solid-state switch is never quite off, because there is leakage through the transistor. The impedance is about 10 megohms, or only one hundredth as good as the electromechanical device. Thus, wherever a designer cannot tolerate a little current leaking through the switch, he has to use.

Another circuit consideration is voltage drop, which is only about 0.01 volts in a relay. In a solid-state device, voltage drop will range between half a volt and 1½ v. If the designer has to put several solid-state devices in series, the voltage drop across them gets quite high, particularly in a low level circuit. It may get so high, no current can pass.

Radiation can affect the conductance and leakage of semiconductor devices. In a nuclear environment, the beta value, or gain, of a solid-state device can degrade sharply. For applications likely to be exposed to such an environment, a designer can choose an electromagnetic relay made of materials that are not much affected by radiation.

As designers come back to the electromechanical relay, they are finding new applications for them. One interesting one is a frequency-sensitive relay, named the 215 type tuned selector (see figure below). Basically, it is a highly precise and stable miniature tuning fork with a light-weight contact. The device is sensitive to frequencies of the order of 0.5 sec. and is insensitive to noise interference. The accompanying graph compares its performance over a wide temperature range at nominal frequencies of 517.5 and 997.5 cycles per sec.

Tuned relay can be carried in pocket and is used as a signal device for Bell system service.

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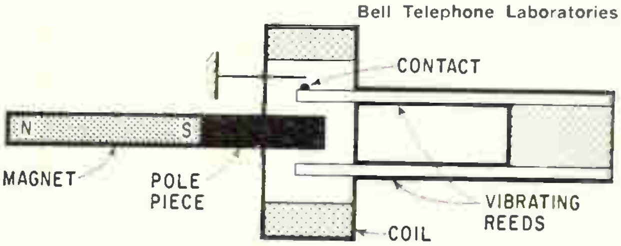


How the tuned relay works

Switching a stepping motor

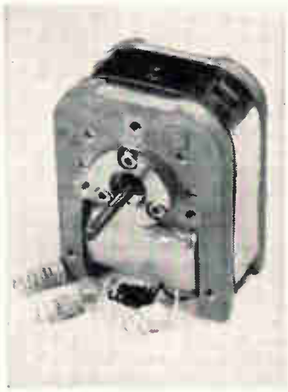
A high speed stepping motor can be switched by either an electromechanical relay or a semiconduc-

Relay versus semiconductor

Sigma Instruments, Inc.

This relay . . .

or this semiconductor circuit . . .



could switch this stepping m

Considerations	Semiconductor	Electromagnetic
List Price	$65.00	$33.00 plus arc suppression
Size	4 1/2 in. x 6 1/4 in. x 1 1/16 in. 31 cu in.	1 5/16 in. x 1 5/16 in. x 2 1/2 in. 3.3 cu in.
Life	Unlimited	10^8 to 10^9 operations
Maintenance	None needed	Replaceable contacts or plug-in relay.

tor circuit. A typical motor speed is 200 steps per second.; driving power is about 0.25 amps from a 100-v d-c source or 24-v d-c. The possibilities for switching are a general purpose polarized spdt (single pole, double throw) magnetic-latching type relay or cyclopulser semiconductor drive. The chart points out how the two compare. You can see the decision depends on the specific application.

Standard relays and their advantages

Single-pole double-throw d-c relays, at right, are available in thousands of combinations of coil resistance, sensitivity, contact material, housing and mounting styles. This type of relay is suitable for applications that require stable and accurate response to an overcurrent condition and frequently can be adapted to fractional millisecond protection of overloaded transistors or meters.

Magnetic latching relay shown has unusually high sensitivity and immunity to shock and vibration. This polarized double-pole double-throw relay latches magnetically in the position last energized, without standby power. The insulating resistance in the contact circuit approaches 10^{15} ohms, making this type suitable for high-impedance circuits.

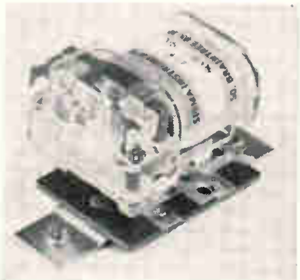
The single-pole double-throw low-cost relay has a mechanical life of 10^9 operations. Input sensitivity of 5 milliwatts can tolerate 100 ampere contact circuit transients. This type is available for either a-c or d-c operation in numerous mounting styles. Streetlight controls subject to lightning transients are typical applications that require a relay of this capability.

The single-pole double-throw magnetic latching relay, shown below, has high speed or no bounce. This relay responds with very little pulse distortion to a variety of signal pulses with approximately one millisecond response time. Telemetering and telegraphy systems require this characteristic.

Sigma Instruments, Inc.

D-c relay

Magnetic latching relay



Low-cost, long life relay

High speed, no bounce relay

Standard relay for a wide range of applications

Advanced technology

Cryogenic flux pump switches high currents

The cryotron was developed for computer circuits; now a modified version has even a brighter future in high power circuits for superconducting magnets

By Theodor A. Buchhold
Advanced Technology Laboratories, General Electric Co., Schenectady, N.Y.

In a work room at General Electric's Advanced Technology Laboratories, a superconductive coil and a flux pump (cover) sit in a liquid helium bath conducting very large d-c currents—up to 500 amps. When a signal from a phase shifter, one of the components, makes a coil superconducting, the magnetic flux generated by another superconducting coil (another of the components) connected to it rises. If the coil flux decreases, energy flows back into the power supply circuit.

This is a new kind of d-c power supply or flux pump. It depends on the properties of superconducting materials operating at 4.2 deg. K. Small a-c current carried by small wires powers the flux pump. It depends on the properties of superconnetic field strength, the field is maintained by induced, loss-free, superconducting currents even though the power supply is disconnected.

The small feeder wires carrying the a-c current are a big asset. In superconducting studies, the trend is to generate bigger magnetic fields in larger and larger solenoids, built of heavy conductors. But these heavy conductors also carry large amounts of heat into the low-temperature container (or cryostat), reducing the efficiency of the cryogenic setup. The new flux pump could handle thousands of amperes of current without heavy conductors.

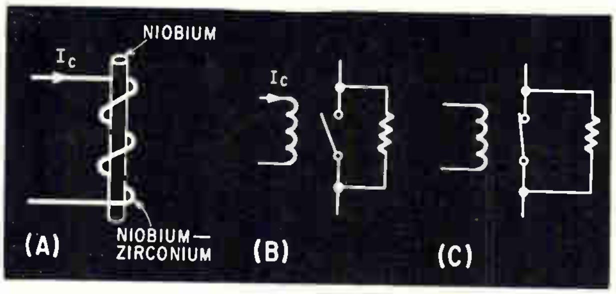
Improving on the cryotron

What makes this flux pump work is a new component called the reactor cryotron. A saturable reactor is added to a specially-made cryotron unit. The reactor can sense when the cryotron is to be switched on or off to make it superconducting.

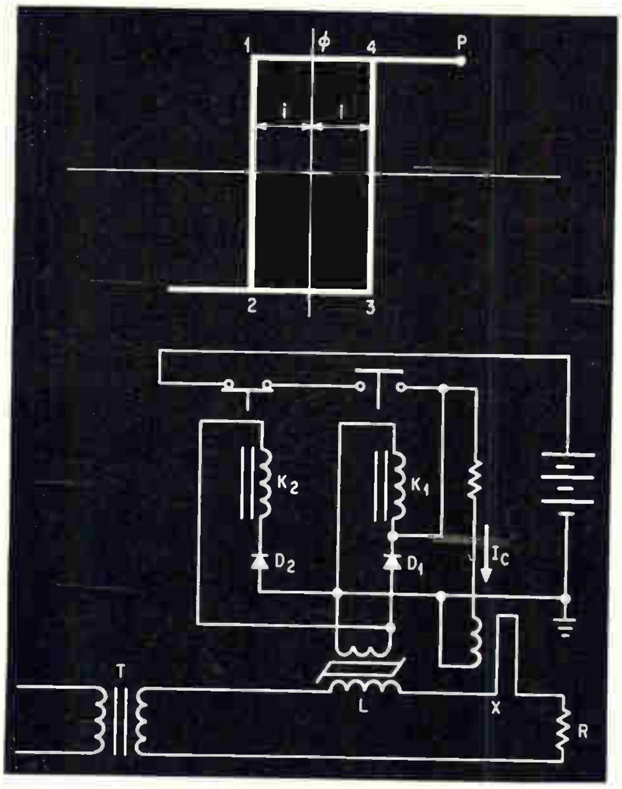
The main difference between the conventional small-current computer cryotron and this new com-

The author

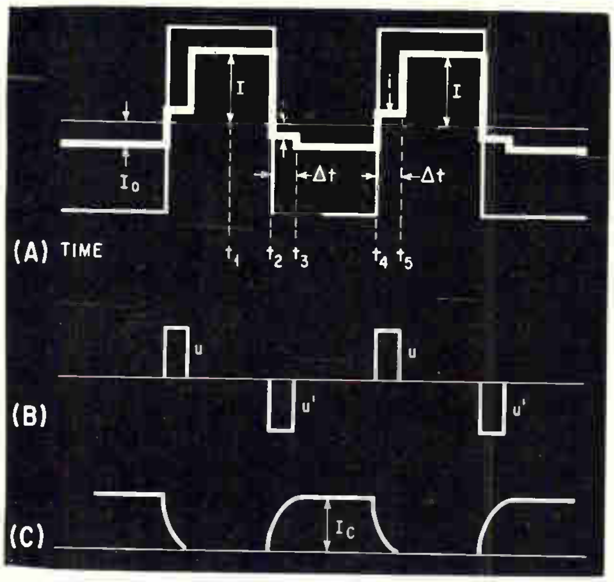
As technical consultant to GE's Advanced Technology Laboratories cryogenic projects, Dr. Buchhold holds five patents for cryogenic devices and has more pending. One of the V-2 missile guidance scientists, he also served as chief of the control and guidance branch of the Guided Missile Development Division at Redstone Arsenal, and there pioneered in gyros and accelerometers with air bearings, special servos, magnetic amplifiers and transistors for missile control. He developed the basic concept for the Redstone Missile Guidance System. Before joining General Electric in 1956, Dr. Buchhold was consultant to the vice-president of engineering of the Ford Instrument Co.



Model of cryotron, (A); equivalent circuit of cryotron when energized, (B); when not energized, (C)



Reactor cryotron control of superconducting coil, bottom; hysteresis loop for saturable reactor used in circuit, top



Waveforms occurring in reactor cryotron: voltage and current, (A); reactor signal, (B); control current, (C)

ponent is the different geometry and the much larger dimensions. The computer cryotron is made of a superconducting wire or metallic film—called a gate—placed near a coil or second metallic film—called the control—which applies a magnetic field to the gate. In a typical cryotron, the gate may be a thin niobium wire and the control coil is a niobium-zirconium alloy which has a higher critical field than plain niobium. With this construction the cryotron can handle milliampere currents.

For large currents, in the reactor cryotron, the gate is made of niobium tape of proper width and length, bifilarly wound. The tape can be folded so that it occupies only a small space and can be surrounded by a control coil of niobium-zirconium.

In either case, when the coil is energized, producing a strong enough magnetic field around the gate, the niobium wire is made resistive. A cryotron corresponds to a switch which is open when the control coil is energized, closed if the control current is interrupted. The resistance of the open cryotron, however, is finite, not infinite like the resistance of an ordinary switch. For most applications, the resistance of the cryotron is sufficient for it to operate as a switch.

The tiny computer cryotron is employed in computer logic and in computer memories. Its most desirable features: simplicity, fast response and potential small size with very low switching currents. The new power cryotron can be used in a variety of applications; for example, as a cryogenic rectifier for large currents.

Cryogenic rectifier

The operation of a reactor cryotron can best be explained in a half-wave rectifier circuit (left), which is also a basic element for the more important full-wave rectifier circuit. Transformer T is maintained at 4.2 deg. K and has its secondary winding connected through saturable reactor L and the power cryotron X to the resistive load, R. The reactor flux ϕ exhibits the hysteresis characteristic shown. It is assumed that transformer T delivers a rectangular voltage pulse V. At time t_1 a large current I flows in the power circuit and the saturable reactor is saturated, represented by point P on the hysteresis loop. At time t_2, voltage V reverses and the current tends to follow. However, when the small negative magnetizing current i is reached, the saturable reactor leaves its positive saturation state and flux ϕ moves along path 1-2 on the loop. The full voltage V now appears across the reactor, inducing in its secondary winding a negative voltage u′, which energizes relay K_1 via rectifier D_1. Its contact closes and control current I_c can flow from the battery through the closed contacts of relay K_2 and K_1 to the control coil of cryotron X. During the interval Δt, in which the reactor goes from positive to negative saturation, only the small magnetizing current i flows and control current I_C builds up.

At time t_3, negative saturation is reached. The power-circuit current becomes $I_0 = V/r_0$, determined by resistance r_0 of the now resistive cryotron. After t_3, the saturated reactor consumes no voltage and its secondary voltage u′ becomes zero. Relay K_1 remains energized through its contact. At time t_4, voltage V becomes positive again and the current again tries to follow. However, the reactor now limits the current to the small positive magnetizing current $+i$ and the flux ϕ follows path 3-4 on the hysteresis loop. In the secondary winding of the reactor, an opposite voltage u is induced. Due to rectifier D_2, this energizes relay K_2, and opens K_1, thus interrupting the control current I_C in the control winding of X. In the absence of a control field, the cryotron becomes superconductive. After this time interval Δt, positive saturation is reached at t_5 and full current $I = V/R$ flows.

The time interval established by the reactor, during which the current is kept small, is quite important since it gives the cryotron time to change from the normal to the superconductive state. Without the current limitation during Δt, the decreasing cryotron resistance would cause an increasing current I and such losses that the cryotron might reach its transition temperature and not to go superconducting.

In the actual experimental circuit, the two relays shown in the diagram were replaced with solid-state switching devices.

In this circuit, the reactor cryotron was switched on and off by voltages derived from the reactor. For many applications only the "on" signal from the reactor is used to produce a high resistance to reverse currents. The "off" signal, which makes the cryotron superconductive, can be derived from any signal source; e.g., the output of a phase shifter. Then the controlled reactor cryotron resembles a controlled rectifier, which is made conductive by a gate signal, and offers very high resistance to reverse currents.

All circuits suitable for controlled rectifiers can be used for controlled reactor cryotrons; for instance, it is possible to build a full-wave rectifier circuit for large d-c currents which can be connected to a superconductive coil. Such a circuit can be made entirely of superconductive material. Since a cryotron has zero resistance in the forward direction, the circuit represents a d-c supply with no internal resistance, having an approximately constant d-c output voltage. Therefore, the current supplied to a superconductive coil increases linearly with time. If the primary current into the transformer is interrupted, the d-c current continues to flow as a persistent current since at least one of the two cryotrons acts as a superconducting short circuit across the coil.

If the reactor cryotron is controlled by a phase shifter, as mentioned above, the magnetic field in the coil can be controlled, and, in fact, a flux decrease can be achieved; energy is then fed back into the power supply. Such a circuit controls the flux in an inductive load with no moving mechanical parts and so might be called an electrical flux pump.

Experimental model

A feasibility model of a full-wave rectifier circuit with reactor cryotrons controlled by a phase shifter was built and connected to a superconducting coil of $L = 1.8 \times 10^{-3}$H. The maximum d-c current was somewhat above 500 A and produced a field of about 25,000 oersteds with a stored energy of 220 joules. When exceeding this value of current, the cryotrons became resistive. With phase shifting, it was possible to adjust the field to any desired value, and also to obtain persistent currents or fields by disconnecting the power supply. The supply could be reconnected at any time to permit changing the field setting. The rectifier circuit was fed with a rectangular voltage of 10 cps and the a-c currents were below 1 ampere. The low frequency allowed sufficient switching time for the cryotrons.

More development work was indicated by the experimental model, especially toward building cryotrons with higher maximum currents, but it is believed that in the future, reactor cryotrons for electrical flux pumps can be built to carry several thousand amperes.

The author thanks P.J. Molenda, R.K. Terbush, S.H. Minnich and R.E. Morgan for their assistance.

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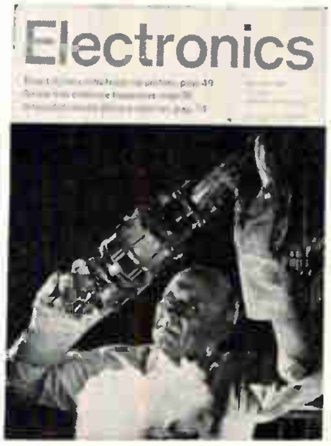
Front cover

In the cover photograph, author Buchhold is holding up the assembly containing all components that operate at 4.2 deg. K. Photograph by Walter B. Halstead, General Electric Company.



Now the gate turn off switch speeds up D-C switching

A logical development of the silicon controlled rectifier, the gate turn-off switch is out of the experimental stage. Its 10 times faster turn-off speed opens up a variety of applications

By Denis R. Grafham

General Electric Co., Rectifier Components Department, Auburn, N.Y.

Although semiconductor devices, such as the silicon controlled rectifier and the power transistor have simplified switching in power and control circuits, both these devices have serious limitations. The power transistor is inherently a low voltage device while the SCR is difficult to turn-off once it has been triggered in d-c circuits. A new device, the gate turn-off switch, has no such limitations. It can be turned off as well as on from its gate input terminal. And it operates at frequencies up to 100 kilocycles per sec.

The new device is a logical improvement of the SCR. It too is a three-terminal, four layer, pnpn switching device. But its structure is more complex. The gate region has a much larger active area in the GTO than the SCR and it is this change which helps give the GTO its unique characteristic.

In d-c circuits, the disadvantages of the SCR are most evident. Its maximum operating frequency is low because it must be reverse—biased for a relatively long time (10 to 20 microseconds) through an external low impedance circuit which dissipates considerable power. These restrictions confine the SCR to operate at frequencies of a few kilocycles, current ratings from 50 ma to 470 amps rms at d-c voltages of 25 to 1,000 volts.

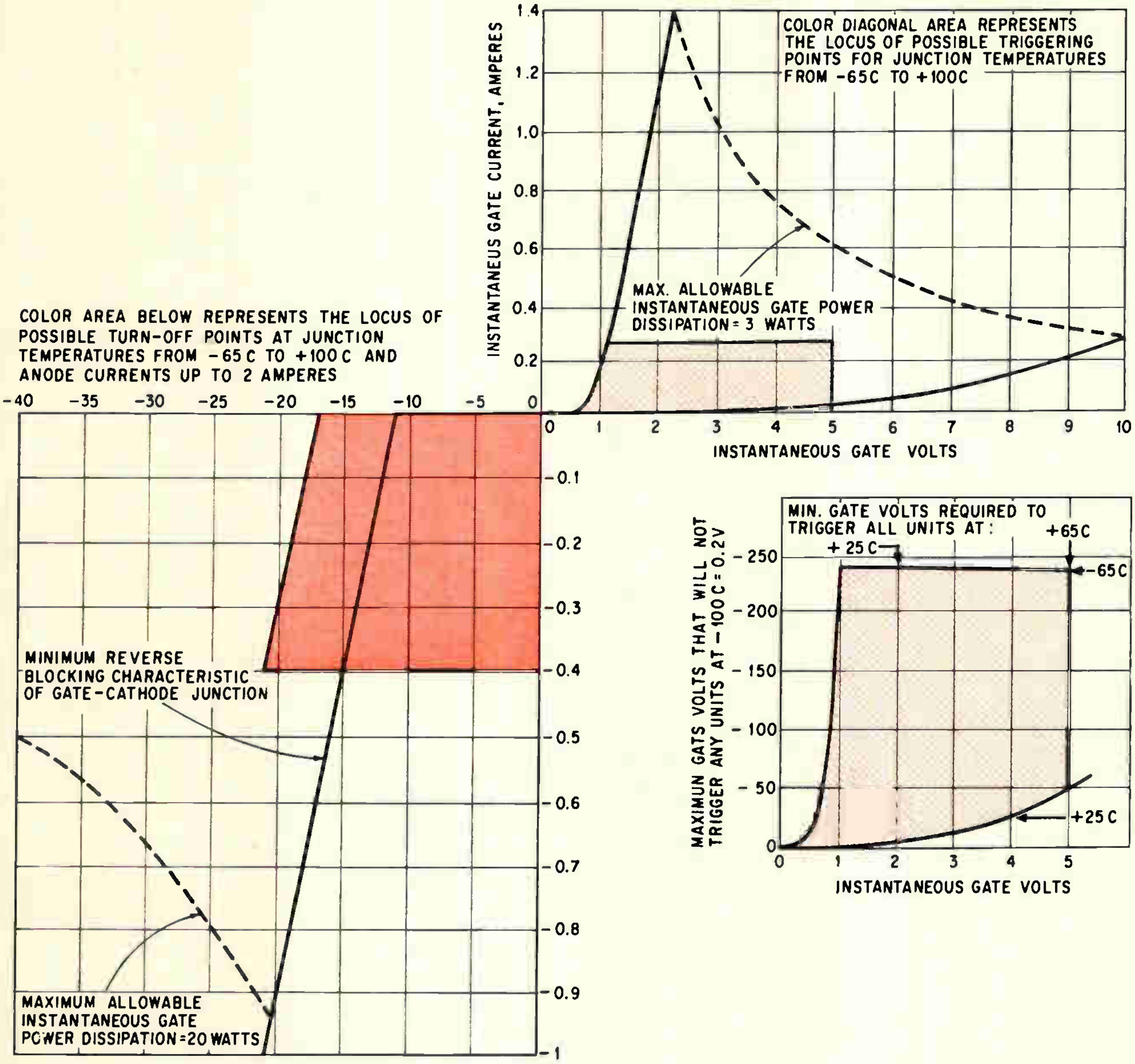
The biggest advantage of the GTO is its ability to be turned on and off by the gate signal, a low power pulse of less than 10 microsec. A positive pulse of gate current latches the GTO into conduction and, once fired, the switch stays closed. A subsequent negative pulse turns it off again. That's an advantage over the power transistor since the power transistor requires the signal be applied continuously to hold the switch closed.

Current gain exists between anode and gate during turn-off as well as turn-on. Thus the GTO has the advantage over the SCR in d-c switching of faster turn-off and higher speed operation. As a result, commutating components can be smaller and cheaper. Turn-off speed is 10 times faster than that of the SCR, with turn-off gains of 5 to 15. Also, load waveform distortion is minimized because commutation transients are remote from the load carrying circuits.

Compared to switching transistors, the GTO requires much less drive power, because of its true bistable nature. The new device can handle much higher load power for the same current rating, because it is inherently a high voltage device, whereas the transistor is not. In a-c applications, the GTO can be phase-controlled for power factor improvement. The GTO is still a low-power device, however, the largest commercially available GTO being rated at about 7.5 amps at 500 to 600 volts.

GTO characteristics

Like the SCR, the GTO is triggered into conduction by injecting a pulse of forward current across its gate cathode junction. Generally, more gate current is required to trigger the GTO than an equivalently rated SCR. Latching and holding currents are higher, and more power is dissipated during forward conduction. As the potential turn-off capability of the GTO is increased the wider these discrepancies between SCR and GTO become. They are the price paid for gate turn-off capability. As an illustration, consider the General Electric G5 series GTO and the G6. The G5 series GTO features low trigger, latching and holding currents,



Gate triggering characteristics are needed to design circuits using GTOs. The first quadrant defines the positive gate triggering voltage-current relationship while the third quadrant displays the equivalent negative turn-off data

with gate turn-off up to one ampere. The G6 series requires higher trigger, latching and holding current, but has turn-off capability up to two amperes.

Since the GTO is intended primarily for d-c switching applications, a high reverse voltage rating is unnecessary in most applications so all standard G5 and G6 devices have a nominal 25 volt reverse rating only. When a higher reverse voltage capability is required a conventional silicon diode may be connected in series.

The GTO is charge-operated in the sense that positive gate current must flow for a finite time to trigger the device "on", while negative gate current must flow to turn it off again. In either case gate voltage must be provided to force the gate current through the GTO's internal gate impedance. Since the gate impedance is not constant, it is most convenient to display the gate volt-ampere characteristics of the GTO in graphical form.

The first quadrant defines the positive gate triggering voltage-current relationship, while the third quadrant displays the equivalent negative turn-off data. To ensure turn-off, negative gate voltages in excess of the static gate cathode avalanche voltage of some units must be provided. This characteristic precludes the use of d-c or long duration gate turn-off pulses, unless a silicon diode is connected in series with the GTO cathode lead. Without such a diode, overheating of the gate-cathode junction after turn-off might result. If the diode is not used, gate pulse duration must be less than specified (see chart) for a given gate pulse magnitude.

Turn-off characteristics

To turn off a conducting GTO, sufficient charge must be extracted from its gate to stop internal regeneration. The charge required can be computed from minimum turn-off gain (G_1) and the gate pulse width at which G_I is specified. (G_I is defined as the ratio of anode current being turned off to the negative gate current required to effect turn-off.) Since gain is a function of several variables, including pulse width, G_I is specified for worst case conditions. The major factors affecting turn-off gain are:

(a) Gate pulse width—As the turn-off gate pulse duration is decreased, gate current magnitude must be increased to maintain the correct charge relationship. The relationship between turn-off gain and pulse duration is shown in chart (A).

(b) Anode current—turn-off gain is dependent on the magnitude of anode current being turned off. As anode current is increased above the holding current level, turn-off drops rapidly from infinity to I_H to some minimum value, and then climbs steadily upward again. At slightly above the maximum anode current that can be gate-commutated, turn-off gain drops suddenly to zero. This effect is caused by the inability of the gate to maintain control over the entire GTO cathode region at high current levels, and is a characteristic of all gate turn-off switches. It is possible to destroy a GTO by attempting to gate-commutate more than the design level of anode current. Chart (B) shows the variation in turn-off gain with anode current for the G6 GTO.

(c) Junction temperature—in general, gain decreases as junction temperature increases. Minimum turn-off gain is usually specified, therefore, at maximum rated junction temperature.

(d) Anode voltage and load impedance—turn-off gain is somewhat dependent on the anode supply voltage, and the nature of the load impedance in the anode circuit. As anode current starts to fall during the final phase of turn-off, the magnitude of the resultant voltage that develops across the center blocking junction of the GTO affects the ability of the gate to complete its job. The higher the voltage, the more difficult it becomes to complete commutation. An unclamped inductive load can generate a high forward anode voltage during turn-off, which will affect gain the same way as does a high supply voltage.

(e) Turn-off gate pulse rise and fall times—a fast-rising negative gate pulse is beneficial to the turn-off process, but too rapid a pulse decay time can degrade the GTO's turn-off gain. Both these effects are associated with the GTO's gate-cathode capacitance. While the negative dv/dt of the pulse leading edge speeds up turn-off by discharging the gate capacitance out of the gate, the positive dv/dt of its trailing edge tends to recharge the capacitance in a direction to retrigger the GTO. A similar phenomenon affects the GTO during turn-on. Here a fast rising trigger pulse facilitates turn-on and a rapid decay encourages subsequent turn-off. The effect manifests itself during turn-on as an apparent decrease in gate trigger sensitivity and as an increase in anode latching current.

Turn-off methods

The GTO may be turned on and off by alternately charging and discharging a capacitor connected in series with its gate lead. When switch S_1 is opened, capacitor C_1 charges to E_1 through R_1 and the GTO's internal gate impedance. For the GTO to trigger, the following equations must be satisfied:

$$R_1 \leq (E_1 - V_{GTM})/3\,I_{GTM} \qquad (1)$$

$$C_1 \geq t_1/(R_1 + V_{GTM}/I_{GTM}) \qquad (2)$$

where V_{GTM} = maximum gate voltage to trigger (volts), I_{GTM} = maximum gate current to trigger (amps), t_1 = pulse duration at which I_{GTM} is specified (seconds).

When S_1 is closed, the charged capacitor C_1 discharges through R_2 and the GTO's gate impedance, and the GTO will turn-off providing:

$$R_2 \leq (E_1 - V_{GTO})/(2\,I_{GTO}) \qquad (3)$$

$$C_1 \geq t_2/(R_2 + V_{GTO}/I_{GTO}) \qquad (4)$$

where V_{GTO} = maximum gate voltage to turn-off (volts), I_{GTO} = maximum gate current to turn-off I_L amps (amps), t_2 = time duration at which I_{GTO} is specified (seconds), I_L = anode current following at instant of commutation (amps).

Equation 3 defines only the maximum value of R_2 for guaranteed commutation. In most practical circuits, for more rapid turn-off, R_2 can be made much smaller than its calculated value. The lower limit on R_2 is determined either by the peak reverse gate power rating of the GTO, or by some other limiting circuit consideration, such as the current rating of S_1.

Series capacitor turn-off

To select R_1, R_2 and C_1 for a G6F GTO operating in the circuit of (A), where $E_1 = E_2 = 28$ V (d-c); $T_A = 25$ C; $R_L = 28$ ohms, equations 1 to 4 are used. Assume $V_{GTM} = 2$ V, $I_{GTM} = 20$ ma, $t_1 = 20\ \mu S$ and $I_L = 1$ amp.

From Eq. 1, $R_1 \leq 430$ ohms. If $R_1 = 390$ ohms (nearest 10 percent value) Eq. 2 gives $C_1 = 0.0235$ μf. From G6 specifications, minimum turn-off gain $C_I = 5$ for 500 ma $\leq I_L \leq 2$ amps; $T_J \leq 100$ C; $t_2 \geq 10\ \mu S$.

The maximum gate current to turn-off, I_{GTO} is given by: $I_{GTO} = I_L/G_I = 1/5 = 200$ ma. From G6 specifications, maximum gate voltage to turn-off, $V_{GTO} = 21$ volts. Equation 3 gives $R_2 \leq 17.5$ ohms

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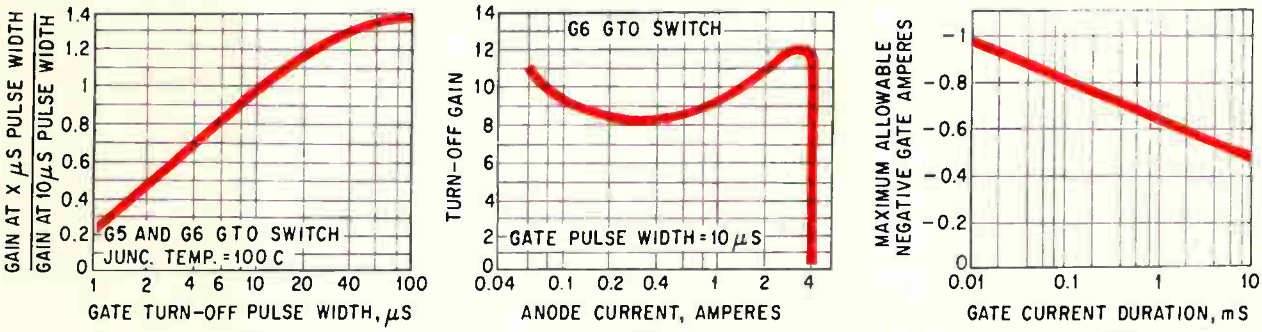
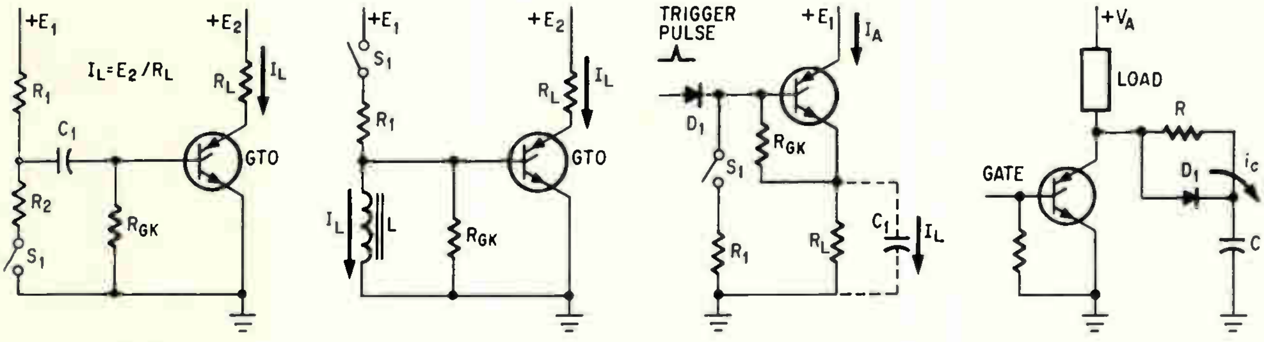
Denis R. Grafham joined GE's Rectifier Components Department in 1960. He has specialized in application work and preparation of technical literature in connection with SCRs, rectifiers, light activated switches and gate turn-off switches.

A native of England, he was educated at Churcher's College and the Royal Aircraft Establishment and holds degrees in mechanical and electrical engineering.

Prior to joining GE, he served as a development engineer with aviation firms in Canada and Seattle, Washington



Turn-off gain for type G5 and G6 GTO as a function of the turn-off pulse width (A) and load current (B). Avalanche gate current is plotted as a function of gate pulse width in (C)



Four turn-off methods for controlling the GTO. Device may be turned on and off by charging and discharging a capacitor in series with gate lead (A). Turn-off is achieved by interrupting d-c current in inductor between gate and cathode (B). Load impedance is connected between the GTO's cathode terminal and ground (C). Use of capacitor C allows higher anode current switching by diverting part of the anode current (D)

and eq. 4 gives $C_1 = 0.129\ \mu F$. Since the value of C_1 calculated for proper turn-off is higher than that required for turn-on, the higher of the two values must be used or let $C_1 = 0.15\ \mu f$ which is the nearest standard value. Using G6 specified peak reverse gate power of 20 watts, the locus of all possible ($V_G \cdot I_G = 20$ watts) is plotted on the gate volt-ampere characteristics. The gate turn-off source load line must lie to the right of this curve. The open circuit gate source voltage $E_1 = 28$ volts. The maximum permissible short circuit current $I_{sc} = E_1/R_2$ where R_2 is the slope of the line drawn on the V-A characteristic from $E_1 = 28$ volts tangential to the 20-watt peak power locus. The slope of such a line is 10 ohms. Thus $R_{2\ (MIN)} = 10$ ohms.

Parallel inductor turn-off

The GTO can be turned off by attempting to interrupt direct current flowing in an inductor connected between its gate and cathode terminals. In circuit (B) when switch S_1 is closed, current will flow through resistor R_1 and into the GTO gate. If the peak value of gate current $(E_1 = V_{GTM})/R_1 >> I_{GTM}$, the GTO will trigger. Assuming the GTO gate impedance is high compared to the d-c resistance of inductor L, in the steady state $i_L - E_1/R_1$. If switch S_1 is now opened, the current i_L must transfer from R_1 to the gate, and the GTO will turn off provided: $E_1/R_1 \geq 2I_{GTO}$ and $(L)(I_{GTO})/C_{GTO} \geq t_2$.

Because the switch S_1 is required to carry the peak turn-off current i_L for as long as the GTO is in conduction, it is usually necessary to select R_1 for minimum permissible turn-off current. In low speed circuits i_L can be minimized by stretching out the turn-off pulse time constant.

Load in cathode commutation

In the next circuit of the figure the load impedance is connected between the GTO cathode terminal and ground. A short positive pulse of gate current applied to the gate terminal through diode D_1 will trigger the GTO and energize the load. Diode D_1, a fast recovery type, decouples the gate triggering source as the gate and cathode terminals jump up to the supply voltage. The GTO can be turned off now by closing switch S_1, when current is diverted out of the gate terminal to ground through current limiting resistor R_1. The value of R_1 is selected so that as the load cathode current and voltage decay during the final phase of turn-off, sufficient current always flows out of the gate to satisfy relationship:

$$R_1 \geq R_L(G_1 - 1) - (V_{GTO} - G_I)/I_A$$

where G_1 = minimum turn-off gain over the anode current range I_A to holding current; V_{GTO} = maximum turn-off gate voltage (volts); I_A = peak anode current during commutation = $I_L/(1 - 1/G_1)$ amps.

Capacitor C_1, which provides a low impedance bypass around the load for the triggering pulse, also aids the turn-off process by "holding up" the load voltage as cathode current falls. In circuits where the load impedance presents a sufficiently low impedance to the trigger pulse, C_1 can often be eliminated.

Because there is no energy storage needed in reactive commutating elements, as in the two previous turn-off methods, GTO circuits employing cathode commutation are inherently capable of very high speed operation. The main disadvantage of the method is that during the turn-off interval anode current is increased by the amount of gate current flowing through R_1. As a consequence the allowable load cathode current must be reduced by a like amount so that the total peak anode current rating of the GTO is not exceeded during turn-off.

Special turn-off circuitry

In some GTO applications it is possible to aid the gate turn-off action by means of a special circuit.[2] As the GTO starts to turn off under the influence of a negative gate signal, part of the diminishing anode current is diverted away from the GTO as charging current to capacitor C_1. The amount of current diverted depends on the size of C_1 and on the rate of rise of anode voltage during turn-off thus: $I_c = C \cdot dr/dt$. This circuit allows higher than rated anode current to be gate commutated, although at the expense of load turn-off speed. Resistor R is added to limit capacitor discharge current through the GTO during turn-on. Diode D_1 bypasses R for maximum current diversion during turn-off.

Putting the gate turn-off to work

Here are six applications that make good advantage of the GTO: a flip-flop, ring counter, sawtooth generator, voltage regulator, high frequency chopper, and high voltage generator

The circuit P. 69 is a GTO adaptation of the SCR capacitor—commutated flip-flop. The diodes are GE1N2613s and the GTOs are GE G611Bs with suitable heat sinks. The circuit transfers load current from one load to the other each time a positive trigger pulse is applied to the common input line. Operation to over 10 kc is possible, and the circuit will accommodate a wide range of load voltages and currents, with suitable component selection.

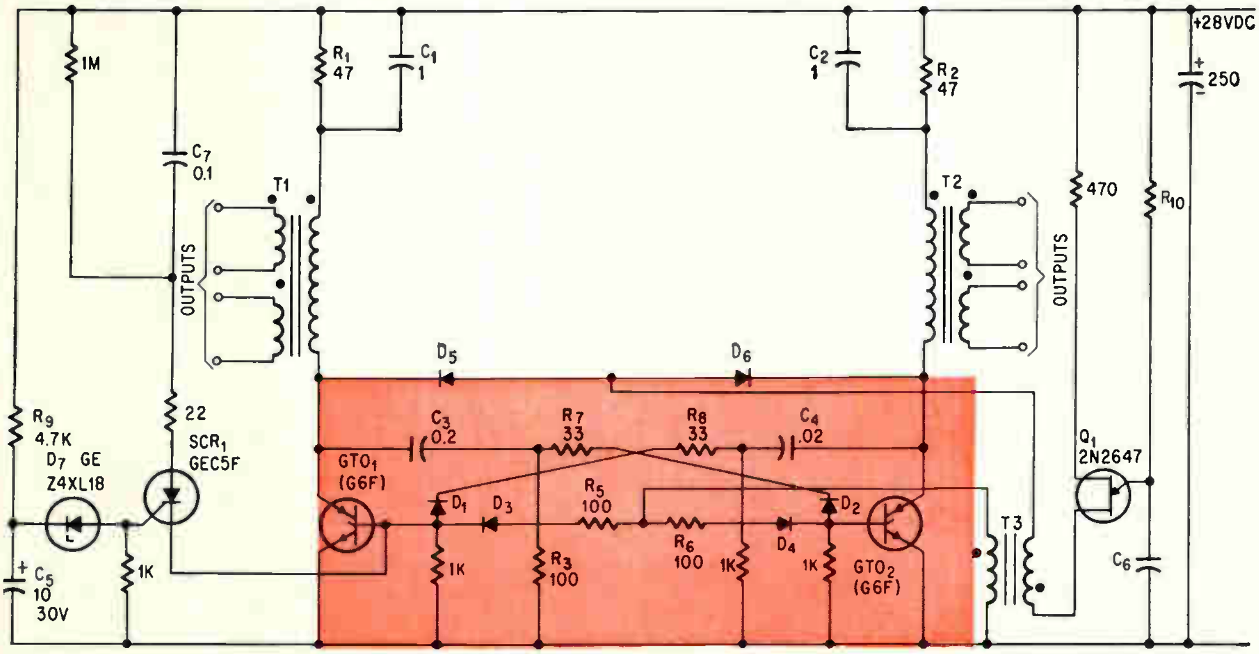
Assume GTO_1 is conducting load current, and GTO_2 is blocking. Capacitor C_2 charges to the supply voltage through load R_{L2} and resistor R_4. When GTO_2 is turned on by the next positive trigger pulse through R_6 and D_4 the gate of GTO_1 is driven negative by the voltage on C_2 and GTO_1 turns off. Peak negative gate current is limited by resistor R_2. GTO_2 is commutated in turn by capacitor C_1, as GTO_1 is triggered on again.

The flip-flop configuration can be used as a trigger pulse generator for high power SCRs in inverter circuits, or in other applications where high peak pulse power is required. The next circuit illustrates such a trigger circuit that incorporates means for positive starting when power is first applied. Each of the four output windings will deliver more than 1 amp peak into a 10 ohm load. But pulse rise time is approximately 1 microsecond and pulse width is around 20 microseconds. The circuit has operated to 10 kc.

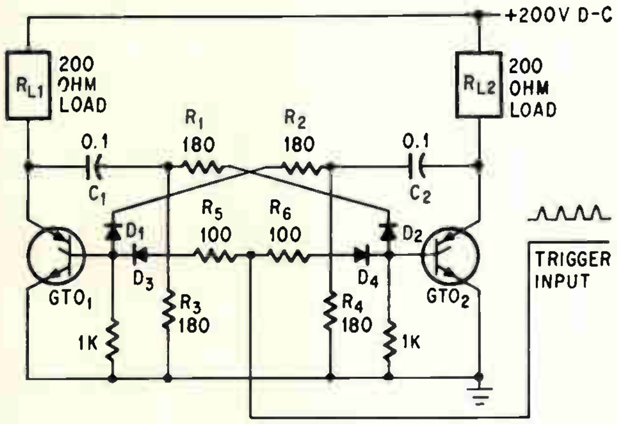
Each time the unijunction transistor Q_1 fires, the GTOs change their state. When GTO_1 turns on, a pulse of current flows in the primary winding of transformer T_1 to charge capacitor C_1; similarly when GTO_2 turns on, current flows in T_2 to charge C_2. These pulses appear as outputs in the transformer secondaries. The positive start feature works as follows: When power is first applied to the circuit both GTO_1 and GTO_2 are off. Diodes D_5 and D_6 are both back biased, interbase current is unable to flow in Q_1, and Q_1 cannot fire. Capacitor C_5 meanwhile charges towards the supply voltage through resistor R_9. As soon as the voltage on C_5 exceeds the breakdown voltage of zener diode D_7, SCR_1 turns on and allows C_7 to charge. The charging current of C_7 then triggers GTO_1. With GTO_1 on, interbase current for Q_1 can flow through D_5 and the conducting GTO, and the unijunction transistor takes over the triggering.

Ring counter

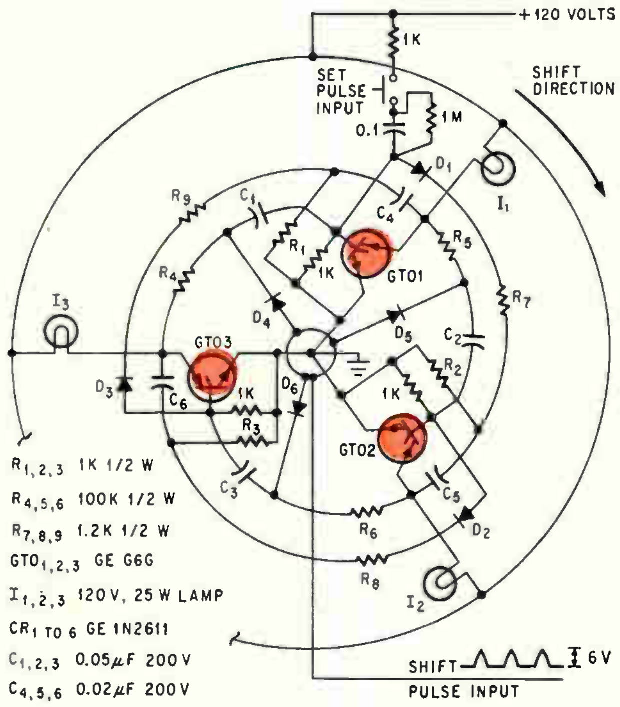
A ring counter may be considered as a circuit that sequentially transfers voltage from one load to



Positive-starting flip-flop may be used in high peak pulse power applications



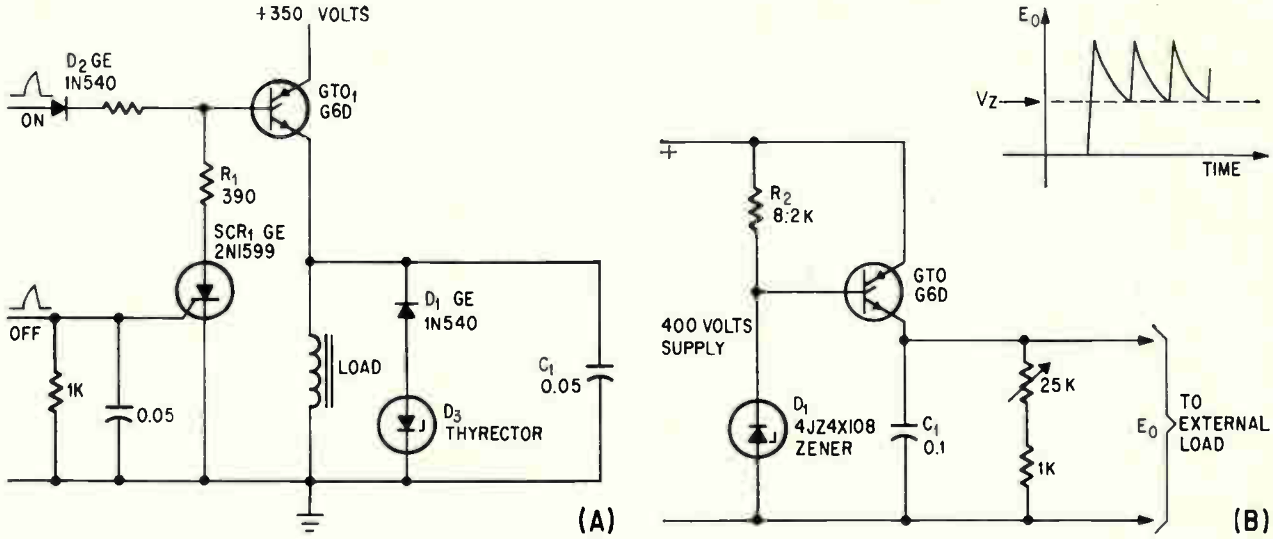
GTO adaptation of the SCR capacitor-commutated flip-flop transfers load current each time a positive trigger pulse is applied



Ring counter may function as decade counter with direct lamp readout

the next, when a number of loads are connected to form a closed loop. Transfer around the loop proceeds always in the same direction, and is initiated by pulsing a common shift line. The ring counter is actually an extension of the basic flip-flop circuit, a flip-flop being a two stage ring counter. In this circuit three GTOs drive a trio of incandescent lamps, but other types of load may be substituted and more stages added as desired. A ten-stage circuit using 10 GTOs can perform the function of a decade counter with direct lamp readout.

When power is first applied to the circuit none of the GTOs will turn on. To start the circuit, the set pulse input button is closed, turning on GTO_1 and applying voltage to the lamp load I_1. At this point diodes D_4 and D_6 will be reverse biased by the full supply voltage while diode D_5 will be reverse biased by less than 2 volts, as determined by the respective anode voltages of the GTOs. If a positive pulse having amplitude greater than 4 volts, but less than the supply voltage, is applied to the shift line, D_4 and D_6 will block the pulse from the gates of GTO_1 and GTO_3 while the pulse will be transmitted to the gate of GTO_2 through D_5 and C_2, causing GTO_2 to turn on. As GTO_2 turns on, GTO_1 is turned off by the negative gate transient coupled into its gate via C_5, R_7 and diode D_1. When the next pulse arrives at the shift line, GTO_3



GTO can be used as a high speed hammer driver for a computer readout mechanism (A) and as a free-running high voltage sawtooth generator (B)

turns on and GTO_2 turns off.

The next figure (A) shows how the GTO can be used as a high speed "hammer" driver for a computer or similar readout mechanism. Since speed is the primary objective here, the load solenoid is deliberately overdriven for a short time by connecting it suddenly across a high voltage bus, and then disconnecting it again before overheating can occur. The GTO has both the switching speed and high voltage ability for this type of duty. Load current rise and fall times for this circuit are both considerably less than one millisecond.

Sawtooth generator

The adjacent circuit (B) illustrates a free-running high voltage sawtooth generator. When power is applied to the circuit, the GTO will trigger and connect the supply across C_1. As the voltage across C_1 rises above V_z (the avalanche voltage of D_1), GTO's gate becomes reverse-biased, current in the gate lead reverses, and the device turns off. C_1 then discharges through R_1 and the parallel external load impedance, if any. GTO will turn on and repeat the cycle when the voltage across C_1 decays sufficiently below V_z for positive gate current to flow again.

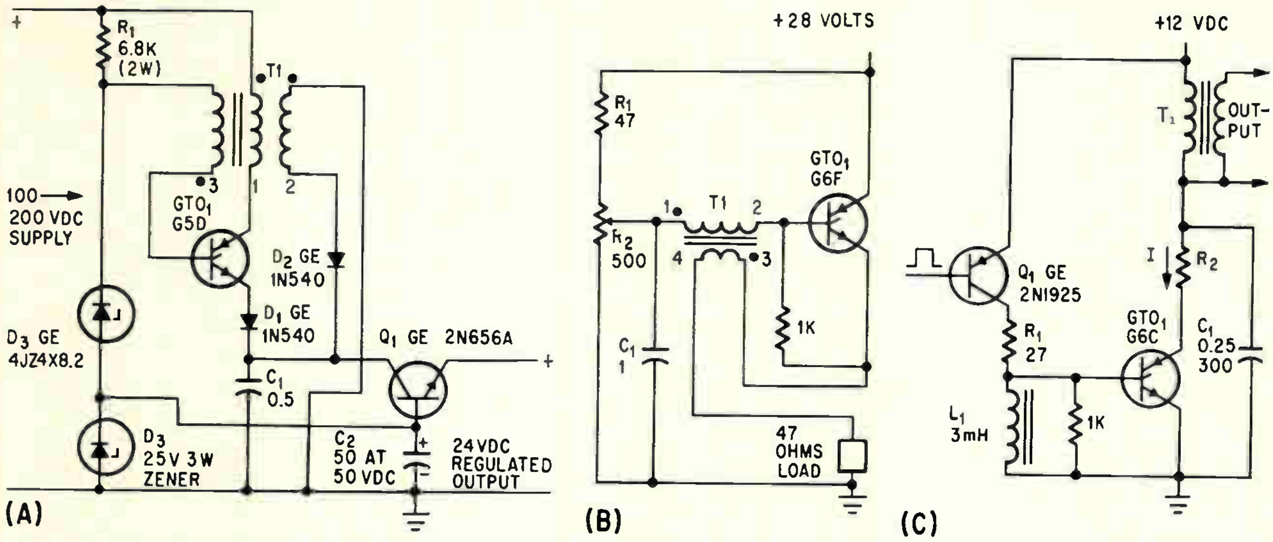
Voltage regulator

The GTO is an ideal device for d-c to d-c step-down transformer applications. It has the necessary

Editor's note

In addition to General Electric, other companies supply turn-off SCRs (or gate controlled switches): Motorola Semiconductor Products, Inc., Texas Instruments, Inc., Westinghouse Electric, Solid State Products, Inc. and Transitron Electronics Corp. Some typical devices with manufacturer's ratings:

Mfgr:	Type Series	Package	Max rms fwd curr.	Fwd blocking voltage	Max gate turnoff curr.
Motorola	MGCS 821	TO-41	5 amps	25–200 V	500 ma @ 5 a
	"		"	300–400	1 a @ 5 o
	MGCS 924 & 925		"	25–400	500 ma @ 5 a
Texas Instruments	X120A0	Stud mounted	5 amps	50 V	360 ma @ 5 a
	X120A1		"	100	"
	X120A2		"	200	"
Westinghouse Electric	241 U	Same as	5 amps	50–700 V	1.5 a @ 4 a
	241 W	JEDEC 2N1770	"	"	1.5 a @ 5 a
	242 X	TO-48 stud	7.5	50–800	1.5 a @ 6 a
	242 Y		"	"	1.0 a @ 6 a
	242 Z		10	"	1.0 a @ 8 a
	243 X, Y, Z	TO-3 diamond		same as 242 series	
Solid-State Products	2N892	TO-18	8 ma	15–200 V	2 ma @ 4 ma
	2C1030	TO-9	100	30–200	1.5 ma @ 100 ma
	3C020		200	"	20 ma @ 200 ma
Transitron	TSW30	TO-5	50 ma	30–200 V	10 ma @ 50 ma
	TSW31	TO-18	"	"	"
	TSW31a		100	"	20 ma @ 100 ma
	2N764		200	"	40 ma @ 200 ma
	2N1686	TO-5	700	"	100 ma @ 500 ma
	SW30	TO-18	30	30	8 ma @ 30 ma



Combined with a silicon power transistor, the GTO operates as a prime switching and regulating element (A). The 100-kc chopper circuit (B) is notable for its versatility and simplicity. Circuit (C) may be used in a very high voltage pulse generator or as d-c step up transformer

voltage capability to work from high voltage d-c power sources, is able to switch efficiently at high frequency for good transformer use, is small, rugged and has silicon reliability. A single GTO (A), operating as the prime switching and regulating element, is combined with a silicon power transistor to form a high performance 200 volt d-c to 24 volt d-c regulated power supply. This type of circuit by virtue of its low weight, small size and efficiency is adaptable to many computer, missile, and airborne power supplies, test equipment and various other industrial applications.

In this circuit, with input voltage varying between 100 and 200 volts d-c, and/or load current-varying between 0-100 milliamperes, output voltage regulation is less than three percent. Ripple at full load is less than 300 millivolts. Circuit efficiency is around 50 percent with the components shown. Most of the circuit losses occur in resistor R_1, which has to provide gate trigger current for the GTO at the lowest expected supply voltage. For optimum efficiency with other supply voltages, R_1 should be selected to provide 10 milliamperes to the GTO gate.

The chopper circuit (B) is notable both for its versatility and simplicity. When power is applied, GTO_1 stays off until the volt-second integral across winding 1-2 of transformer T_1 is sufficient to cause T_1 to saturate. As T_1 saturates, its impedance falls and positive gate current flows through R_1 and R_2 to trigger the GTO. Winding 3-4 provides regeneration to speed up the turn-on process. With the GTO conducting load current, the voltage across winding 1-2 reverses, since the gate and cathode terminals are at + 28 volts, and T_1 comes out of saturation. GTO_1 continues to conduct until T_1 saturates in the reverse direction, when negative gate current flows to ground through R_2 and the GTO turns off. On-to-off time is determined by the setting of potentiometer R_2; alternatively a third bias winding may be added to T_1 to effect control of the duty cycle electrically. With a third winding added, d-c control current in one direction will increase the duty cycle, while control current in the opposite direction will decrease the duty cycle. By applying a-c to the control winding it is possible to modulate the average output load current. With the components the circuit operates at approximately 100 kc.

High voltage generator

Circuit (C) may be used as a very high voltage pulse generator, or as a d-c step up transformer. Operation is as follows: with transistor Q_1 biased on, current flows through R_1 to trigger the GTO on, current builds up both in the primary of transformer T_1 and in the inductor L_1. When Q_1 is shut off, the current flowing in L_1 transfers to the GTO gate, and the GTO turns off. As the GTO turns off, a high voltage pulse is induced in the secondary of T_1. The pulse is in the form of damped oscillation, of frequency determined by T_1 and capacitor C_1. The output may be rectified and integrated if desired. With the components shown, 3 to 5 kv peak is available at the output terminals of T_1.

With suitable components this circuit forms the basis of an extremely high performance automotive-type ignition system. Using a low-inductance ignition coil in conjunction with an experimental 7 ampere GTO, the circuit-develops 25-30 kv with minimal output drop from 0 to 400 pps, equivalent to 0-6000 RPM for a four-stroke V8 auto engine.

References

1. GE SCR Manual 3rd Edition, March, 1964
2. H. F. Storm, Introduction to Turn-Off Silicon Controlled rectifiers, IEEE Conference Paper CP 63-321.
3. J.W. Motto, Jr., Characteristics of the Gate Controlled Turn-Off Transistor Controlled Rectifier, IEEE Conference Paper CP 63-510.

Designer's casebook

Designer's casebook is planned as a regular feature in Electronics. Readers are invited to submit novel circuit ideas, packaging schemes, or other unusual solutions to design problems. Space is limited, so keep them short. We'll pay $30 for each item used

- Circuit measures a battery's charge
- Blotting out an unwanted harmonic
- Micro packaging squeezes in discrete components

Comparator controls battery charging rate

By A. Anton

President, Deltron Inc., Philadelphia, Pa.

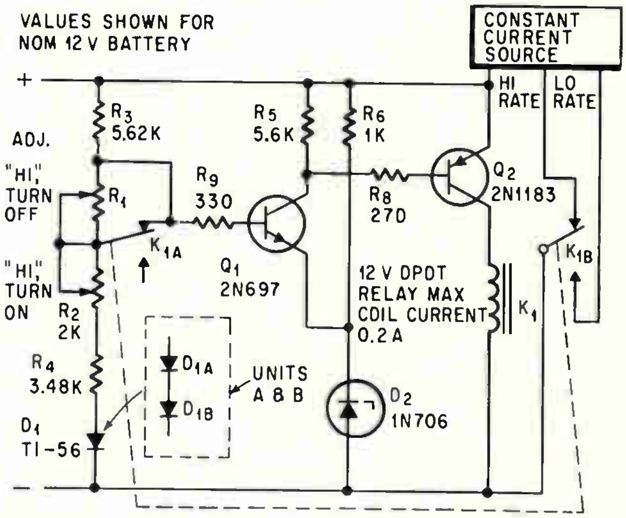
A military communications system required a power supply that kept the system in operation despite a sudden power line failure. The final design called for lead-acid storage batteries as a source of standby power, which were to be switched in and out as required. It was also specified that the batteries must go on charge immediately after restoration of primary power, and be fully charged within a 20-hour period in readiness for a second power failure.

The regulated power supply of the system contains a quasi-constant current source for charging the batteries. The current source has two output ratings selectable by the charge-control circuit.

The circuit shown acts as a precise analog comparator to ascertain the state of charge of the battery, and when full charge is reached it automatically transfers the battery to constant current trickle charge. The reference voltage provided by zener diode D_2 is compared against a fraction of the output, using Q_1 as the comparator. As the battery output rises, and reaches a preset voltage level, transistor Q_1 turns on, applying base current to Q_2 and energizing relay K_1. Immediately upon activation, K_1 is latched into position by the contact in the sampling network.

As polarization gradually subsides, the battery voltage returns asymptotically to its full charge value. If because of temperature conditions or other variables the trickle charge rate does not maintain the battery at full charge, the voltage drops until Q_1 cuts off, simultaneously cutting off base currents to Q_2 and de-energizing K_1. This places the battery again under the 20-hour recharge rate.

With this circuit, overcharging of the battery is eliminated since the cutoff point is experimentally determined by correlating voltage measurements under constant current charging conditions



After system primary power is restored, this controller recharges batteries in 20 hours, provides trickle charge

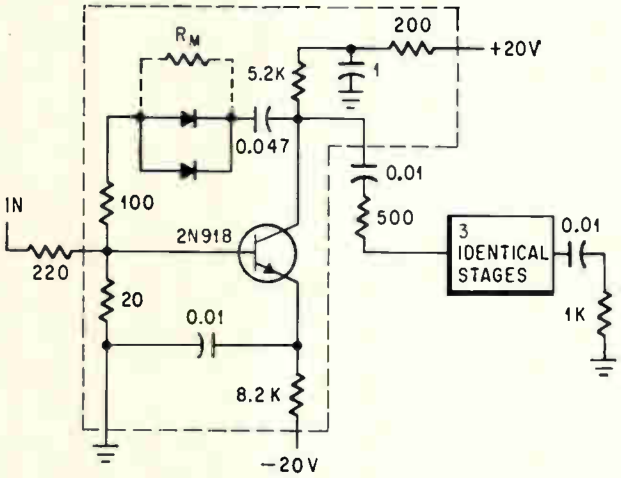
with specific gravity measurements. These data can be used to set the relay for any operating temperature. This system has a particular advantage in the case of a number of short-duration power failures, where timer-type rechargers would overcharge and shorten the life of the batteries.

Symmetrical limiting i-f reduces second harmonic

By R.F. Kirkpatrick and R.C. Stouffer

Bendix Corp., Mishawaka, Indiana

This symmetrical limiting i-f amplifier was developed for the frequency-locked/phase-locked loop of a radar tracking and acquisition receiving system. In this application, it was extremely important to minimize the second harmonic output. The conventional (saturation and cut-off) type of limiting i-f amplifier, previously in use, had an unpredictable second harmonic output which was large enough at some input power levels to cause loop problems.



Harmonic content of i-f output contains primarily third harmonic over a wide range of input power

The second harmonic of the symmetrical limiting i-f amplifier is at least 35 db below the carrier over a voltage input range of 0.03 mv to 30 mv. The maximum variation of the second harmonic was less than 8 db over the same input voltage range.

A slight modification to the four-stage symmetrical limiting i-f amplifier results in a phase shift of less than 25 degrees as the input voltage is varied from 0.01 mv to 100 mv for applications where phase shift considerations are of primary importance. The modification consists of adding one additional stage and adding a resistor R_M in parallel with the feedback diodes (see dashed lines in figure). At low signal levels the resistor R_M reduces the effect of the diode capacitance and Y_{12}, reducing the phase shift per stage. Since R_M also reduces the gain, an additional stage is required.

Another feature of this amplifier is the high gain-space-density of 160 db/in^3. A welded-contact, potted assembly packages the four stage amplifier in 0.5 cu in. The silicon planar epitaxial transistors used yield a high gain-bandwidth product and low noise figure of less than 5 db at low signal levels.

Squeeze in more components by adding a micro amplifier

Designers of military equipment usually cite reduced size and weight and increased reliability as their reasons for going to microelectronics. But designers of consumer items may find microcircuits advantageous for other reasons.

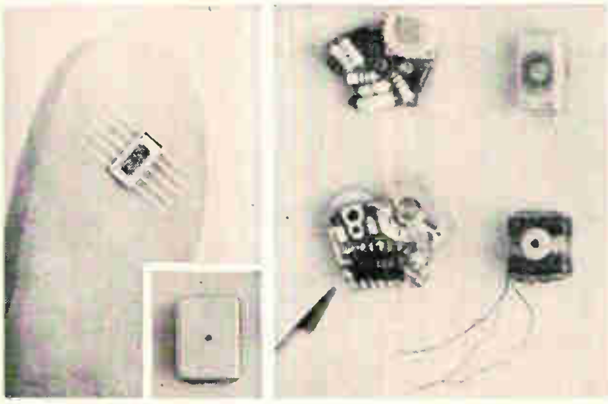
Bill Greenbaum, director of hearing aid engineering at Zenith, designed a Texas Instruments monolithic silicon microcircuit into his latest eyeglass hearing aid to permit adding extra features to the product. For the first time it became possible to build a magnetic pick-up coil into a small-size hearing aid. The coil couples the hearing aid's input directly to the receiving coil of the telephone handset and thus bypasses both the hearing-aid microphone and telephone earphone to achieve less noisy reception. There is also a special telephone switch that has both spring-return and lock modes of operation with a tap return in the lock mode. These features could be added because microminiaturization cut the size of the printed-circuit board in half.

The new amplifier delivers 75 decibels of power gain (transducers account for the 22-db loss). Distortion from 300 to 5,000 cps is less than two percent. This is as good or better than the performance of an equivalent amplifier using discrete components. The integrated amplifier is a triple-diffused, four-layer module that measures only 0.065 by 0.150 by 0.007 inch and occupies only $\frac{1}{16}$ of the volume of its flat pack.

The first stage is an npn common-emitter amplifier with an unbypassed emitter resistor that contributes negative feedback.

The second stage is an npn common-emitter with a grounded emitter. It is directly coupled to the first stage. The top of the volume-control potentiometer is connected to the second-stage collector while the tap on the voltage-control potentiometer feeds the base of the third stage. The third stage is a common-emitter npn transistor. Its emitter resistor is unbypassed and is shared with the fifth stage.

The third, fourth and fifth stages replace a single output stage in the discrete-component amplifier and eliminate the problem of the tight electrical tolerances on this part. The sixth transistor stabilizes the fifth stage against increased current drain when temperature rises.



Monolithic amplifier, old circuit and earphone (top); microphone, new circuit and telephone coil (bottom)

Integrated circuits shrink a doppler radar system

Integrated circuit functions, used most often in digital computer applications, are slowly invading analog circuitry. Here is how off-the-shelf miniaturized components were designed into the linear circuits of an airborne radar system to be flight tested soon

By E.M. Pacifico and Stanley King

Senior Engineers, GPL Division-General Precision Aerospace, Pleasantville, N.Y.

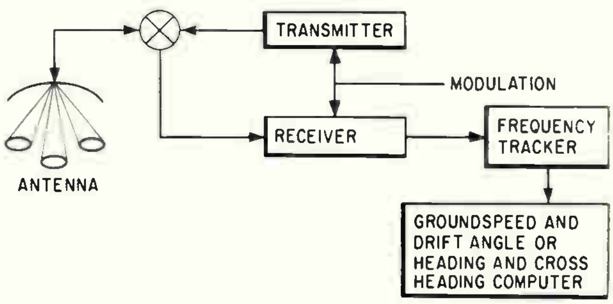
It now seems clear that integrated circuits improve the reliability, maintainability and effectiveness of military electronic equipment by nearly an order of magnitude. At the same time they reduce the size and weight of airborne gear by even more than that amount. So far, most of the successful applications of such microelectric circuits have been in digital equipment, like the computers for the Minuteman missile guidance system, and only few accomplishments have been reported miniaturizing analog circuits this way. General Precision Aerospace has now designed and built a microelectronic dopplar radar navigation system. The major circuits of a radar system, of course, are basically analog.

This program demonstrates a procedure for designing analog circuits with integrated circuits. The equipment is markedly smaller and lighter; more reliable, better performing, easier to maintain, and less expensive. The approach is applicable to most radar systems.

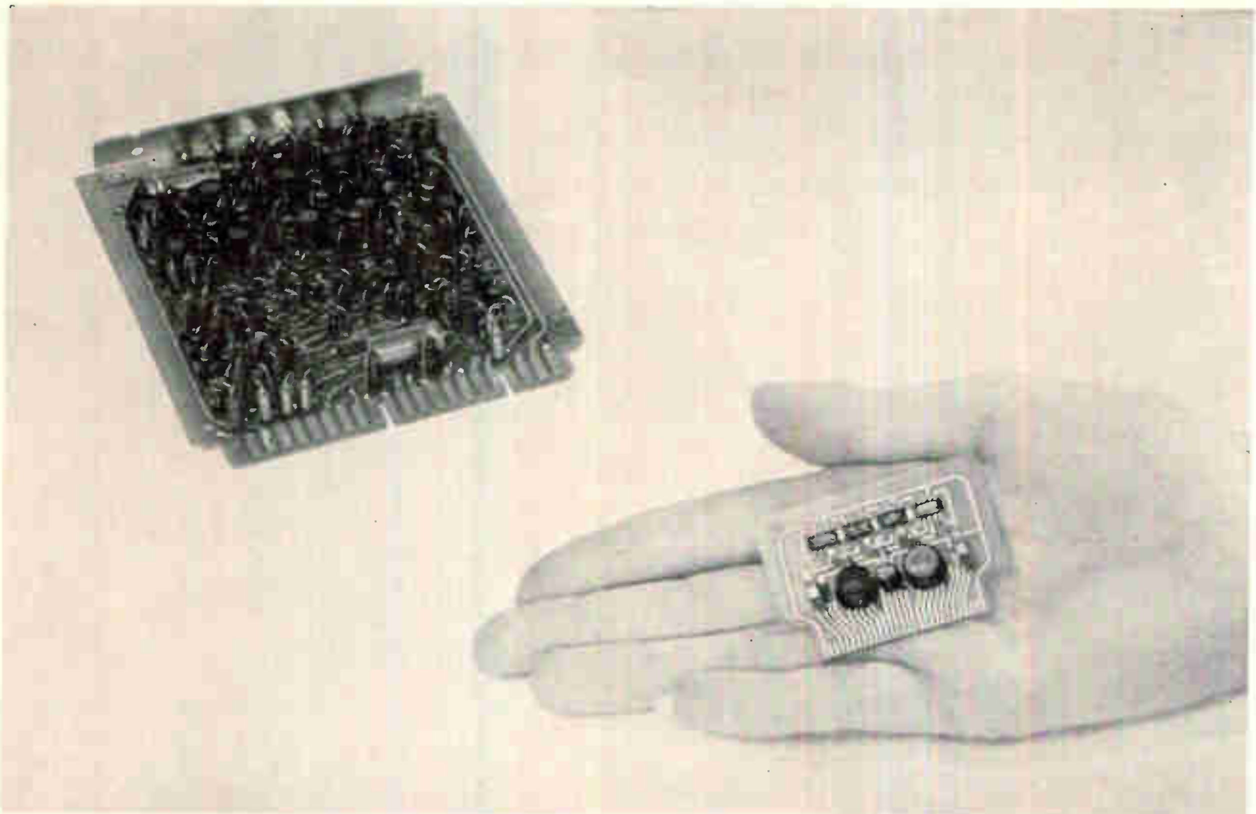
Seventy percent of the General Precision radar has been microminiaturized with off-the-shelf microelectronic integrated circuits (MICs). Application of this technique to the remaining portions of the system would, in certain instances, contribute more complexity and less desirable characteristics than the original conventional circuits. In these cases, an adaptive interconnect approach[1] using uncommitted silicon wafers obtained from major integrated circuits and manufacturers is being applied.

The doppler radar system, with its standard MICs, thin-film adaptive networks, and MICs with special interconnects—will be test flown in mid-1964. Even as the flight test program is underway, a continuing product improvement program will reduce discrete component use by increasing use of special interconnect MICs.

Future aerospace navigation systems will be required for a wide variety of missions and aircraft, including VTOLs, helicopters, advanced manned penetrator strike systems (AMPSS), as well as conventional high performance vehicles. While initial hardware developments have been concentrated on



Self-contained doppler navigation system consists of four principal electronic blocks—transmitter, receiver, frequency tracker and computer



Microcircuit version of frequency tracker audio circuit replaces printed board version that uses discrete components

helicopter and VTOL applications, the new doppler navigation system design promises a universal navigation system for virtually all tactical, strategic and aerospace radar navigation requirements, at unmatched reliability and economy.

Doppler radar equipment measures the velocity of an aircraft with respect to the earth by measuring the doppler frequency shift returned from three or four beams of microwave energy aimed at the ground and reflected back to the vehicle. The measured doppler frequency is proportional to the component of velocity in the direction of the beam; beam velocities are processed to provide outputs of aircraft ground speed and drift angle and/or aircraft heading and cross heading velocities. Doppler systems can be completely self-contained within an aircraft operating without reference to external aids such as ground beacons.

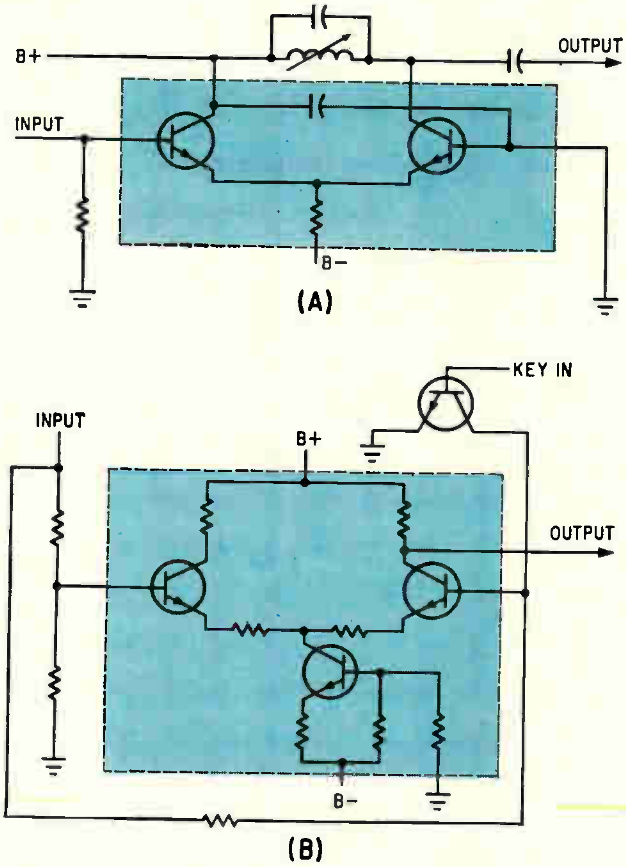
Analog versus digital approaches

MICs, designed for digital applications, can be used repetitively in great quantities, the high volume requirements leading to low unit cost. Since digital circuits indicate one or the other of two states, power dissipation is low and tolerances can be loose. All these factors make digital MICs attractive, low in cost and readily available. On the other hand, analog type circuits have none of these advantages, and applicability of MICs to this type of circuit is not obvious. Thus it is desirable to use digital techniques wherever possible to accomplish a function, and it is often advisable to employ digital circuits even at the cost of additional complexity. On the other hand, trade-offs have to be carefully investigated to avoid digitalizing "at all cost".

A study was made of a doppler radar frequency tracker in an attempt to convert it to digital circuits. The function of a frequency tracker is to measure the doppler shifted frequency of ground returns consisting of a Gaussian frequency distribution superimposed on varying amounts of background noise. Measuring the frequency of this type of signal is incompatible with pure digital techniques, so the digital approach had to be supplemented by analog circuits. This led to a small reduction in total number of analog circuits, but added the complexity of a great number of digital circuits. In this case, the total function is better performed using analog type MICs. The function of computing velocity outputs from the frequency signals was also investigated. Here it was found that frequency-to-current converters and servo loops could easily be replaced by digital computations, with an improvement in accuracy.

Designing analog portions of a radar system in microcircuit form can be accomplished in several ways: the application of thin-film, custom MIC, semi-custom MIC, or off-the-shelf hybrid approaches.

With a minimum of redesign, existing circuits can



Receiver requires external adaptive circuits (A) for the 30-Mc amplifier stage. The suppressed carrier double-balanced modulator (B) has achieved a carrier rejection of 40 db. MICs are in color

be replaced by thin-film networks where active components were added in discrete form. Each circuit requires its own thin-film mask, increasing the expense with little reliability improvement. Size may be greatly reduced, but reliability is only improved by reduction in the number of interconnections.

At the present state-of-the-art, special MICs can be designed and built in single or multichip form to accomplish most analog circuit functions. This is an extremely expensive undertaking, not only in the design effort, but in ultimate high production costs. With little redundancy required in such circuit functions, small quantity requirements of any single MIC lead to excessive cost. In addition, proof of reliability is almost impossible since samples large enough for statistical validity would not be available.

To overcome most of the undesirable features of custom MICs, a semi-custom approach appears to be an attractive alternative. A recent development[1] consists of purchasing from major MIC vendors silicon wafers upon which both active and passive elements exist but without deposited interconnects between elements. These uncommitted wafers can be adapted to a wide variety of circuits by simply depositing the appropriate interconnect pattern. Current development in this area has been quite encouraging and work is continuing to further advance the capability.

Each of the above approaches used independently falls far short of all the objectives sought. In the development of the helicopter doppler radar system, the necessity to minimize the transition time from laboratory to production hardware resulted in an off-the-shelf hybrid approach. In essence, this approach consists of purchasing only those MICs, both analog and digital, which are being offered as standard catalog items and then combining them where necessary with external adaptive networks made up of thin-film and/or discrete components. Actual implementation of this method demonstrates improved reliability, performance, and maintainability, and considerable reductions in weight and size. A slight cost disadvantage now exists but all predictions prevalent in the microcircuits industry are quite optimistic and anticipate a rapid downtrend during 1964.

Design procedures

Although microminiaturization techniques are far from being amenable to "cook-book" design procedures at this time, an orderly succession of design and evaluation steps speeded development of the helicopter doppler radar system. The main steps:

1) The areas most adaptable to the use of MICs are determined on a system-wide basis. Decisions are based primarily on whether analog and/or digital circuits are required to perform the overall functions.

2) Major system functions so chosen are carefully subdivided into their detailed sub-functions.

3) Each sub-function is analyzed separately to obtain required performance parameters and then related to the preceding and following sub-functions. Tentative decisions as to the choice of available MICs and adaptive networks are made.

4) Based on the choices made above, discrete component circuits are designed, bread-boarded, and evaluated. In some instances, this intermediate step can be by-passed in favor of going directly to the ultimate microcircuit version.

5) Regardless of which version is adopted first, the designer must evaluate each circuit on the basis of insuring compatibility with adaptive network requirements. Specifically, all external passive elements are scrutinized to determine whether they can be easily converted to thin-film devices on a practical basis. Circuit redesign may be necessary at this stage to reduce resistor and capacitor values and to lower voltage and dissipation in order to realize compatibility with present state-of-the-art.

6) To avoid the use of an excessive number of different MICs, the designer examines the available devices carefully to decide which units are most universally applicable to a variety of circuits. As an example, the Fairchild MIC differential amplifier type DA10111 has been made to function in a-c and

d-c amplifiers (both single and double ended), modulators, phase splitters, d-c controlled astable multivibrators, crystal controlled oscillators, sum-difference amplifiers, and a d-c inverter. using simple adoptive networks.

7) Design field-effect transistors (FETS) into circuits wherever they may be used to advantage. The trend in microcircuits, and this includes both MIC and thin film, appears to point markedly toward increased use of FETS as integral portions of these devices.

Here is how this system worked during the design and development of the doppler radar system. A completely self-contained doppler navigation system (below) consists of four principal electronic building blocks—transmitter. receiver, frequency tracker. and computers.

High power and high frequency (gigacycle) requirements in the transmitter are not now compatible with microcircuit techniques. But. in keeping with microminiaturization and the use of all-solid-state hardware. conventional magnetrons or klystrons commonly used in a radar system are being replaced by varactor multipliers. Advanced development is also underway to replace microwave plumbing with stripline.

Most adaptable for integrated circuit use are the timing frequency generating circuits required for the transmitter. Low-frequency beam switching is usually accomplished with crystal switches. A large signal is required to drive these switches in their best operating range. This restriction dictates a discrete transistor driver. but MICs may be used in all frequency dividers and gates.

To preserve coherence. and to avoid a multiplicity of oscillator instabilities. all modulation and reference frequencies are derived from a single. high-frequency oscillator. This frequency is divided down in a chain of countdown circuits. Motorola's MECL logic circuits have been found suitable to perform the countdown operation in the megacycle range. and Texas Instruments' Series 53 units are used in the low frequency counters. A single type. low-cost logic circuit, covering the entire frequency range, should be available in the future.

All 30-Mc circuits in the received employ Motorola MC-1110 emitter-coupled MIC amplifiers. These amplifiers require external adaptive circuits for a typical 30-Mc amplifier stage (see A). Here the advantages achieved are not so much in the reduction of numbers of components, as in greatly improved performance. The noise figure for an MIC is similar to that of its discrete component counterpart but the variation from unit to unit is considerably less. Due to greater uniformity obtained using MICs, the need for adjustments to counteract circuit nonuniformities is minimized or completely eliminated. Resultant designs are amenable to volume production with savings in handling, quality control, and eventual repair costs.

Most doppler systems require multiple i-f stages where much of the necessary gain is in the vicinity of 100 kc. Texas Instruments' SN-522 operational amplifiers will supply this gain if negative feedback is used to broaden the frequency response. The open loop gain of these operational amplifiers is 60 db. If only 20 db of closed loop gain is utilized, a bandwidth of 150 kc is available and the resulting gain stability is very high. Similar performance in conventional transistor circuits would require more complexity and many more components.

After amplification. detection. and frequency translation in the receiver, the frequency shift of the doppler returns is measured in the frequency tracker. Circuits, operating in the audio and sub-audio ranges, are required and analog type MICs can be used extensively. Some of the specific functions that have been successfully instrumented using MICs are modulators, integrators. filters. and audio amplifiers.

A suppressed carrier double-balanced modulator is shown in (B). Without balance adjustments. a carrier rejection of 40 db has been achieved. Double-balanced operation is obtained without necessity of using push-pull carrier and signal inputs. The MIC package used is a Fairchild 10111 differential amplifier. This eliminates added circuits to obtain the push-pull signals, such as transformers or transistor phase splitters. The modulator also provides 20 db of gain.

The figure (p 78) compares a conventional integrator (A) with the MIC version (B). Since high gain and low drift are essential. a chopper stabilized integrator is mandatory. To obtain low drift characteristics. minimum offset in the chopper is essential. With conventional circuits. the chopper transistors must be used in matched pairs.

Use of a field-effect transistor (FET) in this application has the advantage of zero offset as an inherent device characteristic. Only one FET is neces-

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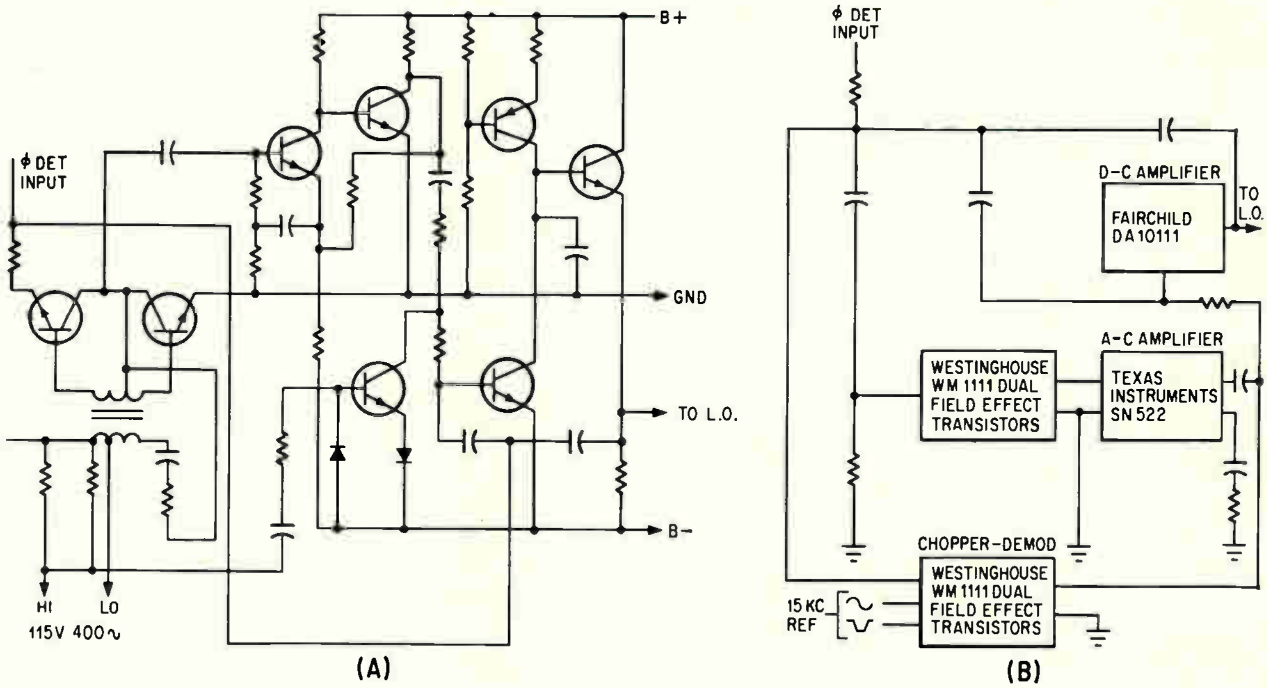
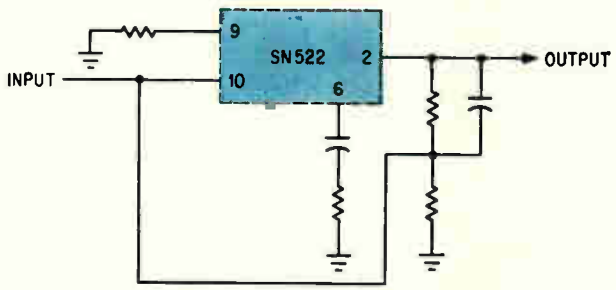


Integrator's conventional circuit (A) uses chopper transistors in pairs while the MIC version (B) uses field-effect transistors to handle chopping and demodulation



1.5 kc single section low-pass filter uses the practical approach of combining MICs and thin-film passive components

sary. Referring to (B), the chopping and demodulation are easily handled with a Westinghouse Electric double Unifet WM1111, housed in a ¼ x ¼ inch flat pack. In addition, an identical unit is used as a high impedance buffer between the chopper and the a-c amplifier. One of the FETs in the package is used in the constant current high-impedance region of its characteristic as a load for the other FET. Essentially, this connection is the source follower circuit. Impedance transformation is needed since resistance of an FET chopper in its "on" state is in the order of 2000 ohms resulting in large loss of gain unless the amplifier input impedance is large. Impedance transformation makes it possible to use smaller values of coupling capacitors, simplifying conversion of external resistors and capacitors from discrete to thin film components.

The Texas Instruments SN-522 operational amplifier is used in an open loop mode to provide 60 db of a-c gain. The signal is then demodulated in one half of the WM1111 as described above. Additional d-c gain which is now considerably less sensitive to drift is supplied by a Fairchild differential amplifier. External capacitive feedback completes the integrator.

R-C high- and low-pass filters with cutoffs in the low audio or subaudio ranges are required in this application. Active filters are used to avoid the use of large value capacitors and resistors combining the inevitable amplifier stage with the filter. Complete filters therefore may be practically fabricated within MICs without using external adaptive networks.

A current approach consists of combining MICs and thin-film passive components. The circuit diagram shows a 1.5 kc single section low pass filter. Due to high gain in the operational amplifier, external resistor and capacitor values have been greatly reduced compared to those required in an equivalent passive filter. Multiple section filters and filters with a twin-T circuit in the feedback loop are practical when this technique of combination is used. The cutoff frequency of these filters will not be consistent from unit to unit, or over a large temperature range. Stabilization of cutoff frequency may be effected by reduction of the operational amplifier gain using negative feedback, but only at the cost of requiring larger resistors and capacitors, and reduced overall gain.

Both the operational and differential MIC amplifiers may be used for audio amplification. As in the applications described above, high gain of the operational amplifier makes it possible to use a great amount of feedback, resulting in excellent gain stability. The differential amplifier is only useful in applications where larger gain variation can be tolerated. Use of active filters and modulators eliminates the need for audio amplifiers since the modulators and filters already have built-in gain.

The outputs of the frequency tracker are frequency analogs of velocities along the beams. To produce the final system outputs, a computation of groundspeed and drift angle or heading and cross heading velocities must be performed. This function is implemented by digital MICs, using mostly counters, registers, and various gating circuits. These circuits represent little that is new in design techniques. Reference to current literature will provide the reader with sufficient background.

The overall benefits to be achieved in using MICs have been repeatedly emphasized. However most comparisons with conventional circuits and other microcircuit techniques have been general, quite philosophic and organized to demonstrate the advantages on a broad system basis. A departure from this viewpoint will be presented here in that only the common system function of amplification will be considered.

Assume that a choice must be made between an operational amplifier such as Texas Instruments' SN-522 MIC or its equivalent in discrete component form. Which factor or factors would determine the final choice—size, weight, cost, power dissipation, performance, reliability, or maintainability?

Conventional circuits vs. MICs—table

	SN-522 MIC	Conventional circuit
Volume per unit gain	0.003	1
Weight per unit gain	0.03	1
Cost per unit gain	1.7	1
Power dissipation per unit gain	0.12	1

Of the many possible figures of merit which may be used for comparison, a useful combination consists of evaluation of the applicable factors noted above on per unit gain basis. Such a comparison normalized for conventional circuits is shown in the table. The conventional circuit referred to is one in which the input-output characteristics are equivalent to that of the MIC. In this case, it is a transistorized operational amplifier typical of those used repeatedly in a dopplar radar system. From the table, the cost based on December, 1963 prices favors the conventional approach. Forecasts point toward at least an equalization in cost by the end of 1964, and a rapidly lowering cost after that.

Performance, reliability and maintainability factors can be evaluated as follows:

Performance: In general, the gains presently available with analog MICs exceed those required for most applications. This excess gain can be used to improve the performance of the circuit. The equivalent gain in conventional circuits could only be obtained with a great number of components and therefore would not be economically feasible. Better linearity, temperature stability and reduced distortion are also possible with much less circuit complexity and cost. Such improvements have been demonstrated in GPL doppler equipment currently under development, particularly in the application of Texas Instruments' SN-522 amplifiers.

Reliability: It is almost an order of magnitude better than that obtained using discrete components of standard military quality. For the conventional circuit operational amplifier used in the comparison (Standard Military Quality components), the failure rate per million operating hours (F_m) is 3.8 while the MIC equivalent is 0.47. The latter figure is based on Texas Instruments, Inc., published data in combination with a GPL reliability study estimate. If the use of high-reliability discrete components of the Minuteman class is considered for the conventional circuit, then the F_m is 0.564. Therefore, it is evident that the MIC approach has some advantage over the use of high reliability components. All industry observations point toward even better reliability figures for MICs as more test data become available.

Maintainability: Fault isolation is greatly simplified if MICs are used. One or more MICs with their external components are combined in a throwaway module. Isolation of a failure to this type of functional module is easily and quickly accomplished. Though the replacement cost is bound to be higher than in conventional circuits, it is justified by fewer repairs and savings in downtime of the equipment.

Future development

From our experience with MICs it is evident that many functions must be implemented in a complex manner because available building blocks must be adapted to uses for which they were never intended. Although the advantage of a minimal number of different MICs is apparent, development of a few more building blocks (mixers, level detectors, universal logic circuits) by MIC manufacturers will help simplify designs.

Major breakthrough[1] in thin-film techniques are being made by several companies where work is in progress leading to deposition of active devices on an inactive subtrate. Also, deposition of thin-film resistors and capacitors directly on an integrated circuit subtrate will further extend the MIC capability. Characteristics of deposited resistors and capacitors can then be better controlled and larger value capacitors, will be available. These techniques will permit further reduction in the number of external discrete components and will broaden the applicability of these circuits to functions not feasible at this time.

Reference

1 Electronics, p 48, Jan. 24, 1964

Space electronics

Dolling up a space probe

First of a new series of scientific satellites to be launched during the International Year of the Quiet Sun, Pioneer 6 will be the most magnetic-field-free deep space probe ever. It has a better control system and communications gear, too

By A.B. Mickelwait
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To investigate the environment in space more closely, in preparation for manned interplanetary space flights, the U. S. in mid-1965 will launch the most advanced of the Pioneer series of spacecraft. Pioneer 6 will be heavier, more accurately controlled, carry more modern communications than previous Pioneers; and be the cleanest probe—magnetically—ever sent aloft. Magnetic purity will allow Pioneer 6 to measure magnetic fields more accurately, and magnetometers can be placed as close as six feet to the ship's surface. The new spacecraft was developed under the direction of NASA's Ames Research Center, located at Moffet Field, California.

In almost every aspect of the design, Pioneer 6 is markedly superior to its earlier brothers. For example, the control system has been changed so it can keep the antenna beam pointed toward the earth. Like its predecessor Pioneer 5, this probe will be spin-stabilized, but with an addition. A cold gas jet exerted through an extended boom will maintain control of the direction of the spin vector so that the high-gain antenna beam will continue to point toward the earth. Better stabilization paves the way for three other improvements:

Spin stabilization aims the antennas always in the same direction, ground reception is better and less power is required. Antenna gain will be 12 db (5-by 360 degree fan beam) requiring a power output of only 8 watts; Pioneer 5 needed a full 150 watts.

Solar cells for power supply will be mounted on the cylindrical surface of the spacecraft instead of on extended rigid paddles as they were on Pioneer 5, since the spin control will keep that surface always perpendicular to the plane surrounding the sun in which all the planets lie.

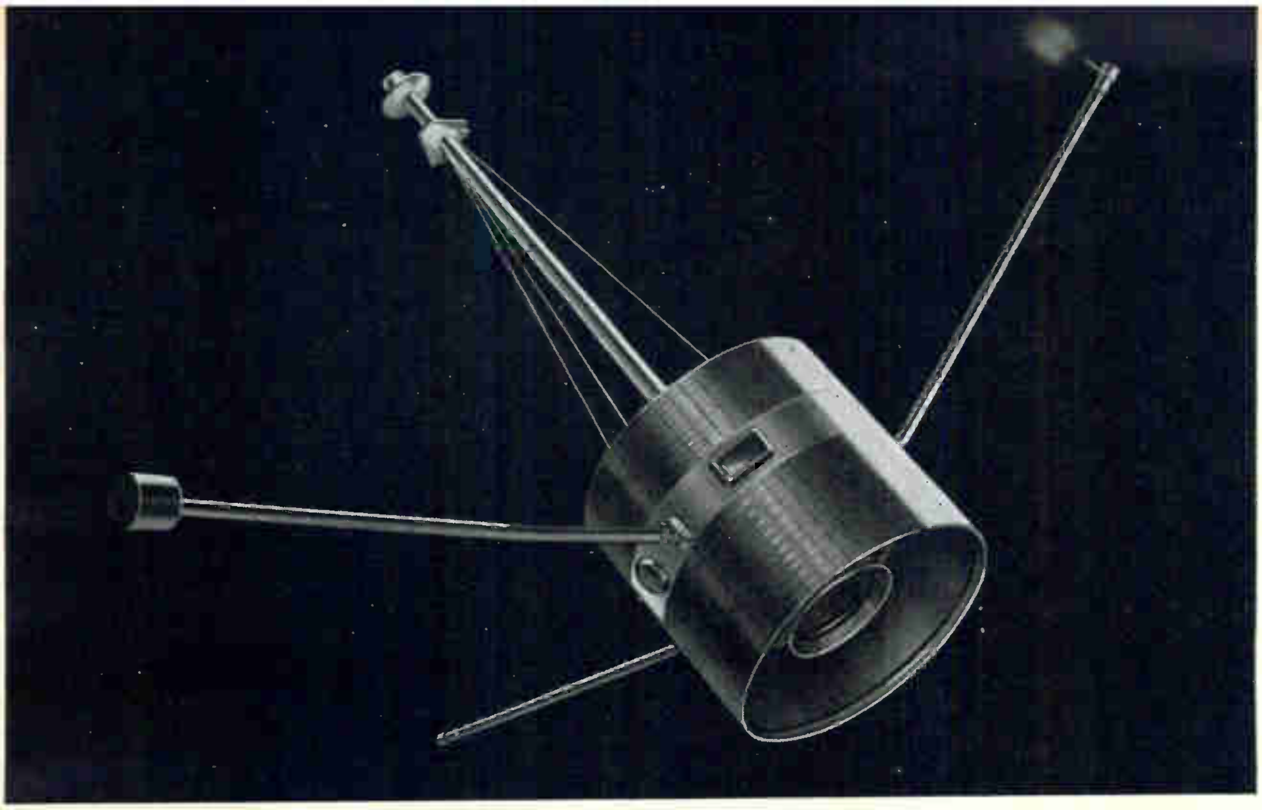
Because the underside of the spacecraft will remain permanently in shade, an active thermal vane system can control temperatures more accurately than passive systems could on previous probes.

By powering Pioneer 6 with a thrust-augmented Thor-Delta booster, NASA has been able to raise the weight load from 95 pounds (in Pioneer 5) to 137 pounds, and still achieve the same trajectories. The addition of continuous spin vector control provides enough weight saving so nearly 20 percent of the 137 pounds can be devoted to scientific payload, compared to only 10 percent of earlier Pioneer probes.

A redesign of communication and data handling components saved enough weight that redundant circuitry was added to back up all critical areas. NASA expects Pioneer 6 to have at least a six month life.

Pioneer's 137 lbs is divided this way: structure and thermal control, 25 lbs; power supply, 29; communication and data handling, 35; orientation control, 7; electrical distribution, 13; and experiments, 28.

Pioneer 6 even looks different. The main spacecraft body is a cylinder 37 inches in diameter and 32 inches long. An antenna extends 52 inches above the main spacecraft upper surface. Three booms, located at 120-degree intervals about the cylinder, extend six feet from the spacecraft. One boom holds the magnetometer, a second the single gas-jet noz-



Pioneer 6 has three booms located at 120 deg intervals about the cylinder supporting a magnetometer, single gas jet nozzle, and balance weights, respectively

zle, and the third, balance weights.

The antenna, an aluminized glass fiber tube, is supported by a tripod from the platform and stiffened by glass fiber guy lines.

Thirty individual louvers on the lower surface of the spacecraft provide the active thermal control. This system keeps the internal temperature of the spacecraft within proper limits at any distance from the sun between 0.8 and 1.2 Astronomical Units (AU = 92,956,100 miles ±500 miles). As the inside temperature rises, bimetallic coil springs move to open the louvers, cooling down the interior.

The magnetometer will measure magnetic field in three directions with a sensitivity of about 1 gamma. The relatively short length of the boom (the magnetometer on the Orbiting Geophysical Observatory (OGO) is carried at the end of a 22-foot boom) and the sensitivity of the sensor has imposed a unique requirement on the Pioneer; its residual and generated magnetism must be less than 1 gamma at the site of the magnetometer.

Magnetic purity

If the magnetometer is to obtain sensitive readings of interplanetary background fields, the spacecraft itself must be virtually nonmagnetic, at least magnetically purer than any other spacecraft has ever been. The weight and simplicity of Pioneer does not permit deployment of the magnetometer more than six feet from the spacecraft body or the inclusion of shielding around magnetic equipment in the spacecraft. Trying to reduce total magnetic field from all sources to a value of 1 gamma or

Magnetic purity comparisons (in gamma)[1]

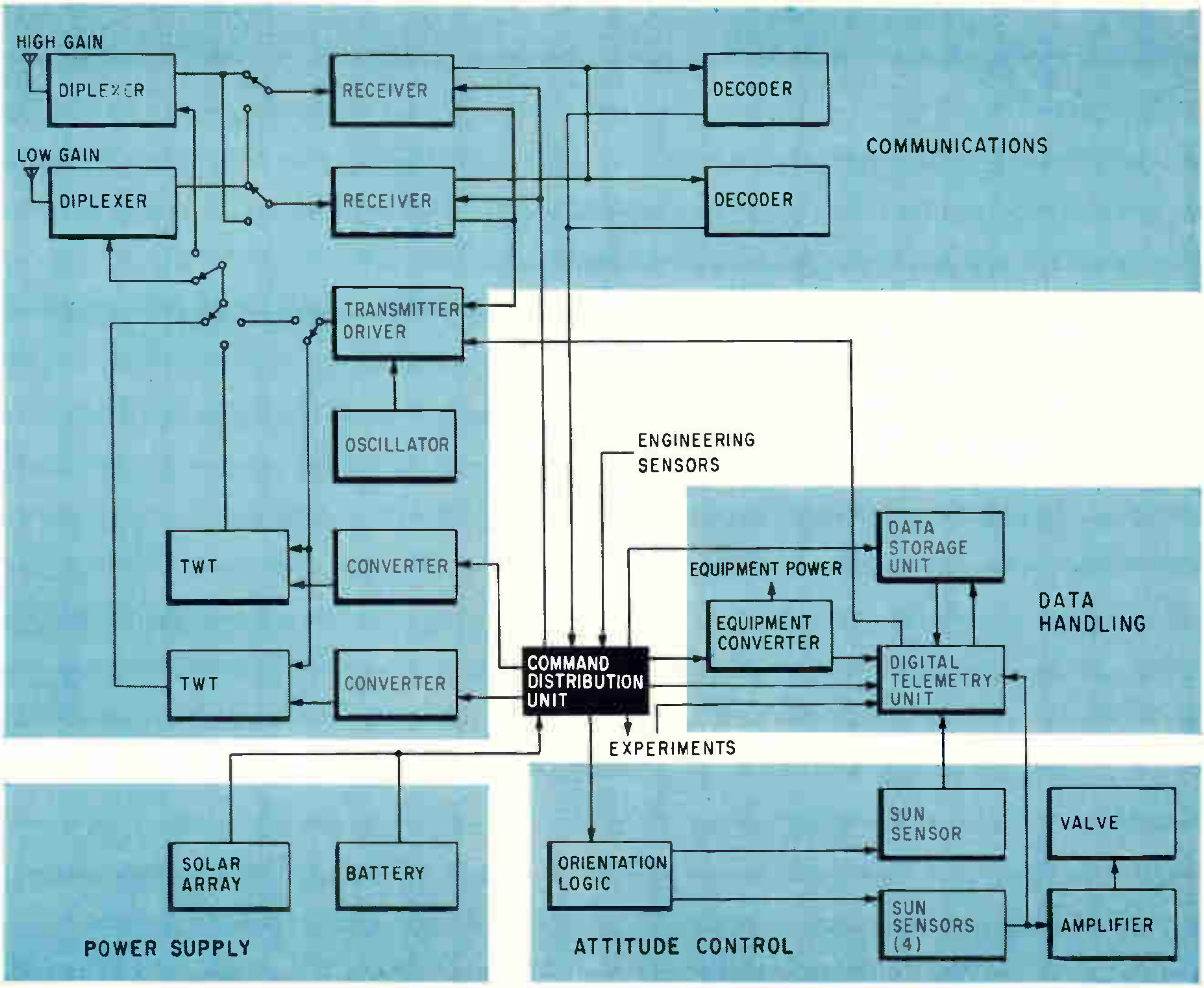
	Orbiting Geophysical Observatory	Pioneer
Command distribution unit	3.0	0.8
Converter	0.6	0.01
Battery	1.0	0.1
TWT	0.8	0.01
Decoder	0.8	0.2
Coaxial switch	0.8	0.1
Receiver	0.2	0.01
Diplexer	0.02	0.02
Digital telemetry unit	12.5	0.1
Signal conditioner	5.0	0
Data storage unit	4.0	0.1
Pneumatic valve	0.5	0.2
Logic assembly	1.0	0.05
Sun sensor	0.1	0.05

[1] Comparing maximum magnetic field strength at six feet from various components on-board OGO (typical spacecraft) and Pioneer 6.

Pioneer's experiments

The 28 lbs. of experiments include:

- Magnetometer, by Goddard Space Flight Center, NASA
- Cosmic ray detector, University of Chicago
- Cosmic ray detector, Graduate Research Center of Southwest
- Plasma probe, Massachusetts Institute of Technology
- Plasma probe, Ames Research Center, NASA
- Micrometeoroid detector, Ames Research Center, NASA
- Radio propagation experiment, Stanford Center for Radar Astronomy



Electronics assembly receives commands from the CDU to engage the appropriate sun sensor at the proper time

less six feet from the spacecraft surface, engineers have produced a virtually nonmagnetic design.

Main sources of magnetism—residual fields in equipment and induced fields as the equipment is operated—have been carefully controlled. It has been found, for example, that significant residual magnetism results from nickel welding and cold working of series 300 steel alloy. Both of these processes will be avoided.

Every component is screened for magnetism. A glass fiber rod, for example, originally chosen for the magnetometer sensor mount was found to have a field of 2 gamma at one inch, presumably from metallic contamination in the glass fiber.

Induced magnetism has been reduced wherever it appeared. The clock source in the digital telemetry unit (dtu) will be a crystal oscillator because turning fork oscillators normally used have magnetic effects. The solenoid valve for gas release incorporated a ringing circuit with a 60-cycle field to counteract 75 percent of the magnetism induced by the operation of the valve each time it is fired. Locating the valve at the end of one of the three booms serves to separate it from the magnetometer by at least 13 feet, as well as increasing the moment arm. All interassembly wiring carrying d-c current return is by twisted, paired wires to produce field cancellation. Single-point grounding of current loops rids the spacecraft structure of circulating d-c currents, and all equipments except the receiver have complete isolation of d-c circuit paths from the structure.

Because the field at the magnetometer is the vector sum of the assembly fields, a permanent magnet, which is a part of traveling wave tubes, can be included. Each Pioneer will carry twt's in redundant pairs, and orientation of the two, which are closely matched pairs, with respect to each other is arranged so each's magnetic field cancels the others at the magnetometer. How magnetically pure Pioneer 6 will be is shown in the table.

Orientation control

The control system has to place and to keep the spin axis perpendicular to the sun-spacecraft line to within ±1.5 degrees and perpendicular to the ecliptic plane to within ±1 degree.

The orientation control subsystem uses five sun sensors, an electronics assembly, and a pneumatic assembly powered by nitrogen regulated to 50 psi.

Since the spacecraft is spinning, the repeated application of torque at a particular point in the spin will cause a precession, as in a gyroscope.

Four sun sensors are necessary to permit rotation in either direction about either of two orthogonal axes. These four sun sensors are located 90 degrees from each other around the spacecraft. A fifth sun sensor is used to provide sun reference pulses to the experimenters.

The electronics assembly receives commands from the command distribution unit (CDU) and uses these commands to engage the proper sun sensor at the proper time. When the sun sensor is illuminated a signal is received and amplified to turn on the pneumatic solenoid valve.

The command distribution unit is the central point for power and command signals. It distributes switching and power, distributes signals from the command decoder to other equipment and has test points at the interfaces of spacecraft systems. It also contains sequencing functions and indicates various operating modes. It consists of a matrix of SCR's which operate magnetic latching relays and other commandable loads.

Antennas

The high-gain antenna is a 10-element series-fed collinear array of stacked dipoles excited in-phase and with equal amplitude. The radiated energy is polarized parallel to the axis of the antenna. The beam of the antenna is narrow in the pitch and yaw planes but omnidirectional in the spin plane. It is center fed by a coaxial air line (an integral part of the antenna) which insures radiation normal to the antenna by virtue of symmetrical phasing.

Equal phase and amplitude excitation of the individual elements of the collinear array is achieved by separating the elements by exactly one wavelength. Skirt on each element produces in-phase currents at all points along the element. These precautions will produce radiation in the broadside direction; however, as the frequency is changed, the separation between elements becomes something other than one wavelength, resulting in beam tilt, which can be avoided by feeding the array at the center. Center feeding does not solve the problem of phasing errors among the elements; it does, however, produce a symmetrical illumination along the array which keeps the beam in the broadside direction even though it does deteriorate slightly as frequency changes. The result is about 13-db gain at the transmitted frequency of 2,300 Mc but a 10-db gain at the received frequency of 2,100 Mc.

The low-gain antenna is discone type fed by a coaxial line through the center of the high-gain antenna. The pattern is omnidirectional with polarization parallel to the spin axis of the spacecraft.

The antenna and feed lines are constructed of low-density foam dielectric sleeves, upon which a thin film of metal is deposited. The entire structure is then inserted into a glass fiber tube for mechanical support.

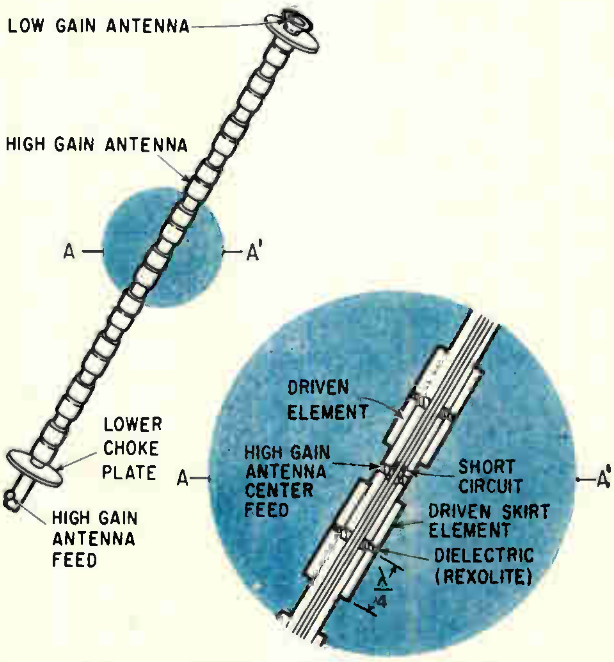
Communications equipment

The need for transmitting data from seven different experiments aboard the spacecraft coupled with the limited size and weight restrictions imposed on Pioneer 6 has resulted in an interesting design for the communications subsystem, which will operate at S-band.

Two antennas, two redundant phase-lock receivers, two redundant decoders, two redundant 8-w twt power amplifiers, a transmitter driver assembly, two diplexers, and coaxial switches comprise the system.

Either receiver and either amplifier can be connected on command to either antenna. A low-power transmit mode is provided for operation before the power supply is functioning optimally and while range is sill quite low by transmitting directly from the 50-mw transmitter driver. Signal-present logic provides automatic switching from noncoherent, when the spacecraft is not locked to ground transmission, to coherent transmission, when it is.

The two receivers operate on slightly different frequencies near 2,100 Mc with entry by frequency address. The demodulated command output of the selected receiver is automatically connected to both decoders via signal-present switching gates; selection of the desired decoder is by command address. During the boost phase, the receivers operate in wideband mode (300 cps). Then they are switched by command to the narrowband mode (20 cps) for



High-gain antenna is 10-element series fed collinear array of stacked dipoles; low gain antenna is a discone type fed by a coaxial line through the center of the high gain antenna operation during the remainder of the mission.

There are two prime functions for each receiver. One is to generate a phase coherent output to the transmitter driver at 12/221 of the input frequency. This signal is then multiplied by 20 in the transmitter driver to produce a transponding ratio of 221/240 to allow measurement of two way doppler. The second function is to demodulate the command tones which are phase modulated on the received signal.

The receiver is a triple conversion phase-lock unit. The received signal is converted in the first mixer by a locally generated signal and is applied to an i-f preamplifier. The balanced diode mixer and first stage of the preamplifier determine the receiver noise figure to be about 10 db. The signal is band-limited to 2 Mc in the first i-f. A crystal filter with a 3-db bandwidth of approximately 2 kc provides the i-f narrowbanding. After amplification the signal is translated in a balanced mixer by the third local oscillator signal, and the output is hard limited ($\approx$ 30 db) in two stages and amplified to 15 volts peak-to-peak and applied to the loop phase detector. A 5-v peak-to-peak signal is applied in parellel to the quadrature detector. The reference drive to the loop phase detector is a crystal oscillator operating at 30 Mc. The reference drive to the quadrature detector is the 3-Mc oscillator signal shifted by 90 degrees.

The three locally generated signals for the three mixers are supplied by the reference oscillator at 3 Mc and voltage controlled oscillator (vco) at 19.125 Mc. Phase instabilities of the 3-Mc reference oscillator cancel in the phase detector and do not add to the phase jitter in the loop. The vco phase jitter appears in the output of the phase detector; an extremely stable oscillator design is therefore required for a high sensitivity receiver. Threshold sensitivity in the wideband mode is —136 dbm, in narrowband —147 dbm.

The output of the loop phase detector is filtered in a lead-lag network and returned to the vco control input, where it completes the feedback loop. The loop is locked by sweeping the S-band input signal in frequency. When the signal is near enough to the rest frequency of the receiver the loop will lock to it in frequency and phase. The reference drive and third i-f are in phase quadrature during lock and if the incoming signal is unchanging, the output is zero. The signals in the quadrature phase detector are in phase and produce an output which is approximately equal to peak signal drive. This output after being filtered is therefore used to indicate the presence of a signal and can be used as an indication of signal strength. Output of the loop phase detector is telemetered as an indication of loop error and the output of the quadrature phase detector is telemetered to indicate receiver lock.

Although the decoder receives its signal from two receivers, there is only one input line since the outputs of the receivers are strapped together. The signal will consist of frequency shift keyed subcarrier tones modulated at a rate of 1 bit/sec. The presence of the higher tone will indicate a one, and the presence of the lower tone a zero.

At the input to the decoder, a buffer amplifier will provide protection against shorting the signal line to prevent any malfunction in one decoder from disabling the other.

Data handling

On-board storage capability makes the data handling unit unique in interplanetary spacecraft.

The Pioneer digital telemetry unit (dtu) processes all inputs into a pulse code modulation time multiplex format which biphase modulates a 2,048-cps subcarrier sent to the transmitter driver. The inputs to the dtu consist of both digital and analog signals from the experiments and spacecraft performance measurements. The data storage unit has a capacity of 15,323 bits, for special processing during real time and when the spacecraft is not being tracked. The memory consists of 30-mil square loop ferrite cores arranged in an X-Y matrix.

Seven bits make a word, and the last bit of each word generally is used for odd parity. The number of words per frame is 32 for all formats. There are four formats, three of which are for experiment measurements and the fourth for engineering data. Two synchronization words appear within each group of 32 words. These synchronization words are 7-bit Barker codes separated by 16 words. The Barker code is a group of bits that identifies a frame and the beginning of a word simultaneously.

Other fixed words in each frame consist of format identification (always appearing directly after frame sync word) and subcommutation word position identification. During real-time transmission, the experiments are sequentially sampled at bit rates chosen by command of 512, 256, 64, 16 or 8 bits/sec.

The authors

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Mr. Spangler has assisted in communications satellite studies and managed technical information for Pioneer 1, 2, 5 and Explorer 6. An M.A. in English in 1950 from University of Chicago, he has completed course work for the PhD

A new look for the old telegraph

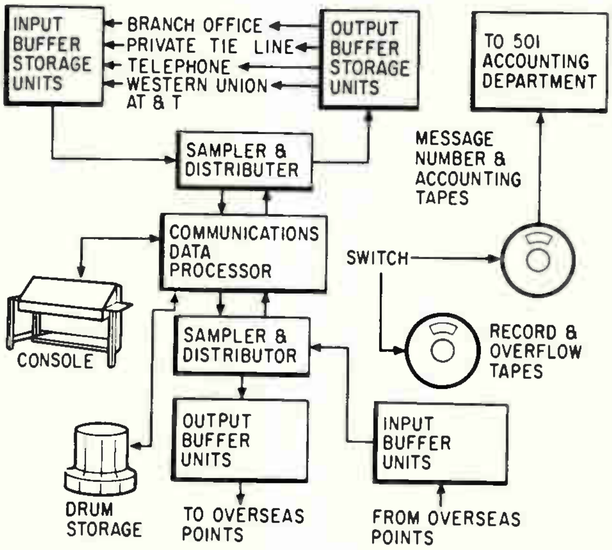
Booming traffic forces the design of an electronic system to handle overseas messages. The big problem is matching the high speed computer to the slower speed teleprinters.

By Roy K. Andres and L.P. Correard
Manager Group Leader
Automation and Terminal Systems Engineering, RCA Communications, Inc., New York, N.Y.

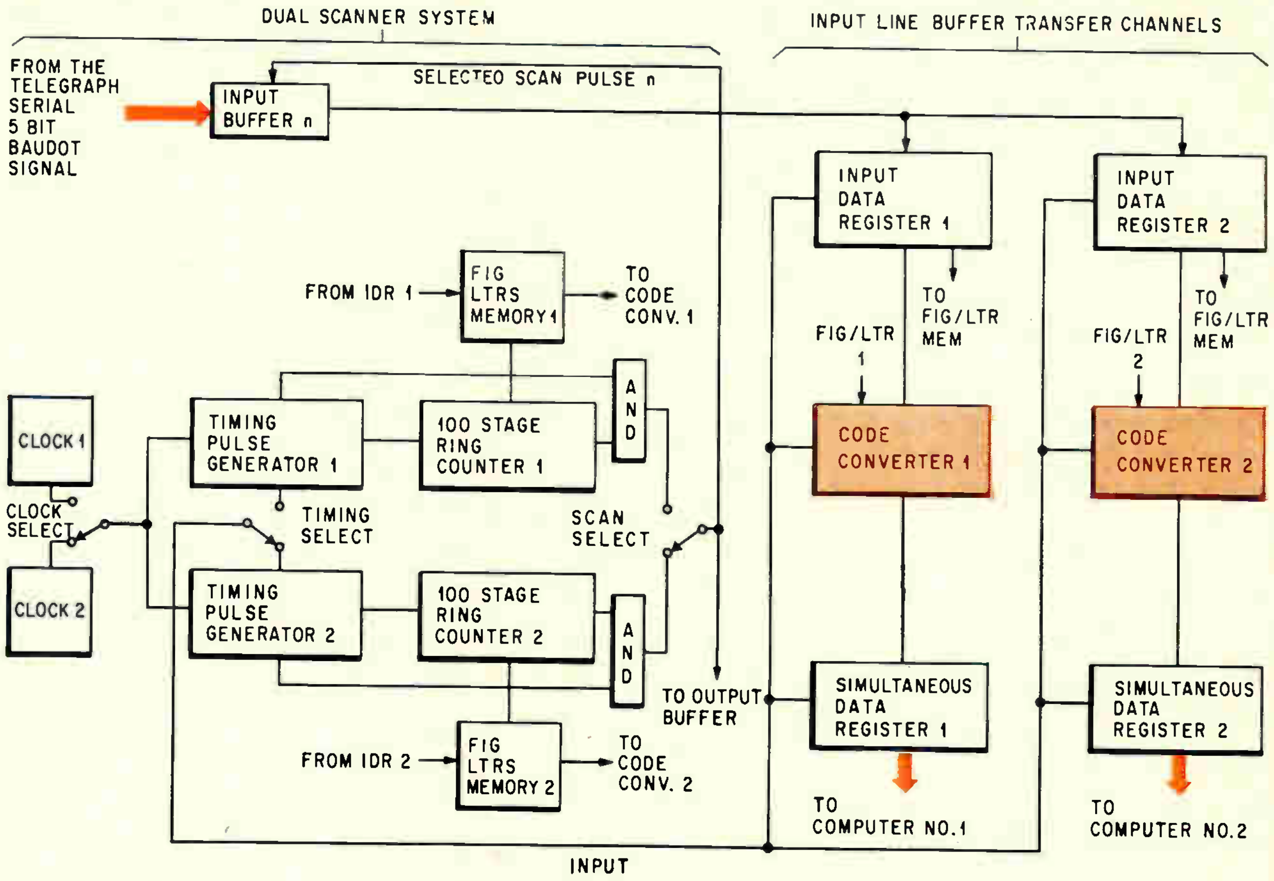
Every day, RCA Communications, Inc. moves over one and a half million words around the world. Messages pour into New York from hundreds of stations to be relayed to hundreds of other stations in all parts of the world. Traffic grows steadily, nearly doubling every twenty years. Now the international telegraph system has outpaced the torn tape relaying of messages introduced in 1944. Within the next few months, RCA will replace the old system with a specially designed electronic computer that will sped the relay of messages, as well as automatically correct errors, store messages, and bill customers.

To appreciate the equipment you first have to understand how RCA's traffic is handled now. A message arrives at the relay center as a perforated tape. A girl reads the address, rips the tape from the teleprinter and hand carries it to another transmitter connected to the message's destination.

In 1957, when it was clear traffic would soon outstrip the mobility of even electromechanical systems augmenting the torn-tape method, planning began with RCA Electronic Data Processing for an electronic telegraph system (right) built around a pair of high-speed stored-program digital computers. Since existing RCA commercial computers were not suited to on-line communication requirements, a new generation processor, the communications data processor (CDP) had to be designed. This machine, created as a real-time computer, examines and switches international messages to their proper destinations in milliseconds instead of the cross-office, perforated-tape relay time measured in minutes. Messages from 70 countries via millions of route miles of radio and cable links will move continuously through the CDP as rapidly as the international communications link



Electronic telegraph system controlled by computer is aided by input-output buffers and storage facilities



Input block diagram (left) shows special features of the electronic telegraph system front-end design. Incompatibility between conventional teleprinter signaling code and faster computer language is resolved with buffers. Difference between figures and letters normally handled by short-term mechanical memory in teleprinters, requires

can carry the load. To insure continuous operation, 24 hours a day, RCA installed two computers, each programmed to handle the full traffic load. It is possible to switch from one to the other without interrupting traffic flow.

The CDP will handle, through its 100 full-duplex channels (simultaneous reception and transmission), all classes of message traffic and all types of service communications flowing through the central telegraph office. Each message entering the CDP is automatically examined to determine the proper routing and then switched to the proper outgoing channel by priority in chronological order. If all the destination channels are occupied, the message is queued in the intermediate drum storage to await its proper turn. As rapidly as each outgoing circuit becomes idle, the CDP will automatically select, in chronological order, the highest priority message within the system for transmission.

Editors note

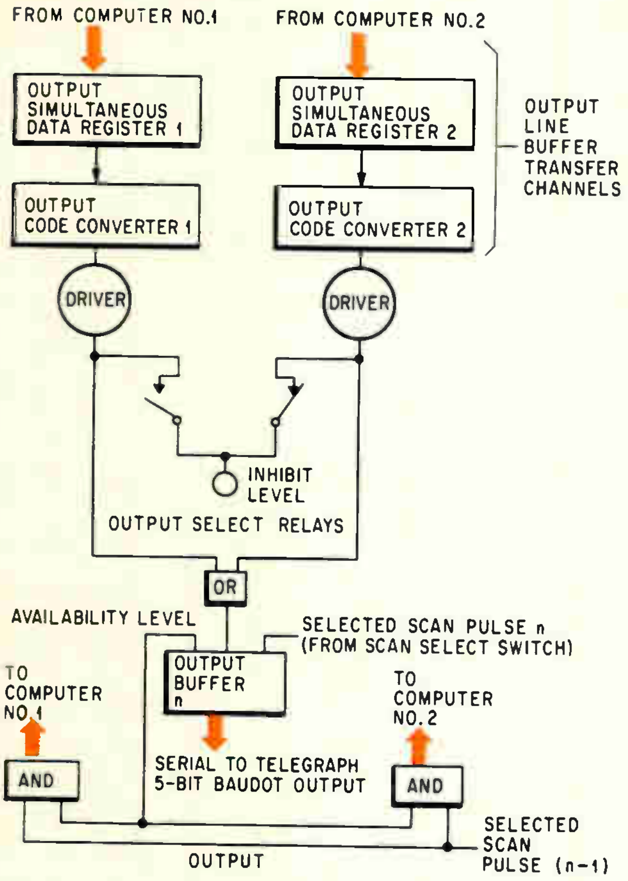
Although it will operate like the computer-run communications systems installed by Chrysler Corp., Westinghouse Electric, and Delta Airlines, RCA's equipment is an order of magnitude more complicated because RCA's traffic is so much heavier than anybody else's. In fact, the computer is not very different from those RCA's Computer Division supplied for Autodin, the giant Defense Communications complex.

In addition to the prime task of routing messages, the CDP has been programmed to perform a variety of control, service and accounting functions (see box, page 89).

Here's how a message will move through the system. Prepared in the required format, it enters the system through the input buffer storage units. These buffers momentarily hold each character of the message since the teleprinter equipment is slow speed (45 to 75 bps), and the CDP is high speed—then dump it into the computer. The traffic is stored in the computer, it is examined for destination and priority and switched to the proper outgoing channel by priority in chronological order.

The message is dumped at high speed into the output buffer units character by character and clocked out to the low speed outgoing transmitting channels and teleprinter equipment that handle it. All traffic passing through the system is recorded on magnetic tape for future reference.

The task of connecting 100 5-unit Baudot code serial start-stop telegraph lines operating at speeds ranging between 45 to 75 bits per second to one central computer operating at much higher speed, with different codes and parallel transfer of large numbers of bits was solved by the design of the ETS front end. The input subsystem has 100 buffers that provide serial-to-parallel conversion of the



code converters (colored blocks) in the CDP. Simplified output circuits are shown at right

5-bit teleprinter Baudot-code character by means of two shift registers. A parity bit is added to each character in the input buffer (above) by a flip-flop that counts the marking bits as they are shifted into the first register from the telegraph line. The character is then shifted to a lower register and is available in parallel to be transferred into the CDP.

A scanner-timing pulse generator comprising a crystal controlled oscillator and countdown chain plus a 100-stage ring counter, supplies timing pulses to the line buffer transfer channels (LBTC) of both communications data processors as well as scan pulses to both input and output buffers.

The nth scan pulse transfers the parallel 6-bit character from the nth buffer to the first register of the LBTC, the input data register (IDR) and checks the availability of the (n + 1)th output buffer. If the character contained in the output buffer was previously transmitted on the last cycle, a new character will be loaded and transmitted out by the (n + 1)th scan pulse.

As the character is moved into the IDR, its previously generated parity is checked and a new bit, the FIG/LTR bit is added to establish the 5-unit character (now 7 bits) as upper or lower cases on the teleprinter equipment. The seven-bit character is now processed through a Baudot-to-CDP encoder that properly encodes the 7-bit character into the octal code of the CDP.

A four-count circuit allows four such characters to accumulate in the simultaneous data register (SDR) such that one group of 28 bits (four characters of six bits each plus parity and tags) is available in parallel form. This group constitutes the halfword (HW), which is the minimum size simultaneous transfer within the CDP. Each consecutive halfword consists of a character from Buffer 1-4, 5-8 96-100. From the SDR, transfer is made directly into the high speed memory input area.

The line buffer transfer channel generates the address in memory where the accumulated halfword is to be stored. The address counter addresses two continguous memory blocks (pages), each consisting of 200 halfwords. When the block is filled, the page is transferred to the memory work area where the program accumulates character strings on a per-channel basis and proceeds to subject these character strings, called line blocks, to the message recognition and routing programs. As this occurs, the secondary page in memory is being filled.

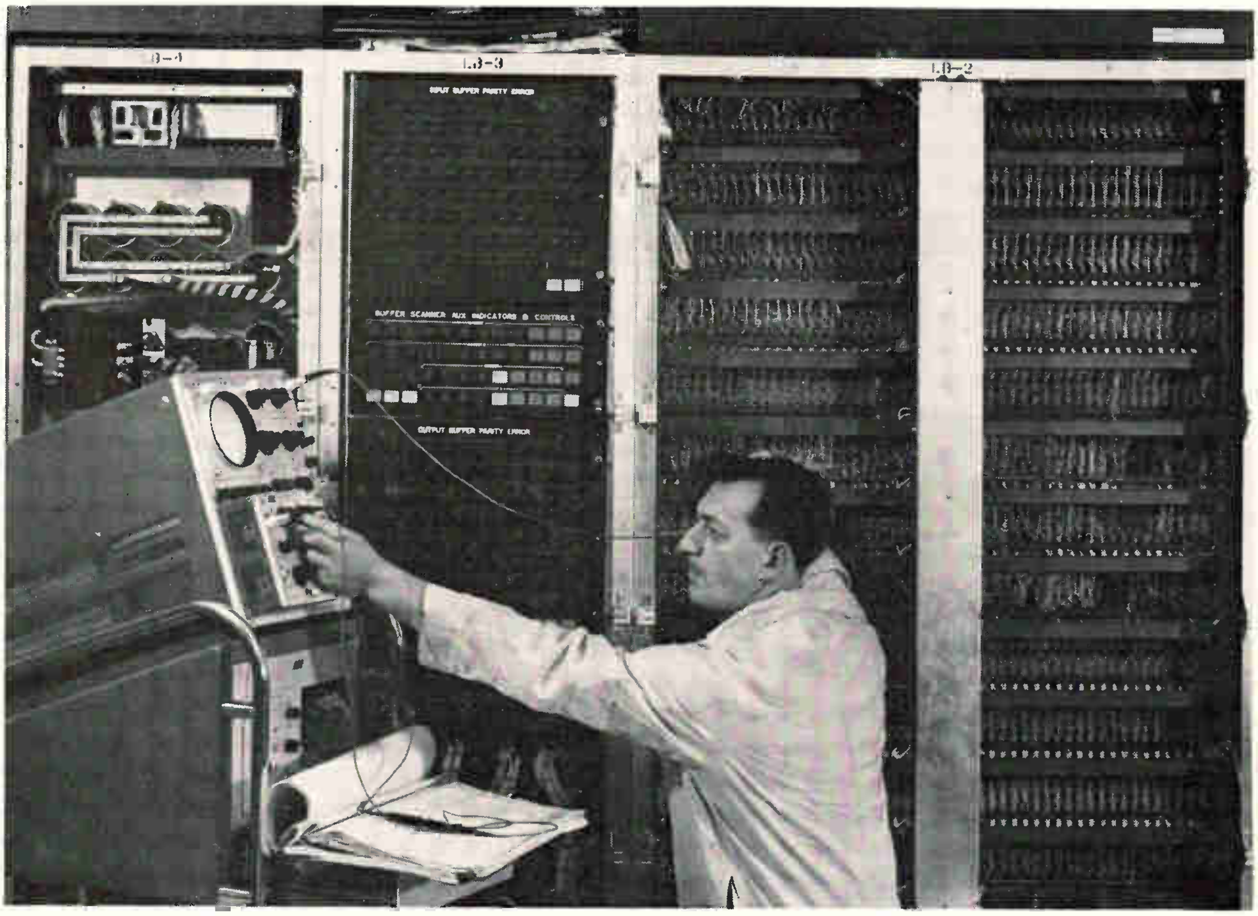
The output cycle referred to previously makes use of line blocks of routed messages that have been stored on magnetic drums awaiting their turn to be transmitted. When the queue list maintained in memory selects a particular message for each channel for transmission, the line blocks of these messages are moved to an output area in memory. A counter in the output LBTC generates the address of a full word in memory for each of the 100 output lines. This full word contains the next two information halfwords to be transmitted.

When a buffer is found to be available, the CDP transfers a halfword to the output simultaneous data register from the location generated by the address counter. The SDR gates out one 6-bit character and returns the partly-emptied halfword to memory, shifting the HW by one character in

The authors

Roy Andres received his electrical engineering degree from New York University and has taken graduate work at MIT in switching and computer theory. Since 1946, he has engaged in development of 5-unit telegraph switching systems, multiplex systems and switching for microwave links and data communication systems. He holds patents in these fields. In addition to membership in IEEE professional groups, Mr. Andres is a member of study groups of CCITT and also of a U.S. group on international data transmission standards

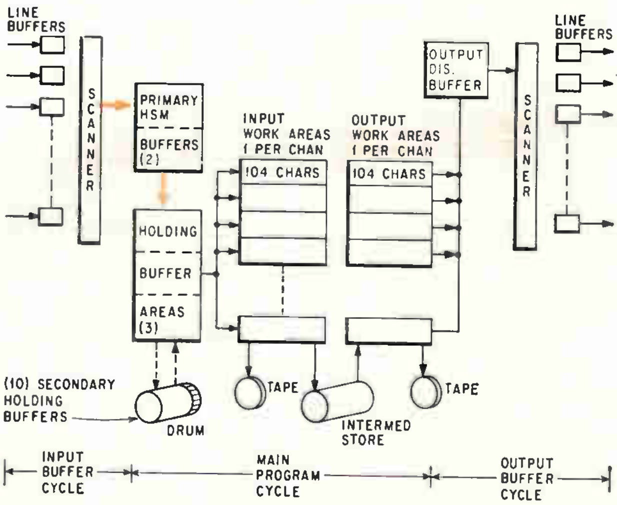
Louis Correard graduated as a BEE from Manhattan College and has done his graduate work at Columbia. Since joining RCA Communications full time in 1960, he has worked on the interface and integration of data processing equipment with the remainder of the operating plant. He is a member of IEEE and NYSSPE



Technician checks the line buffer/scanner unit that provides interface between 100 telegraph lines and CDP. Channel-parity error lights and scanner indicator are housed left of center

the most significant direction. The character just transmitted is passed through the output decoder, has parity generated for the Baudot character and transmits it to the scanner, which inserts the character into the output buffer for transmission.

The scanning function is a dual system employing two clocks, timing generators, scanners, and registers. Error detecting circuits monitor the actions of these units and will automatically substitute back-up equipment without loss of traffic whenever failure is detected.



Traffic cycle requires accepting slow-speed teleprinter characters, conversion to computer language, storage and reconversion to slow code

Likewise, two LBTC's, one-per-CDP, are used to accumulate input data simultaneously in the memories of both machines. This unique feature allows automatic switch-over between computers without loss of messages.

The entire two-scanner unit is composed of 250 plug-in cards. These circuits, along with 100 input buffers each consisting of 4 cards and 100 output buffers each comprising 5 cards and a dual power supply are housed in separate racks.

The line buffer transfer channels, one-per-CDP, consists of 150 plug-in cards and are a physical part of the communications data processor itself.

Traffic processing

The traffic processing cycle (illustrated) is initiated by transferring data from the holding buffer area to a work area referred to as a line slot. One such area is assigned to each of the 100 input lines. The message is reconstructed in this area, and validity checks are performed, routing and priority are determined. When the line slot area for a message is filled (up to 104 characters) or if the end of the message is reached, the message segment is written to the intermediate storage drum.

When the end of the message is reached, the message is linked into the proper output queue by priority. As each message segment is written onto the intermediate drum, the segment is also copied onto the recovery tape to provide a back-up copy.

When the start-of-message segment is detected, a determination is made as to whether overflow conditions exist or are imminent. If the intermediate drum or output queue table is reaching saturation, the message segment and all continuing segments, will be written to the overflow tape. Messages written to this tape are re-entered later when the traffic load is low.

After a message is linked to its proper output channel queue it is available for transmission. Transmission is accomplished on a first-in, first-out basis within priority class. As each data block from the intermediate drum is placed into a work area (called the output line slot area), the output buffer cycle control is set so line-slot areas containing data will be examined for output by the output buffer cycle and data delivered to the output distribution buffer area, thence to the scanner and on to the telegraph line buffers, as previously described.

After each message segment is transmitted, a copy of the segment is written to the journal tape to provide a record of each transmission. At the end of each message, a ledger record is written to the number list tape to provide a correlated record.

In addition to handling the normal flow of traffic through the system, the traffic processing cycle executes various commands called for by the supervisor. These commands may require the program to produce status reports or to change certain internal tables, thus modifying future program behavior. An important function in this category is the rerunning of recently transmitted messages (or the production of printed copies of messages stored in the system). To accommodate these demands a re-run or short-term queue is provided, messages eligible for retention in this queue being transferred to this control after completion of initial transmission. This queue is cyclic in its use and a fixed number of messages is contained in the area at all times.

When the queue space allocated to a message is preempted by another message, the drum store associated with the pre-empted message is released for re-use in the system. Another important feature employing the queue is the divert, which will move all of the messages queued for a destination and transmit them via a specified alternate route. This command allows re-routing of traffic around undersea cable breaks and radio blackouts.

Communications data processor

The CDP is a multi-programmable real-time computer with the outstanding characteristics of having a theoretically unlimited number of interrupts. It is a modular system consisting of a basic processor, 1 to 4 banks of memory and 1 to 16 transfer chan-

What the CDP does

1. Verifies sequence of inward channel message number
2. Automatically inserts an outward channel message number
3. Records and prints out a list of the inward message numbers with their corresponding outward message numbers for each channel
4. Recognizes the international four-letter destination code; when absent, examines the address line for city and country of destination, and looks up the proper destination code in the internal geographic index
5. Recognizes registered addresses, compares them with the internally recorded directory and inserts the necessary code for local delivery
6. Recognizes and establishes precedence in forwarding all messages
7. Provides facilities for retransmitting messages when necessary
8. Provides a long-term record storage (6 months) of all messages flowing through the central office
9. Provides automatic detection of lost messages and character distortion within the system
10. Edits and extracts necessary information from each paid message for automatic customer billing and settling the international traffic accounts

Characteristics of the CDP

Memory Parameters:
Each bank of high-speed memory consists of 8,196 words, each of 56 bits with a read-write cycle of 1.5 usec. A memory word consists of two half-words each containing 24 data bits, 3 tag bits, 1 parity bit.

The memory is addressable by word, half-word, 3, 4, 6, 8 bit character.

Instructions

Instruction are variable in length and may have 0, 1, 2, or 3 addresses.

There are 97 standard instructions providing word, half-word, and character operations, binary and decimal arithmetic.

All instructions are sub-routines of Elementary Operations. New instructions may be developed for any particular application without involving hardware changes.

Address control

Multi-level indirect addressing plus incrementing or non-incrementing address modification is individually applicable to any or all addresses of each instruction. Addresses may be assumed from previous instructions.

Interrupt System and Real-Time Features:

Simultaneous operation of several transfer channels. Automatic back-logging of instructions for busy peripheral devices.

Termination of peripheral device instruction causes program interrupt at which time program change may be made.

Program interrupts may be caused by errors, external signals, millisecond clock or program operations.

Two levels of interrupt:

1. Servicing peripheral devices by short service routines that interlace but do not disrupt main program.

2. Program interrupts and switch-over, which require exchange of contents of all machine registers.

nels through which a full range of standard EDP peripheral devices and communications channels may be controlled. Its characteristics are listed in the panel on page 89.

The CDP is designed to accept and deliver (through line buffer transfer channels) data to and from a large number of channels simultaneously. Since the internal operating speed of the CDP permits character handling rates up to 2.5 million characters a second, the total incoming and outgoing communications load of all channels (3,000 characters per sec) only consumes a small fraction of the available CDP time. The remaining CDP time is available to perform the necessary logic functions associated with examining the message format, comparing this information with recorded tables of routing instructions, transferring the message from one storage point to another and controlling the flow of all output channels.

Since many system functions require message storage facilities of different capabilities, three principal methods of storage are used in the system: magnetic cores, drums, and tapes.

Magnetic cores are used for the high-speed memory of the CDP. The core memory of each CDP has a capacity of 131,072 characters and a read-write cycle time of 1.5 μsec. (The read-write cycle is the minimum time to record and recover information in the computer memory.) The high-speed memory along with the CDP logic operates with a duty cycle of 2.0 μsec and is used for storing the CDP program instructions, message accumulation and distribution, destination tables, queue lists, code conversion and message storage for processing.

Four magnetic drums, each with a capacity of 384,000 characters are used for storing information that does not require the extremely short access time provided by the core memories. The average and maximum access time for any information stored on the magnetic drums is 33 milliseconds and 66 milliseconds, respectively. Two drums are used for intermediate message storage and short-term reference storage (rerun) providing a capacity for 1,600 to 2,000 average messages. One drum, used for short term reference storage, provides the ability to retransmit any of the last 800 to 1,000 messages to leave the system without having to refer to the record copy in the magnetic tape. The third drum contains 12,000 registered addresses and their routing instruction codes and geographical index of 150,000 characters for the world's cities and countries in three languages. The fourth drum operates as a floating spare.

Standard RCA 581 magnetic tape stations operating at 33,000 character per sec are used for providing overflow storage, permanent monitor copies of all traffic and for recording the message numbers and accounting information.

Mutilated messages

The ARQ (automatic repeat) used on RCA overseas radio circuits provides an extremely low bit error rate. Cable channels have low noise, which keeps error rate low. It is, however, statistically possible to have a mutilated character, or several, in a message. Human error can also cause a wrong character to be transmitted.

The Electronic Telegraph System is programmed to detect, reject and hold for manual attention, errors in the message preamble and format. If characters being received cannot be recognized as a new message, the ETS routes these characters to a spurious character position together with an indication on which channel they were received and the number of the last good message.

If a group of characters is recognized as a valid message but the routing does not agree with stored routing tables, the message is sent to the manual router position for attention.

International destination indicators were selected so a one-bit mutilation in any character will not cause the bad indicator to match any other. When this scheme is impossible, owing to a country having many indicators, the code was chosen so single-bit mutilation will transpose the code to another valid one for another city in the same country.

The requirement for continuous 24-hour service precludes the use of scheduled service periods for routine preventive maintenance. To insure continuous operation, the system employs two CDP's, each programmed to handle the full traffic load. Since possible common equipment failure involves the input accumulation cycle in the high-speed memories, the second CDP will perform these functions simultaneously. Similarly, the queue lists and drum vacancy tables should be continuously accessible to both the on-line and standby processors so the second CDP will be continuously aware of the location of every message in the system. Thus, it is possible to switch from one CDP to the other without interrupting traffic flow. To preserve and guarantee retrieval of this vital information, it is assembled and stored in two different locations within the system and accessible to either processor via transfer channels.

Hardware for the total system cost nearly $4 million; System engineering took nearly seven years.

The authors wish to express their appreciation to A. E. DiMond and W. A. Levy, of the Electronic Data Processing Division of RCA, for permission to make use of portions of their recent article "Design Of A Data Communications Computer System".

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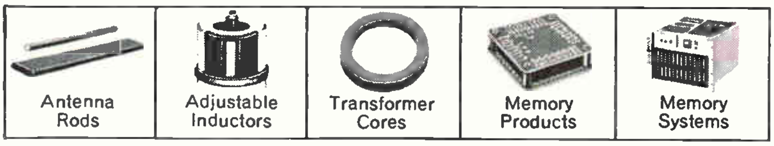

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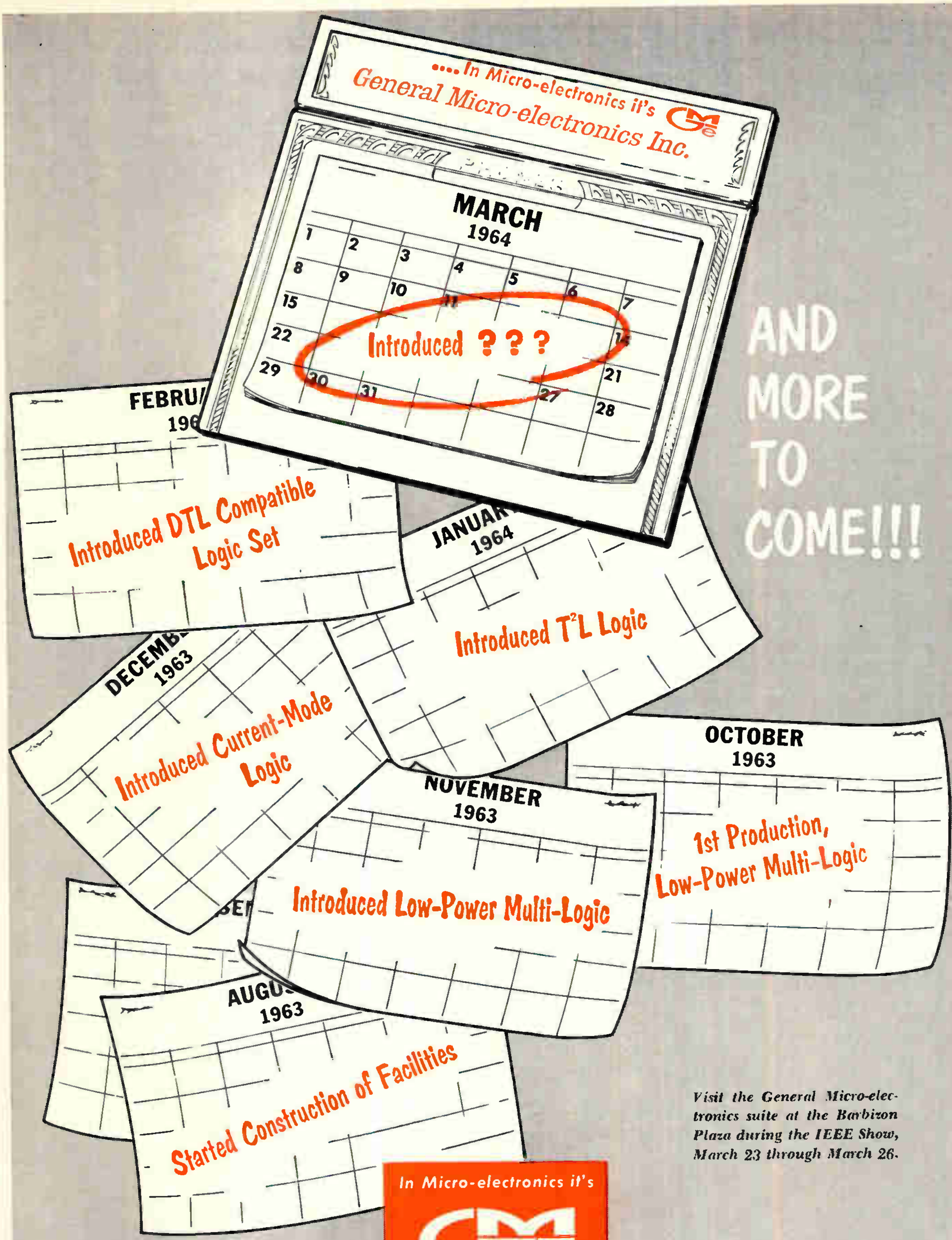

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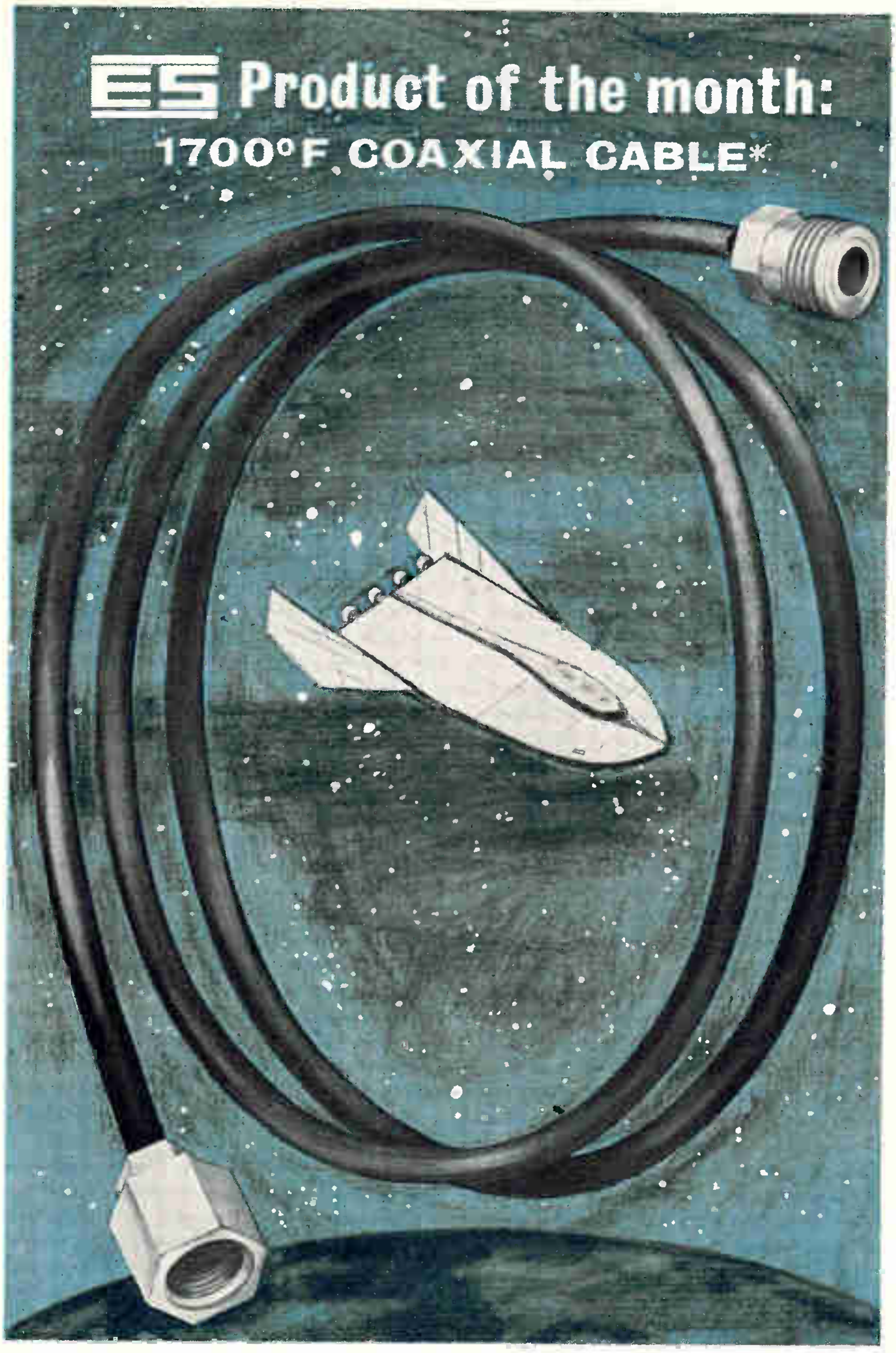

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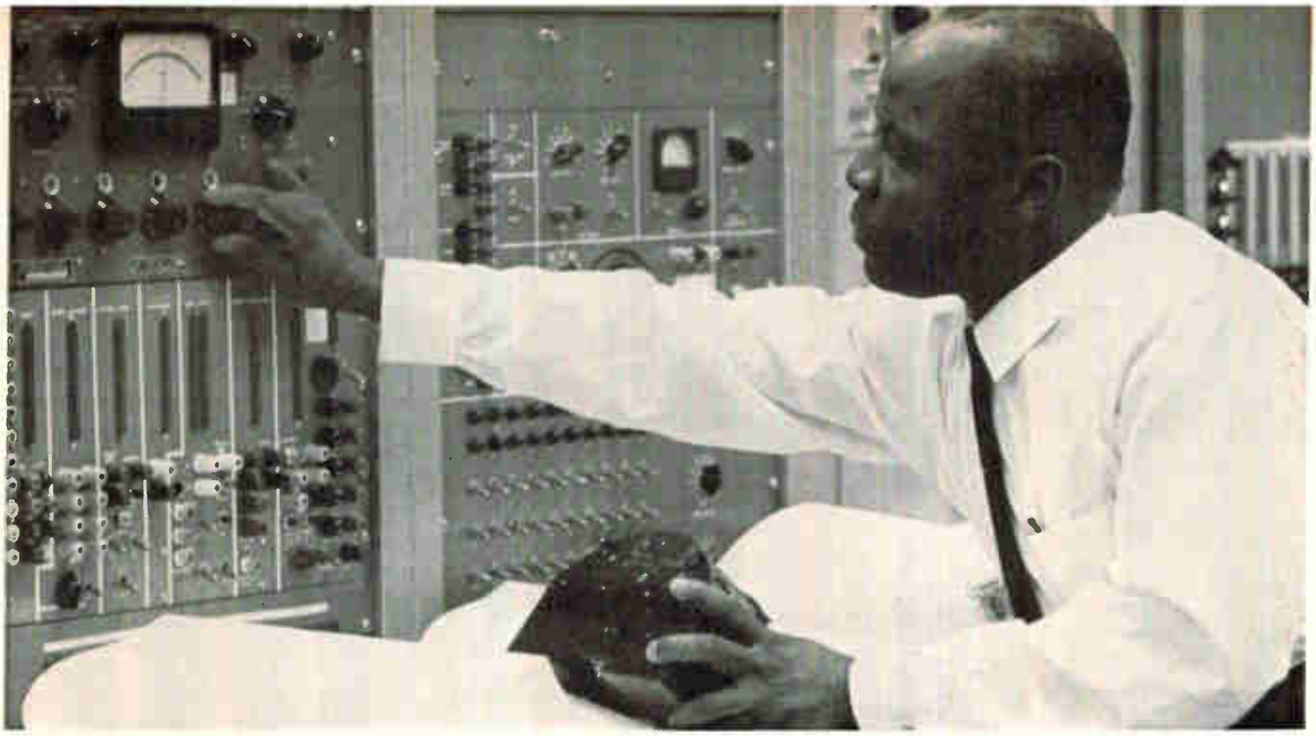


Richard Barrett, electronics engineer at Honeywell, Minneapolis: Education "has made the difference between a dull job and a really exciting one."

Manpower

Help wanted: Negro

Jobs in electronics are plentiful, but qualified Negro engineers are sometimes hard to find

By Dan Smith

McGraw-Hill World News

Electronics seems to be a growth industry for the qualified Negro job-seeker, although his path to a supervisory position is still often obstructed by bias among some individuals.

This estimate comes from company executives and engineers, both white and colored.

James R. Colvin, manager of employment and training at Litton Systems, Inc., expresses a view prevalent among industry officials. "Electronics is probably the best industry in the United States for a minority group member to enter," says Colvin, a white man, "because it's so desperately in need of talent."

A Negro official of the Urban League concurs. Joseph W. Walker, the league's director of job development and employment in Los Angeles, says: "Electronics is one of the most receptive fields for Negro engineers. The industry is one of the best examples of democracy in action in business."

Cost of bias. Some Negroes credit the profit motive, rather than altruism, for their improved position in the electronic industry. Walter Collymore, a research engineer at the Autonetics Division of North American Aviation, Inc., cites the Government's policy of barring contracts with firms that practice discrimination in hiring. "If they feel they can get contracts by hiring Negroes they're going to do it," he says. "They'll figure, 'I want this contract, so I'll put myself in the best spot for it'."

Paul H. Ware, a Negro member of an advance missile technology group at the Douglas Aircraft Co., takes a similarly pragmatic approach. "Face it," he says, "discrimination is just too damn expensive. If companies want contracts they have to hire Negroes."

Whatever the reasons, there's general agreement that the electronics industry is anxious to get more Negro employees with the proper qualifications.

A young Negro electrical engineer in Detroit declares: "A qualified Negro engineer has no difficulty getting a job. In fact, today a Negro may get a better job in electronics than his experience entitles him to. And salaries are high."

Another Detroit EE, also Negro,

Douglas' Paul H. Ware: "Discrimination is just too damn expensive"—no Negroes, no government contracts.

NASA's John E. Moss: "Even in the North living conditions are bad." He travels 20 miles a day to his job.

Lockheed's Brennan Thompson: "In 1941, I was hired on a Wednesday . . . on Thursday the job was gone."

adds: "There are so few Negroes who have studied electronics that there are not enough to go around. Every major company now wants to prove that it is not prejudiced, and is scrambling around to hire one."

I. No getting ahead

While the Negro engineer seems to be more than welcome at the hiring office, his chance for promotion to a supervisory position isn't always as good as that of his white colleague.

"It's rare to find a Negro in a supervisory position," a Negro EE in Detroit says. "You may find a Negro with a fancy title and a high salary, but these things are usually meaningless, because he won't have responsibility over people. The employer argues that you can't put a Negro in a position where he will give orders to white engineers, because it will cause too much friction.

"That's the rationalization that's always offered," he continues, "but the companies have no basis in fact, because they never try it. I know of only one Negro supervisor, and he gets along fine with his employees.

"There are lots of white supervisors who can't get along with their employees. Why not at least try a qualified Negro? If he really has difficulties, then he should be treated the same way that management treats any kind of troublesome superior."

Often a company free from prejudice is subject to the pressures of prejudice. Besides the need to avert friction among its employees, there's the fact that some of its customers object to dealing with Negro representatives of electronics companies.

Supply and demand. Despite the optimistic outlook, Negroes are usually scarce and sometimes absent entirely at electronics laboratories.

The Atlanta director of a Quaker-sponsored "employment on merit" program says his biggest problem in that Southern area is finding qualified Negroes. "Breakthroughs have come along so rapidly," he says, "that I am now getting calls for help from the very same companies that two years ago gave me reasons for not hiring Negroes. Now they are asking me to help find qualified Negro personnel."

Mahlon T. Puryear, associate director of the national Urban League, agrees that demand has far outstripped the supply of Negro engineers. "There are plenty of jobs available for qualified Negro engineers," he declares. "The big problem now is educational opportunities" for prospective Negro EE's.

In the past, when a Negro has been fortunate enough to acquire a college education, he usually has chosen a career where members of his race have a relatively good record of success: medicine, law, teaching and the clergy. Law and medicine have been especially appealing because they allow the Negro to be his own boss, not subject to the possibility of prejudice among white supervisors.

Segregated public schools in both South and North have often deprived the Negro of training necessary for admission to an accredited engineering college. He has found it easier to get into the predominately Negro colleges, but only one of these—Howard University in Washington—has won professional accreditation so far.

But help is on the way. Educational opportunities are improving, and more and more Negro youngsters are expected to be eligible for admission to top technical colleges. And more and more company recruiters are offering jobs to the most promising graduates of Southern Negro colleges, allowing for deficiencies in training that are not the student's fault.

At Howard, 100 engineers were graduated in the Class of 1963, up sharply from 61 three years earlier. Yet. Col. James Robinson, assistant to the dean of the engineering school, says that every member of the Class of 1964—size undetermined but possibly a record—already has been offered a job after graduation.

II. Bitter legacy

The existence of prejudice among whites undoubtedly has discouraged some Negroes from going into electronics. Many of them know of specific instances involving relatives or acquaintances.

A 35-year-old Negro in New York says he has held nine different engineering jobs since his graduation from a Northern college in 1950.

To gain professional advancement, he finds that he has to move from job to job. He feels that his color blocks his chances for promotion. All but one of his jobs have been with government agencies. He says he received so many outright rejections from private companies in the 1950's that he gave up

Autonetics' Walter Collymore: "If they feel they can get contracts by hiring Negroes, they'll do it."

Litton's Ben F. Handy: "We won't have Negro vice presidents in big corporations for the next five years."

Raytheon's Major M. Cousens finds Negro youngsters are unfamiliar with opportunities in electronics.

seeking jobs with private firms.

Inequities are reflected too in the experience of Brennan I. Thompson, 65, a Negro electronics flight research engineer with the Lockheed-California Co.

"In 1941," he recalls, "I was hired by a firm (not Lockheed) on a Wednesday, to report for work the following Monday. On Thursday, I was notified that the situation had changed and the job was no longer available. I later found out that the person who was to be my superior had asked the 17 engineers I would have had to work with if they'd work with a Negro. Three said no, so I lost the job."

In Boston, Major M. Cousens, a Negro who designed control sections for the Hawk and Sparrow missiles at the Raytheon Corp., believes that indifference begets more indifference among Negroes toward engineering as a career. The typical Negro child, he explains, has not been exposed to engineering among his family or friends, and therefore knows little about the profession.

Southern discomfort. As might be expected, social prejudice is a strong deterrent to Negro engineers' going South. A spokesman for an electronics firm in the Atlanta area cites two recent instances in which Negro applicants visited a plant, came to a salary agreement with management, then decided against taking the jobs. "When they began to explore the social aspects of living in our town," the company spokesman explains, "they decided that discrimination in housing, restaurants and so on would prevent their living at the level which their incomes would otherwise allow."

Social prejudice can hamper professional advancement in the North, too. "Engineers are a clannish group," a Negro EE in the Midwest explains. "They take their work home with them and discuss it with each other in a social situation. Most Negroes' relationships with fellow workers and the boss—with few exceptions—exist only from nine to five. There's no socializing after that. And there's no doubt that this is a handicap when it comes to advancement."

Housing is another sore point, even in the North. John E. Moss, a 33-year-old EE at the Lewis Research Center of the National Aeronautics and Space Administration, has always worked at suburban installations, but has never been able to find a place to live close to his job. Currently he travels about 20 miles each way between Lewis and his home near Cleveland.

His complaint is echoed by company officials. A recruiter for an electronics company in the Northeast says the biggest obstacle to hiring Negro engineers is the problem of finding suitable housing for them. "It takes me six to seven weeks sometimes to break down neighborhood and community barriers," he explains. "I not only have to bend company regulations about personal expenses, but I have to break them completely in order to wait out the prejudice and settle an engineer moving his family."

Despite persisting problems, industry officials see an ever-brightening future for Negro engineers. One Negro executive, Ben F. Handy, Jr., manager of systems engineering at the Litton computer systems laboratory, in Woodland Hills, Calif., says: "We won't have Negro corporate vice presidents or managers of large installations for major corporations in the next five years, but the barriers will let down. One day, 5 to 10 years from now, a man's position will not depend on color."

A lot of young Negroes may be watching the electronics industry to see whether this prediction comes true.

Negroes help themselves

By Frank Pitman

McGraw-Hill World News

Negroes are making their own opportunities at the K-Alpha Corp., a small electronics firm in Denver. The company, made up almost entirely of Negroes, manufactures an 18-ounce device, the Distress Marker Generator, which sends out an SOS signal to guide rescuers to a lost or crashed plane.

Orville Slaughter, 35 years old, president of the corporation and inventor of the device, says, "We hope our small plant will show the way to more opportunity for minority groups." Slaughter is convinced that Negro businessmen will invest

Among principals of K-Alpha are Thomas Morrison, the only non-Negro in the firm; Marion Malone, Lorenzo Francis and president Orville Slaughter, Jr.

in similar businesses as skilled Negro labor becomes more plentiful.

K-Alpha was founded in December, 1959, by Slaughter, an instructor in classified electronics at Lowry Air Force Base in Denver. He invented the signal device after a boyhood friend, Lt. Russell G. Pigford, had been lost in the Pacific on an Air Force flight from Okinawa.

Modern plant planned. The company operates in a 1,500-square-foot area consisting of two large house trailers. K-Alpha has just obtained a Small Business Administration loan for $15,000, according to Lorenzo B. Francis, a director and head of the firm's sales committee. Most of the money will be used to buy additional land around the present plant, he says. A modern factory is scheduled for construction on the site this summer.

The management and production staff, with one exception, is made up of Negroes who have fulltime employment elsewhere. Each devotes an average of 25 hours a week, outside his regular job, to training classes and manufacturing or administrative duties.

Most of the 17 principal employes are college graduates with degrees in such fields as architecture, finance, business administration and engineering.

Twenty other participants are volunteers enrolled in the plant's training program. The 15 men and five women report twice weekly for two hours of instruction by William Walters, an electronics engineer. Courses include fundamentals of electricity, alternating- and direct-current circuits, electron tubes, transmitters, receivers and antennas.

Skilled labor pool. In about a year, when the trainees finish their courses, they will provide a pool of skilled help for K-Alpha or other electronics firms, according to Francis. He says, "They are under no obligation to us for the training. They're welcome to get better jobs in the community if they can. We're just trying to help them as individuals and to be of service to the community as a progressive company."

Negroes in Denver and elsewhere, said Slaughter, the president, "lack confidence and experience in the more skilled operations.

Evening classes are part of the training program. Trainees Lewis Planter, 21, an airman, and Harold J. Butcher, 41, a trucker, work part-time for K-Alpha.

That's one of the problems in race relations." Slaughter feels that there is "dire need for technical advancement in Denver and it's our duty to give this, irrespective of race."

Slaughter, Francis and other company officials have traveled to major southern cities to talk to Negro businessmen. Slaughter said he found, on visits to Atlanta, New Orleans and Mobile, that: "Negro businessmen there have the capital and are ready to establish industries for minority groups. We think some of our people, after training here at K-Alpha, will be qualified to go to those cities and help establish manufacturing plants in electronics."

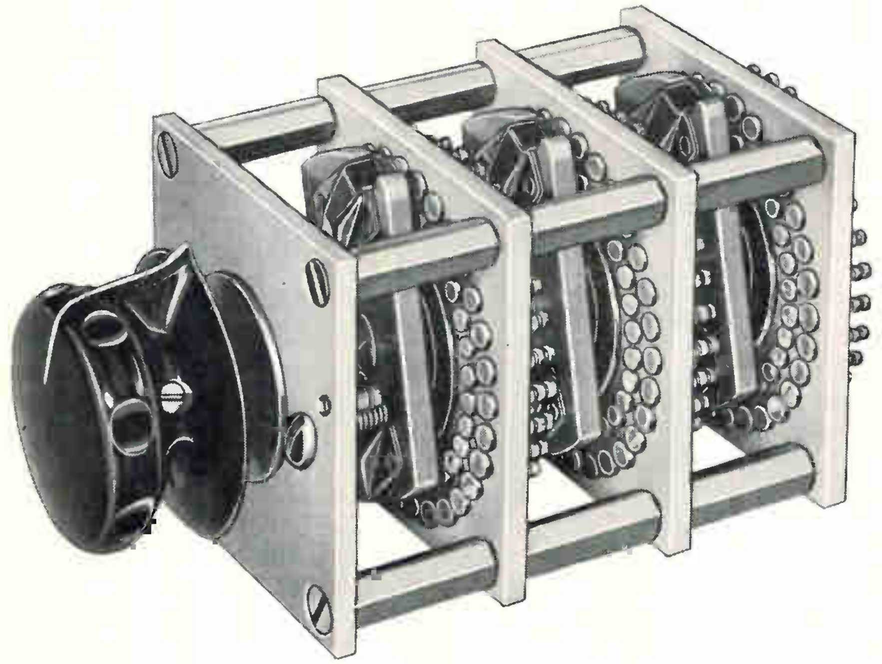
Money problems. Financing the firm has been a struggle. K-Alpha is incorporated for 49,000 shares. Slaughter holds controlling interest with 25,000 shares. All but 8,500 of the remaining shares have been sold, nearly all in blocks of $25 and $50. Cost of the shares went from $1 to $2 on March 6, Francis said, because of increased land value and the planned new building.

The only non-Negro in K-Alpha's operation is Thomas Morrison, owner of the Morrison-Bush Co., a marketing firm. "We felt it was necessary to engage a marketing specialist," Francis said, "and there just was no one available in our Negro community who had any experience in marketing electronic products."

K-Alpha's annual sales have been small—about $2,000. However, Morrison is establishing distributorships, through manufacturers' representatives in Chicago, Los Angeles, San Francisco, Hawaii, Germany, South Africa, France, Canada and Italy. Francis expects sales to climb rapidly.

Morrison extolls the participants' missionary zeal. "These fellows have worked long hours improvising plant facilities they couldn't afford to buy," he declares. "A good example is the silk-screening process they use in fabricating printed circuits. Nobody here knew much about it, but they studied and experimented until they could do it themselves. That's typical of all phases of their manufacturing."

Quality switches—available from stock!



48 hours from Daven to you!

87 adjustable stop switches that replace 2,001 standard types!

Daven revolutionizes switch availability by putting the equivalent of 2,001 standard types as close as your telephone. That's 97% of all your switch needs brought right to your door — direct from Daven within 48 hours! Daven does it by designing the characteristics of 2,001 switches into 87 easy-to-stock, easy-to-use adjustable stop switches. The result: instant availability and **maximum flexibility** (you can change the number of switch positions at any time). The cost is the same, **or less,** than its standard counterpart.

Daven adjustable stop switches are built in **square** configuration, in 1¾″ and 2¼″ sizes. Like all Daven switches, their metal parts are fabricated from corrosion-resistant materials . . . plastics are heavily filled with non-organic fibres and are capable of withstanding high temperatures . . . switch contacts and rotor arms are solid silver alloy. Daven's patented knee action, tamper-proof rotor is standard. Designed to meet the requirements of MIL-S-3786.

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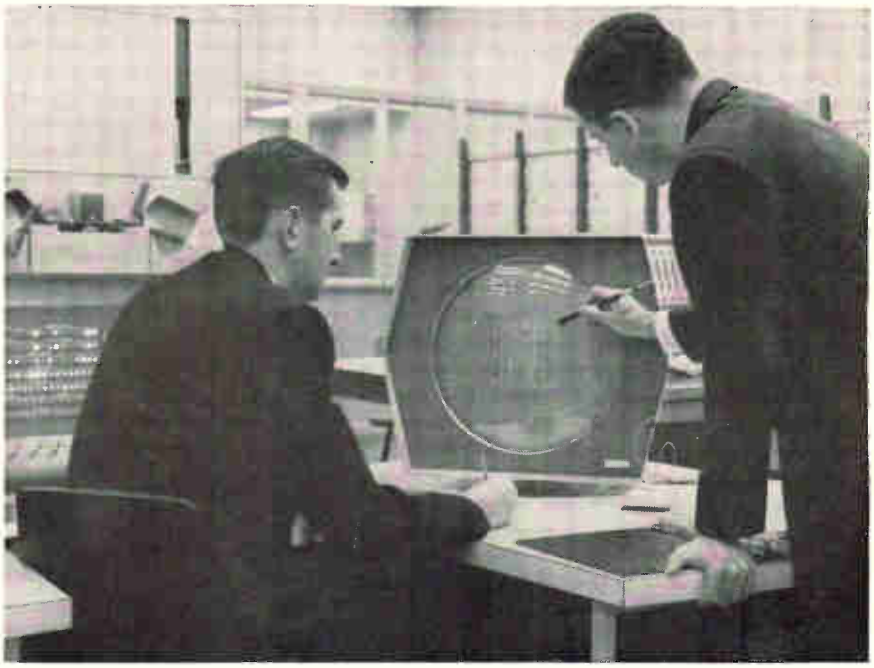
CIRCLE 99 ON READER SERVICE CARD



Engineers improve on the computer's topological diagram, using a light-pen

Computer in the microcircuit design room

Engineer's mechanical aide indicates ability to speed the layout and manufacture of integrated circuits

By Michael F. Wolff
Senior Associate Editor

In designing an integrated circuit, many an engineer has spent days positioning areas of different kinds of semiconductor materials. Now there are signs that computers can speed the process, thereby cutting costs of producing complex microcircuits.

If scientists of the Norden division of the United Aircraft Corp. are correct, the circuit designer may one day have a fast, accurate mechanical aide — one that can obey specific rules for locating all the p-n junctions and interconnections, display the resulting design on a cathode-ray tube, and follow designer's subsequent suggestions for improving the circuit.

The engineer's role may evolve toward that of a computer supervisor.

In the Air Force-sponsored program in Norwalk, Conn., which began only seven months ago, the Norden researchers successfully applied computer techniques to the two most time-consuming phases of linear microcircuit production: design analysis and mask layout.

The major part of the cost of a nonstandard microcircuit, such as a 100-component, six-watt servo amplifier, is in preparing a design capable of good integration and transferring this design to the best possible topological layout in a silicon chip. "Topological" refers here to the arrangement of p-n junctions, which define the active and passive zones of the crystal, and to the interconnections on the oxide surface, which complete the electrical network.

The missing breadboard — The flow diagram (bottom, page 102) shows how the computer is used in the Norden program.

When an engineering problem arrives, a designer prepares a preliminary basic circuit. The design is then fed into the computer, which makes a complete electrical analysis of the design and equivalent circuit, thereby eliminating the need for breadboarding. Norden has developed programs permitting a-c, d-c and transient analyses in 28 minutes that would normally take several man-months.

The next step is mask layout—deciding where the components should be placed on the crystal, how they should be connected, and what fabrication processes should be used. The goal is maximum yield and performance using a minimum area of crystal and as few interconnections and crossovers as possible.

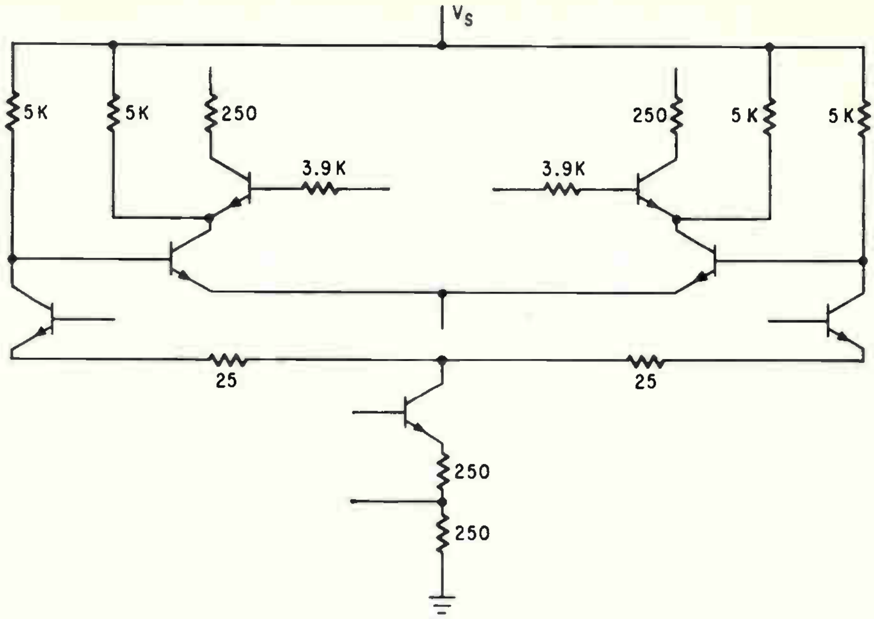
In the past the mask designer was guided by an informal set of topological rules accumulated from previous experience. Now these rules have been expanded and organized so that design criteria, constraints and degrees of freedom can be specified in a language that can be handled by a digital computer.

For design by computer, the leads from every element are tabulated, as are the external points and the nodes connecting three or more points of the circuit. The computer searches this list for the reference cycle—the closed loop containing the largest number of circuit elements. The computer then constructs an initial topological layout by arranging the components of the reference cycle into a rectangle and distributing the various component appendages along the rectangle according to previously programed rules governing the spacing of circuit elements and interconnections.

Commands for the computer — Several hundred instructions have already been developed for the computer. Eventually there will be thousands to cover all possible manufacturing processes. Typical instructions are:

"Break the circuit at the most negative potential and tie into the

"Find a line or point of symisolation moat."



Two-strobe sense amplifier, designed with computer techniques into a single silicon chip

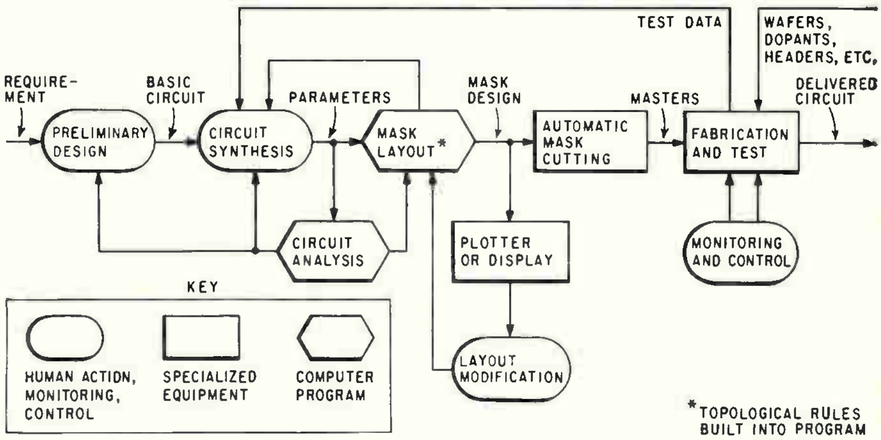
metry and place symmetrical circuit elements around it."

"Keep sensitive elements away from regions of power dissipation."

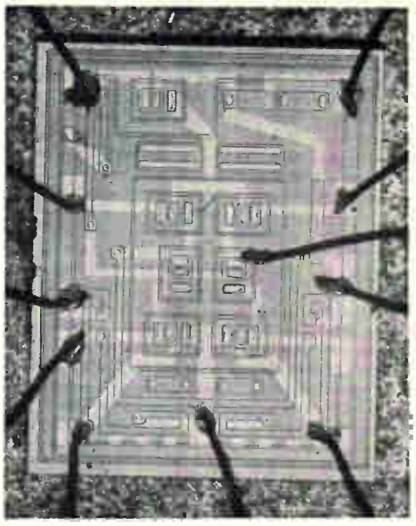
When the computer finishes its calculations, the resulting topological diagram is displayed on a cathode-ray tube. From the display, it may be evident to the mask designer that some space has been wasted or that other elements should have been added. He can reshape and reposition the elements in any way with a light pen—a small photocell. The technique is similar to that used in the Sketch-pad program at the Lincoln Laboratory of the Massachusetts Institute of Technology (Electronics, May 17, 1963, p. 16). The computer will display the consequences of the changes, as determined by the design rules built into the computer's program.

Broader role for automation — Ultimately, Norden expects automation to play a role not only in mask-cutting and manufacture, but also in complete circuit synthesis and analysis from a transfer function. Because it would depend on geometric considerations rather than on particular manufacturing processes, such a system also would have great flexibility, and ability to quickly reproduce existing circuits that might have been lost or destroyed. Such a system might only be 3 to 5 years off.

Norden scientists have used their design instructions to build a basic integrated circuit that could be either a two-strobe sense amplifier or a two-stage differential amplifier, depending on the final interconnection pattern. The differen-



Hexagons show where computer techniques fit into Norden's design and manufacture of microcircuits



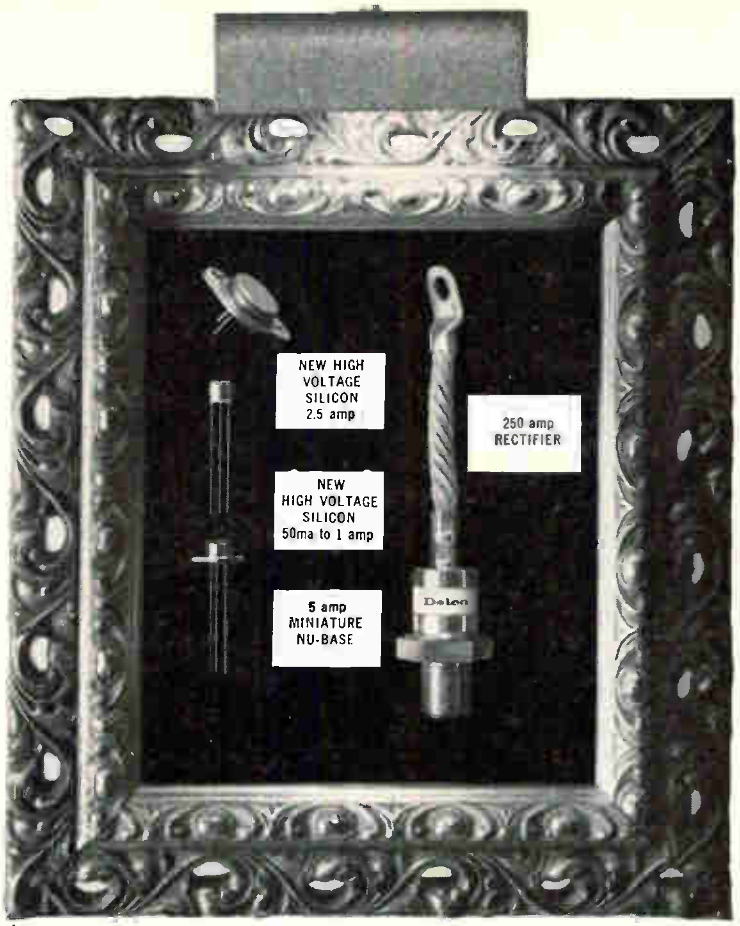
Two-stage differential amplifier was designed with computer techniques. Note the arrangement of circuit elements about a vertical line of symmetry

tial amplifier (see photo) has an internal common-mode feedback rejection of about 100 db and a power-supply rejection of about 40 db. Depending on external resistor ratios, signal gain can be adjusted from one to 1,000. The stabilized feedback amplifier is flat to about 20 Mc and rolls off 12 db per octave.

The sense amplifier (see circuit diagram) has an over-all gain of 200. Both amplifiers use aluminum interconnections and leads, and consequently have shelf storage in excess of 350°C.

These amplifiers were built according to the flow chart accompanying this article. Circuit analysis was done by the computer, but the topological rules were applied manually. However, other amplifier mask designs have been carried out on the computer. One design cut the size of a 61-by-70-mil sense amplifier to 35 by 51 mils.

Norden believes it has shown that automated design for the manufacture of microcircuits is practical. Future work will be aimed at applying these concepts more fully. The project is conducted in Eugene Tatom's solid-state engineering section. Dr. Melvin W. Aarons, chief of the research and development branch of solid-state engineering, is project engineer. The study is sponsored by the Manufacturing Technology Division of the Materials Laboratory at Wright-Patterson Air Force Base, Ohio.



SEE OUR PRODUCTS AT I.E.E.E. BOOTHS NO. 1522-1524

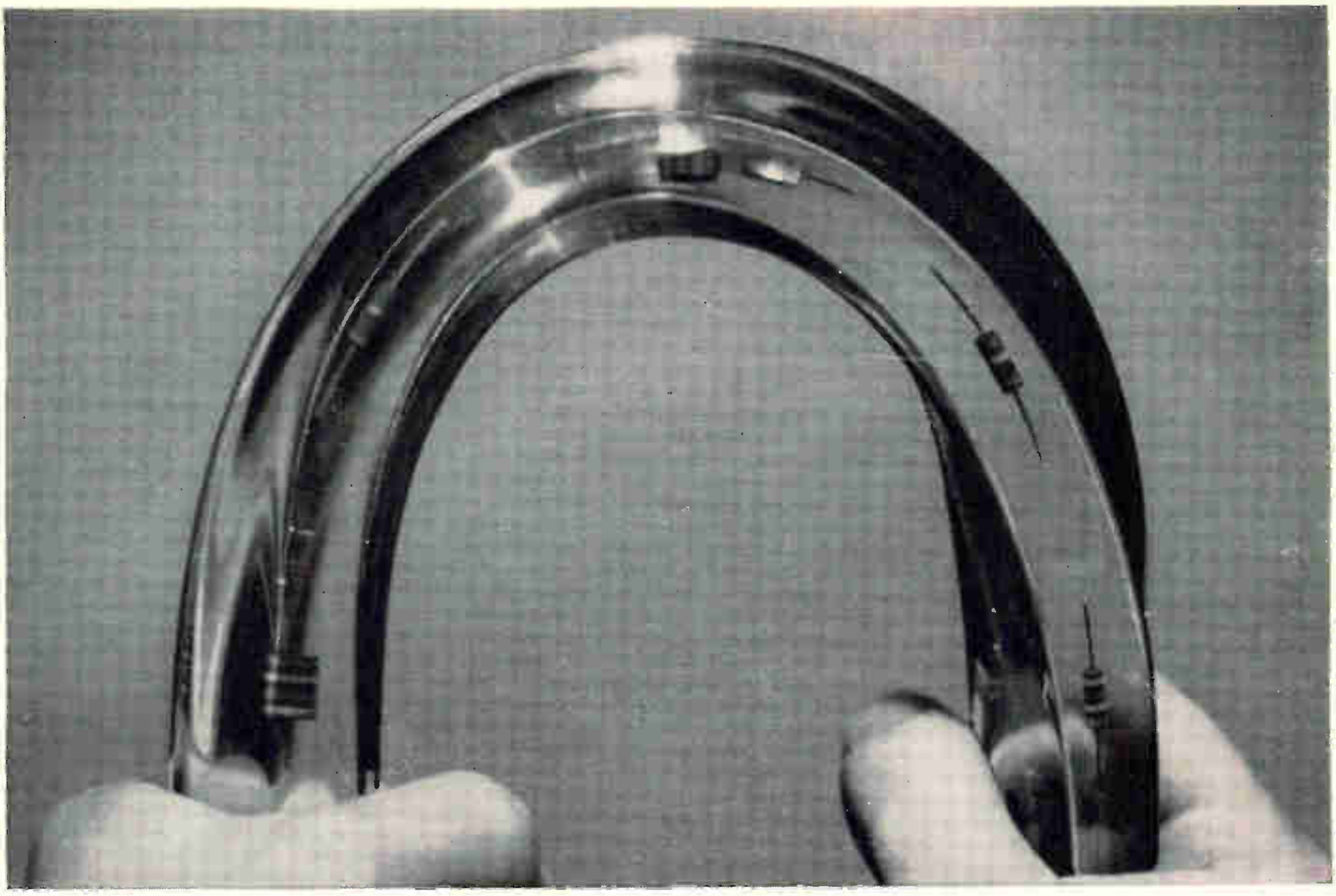
This is a sneak preview. You are looking at four new Delco Radio devices. Some have just been announced. Others are still under development. All of them will be in our display at the I.E.E.E. Show. We'll be showing new high voltage silicon transistors, miniature nu-base germanium transistors, zener diodes, high current, high voltage rectifiers, axial lead rectifiers ... the devices we're producing, the ideas we're developing. These are all products we can turn out in the quality and volume that make them practical for a lot of applications. Maybe for something you're working on right now.

...so what's new with you?

DELCO RADIO

DIVISION OF GENERAL MOTORS, KOKOMO, INDIANA

CIRCLE 105 ON READER SERVICE CARD



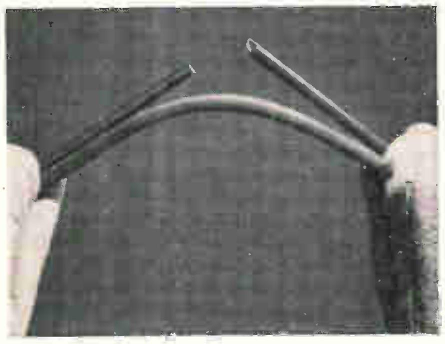
Tough new silicone speeds potting rates

Higher strength RTV-615 cures to a clear resilient compound in 15 minutes at 150°C

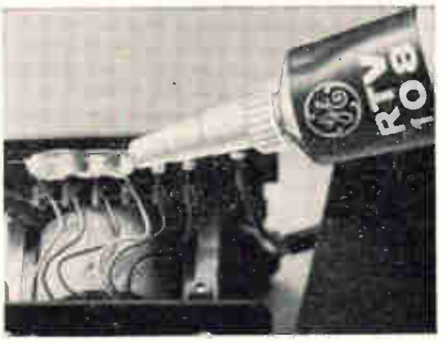
RTV-615 is a new addition to General Electric's family of rubber-like potting and encapsulating compounds. It offers the interesting combination of greater strength (1000 psi), toughness, low viscosity (very pourable) and excellent transparency.

RTV-615 lends itself to production line potting since it can be cured tack free in 15 minutes at 150°C, in one hour at 100°C, in 4 hours at 65°C or 24 hours at room temperature. Pot life at room temperature is 4 hours. Mixing procedure has been simplified over previous materials.

RTV-615 is designed to protect assemblies against thermal shock, vibration, moisture, ozone, corona, dust and chemicals from −65°C to 200°C. Its complete transparency permits easy component identification and repair.



NEW! RTV's that protect to —150°F. RTV-511 and RTV-560 stay resilient at temperatures that cause other types of potting materials to crack. They also have a higher degree of flame resistance than other RTV's. Excellent for aerospace use, both new RTV's retain full ozone, corona and weathering resistance.



NEW! RTV-108 translucent adhesive sealant. Combining easy tube dispensing with powerful adhesion, RTV-108 is a translucent seal and insulator for terminals, joints and other electrical and mechanical sealing jobs. There is no mixing. RTV-108 air cures to a flexible, resilient silicone rubber.

NEW! RTV-30 combines low viscosity with high strength. RTV-30 is a new compound with low viscosity for filling small and complicated configurations. Yet it also possesses excellent physical strength, making it a superior flexible mold material for prototypes and short-run production.

If you would like a free sample of one of these new General Electric RTV silicones for evaluation, write on your letterhead, describing your application. For additional information, check reader service card. Section N3107, Silicone Products Dept., General Electric Company, Waterford, New York.

GENERAL ELECTRIC

Voltmeter displays amplitudes of transients

All-silicon solid-state instrument is useful for determining reliability of missile systems

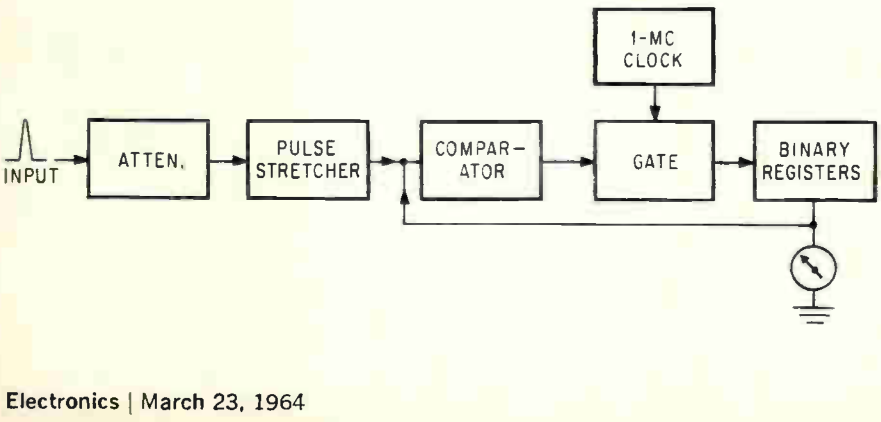
The model 5201A transient amplitude voltmeter (shown in diagram) fills a requirement for direct measurements of transients or other nonrecurring voltages. The instrument has a range to 1,000v either a-c or d-c. It is primarily intended

for system checkout, circuit investigation and general lab use, and may also be used for unattended monitoring of power supplies, power lines and life-test systems.

Unit is used in the same manner as a conventional voltmeter. It is connected to the system or circuit being tested and will read and register the maximum peak voltage amplitude occurring. All voltages including transients having a pulse width of 50 nsec or longer will be read out and registered on the 4½-in. rectangular panel meter. The registered transient will be displayed indefinitely until manually reset or until a higher amplitude transient is registered. There is no threshold nor preset voltage level to be exceeded before a transient will be registered and a one-shot transient can be measured.

Voltage transients that might damage newly designed systems or equipment are readily traced to their source and eliminated. Peak inverse voltage ratings in new power supplies are readily measured with this instrument. Model 5201A is considerably more simple to use than an oscilloscope for these applications as there are no sync, gain, triggering level, sweep speed nor other controls to adjust. It may be used unattended in applications where transients occur at random.

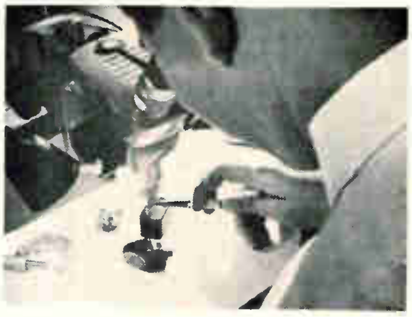
The all-silicon solid-state instrument has an electronic memory and is available with an output for strip-chart recorders. Price is $695. Micro Instrument Co., 2245 S. Federal Ave., Los Angeles, Calif.
Circle **301,** Reader service card



Tiny autocollimator monitors remotely

A truly miniature electro-optical instrument, the MINEAC, can be used without physical or electrical contact to measure and continuously monitor the angular position or deflection of guidance and stabilization components, or the flexure of structural elements. Complete with optics, detector and electronics, it weighs less than 1 oz and is no larger than 1½ in. in any dimension. Power consumption is less than 0.2 w.

MINEAC is intended primarily for installation in missiles and spacecraft and their test systems.



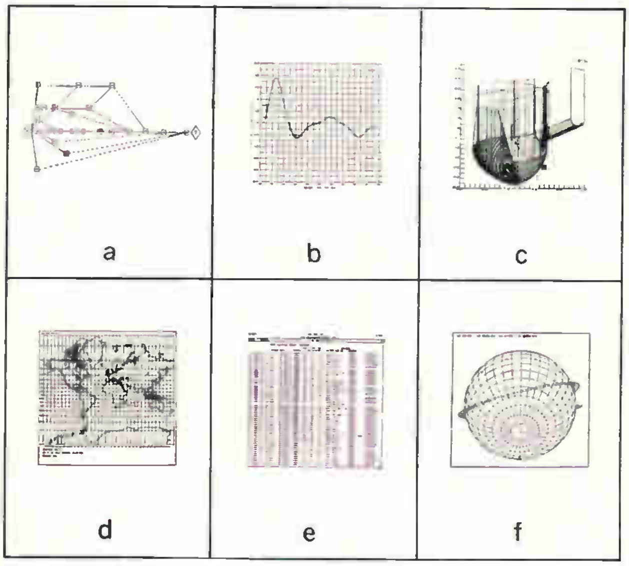
It can also be used in any military, scientific or industrial application where small position changes must be measured without physical or electrical contact, and where there are severe space and weight limitations on the measuring instrument.

Resolution is 0.048 second of arc (taken at a range of 24 in., lamp frequency at 60 cps and color temperature of 1925 deg K). Operating range is 0 to 5 ft. Long-term null stability is better than ± 5 minutes. Acquisition range is ± 25 minutes of arc. Output signal characteristics—up to 5 mv/arc-sec (a-c); output impedance, 150 ohms. Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. **[302]**
[Continued on page 109]

Computer Output Questionnaire

Test your knowledge of the latest methods available for displaying and recording the output of large-scale digital computers.

Questions



1 How much time was required to record the above output sample "b" on film.

a. One hour ☐ b. One minute ☐
c. One second ☐ d. One-half second ☐

2 How much time was required to print all of the above samples from tape transport start to delivery of finished paper to the engineer?

a. Thirty seconds ☐ b. Six minutes ☐
c. Twenty-five minutes ☐ d. One hour ☐

3 How much time was required to write the computer program for producing sample "b"?

a. One minute ☐ b. Five minutes ☐
c. One hour ☐ d. Four hours ☐

4 How much large-scale computer time (IBM 7090 class) was required to prepare tape for output sample "b" shown above?

a. Less than three seconds ☐ b. One minute ☐
c. Five minutes ☐ d. Ten minutes ☐

5 How many of the following output types can be produced by one versatile computer recorder already in commercial operation? (1) 16mm microfilm for automatic storage and retrieval; (2) 35mm microfilm; (3) quick-look paper copy; (4) high-quality paper copy for reports and distribution; (5) vellums; (6) page-size film negatives; (7) animated motion picture strips.

a. (1) through (3) ☐ b. (1 through 4) ☐
c. All except (7) ☐ d. All of these ☐

6 Each of the six samples above represents a specific computer output application. Match correct letter code of above samples to each of the applications listed below.

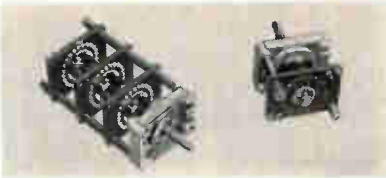
Curve Plotting _____
PERT Charts _____
Tool Path Drawings _____
Orbital Plotting _____
Mapping _____
Alphanumeric Line Printing _____

7 What is the minimum number of hours of daily usage required to justify economically an output device capable of producing all of the above samples in a matter of seconds?

a. Sixteen hours ☐ b. Eight hours ☐
c. Three hours ☐ d. One hour ☐

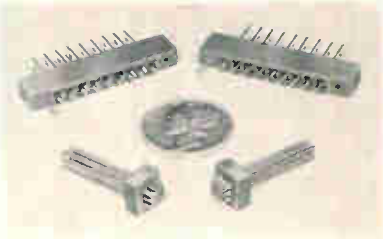
(Answers may be found on following page)

GENERAL DYNAMICS | ELECTRONICS GD SAN DIEGO



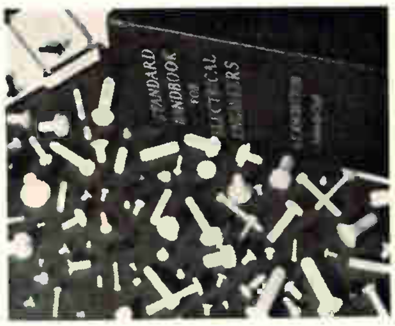
Rotary stud switches are miniature size

Type D-951 miniature rotary stud switches combine small physical size with the advantages of low contact resistance and minimum maintenance. The studs are made from fine silver and the wipers from silver-graphite, giving smooth operation and a constant low contact resistance of 3 milliohms. Insulation resistance between studs exceeds 100,000 megohms. No lubrication is required and sample switches have been rotated 10 million times at 240 rpm with no appreciable wear. Muirhead Instruments, Inc., 1101 Bristol Road, Mountainside, N. J.
Circle **303**, Reader service card



Connector suited for core memory stacks

An ultraminiature Varicon connector, called the BI/Con, is announced. Illustration shows the comparative size of 9-contact Bi/Con with 9-contact series 8129 microminiature model. Bi/Con concept makes it possible to substrate, with rapid disconnect features, units previously integrated or unitized because of space limitations. New connector is ideally suited for magnetic core memory stacks which presently do not possess advantage of convenient stack assembly. Therefore the current, contact density and retention capabilities of Bi/Con are compatible with the requirements of any miniaturized equipment. Two contacts, when engaged, form cross mating area 0.035 in. by 0.035 in. Mating area, along with the 0.020-in. diameter bi-channel tails readily permit contact spacing at 0.050 in. square grid pattern. Elco Corp., Willow Grove, Pa. **[304]**



Nylon screws are automatically molded

An extensive range of automatically molded nylon screws—from 0.80 "watchmaker" size miniatures to standard ¼-20—is available. Molded nylon machine screws are manufactured in a wide range of slotted and phillips recessed heads, including binding, round, fillister, washer, two types of flatheads (82 and 100 deg) and an oval head (82 deg). Headless set screws are available with plain, oval, flat, cone, half dog, and full dog points. Nylon has excellent electrical insulation properties: dielectric strength, 625 v/mil at 0.050 in. thickness; dielectric constant, 5.1 at 60 cps, 73 F. Gries Reproducer Corp., New Rochelle, N.Y. **[305]**

Readout memory uses silicon controlled switch

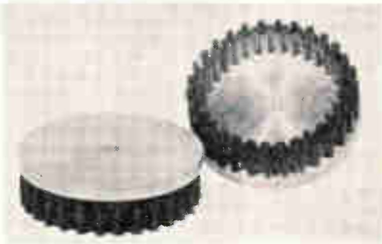
Nixie tube memory has eliminated the need for flip-flops and replaced them with a new silicon controlled switch (scs). Each scs replaces 2 transistors, 4 resistors, several diodes and capacitors per memory element. In a standard 15-position

New Components

readout memory, this would mean a saving of almost 150 components. Use of the planar passivated switch has permitted a 40-percent reduction in cost, and shrunk the size by 60 percent. Company says the new memory is more than 100 percent more reliable than former readout memory devices. Burroughs Corp., Electronic Components Div., Plainfield, N.J.
Circle **306,** Reader service card

Transistor chopper features low noise

Solid-state chopper type 6015 is designed for operation in some circuits previously requiring electromechanical choppers. Maximum noise level is 0.4 mv; maximum offset is 0.3 mv. Type 6015 provides spdt switching and can handle d-c signal levels up to 30 v, 3 ma. Drive can be 50 cps to 5 kc, 5.7 to 14 v rms, sine or square wave. Airpax Electronics Inc., Cambridge, Md. **[307]**

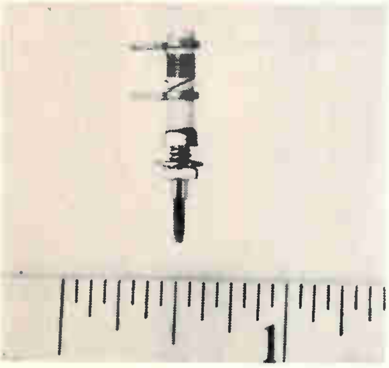


Rotary brush cleans printed circuit

Rotary brush for cleaning printed circuits helps insure reliability in electronic equipment. The Metlkor brush is perfectly balanced, designed to rotate at high speeds while distributing the brushing action evenly and efficiently over the entire surface. It will provide a long service life and vibration-free performance. The brushes are available with either nylon, fibre, wire, or horsehair bristles, and are refillable. The blocks are available in aluminum with diameters of 2 to 8, and more, inches. M. W. Jenkins' Sons, Inc., 444 Pompton Ave., Cedar Grove, N.J. **[308]**

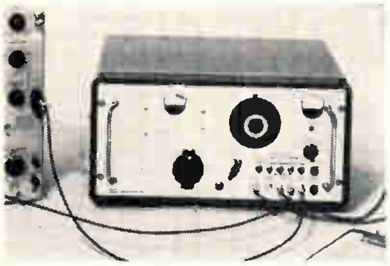
Heat sinks cool semiconductors

Now available is a line of new coolers: (a) 4 by 4 by 5 diode and scr heat sink designed to accept 1 1/6 in. hex stud mounting semiconductors . . . with a typical thermal impedance of sink to ambient of 0.6 C/w; (b) 5 by 5 by 5 for 1¼ in. hex at 0.45 C/w thermal impedance; and, (c) 6¼ by 6¼ by 9 for 1¾ in. hex at 0.35 C/w impedance. Wakefield Engineering, Inc., Wakefield, Mass. **[309]**



Tiny variable coils offer wide range

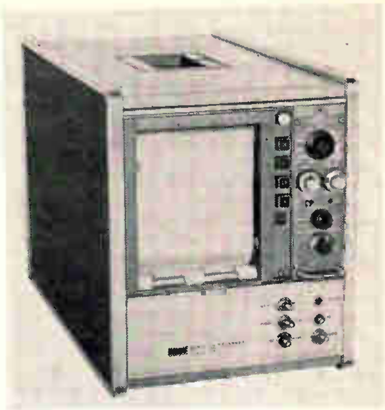
Series 3500 miniature variable coils are wound on the smallest Cambion ceramic coil form (Part No. 2689). The new coils are only 1.227 in. high (maximum) and 0.156 in. in diameter. They are offered in 28 values ranging from 0.1 μh to 18 μh, and have excellent minimum Q's that are guaranteed. All are solenoid-wound and color-coded for ease of identification. They are priced in quantities of 250-499 at $0.79 to $0.84 depending on inductance values. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. 02138. **[310]**



Sweep generator operates in 4 modes

A sweep/signal generator capable of producing up to 4 w of swept r-f power over a range of 330 to 1010 Mc is announced. The PD-8 operates in any of four modes—swept r-f, modulated swept r-f, modulated c-w, and c-w. It employs a high-power uhf triode and a new method of sweeping a tuned cavity oscillator. The 4w of r-f power in the swept modes, or 2 w in the c-w modes, are provided after 3 db of fixed attenuation. The attenuation is included to stabilize the output with variable loading and to establish a 50-ohm impedance reference. A high-gain automatic level control circuit counteracts tendencies of the r-f output level to vary with frequency, line voltage, or loading. The PD-8 generates a properly phased signal to provide the horizontal deflection voltage for an oscilloscope. Price is $2,750. Telonic Industries, Inc., 60 N. First Ave., Beech Grove, Ind. Circle **311,** Reader service card

Wide-chart recorder has four speeds



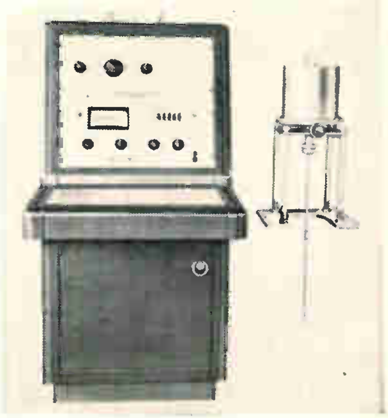
Compact single-channel direct writing recorder with 100-mm chart width, four pushbutton-selected chart speeds and a choice of solid-state plug-in preamplifiers is announced. Model 7701A provides greatly increased trace resolution; plug-in signal conditioning capabilities for d-c, low level, carrier, a-c transducer and other signal inputs; four recording speeds from 0.5 mm/sec to 50 mm/sec; full scale frequency response d-c to 30 cps within 3 db; linearity better than ±½ percent of full scale; sensitivity (with high gain preamp) of 1 μv/chart division. Sanborn Co., 175 Wyman Court, Waltham 54, Massachusetts. **[312]**

Multi-range ammeter covers 1 to 100 amp

High-current, high-frequency true rms current meter model 560-CT is available. Using a miniature current transformer the self-contained multi-range meter can measure true rms currents from 100 amp down to 1 amp full scale with an accuracy of ±0.5 percent. At 100 amp the frequency response is from 30 cps to 25 kc. With a slight reduction in accuracy the frequency response is extended to 50 kc. Irregular waveforms (without d-c components) with crest factors up to 4 can be measured by the instrument. Unit's ranges are 1/2/5/10/20/50/100 amperes. It incorporates the Transquare solid-state transducer to provide true square law response. Unlike thermocouples they have a high overload capability. Price of the 560-CT is $725. Greibach Instruments Corp., 315 North Ave., New Rochelle, N.Y. **[313]**

Spectrum analyzer uses plug-in modules

All-transistor portable spectrum analyzer, Panoramic model TA-2, with interchangeable plug-in modules is available with several modules covering sonic through r-f bands. It may be operated from an internal battery pack or a-c line. It enables swept band visual analyses to be obtained aboard vehicles and in the field where less satisfactory methods had to be used previously. Singer Metrics Division, The Singer Co., 915 Pembroke St., Bridgeport, Conn. **[314]**



Instrument measures magnetic moments

Vibrating sample magnetometer measures permanent or induced magnetic moments over an extended range of temperature, field and crystallographic orientation. The instrument vibrates a sample in a relatively uniform magnetic

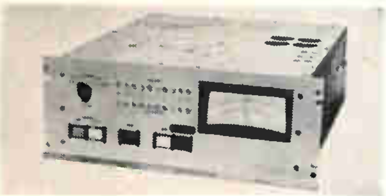
field. The moving sample produces an a-c signal proportional to its magnetic moment, which is detected and analyzed by the associated electronic system. Unit can be used with any conventional laboratory electromagnet or can be readily adapted to superconducting magnets. Differential sensitivity: minimum detectable change in magnetic moment of 5×10^{-4} to 5×10^{-5} emu corresponding to a change in magnetic susceptibility of 5×10^{-8} to 5×10^{-9} cgs for a 1 gram sample at 10^4 gauss. Princeton Applied Research Corp., Box 565, Princeton, N.J.
Circle **315,** Reader service card

Low-temp chamber for component testing

A portable low-temperature chamber for testing electronic components and small parts is announced. The Templo-Trol cabinet (24 in. long by 16 in. wide by 28 in. high) is caster mounted and the stainless steel chamber (10½ by 20½ in. by 6 in. deep) is designed for use with convection fluid or it can be operated as a still air chamber. Temperature is indicated and controlled from 70 F to −100 F and the thermal capacity of 400 BTU/hr is sufficient to cool approximately 10 lb of metal per hr or dissipate a heat load equivalent to 157 w. Cincinnati-Sub-Zero Products, Inc., 3930 Reading Road, Cincinnati 29, O. **[316]**

Frequency standard is solid-state unit

Type 1115-B standard-frequency oscillator is designed to withstand the shock and vibration of military environments. The all-transistor unit includes a built-in emergency power pack which is automatically switched in upon failure of the a-c line. The nickel-cadmium battery which is automatically maintained during normal a-c operation will power the unit for at least 24 hours after takeover. The standard can also be operated from any external source of 22 to 34 v d-c. Frequency base of the standard is a 5-Mc crystal oscillator and agc section, enclosed in a proportionally-controlled oven. Output frequencies are 100 kc, 1Mc, and 5 Mc. Price is $2,050. General Radio Co., West Concord, Mass. **[317]**



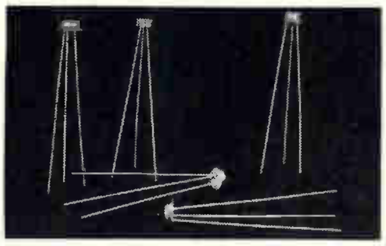
Phase voltmeter gives rapid readout

A programmable phase/voltmeter for use with digital voltmeters is designed for use in production and automatic checkout applications, where multipurpose response and rapid readout are required. The 365-A measures fundamental signal levels, in-phase and quadrature voltage components, to accuracies of ±0.15 percent, phase angle to ±0.1 deg and can be stopped manually, or automatically among these parameters in any required sequence. This capability provides broad application flexibility in a single organization, of measurement instruments. Automatic ranging in 10 scales from 0.01 to 300 v is also a feature, with the indexed scale being indicated by one of 10 panel lights. Output to digital instruments ranges to 3 v d-c in the voltage measuring mode, and to 3.6 v d-c in the phase measuring mode. Acton Laboratories, Inc., 533 Main St., Acton, Mass. **[318]**

New Semiconductors

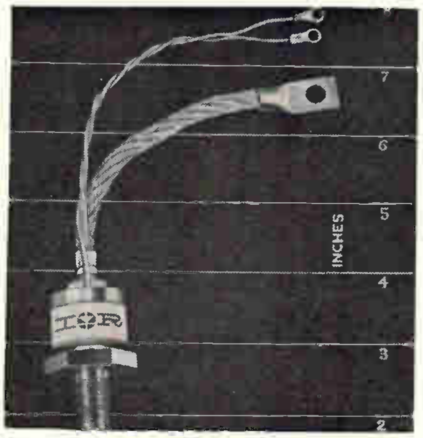
Photoconductive cells have dual elements

Six new photoconductive cells—the CL703/2, 703L/2, 704/2, 704L/2, 705/2 and 705L/2 are announced. Each cell contains two elements, each connected to one common and one separate lead, forming a three-terminal device. Position servo and slope shaping circuits are two of the many areas of application for these light-sensitive resistors. Cells are available in either cadmium selenide or cadmium sulfide in TO-5 hermetically sealed metal cases. Light resistances range from 1.5 K to 166 K. The resistance of each half of the cells may be matched to within 10 percent if required. Spectral response ranges from 5500A to 7350A. Voltage rating is either 60 or 300 v and power dissipation, 75 to 125 mw. Clairex Corp., 8 W. 35th St., New York City.
Circle **319,** Reader service card



Chopper transistors have low offset voltage

Models 2N2944-5-6 (TO-46) pnp silicon chopper transistors are designed for low-level switches, choppers and multiplexers. Features include very low offset voltage, high emitter breakdown voltage, and ultra-low leakage current. Pairs matched in offset voltage to 50 μv from −25 C to + 100 C are available. Key parameters for the 2944, −5, and −6, respectively are: min BV_{CBO} & BV_{EBO}—15, 25 and 40 v; min BV_{CEO}—10, 20 and 35 v; max I_{CBO} & I_{EBO}—0.1, 0.2 and 0.5 nanoamp; max offset voltage—0.3, 0.5 and 0.8 mv; unit price (1-99)—$9, $8 and $8. Crystalonics, Inc., 147 Sherman St., Cambridge 40, Mass. **[320]**



Epitaxial scr resists high transients

A series of 35-amp epitaxial silicon controlled rectifiers, rated at 55 amp rms, are capable of handling non-repetitive current surges of up to 700 amp. The devices are rated for 600 to 1,300 v prv. Because of controlled avalanche reverse characteristics, the series assures built-in protection against high transient voltages encountered in a-c supply or d-c output. Either single or dual control leads, flexible or flag terminals are available. International Rectifier Corp., 233 Kansas St., El Segundo, Calif. **[321]**

Power transistors offered for industrial market

Low-cost silicon power transistors, 2N3232 through 2N3240, are designed specifically for the indus-

...you can gain crucial cubic inches using TRI-PLATE® techniques. TRI-PLATE microwave packages weigh less and use less space (propagation through solid dielectric lets you work in shorter wavelengths). Better isolation permits denser component grouping. And with components integrated in a single assembly, interface problems exist *only where the TRI-PLATE network ends.* □ Example: this L-band mixer delay line is only 9¾" x 3¼" x ¼", weighs 8 ounces — less than the mixer *alone* in coax! Internal mounting of mixer diodes contributes to compactness. So does transforming impedance from 50 to 100 ohms. And packaging the delay line more closely than possible in any other microwave medium — yet with no cross-talk. □ TRI-PLATE techniques improve *any* microwave system in most frequency ranges. At less expense — because photo-etching techniques reduce quantity costs. And TRI-PLATE modules minimize design risks, enabling you to breadboard complete operating systems. To get your microwave design ideas off the ground, write Sanders Associates, Inc., Microwave Products Department, Nashua, New Hampshire.

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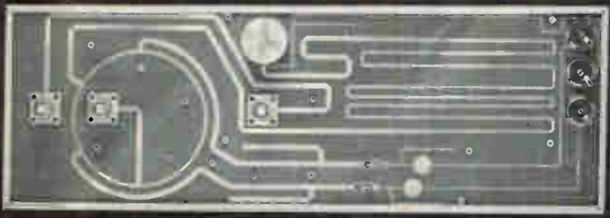

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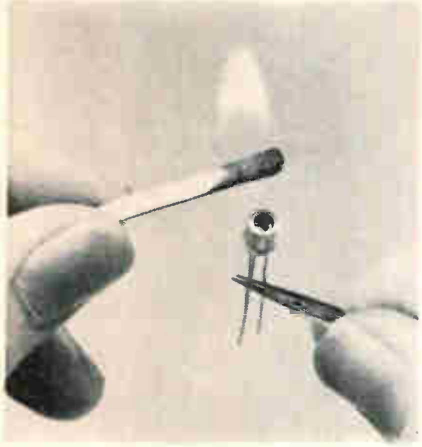
trial market. Manufactured by the all-diffused process, they allow maximum junction temperature of 200C for high power and high temperature operation. Power capabilities are from 117 to 200 w; maximum current capabilities from 7.5 to 20 amperes and maximum breakdown voltages from 60 to 160 v, and peak switch power ratings of approximately 20 times the d-c ratings. Silicon Transistor Corp., Carle Place, New York.
Circle **322,** Reader service card

Germanium transistor amplifies a-f signals

A low-cost germanium transistor has been designed for audio-frequency signal amplification. Type SFT 325 germanium pnp transistor has many applications, especially in Class B output stages. The power output is 1.5 w with heat sink and is supplied in TO-1 case. Its C_{EB} maximum is 32 v; I_c maximum is 500 ma. Average gain is 70 at 250 ma. Nucleonic Products Co., Inc., 3133 E. 12th St., Los Angeles, Calif. 90023. **[323]**

Silicon rectifiers are flangeless

Miniature line of axial lead flangeless silicon rectifiers include types that exhibit currents to 1 amp and voltages to 1,200 v, and low-leakage units operating to 200 C. Construction and small size facilitate circuit board and point-to-point wiring needs in industrial and commercial power supply applications. The glass-to-metal hermetically sealed package and ruggedness permit reliable operation even with extreme humidity and other severe environmental conditions. Weight is one gram, body length is 0.225 in. and diameter, 0.230 in. Edal Industries, Inc., East Haven 12, Conn. **[324]**



Phototransistor uses glass window

Because of its excellent sensitivity through a wide range of light levels, the GS-600 two-terminal silicon npn phototransistor is especially useful in character recognition, card reader and other pulse generation applications. It features a large base area providing optimum sensitivity from extremely low-level to high-level light detection. To provide superior optical characteristics, a glass window, rather than a lens, is hermetically sealed into the standard TO-18 header. General Sensors, P.O. Box 231, Athens, Texas. **[325]**

Silicon rectifier with nanosecond recovery

High-reliability silicon rectifiers have peak inverse voltage ratings from 300 to 1,000 v. They feature nanosecond recovery, controlled avalanche reverse characteristics, and maximum leakage current of 0.1 μa at rated piv at 25 C. Units are 0.140 in. in diameter by 0.250 in. in length with 0.031 solid silver leads. Solid internal construction presents a low thermal impedance to the leads allowing for ratings above 1 amp when properly mounted. Price is approximately one penny per v of piv in thousand lots. Semtech Corp., 652 Mitchell Road, Newbury Park, Calif. **[326]**

Pulse laser features 500-Mw peak power

New pulse laser, which requires no amplifier, has a guaranteed peak power of at least 500 Mw, with a pulse rise time of 3 to 6 nsec. Device can be used to measure both the orbital position and the trajectory of space vehicles. Elimination of the amplifier is made possible by using a much larger ruby crystal and flash lamp. The device operates at room temperature, and can be cooled with a small flow of tap water. The 500-Mw laser has a typical energy output of 4 joules but can be converted to a conventional laser oscillator with a typical 0.5-millisec output of at least 50 joules. Beam width is nominally 7 milliradians. Repetition rate is once-per-minute. Korad Corp., 2520 Colorado Ave., Santa Monica, 6, Calif.
Circle **327**, Reader service card

Static inverters operate from 125 v d-c

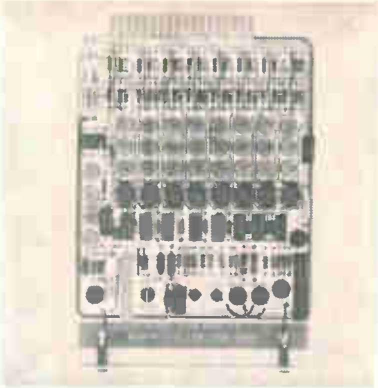
Static power inverters are available with sinewave outputs of 60 cps and 400 cps. Outputs of 100 and 250 v-a available in 60-cps models; 100, 250, 500 and 750 v-a in 400-cps units. All units are built to strict industrial standards for ambient temperatures ranging from —20C to +55C. All have output voltage and frequency trimming controls, fuse, on-off switch and pilot light. Output voltage and frequency are regulated against input voltage swing. Model P-163 produces 100 v-a output at 60 cps and measures 14 in. long by 10 in. wide by 8 in. high. Price is $535 each. Lin Research Corp., 2412 Reedie Drive, Wheaton, Md. **[328]**

Packaged blowers cool circuit cards

New series of packaged centrifugal blowers are designed to meet the need for a compact high-velocity blower using a minimum of panel space with the air exhausted in a vertical position to cool rows of solid-state component cards. They produce 290 cfm of cool, filtered air to pressurize the electronic rack. For cooling circuit cards, the top front vertical exhaust position models 2EB350D or 2EB351D are recommended. These bring the air out directly under the cards which are approximately 6 in. in depth. For general chimney effect cooling, models 2EB350A or 2EB351A are recommended. Blowers are available in 3½ in. or 5¼ in. panel height. Price of the blowers is approximately $70. McLean Engineering Laboratories, Box 228, Princeton, N.J. **[329]**

D/A converter fits on one standard module

Model 488 incorporates on one standard module complete digital/analog conversion circuits which usually occupy two or more modules. It contains a highly regulated reference voltage supply, precision resistor ladder, and a stable oper-



ational amplifier. It accepts eight binary input bits and produces an analog output voltage at one of 256 discrete steps. Model 488D accepts two decimal digits in binary-coded-decimal form and provides an analog voltage at one of 100 discrete steps. Both models produce an analog output voltage proportional to the value of the input data. The 488 may be used wherever digital data must control analog devices such as oscilloscope displays and plotting devices, driving pen recorders, and process control sensors. Navigation Computer Corp., Valley Forge Industrial Park, Norristown, Pa. **[330]**

Magnetic core memory offers versatility

General-purpose random access storage system, the Ministore III, operates at a cycle time of 10 μsec and a data access time of 4 μsec. Applications include areas such as input/output buffering, tape storage, data communications, format control, special purpose data systems, and as a smaller computer working memory. Unit is available with storage capacities from 64 to 1,024 words and with from 2 to 8 bits per word. Address locations

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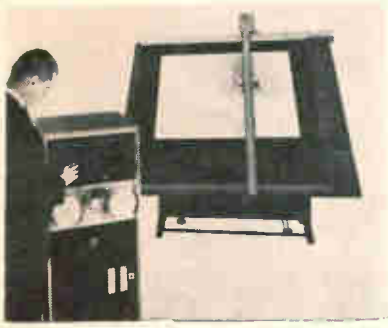
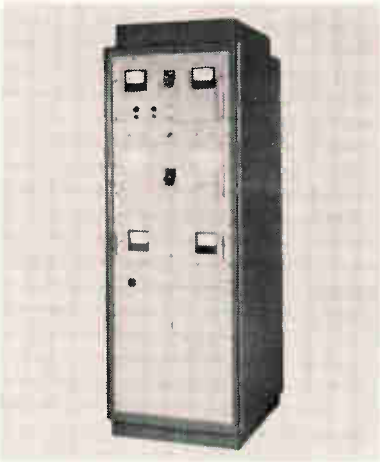
are expressed in pure binary format with 2 lines/bit input. Data are stored and retrieved in parallel form. All inputs and outputs operate at standard transistor logic levels of 0 and —6 v. Power requirements include —15 to —30 v at 4 amp max and +15 to +30 v at 0.5 amp max. Operating temperature of the memory is from 0 to +50 C. Rese Engineering, Inc., A & Courtland Sts., Philadelphia, Pa.
Circle **331**, Reader service card



Digital input controls drafting machine

All-solid-state VP 600 is basically a continuous path automatic drafting machine capable of producing a high-quality graphic display derived from digital information on drafting film, paper, vellum, cloth, Mylar, sensitized sheet metal or comparator screen material to a standard size of 50 by 60 in. Input data in the form of punched paper tape containing the incremental distance to be traversed between coordinate points is entered into the electronic control unit via the self-contained tape reader. The operator may select any two axes from three-axis tape. Controls are provided for producing right and left hand drawings from a single tape. Drawing speeds up to 200 in. per minute are internally computed. Manual speed reduction is available for high precision applications. Company says the VP600 offers at a selling price of less than $20,000 many features which have been available only in systems selling at many times this price. The Gerber Scientific Instrument Co., P.O. Box 305, Hartford 1, Conn. **[332]**

New Microwave



Power generator for microwave testing

A new d-c filament controller, ferrite load isolators, and water cooling are among features contributing to less than 0.1 percent f-m output, 150-kc bandwidth, 0.2-percent frequency stability, 0.25-percent power stability, noise more than 40 db down, and vswr's permissible up to 10:1 by the new 975 to 10,475-Mc microwave power generator having up to 150-w c-w and 750-w pulse output power. Specially-designed r-f shielding eliminates the danger of stray radiation. Pulse width is variable from 1 to 10,000 μsec. The prr is variable from 10 to 10,000 pps. Pulse rise time is less than 0.3 μsec. Energy Systems, Inc., 3180 Hanover St., Palo Alto, Calif.

Circle **333**, Reader service card

L- & S-band sources deliver high power

Microwave signal sources for L- and S-bands are announced. Model 1205 L-band covers 0.95 to 2.40 Gc, and model 1206 S Band covers 1.95 to 4.20 Gc. Both provide direct-reading, digital, ±0.5 percent accurate frequency dials and wide-range attenuation, for maximum flexibility in application. Through the use of advanced cavity-design techniques and the Velocitron ceramic klystrons, the sources deliver consistently high power outputs over their frequency ranges, with a guaranteed minimum of 50 mw. Over most of the band power output is in excess of 125 mw. This feature implements the performance of many tests not previously possible by direct signal excitation. Among these are antenna directivity pattern measurements, wide-range attenuation, and extreme vswr measurements on L&S band components. Polarad Electronic Instruments, 34-02 Queens Blvd., Long Island City, N.Y. **[334]**

Twt amplifier has broad bandwidth

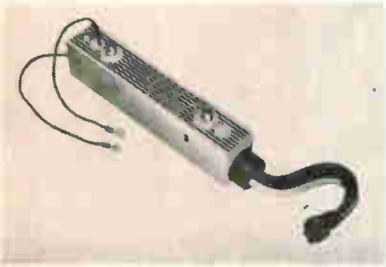
Now available is the model T602 twt amplifier, with a nominal 1-w output (0.8 w guaranteed) in the frequency range of 10.0 to 20.0 Gc. The new design has eliminated the sharp drop-off (to as little as 0.25 w), formerly a characteristic of the extremes (10.0 to 12.0 and 18.0 to 20.0 Gc) of the range. American Electronic Laboratories, Inc., Richardson Road, Colmar, Pa. **[335]**

S-band transponder aids space probes

Qualified to severe missile environment, the 201 S-band radar transponder also has application in space probes and targets due to its small size, light weight, and low power consumption. Frequency range is 2,700 to 2,950 Mc. Receiver sensitivity is −41 dbm (minimum); pulse width, 0.25 to 1.0 μsec. Transmitter power is 100 w (minimum); pulse width, 0.5 ± 0.1 μsec. Unit measures 65.70 cu. in., weighs 3.625 lb. Temperature range is −20 to +70 C; vibration, 5 to 2,000 cps at 10 g, 3 minute sweep; shock, 100 g all planes; acceleration, 80 g all planes. Vega Precision Laboratories, Inc., Maple Ave. W., Vienna, Va. 22180. **[336]**

High-power r-f loads occupy small space

A major accomplishment in size reduction of high power r-f load resistors is announced. The 25-kw water-cooled model 8750 load held by the operator occupies nearly 300 times less installation space than the model 502, also rated at 25-kw continuous duty. At 13½ lb it is 55 times lighter and operates from d-c to 500 Mc with a vswr of only 1.1 max. Connections are 3⅛ in.-EIA flange for r-f and ¾-in. pipe fittings for 8 gpm of cooling water. Bird Electronic Corp., Solon, O. **[337]**



X-band t-w tube delivers 1 kw

X-band, helix twt with periodic permanent magnet focusing has been introduced. The QKW-1132 is a broadband tube for high-duty-cycle pulse operation in the 7 to 11-Gc range. The grid-controlled tube

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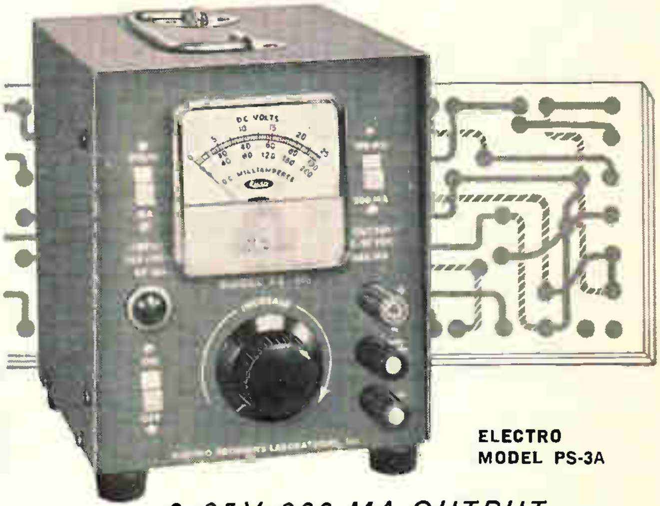

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New Microwave

delivers a peak power of 1 kw at a gain of 34 to 40 db. It can operate at duty cycles up to 1 percent. Less than 12 in. long and weighing less than 5 lb, the twt has cooling fins built into its case for cooling by convection, conduction, or forced air. Raytheon Co., Wayside Ave., Burlington, Mass. 01804.
Circle **338**, Reader service card

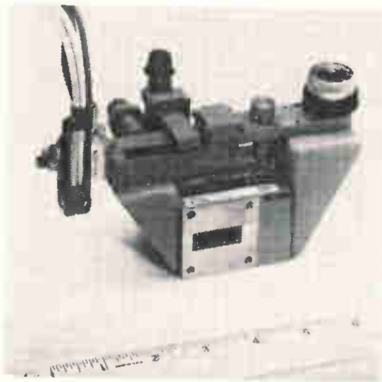
Fixed attenuators cover 30 Mc to 4 Gc

Fixed attenuators in values of 3 db, 6 db, 10 db, 15 db, or 20 db offer operation over a frequency band of 30 Mc to 4 Gc. Accuracy of attenuation is ±0.2 db from nominal value and ±0.3 db variation with frequency. Calibration data are furnished with each unit. The attenuators weigh only 3½ oz and measure 3 in. by 1¼ in. by 1¾ in. with 1½-in. center-to-center between connectors. Standard units are supplied with type N male and female connectors but other types including subminiature are available. Price is $55. LEL, Inc., 75 Akron St., Copiague, N.Y. **[339]**

Solid-state sources replace C-band klystrons

Two new solid-state frequency sources, the MS80 and MS110, designed as klystron replacements are mechanically single-screw tunable in the 4.4 to 4.9 and the 5.9 to 6.4-Gc range, respectively. Both 6-cu-in. devices are voltage tunable over a 1-percent bandwidth, require about 3 w of input power (making them ideal for airborne missile and satellite communica-

tions systems), weigh less than 10 oz, and are priced at $1,800 in quantities of 1 to 5. The MS80 develops 10 mw of output power minimum, and the MS110 develops 5 mw minimum, with spurious noise 60 db down, over their rated frequency ranges. Fairchild Semiconductor, 545 Whisman Road, Mountain View, Calif.
Circle **340**, Reader service card

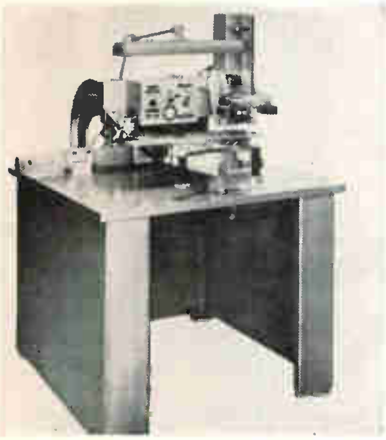


Paramp designed for airborne use

A low-noise, solid-state X-band parametric amplifier weighing only 24 oz including klystron, model X-1003, is designed to increase the range of navigational, airborne-weather and detection radars. Single-knob tunability is 300 Mc within the range 8.5 Gc to 10.5 Gc. Noise figure is 3.5 db, single channel, rising to 4.0 db in the range 9.7 Gc to 10.5 Gc. Minimum bandwidth is 100 Mc. Unit measures only 6.5 in. by 4.0 in. by 2.5 in. and is designed to meet military specifications. Micromega Corp., 4134 DelRey Ave., Venice, Calif. **[341]**

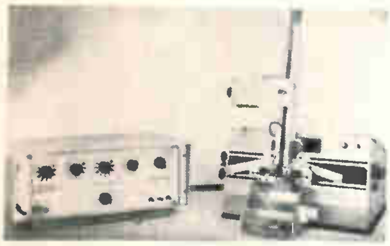
Coaxial devices in varied sizes

A full line of 50 and 75-ohm subminiature coaxial connectors, and 50-ohm microminiatures are being offered. The company is also displaying stripline connectors, coaxial adapters and special coaxial devices. Micon Electronics Inc., Garden City, N.Y. **[342]**



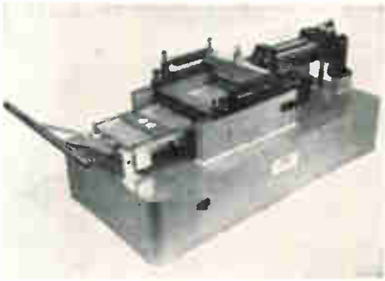
Machine assembles p-c card components

On the market is the Pert Mark 1 which cuts and forms the leads of a wide variety of axial lead components and automatically assembles and attaches the components to p-c cards. It is available as a semiautomatic machine or may be obtained in more sophisticated versions to include: numerical control, selective sequencing and orientation of various components, multiple insertion heads and other variations. It meets all requirements of the high reliability programs of the military and aerospace. The semiautomatic model can process 3,000 to 4,000 components per hr. Technical Devices Co., 11242 Playa Court, Culver City, Calif. **[343]**



Processing system trims and tests components

Axial leads of resistors and diodes can now be trimmed and formed, and the components inspected for correct values on a go-no go basis at the rate of 4,200 per hr. with the series 500 component processing system. Components that do not meet required specifications are dropped into a reject bin. Resistors from 10 ohms to 1.111 megohms can be processed by the model 501 Bend-Amatic, which trims and forms the leads, and the model QC501 automatic resistor tester, which determines if the resistors are within specified tolerance limits. System accuracy is typically ±0.1 percent. Model QC502 automatic diode tester makes four tests —forward current, reverse current, automatic polarity test, and a validation check of the internal test power supply—within 60 millisec after the Bend-Amatic trims and forms the diode leads. Develop-Amatic Engineering, 923 Industrial Ave., Palo Alto, Calif. **[344]**



Screen printer aids microcircuit work

Laboratory screen printer model MA-12 is designed for imprinting metal slurries or resist on the flat surfaces of such substrates as glass, mica, ceramics, phenolics, laminants or plastics. Printing speed is one impression every two seconds. Unit measures 12 in. high by 12 in. wide by 24 in. long. It is valuable for R&D work as well as for production line use—especially where numerous short runs are involved. Model MA-12 is said to be excellent for the extremely precise, close-tolerance work required for miniature to micro circuits. It can be equipped with automatic ejection fingers for dispensing printed parts to a conveyor belt or other carrier. Basic machine price of the printer is $975. Automation Equipment Division, Affiliated Manufacturers Inc., Whitehouse, N.J. **[345]**

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New Materials

Epoxy solder bonds delicate devices

One-component epoxy silver cold solder makes it possible to bond the most delicate devices without mess, heat or soldering irons. The all-in-one conductive compound comes already combined with the hardener, requires no heat or tools to apply and hardens at room temperature in 24 hr. Shurbond 111 comes in a plastic hypo applicator that permits the paste-like epoxy solder to be applied directly to the component being bonded, eliminating virtually all waste and reducing application time substantially. It retails at $7.50 for 6 cc, $14.50 for 12 cc, and $30 for 30 cc. Typical applications include connections made to heat sensitive diodes and transistors, electrical shielding, repairing printed circuits and bonding electronic tube caps to the glass tube. Anchor Alloys, Inc., 966 Meeker Ave., Brooklyn 22, N.Y.
Circle **346,** Reader service card

Machineable material withstands 1800 F

Machineable high temperature material — Micaceram 1802 — shows unusual dimensional stability properties, even after extended periods in temperatures up to 1800 F. At 1600 F for 4 hr, less than a 0.0002 growth was measured. At 1800 F for 4 hr, less than 0.0005 growth was measured. Material does not outgas. It has excellent dielectric properties. Dissipation factor is 0.0036; dielectric constant, 6.3; loss factor, 0.025; flexural strength, 8000 psi. Molecular Dielectrics, Inc., 101 Clifton Blvd., Clifton, N.J. **[347]**

New Literature

Snap-action switches Cherry Electrical Products Corp., 1650 Old Deerfield Road, Highland Park, Ill. "Successfully Specifying Snap-Action Switches" is the title of a pamphlet now being offered. Circle **487,** Reader service card

Soldering irons and tips Alpha Metals, Inc., 56 Water St., Jersey City, N. J. A technical article on considerations involved in the selection of the right soldering iron and tip is available. **[488]**

Compact fan Rotron Mfg. Co., Inc., Woodstock, N.Y., has released bulletin E-2901 which describes in detail its 220-cfm Propimax 3 fan. **[489]**

Semiconductor test equipment Texas Instruments Inc., P.O. Box 66027, Houston, Texas 77006. A complete line of semiconductor test equipment is described in bulletin A-706. **[490]**

Shock and vibration control Barry Controls, 700 Pleasant St., Watertown 72, Mass., has published a product digest containing highlights on its products and services for controlling shock and vibration in military and industrial applications. **[491]**

Medium power load Microwave Development Laboratories, Inc., 87 Crescent Road, Needham Heights 94, Mass., offers a bulletin on the WR90 medium power load that features broadband coverage and very low vswr. **[492]**

Microminiature capacitors Aerovox Corp., New Bedford, Mass. Technical data on type P95ZN microminiature dipped metallized paper capacitors is available in bulletin 131B9. **[493]**

Electronic timers Leach Corp., 1123 Wilshire Blvd., Los Angeles 17, Calif. Brochure TDS-264 contains information on a line of electronic timing devices for many applications in aerospace and electronic industries. **[494]**

Nuclear equipment Hamner Electronics Co., Inc., P.O. Box 531, Princeton, N.J. The 1964 line of nuclear scalers, timers and count ratemeters is introduced in a new brochure. **[495]**

Variable resistors CTS of Berne, Inc., Berne, Ind., offers data sheet 8400 on series 660, a cermet ⅜-in. diameter transistor size variable resistor. **[496]**

Time delay proximity switches Micro Switch, Freeport, Ill. Four-page data sheet describes a new series of all-metals-sensitive time delay proximity switches. **[497]**

Operational selective amplifiers White Instrument Laboratories, Box 9006, Allandale Sta., Austin 17, Texas. Bulletin describes two high-gain operational vacuum-tube amplifiers designed to use RC feedback networks to obtain prescribed frequency response at audio and subaudio frequencies. **[498]**

Fixed station antennas Andrew Corp., P.O. Box 807, Chicago, Ill. 60642. The 1964 fixed station catalog features several new antennas in the frequencies used for mobile communications. **[499]**

New Books

Around the computer

Electronics in Business Machines, By Tom Jaski, A. S. Barnes & Co., Inc., New York 309 p, $5.95.

What's new about this book is the amount of space devoted to peripheral equipment such as card punches and their circuits, verifiers, sorters and data transmission systems.

Machine logic and computing circuits, storage and input-output are treated in the computer chapters, though much of the material has been published before. The emphasis is on IBM equipment.

This book gives a well-rounded view of electronic data-processing, rather than just of computers.

—S.B. Gray

Basics on semiconductors

Semiconductor Fundamentals, By A.H. Seidman and S.L. Marshall, John Wiley and Sons, Inc, N.Y. 278 p, $6.50.

This text for students and technicians requires a knowledge of only elementary physics and electronics, and is also useful to the engineer seeking information on the subject.

The book discusses such subjects as the construction, technology and measurements of diodes and transistors, equivalent circuits, biasing and stabilizing of transistors, transistor circuits for digital computers, and tunnel diodes. Problems and examples are provided in each chapter.

The scope of physics

Encyclopaedic Dictionary of Physics, J. Thewlis, Editor in Chief, The Macmillan Company, New York, 8 vols., total of 5,491 p, plus glossary, $298 the set.

The first large physics dictionary to be published in many years, this set of eight volumes deals with physics in its widest sense—general, nuclear, solid-state, molecular, chemical, metal and vacuum physics, astronomy, biophysics and the like.

The individual subjects are treated by authorities of international reputation. The articles, ranging up to 2,000 words in length, are well written and illustrated. Entries, enhanced by formulas, tables, figures, bibliographies and cross-indexing, are definitive technical references rather than semipopular explanations.

As electronics branches out and overlaps heretofore obscure areas of physical science, the engineer is increasingly in need of a comprehensive physics book to help orient him in a new discipline. The scope of this dictionary and its clear, practical organization leads the searcher directly to the desired information.

Although immensely useful for an engineer or scientist, these volumes are not recommended for a reader who lacks a scientific background.

—G. V. Novotny

Working in vacuum

High Vacuum Engineering, By Alfred E. Barrington, Prentice-Hall, Inc., Englewood Cliffs, N.J., 198 p, $12.

In the past several decades, vacuum technology in electronic research, development and production has advanced at a rapid rate, stimulated initially by the war effort and then by the greater impetus of space endeavors.

Extensive theory, research, experimental and practical work have been applied in this new field. A large number of texts have appeared, but the majority are highly technical and mathematically complex. Thus, many who find themselves in the field and who lack specialized training in high vacuum will welcome Alfred Barrington's new book.

In "High Vacuum Engineering," Barrington sets the stage by bringing together adequate data, theory and background to provide the reader with a basic understanding of the subject. He then proceeds to explain in a clear, concise manner the theory and function of the building blocks of high-vacuum systems. The stress is on commercially available components.

The outstanding features of the book are its authoritative treatment and presentation of the theory of commercial sputter-ion and sorption pumps and high-vacuum system design, coupled with their practical application. For the first time these topics are offered in reasonable detail, without the usual preponderance of mathematical formulas.

Certainly this book has been written for all those working in the high-vacuum field. It is a valuable, easily comprehensible tool. By its very nature the text is suitable for basic instruction, and as such should find extensive use in college courses.

—John H. Leary,
Vacuum Equipment Division
Hull Corporation, Hatboro, Pa.

For the social sciences

The Design of Electric Circuits in the Behavioral Sciences. By Tom N. Cornsweet, John Wiley & Sons, Inc., New York, 329 p. $8.95.

This book will be warmly welcomed by those in psychology and allied sciences who have a minimum background in electricity. The author starts with basic electricity and components, then goes into switching, shock and time-delay circuits, amplifiers, sensors, and feedback and null-sensing devices.

Highly informative and written in conversational style, the book has excellent illustrations, includes problems for the circuit-design chapters and gives practical directions for assembling a kit of parts to be used in constructing electrical circuits.

Handy background

Logic, Computing Machines, And Automation, By Alice Mary Hilton, Spartan Books, Baltimore, Md., 457 p, $9.

This book covers much basic background, including such areas as symbolic logic, classes (sets), logic algebra, logic circuits and programing. The book describes the relationships between machematic and logic, and how they lead to applying logical principles.

The material is not new, but it has seldom if ever before been put together in such a handy reference volume. Even Bertrand Russell considers that "her work is very thorough."

—S. B. Gray

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Technical Abstracts

Optical avalanche diode

Photodiode Signal Enhancement Effect at Avalanche Breakdown Voltage,* K.M. Johnson, Texas Instruments, Inc.

A measurable improvement in signal gain, believed to be similar to the gain effect in a multiplier phototube, has been observed in both planar and mesa silicon photodiodes when they are reverse-biased to avalanche breakdown. If this similarity is verified, there are possibilities of a device better than 20 db more sensitive than others now available. Benefits are possible in optical communications and computing systems.

In the experiment described, a 5-db improvement in signal-to-noise ratio was measured at 1.25 Gc. This is believed to be due to avalanche multiplication of the signal; that is, photons create electron-hole pairs that collide with the lattice to create more pairs, and so on. The device used was a TI LS900 planar diode, epitaxially grown with an 0.1-mil depleted p layer, an 0.8-mil intrinsic layer and a 7-mil n-type wafer. The avalanche breakdown was –180 v.

Theoretical considerations show that the actual improvement in signal-to-noise ratio should have been closer to 13 db. It is believed that performance can be improved significantly, regardless of frequency, by cooling the photodiode to very low temperature.

Plasma-pumped laser

Laser Pump Employing the Plasma Pinch,* R.H. Crompton, J.A. Hitt and R.A. Williams, Philco Corp.

A laser pump has been developed that employs the so-called theta pinch effect in a plasma. Plasma is ionized gas with a net charge of zero. The new pump has several advantages over the conventional flash-tube method of laser pumping.

The laser rod, for example ruby, is placed inside a coaxial flash tube filled with an inert gas such as xenon. The tube has no electrode. A one-turn coil surrounds the tube and is connected, through a triggerable spark gap, to an energy-storage capacitor. When the capacitor is discharged rapidly, the gas surrounding the laser rod is ionized and becomes highly electrically conductive. The resulting plasma acts, in effect, as a secondary winding to the discharge coil. A current is induced in the gas, which produces a magnetic field that exerts an inwardly directed force on the plasma. This force tends to "pinch" the plasma away from the wall of the tube, thus reducing heat transfer to the wall.

The high peak powers and repetition rates possible with this technique are important in laser research. The over-all efficiency of system-pumping is increased because the light output of the pump can be adjusted, by the proper choice of gas mixture, so that its spectral emission matches the absorption bands of the laser crystal.

Initial experiments with inert gases have demonstrated efficiency greater than that possible with conventional electrode-discharge flash tubes. Also, the pumping rate for a given energy input is about 1,000 times faster than that available in the best flash tubes. Laser pulse durations of 0.25 μsec have been achieved, with rise times of 25 nsec.

Thin-film filter

Precision Tuning of a Thin-Film Notch Filter,* W.H. Orr, Bell Telephone Laboratories.

One advantage of using thin films in filter design is that they allow L-C filters to be replaced with high-performance active R-C filters. This paper describes a tantalum-film R-C network that compares favorably with a network of conventional components in tuning precision, temperature coefficient and long-term stability. Specifically, thin-film notch filters with –80 db notches at 2182.5 cps and temperature coefficients of the notch frequency of 25 parts per million per degree centigrade have been built with frequency characteristics within ±0.02 percent of the desired values.

The notch filter is a twin-T network that almost totally rejects a particular frequency when properly tuned. The circuit consists of resistors, capacitors and interconnections that are formed by photoetching a tantalum film that has been sputtered onto a glass substrate. The film is anodized to produce the capacitor dielectrics and to adjust the resistance values. Evaporated gold is then used to form the capacitor counterelectrodes.

Without special adjustment procedures the component values, and hence the tuning of thin-film circuits, can be controlled only to within a few percent – – not acceptable for many applications. Tuning of this thin-film filter is achieved through a sequence of measurements and precise adjustments of the resistance values by anodizing. Once the filter is operating, the tuning is fixed permanently.

The unique tuning method is based on a detailed analysis of the filter's frequency response to determine resistance values. This procedure compensates for stray capacitance and resistance, and also makes it possible to control the depth of the notch and the phase shift at the notch frequency.

While the techniques for making these precise resistor adjustments have been mastered, the stability of the capacitors is not sufficient to maintain the frequency response precisely over a period of time. Improvement in capacitor stability is, therefore, the major factor requiring further development.

Hall-effect radar displays

A New Technique for Polar Displays Using Hall-Effect Multipliers,* F. H. Smerage, Sylvania Electric Products.

Hall-effect multipliers can both simplify construction and increase the efficiency of polar displays for such applications as sonar and direction-finding systems, and plan-position indicators for radar systems.

Hall effect is the development of a voltage between the two edges of a current-carrying metal strip whose faces are penpendicular to a magnetic field.

A Hall-effect multiplier consists of a Hall generator placed in the air gap of a fixed magnetic circuit. Its output voltage is proportional to the scalar product of two input currents. A polar display—one that shows objects and radio signals as fluorescent images on a cathode-ray tube—is built by implementing the multiplications required for transforming polar to rectangular coordinates.

$$X = R \cos \theta,\ Y = R \sin \theta$$

These terms can be computed by feeding electrical signals representing R and sin θ to one Hall multiplier, and R and cos θ to another. The output signals are then fed to a cathode-ray tube employing X and Y deflection. For a direction-finding system, the radial signal R is proportional to the strength of a received signal at azimuthal angle θ. The radial signal for a radar plan-position indicator is the radial sweep at angle θ. Since the linearity of some Hall multipliers is better than one percent, it is possible to obtain radial accuracy better than ±2 percent of the display radius and angular accuracy better than ±2.5 degrees.

* All these papers were presented at International Solid-State Circuits Conference, Philadelphia, February, 1964. A digest of technical papers is available at $5 a copy from Solid-State Circuits Conference, c/o H.G. Sparks, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia 4, Pa.

Satellite prediction display

SPAD—A Satellite Position Prediction Display, Harvey G. Talmadge, Jr., and Robert J. Orsino, U. S. Naval Research Lab., Washington 25, D. C.

An experimental Satellite Position Prediction and Display equipment (SPAD) is being developed by the Naval Research Laboratory. For shipboard use, the equipment will predict and display the position and height of classes of satellites at an arbitrary time. The operator will be able to select satellites, either individually or according to category, and view the predicted positions against a map background, together with height, vector and orbit information and surveillance circles. Additional information on a single satellite will be viewed on a separate display.

SPAD operates with the AN/UYK-1 stored-logic digital computer. The computer memory is updated weekly with new values of orbital elements. The positions and heights of as many as 10 satellites can be computed in 1.4 seconds and displayed with category on a world map.

(Presented during week of Feb. 24-28 at the third national symposium of the Society for Information Display in San Diego, Calif.)

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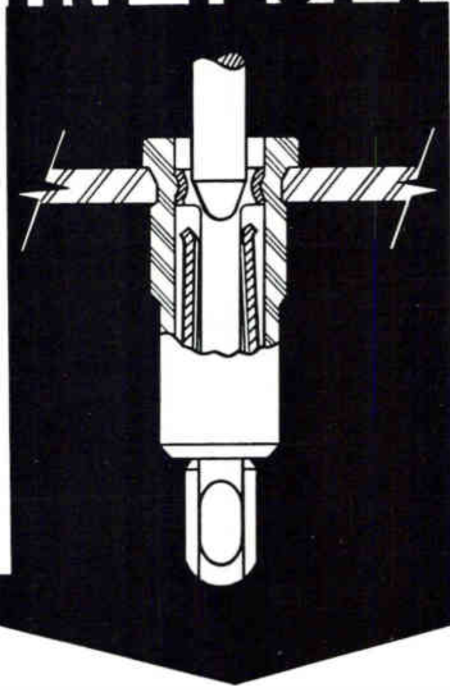

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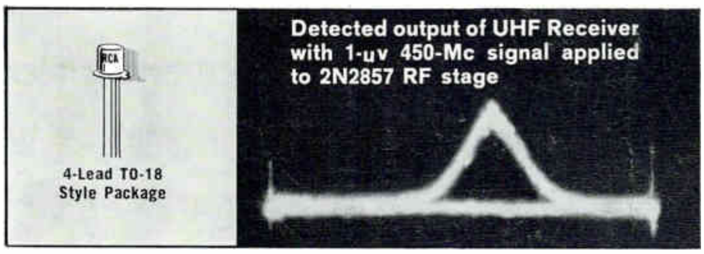
4 db NOISE FIGURE AT 450 Mc



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The low-noise npn 2N2857 uses a new miniature structure to achieve these outstanding characteristics:

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- High Gain...14 db typical at 450 Mc in neutralized 20 Mc bandwidth amplifier
- Excellent 450-Mc Mixer Performance...NF=7 db, Gain=15 db (typical)
- Excellent UHF Oscillator Performance...Power Output=40 mw typical at 500 Mc, 20 mw typical at 1 Gc (unit will oscillate at frequencies to 2 Gc)
- Maximum Ratings...$V_{CBO}=30V$, $V_{CEO}=15V$, $P_t=200$ mw at 25°C free-air
- Gain–Bandwidth Product=1200 Mc Typical

Each RCA 2N2857 is tested for maximum noise figure and minimum power gain @ 450 Mc as a standard factory procedure. Specified 2N2857 values are based on ½-inch leads. With shorter leads gain can be improved as much as 1.5 db gain and noise figure as much as 0.5 db.

RCA also offers New Silicon NPN Transistor 2N2708 designed specifically for VHF Applications. The new RCA 2N2708 planar epitaxial transistor is specifically designed for VHF applications to 500 Mc. Here are some of the features of this new transistor:

- 200 Mc wideband RF amplifier...15 db min. gain (neutralized common-emitter)
- Maximum ratings...$V_{CBO}=35V$, $V_{CEO}=20V$, $V_{EBO}=3V$
- Gain–Bandwidth Product...700 Mc min.
- NF=8.5 db max. at 200 Mc, $I_C=2$ ma

Each RCA 2N2708 is tested for maximum noise figure and minimum power gain @ 200 Mc as a standard factory procedure.

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