Electronics®

Analyzing circuits numerically: page 88
Inside the Apollo computer: page 109
Electronics markets for 1967: page 123

January 9, 1967
$1.00
A McGraw-Hill Publication

Below: Integrated electronics invade all U.S. markets in 1967, page 129

AUDIO TRANSFORMERS

DO-T No.	Pri. Imp.	D.C. Ma.‡ in Pri.	Sec. Imp.	Pri. Res. DO-T	Pri. Res. DI-T	Mw Level	DI-T No.
DO-T44	80 CT 100 CT	12 10	32 split 40 split	9.8	11.5	500	DI-T44*
DO-T29	120 CT 150 CT	10 10	3.2 4	10		500	
DO-T12	150 CT 200 CT	10 10	12 16	11		500	
DO-T13	300 CT 400 CT	7 7	12 16	20		500	
DO-T19	300 CT	7	600	19	20	500	DI-T19
DO-T30	320 CT 400 CT	7 7	3.2 4	20		500	
DO-T43	400 CT 500 CT	8 6	40 split 50 split	46	50	500	DI-T43*
DO-T42	400 CT 500 CT	8 6	120 split 150 split	46		500	
DO-T41	400 CT 500 CT	8 6	400 split 500 split	46	50	500	DI-T41*
DO-T2	500 600	3 3	50 60	60	65	100	DI-T2
DO-T20	500 CT	5.5	600	31	32	500	DT-T20
DO-T4	600	3	3.2	60		100	
DO-T14	600 CT 800 CT	5 5	12 16	43		500	
DO-T31	640 CT 800 CT	5 5	3.2 4	43		500	
DO-T32	800 CT 1000 CT	4 4	3.2 4	51		500	
DO-T15	800 CT 1070 CT	4 4	12 16	51		500	
DO-T21	900 CT	4	600	53	53	500	DI-T21
DO-T3	1000 1200	3 3	50 60	115	110	100	DI-T3
DO-T45	1000 CT 1250 CT	3.5 3.5	16,000 split 20,000 split	120		100	
DO-T16	1000 CT 1330 CT	3.5 3.5	12 16	71		500	
DO-T33	1060 CT 1330 CT	3.5 3.5	3.2 4	71		500	
DO-T5	1200	2	3.2	105	110	100	DI-T5
DO-T17	1500 CT 2000 CT	3 3	12 16	108		500	
DO-T22	1500 CT	3	600	86	87	500	DI-T22
DO-T34	1600 CT 2000 CT	3 3	3.2 4	109		500	
*DO-T51	2000 CT 2500 CT	3 3	2000 split 2500 split	195	180	100	DI-T51*
DO-T37	2000 CT 2500 CT	3 3	8000 split 10,000 split	195	180	100	DI-T37*
*DO-T52	4000 CT 5000 CT	2 2	8000 CT 10,000 CT	320	300	100	DI-T52*
DO-T18	7500 CT 10,000 CT	1 1	12 16	505		100	
DO-T35	8000 CT 10,000 CT	1 1	3.2 4	505		100	
*DO-T48	8,000 CT 10,000 CT	1 1	1200 CT 1500 CT	640		100	
*DO-T47	9,000 CT 10,000 CT	1 1	9000 CT 10,000 CT	850		100	
DO-T6	10,000	1	3.2	790		100	
DO-T9	10,000 12,000	1 1	500 CT 600 CT	780	870	100	DI-T9
DO-T10	10,000 12,500	1 1	1200 CT 1500 CT	780	870	100	DI-T10
DO-T25	10,000 CT 12,000 CT	1 1	1500 CT 1800 CT	780	870	100	DI-T25
DO-T38	10,000 CT 12,000 CT	1 1	2000 split 2400 split	560	620	100	DI-T38*
DO-T11	10,000 12,500	1 1	2000 CT 2500 CT	780	870	100	DI-T11
DO-T36	10,000 CT 12,000 CT	1 1	10,000 CT 12,000 CT	975	970	100	DI-T36
DO-T1	20,000 30,000	.5 .5	800 1200	830	815	50	DI-T1
DO-T23	20,000 CT 30,000 CT	.5 .5	800 CT 1200 CT	830	815	50	DI-T23
DO-T39	20,000 CT 30,000 CT	.5 .5	1000 split 1500 split	800		50	
DO-T40	40,000 CT 50,000 CT	.25 .25	400 split 500 split	1700		50	
DO-T46	100,000 CT	0	500 CT	7900		25	
DO-T7	200,000	0	1000	8500		25	
DO-T24	200,000 CT	0	1000 CT	8500		25	
DO-TSH	Drawn Hipermalloy shield and cover 20/30 db						DI-TSH

‡DCMA shown is for single ended useage (under 5% distortion—100MW—1KC) ..for push pull, DCMA can be any balanced value taken by .5W transistors (under 5% distortion—500MW—1KC) DO-T & DI-T units designed for transistor use only. U.S. Pat. No. 2,949,591; others pending.
§Series connected; §§Parallel connected

→ *Units newly added to series

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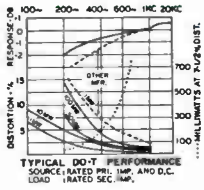

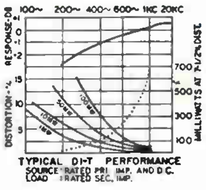

High Power Rating ....up to 10 times greater
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High Efficiency .... up to 30% better . . . compare DCR
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Anchored Leads ....will withstand 10 pound pull test
Printed Circuit Use ....(solder melting) nylon insulated leads
Suited to Clip Mounting ....use Augat #6009-8A clip

INDUCTORS

DO-T No.	Inductance Hys @ ma	DO-T DCRΩ	DI-T DCRΩ	DI-T No.
*DO-T50 (2 wdgs.)	§.075 Hy/10 ma, .06 Hy/30 ma §§.018 Hy/20 ma, .015 Hy/60 ma	10.5 2.6		
DO-T28	.3 Hy/4 ma, .15 Hy/20 ma	25		
	.1 Hy/4 ma, .08 Hy/10 ma		25	DI-T28
DO-T27	1.25 Hys/2 ma, .5 Hy/11 ma	100		
	.9 Hy/2 ma, .5 Hy/6 ma		105	DI-T27
DO-T8	3.5 Hys/2 ma, 1 Hy/5 ma	560		
	2.5 Hys/2 ma, .9 Hy/4 ma		630	DI-T8
DO-T26	6 Hys/2 ma, 1.5 Hys/5 ma	2100		
	4.5 Hys/2 ma, 1.2 Hys/4 ma		2300	DI-T26
*DO-T49 (2 wdgs.)	§20 Hys/1 ma, 8 Hys/3 ma §§5 Hys/2 ma, 2 Hys/6 ma	5100 1275		

POWER TRANSFORMERS

*DO-T400	Pri 28V 380-1000 cycles, Sec 6.3V @ 60 ma
*DO-T410	Pri 28V 380-1000 cycles, 2-Sec 6.3 @ 30 ma each
*DO-T420	Pri 28V 380-1000 cycles, Sec 28V @ 20 ma (Isol. Electrostatic Shld.)

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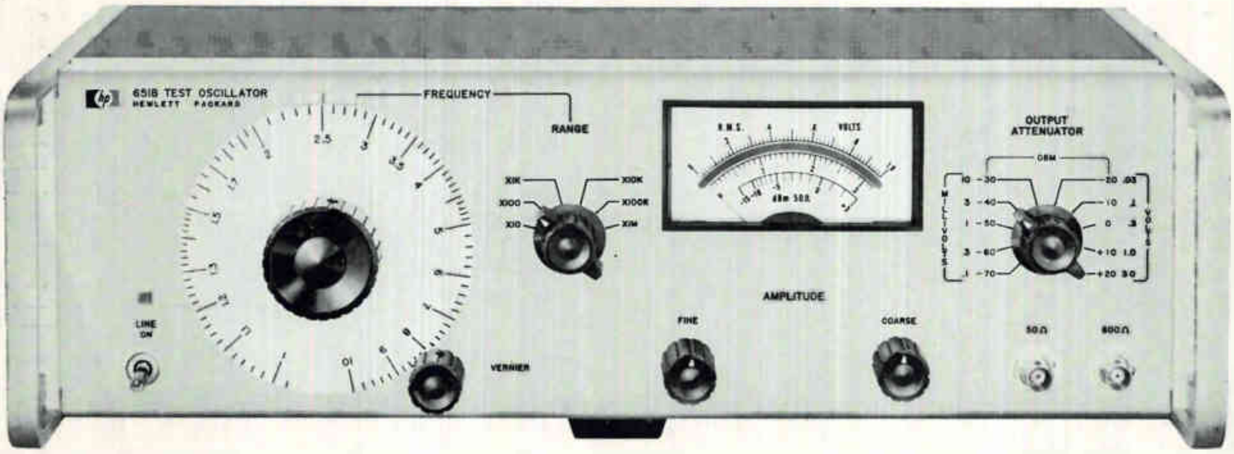
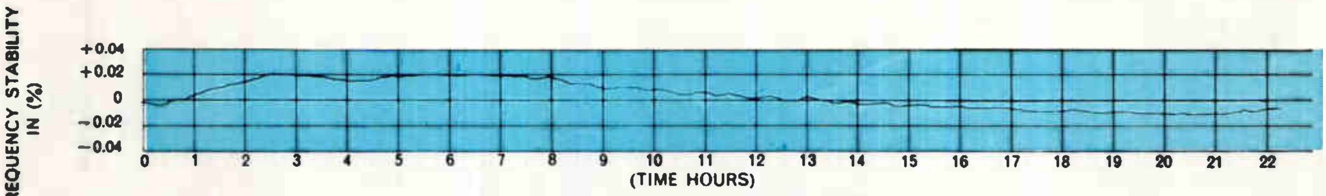
Circle 900 on reader service card

New hp 651B and 652A Test Oscillators:

FLATNESS, STABILITY and ACCURACY

from 10 Hz to 10 MHz





Typical Frequency Stability (±0.02%) at 5 MHz for 22 Hours.

- **Amplitude stability ±0.1%**
- **Frequency stability ±0.02%**
- **1% Accurate 90 dB output attenuator**
- **Two outputs: 200 mW into 50Ω, 16mW into 600Ω**

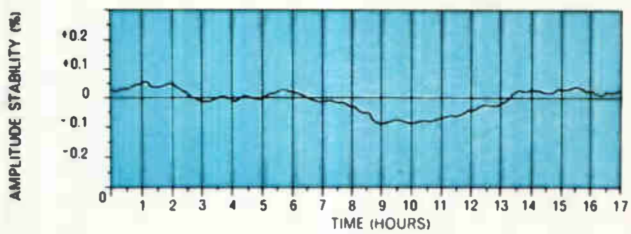
APPLICATIONS: Use the new wide-band, solid-state hp 651B and 652A Test Oscillators for laboratory and production applications, in the presence of shock, vibration or high-frequency radiations. Both models are ideal for calibration of voltmeters because of accurate attenuator and output monitor.

These oscillators are specifically designed for testing television amplifiers, audio amplifiers, filter networks, tuned circuits, telephone and telegraph carrier equipment, and for testing audio and video tape.

PERFORMANCE FEATURES: Oscillator circuitry has hp precision tuning capacitor and peak detector automatic gain control to insure a flat output throughout the entire frequency range. Solid-state, low-impedance circuitry and a shielded power supply transformer reduce output hum and noise to less than 0.05%.

Output attenuator has a 90 dB range in 10 dB steps, with a 20 dB coarse and fine concentric amplitude control for increased resolution in setting output voltage. Output monitor is calibrated to read volts or dBm into a matched load.

652A: Specifications of two oscillators are identical except that the 652A has the ability to monitor output



Typical Amplitude Stability (±0.1%) at Mid-Band Frequencies for 17 Hours.

amplitudes within 0.25% *over the entire frequency range* of the instrument using the X20 expanded scale. Readings on the uppermost scale of the 652A are in percent for quick reading of frequency response measurements.

652A Expanded Scale Monitor

For full specifications on the new hp 651B and 652A Test Oscillators, contact your nearest hp field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva. Price: hp Model 651B Test Oscillator, $590.00; hp Model 652A Test Oscillator, $725.00.

116A

HEWLETT hp PACKARD

An extra measure of quality

Electronics

January 9, 1967
Volume 40, Number 1

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Readers Comment

Engineer inertia

To the Editor:

In reading the article "Low-frequency noise predicts when a transistor will fail" [Nov. 28, 1966, p. 95], I was rather more surprised than pleased to note the first sentence: "A new method for predicting the life expectancy of a transistor—based on measuring the device's noise at 1,000 hertz—could make transistor reliability studies simple and more accurate." We developed this concept over five years ago.

We are not overly disturbed by the fact that credit for the origination of an important reliability tool was given some five years late to the wrong source. After all, mistakes can be made with the best intentions. But we continue to be disturbed by the fact that this concept has never been fully accepted by the engineering public, especially those who should be most interested in the ultimate in reliability, such as the military and aerospace agencies.

Quan-Tech has never claimed that noise analysis would supplant other methods of reliability testing. We have always proposed it as an additional method of weeding out failure-prone components that could not be detected by any of the more commonly accepted means.

It is a sad commentary on the rigidity of thinking and mental inertia of the majority of reliability engineers that they have been unwilling to experiment with a new concept. Their blind insistence on sticking to a purely statistical approach to reliability indicates a lack of original thinking and flexibility. After all, the failure of one transistor can endanger the life of an airplane or spacecraft pilot; yet most of the reliability people were unwilling even to investigate whether noise analysis could possibly eliminate failure-prone components.

Some two years ago we finally received a NASA contract for a statistical analysis of the relationship between noise and reliability in silicon planar transistors. Correlation between excessive noise and failure was excellent during the early part of the test; however it

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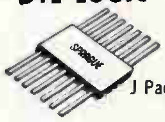
*SERIES SE100, NE100, US700 (Signetics CS700) DTL LOGIC



J Package

Two operating temperature ranges: —55 C to +125 C and 0 C to +70 C. NAND/NOR gates, clock and line drivers, gate expanders, RST and JK binary elements, one-shot multivibrator.

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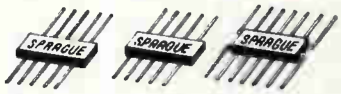
MULTIPLE TRANSISTORS (NPN-PNP PAIRS/QUADS)



AMPLIFIERS SWITCHES CHOPPERS

Pairs	Quads
2 NPN	4 NPN
2 PNP	4 PNP
1 NPN—1 PNP	2 NPN—2 PNP

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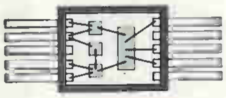
UNICIRCUIT® CUSTOM HYBRID CIRCUITS



Combine monolithic silicon circuits with tantalum or Ni-Cr alloy resistors. Close resistance tolerances, low temperature coefficient. Resistor matching, ±½%.

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Low Level Amplifiers
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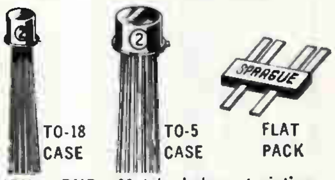
DIFFERENTIAL AMPLIFIER TRANSISTOR PAIRS



TO-18 CASE TO-5 CASE FLAT PACK

NPN or PNP • Matched characteristics. h_{FE} = 10-20%. ΔV_{BE} = 5-20 mV. ΔV_{BE}/Temp = 5-20μV/°C.

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UT-1000—Four-bit ladder network
UD-4001—Ladder switch for driving resistor ladder networks
UD-4024—Buffer amplifier

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TW-3000 MICROPOWER PNP SILICON HIGH-SPEED SWITCHING TRANSISTORS

TO-18 CASE

Fastest switching transistor available in the 1 to 100μA range

C_{ib} = 0.7 pF typ., 1.5 pF max.

C_{ob} = 1.5 pF typ., 2.5 pF max.

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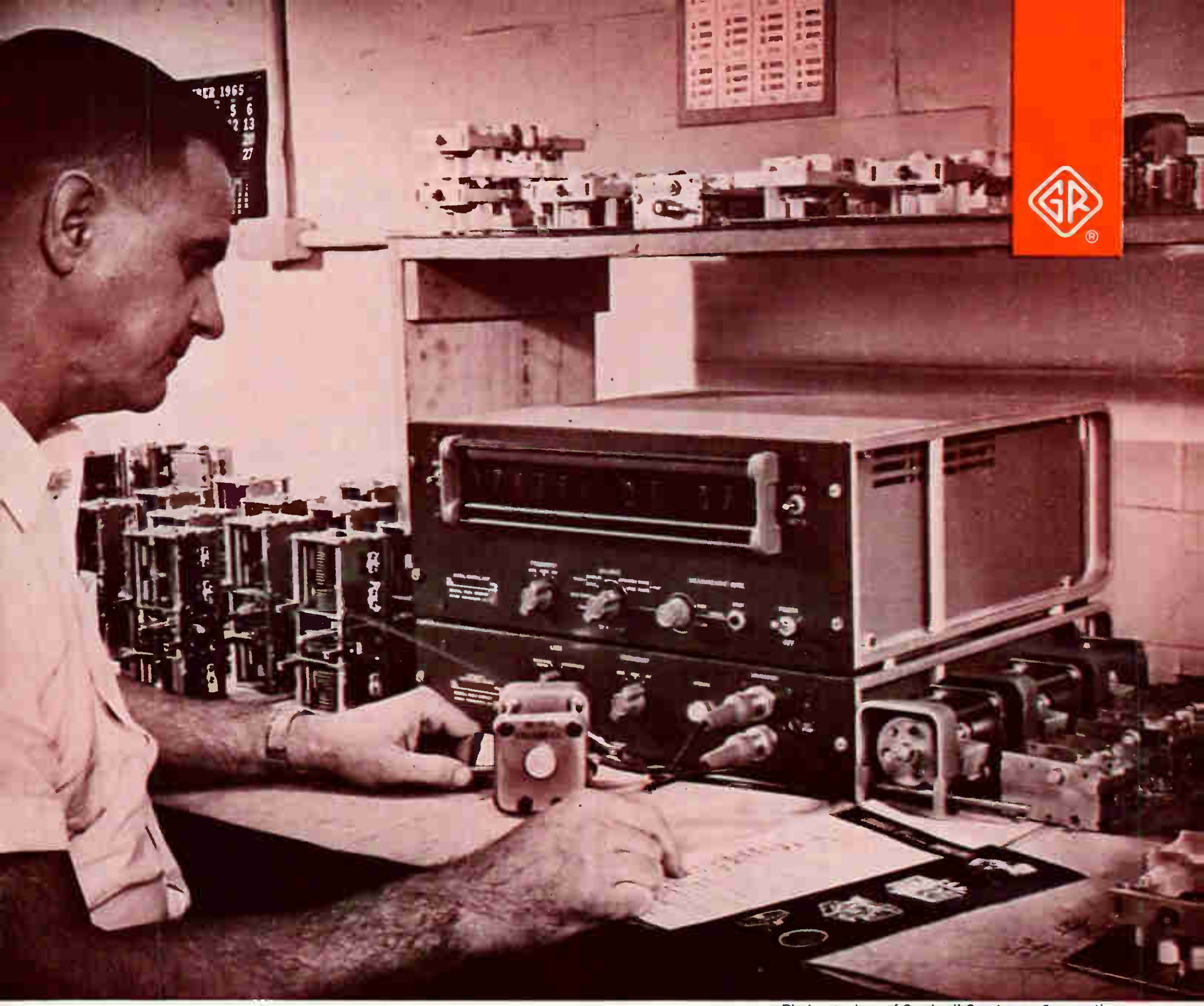


Photo courtesy of Cardwell Condenser Corporation

Customer Report:

1680-A Triples Output

Cardwell Condenser Corporation uses the Type 1680-A Automatic Capacitance Bridge Assembly to test variable air capacitors by checking them at more than five points across the dial. The 1680-A is not only more accurate than the bridge it replaced, but the remarkable speed with which it measures has tripled output and eliminated the need to hire additional test personnel. Government inspectors find this bridge thoroughly acceptable.

The 1680-A automatically selects C and D (or G) ranges, then balances and displays measurements in digital form showing decimal point and units of measurement. Measurement takes only 0.5 second at 1 kHz under worst conditions. Basic accuracy is 0.1% of reading for C and G, 1% ±0.001 of reading for D. Measurement range is 0.01 pF to 1000 μF. The bridge provides BCD output; completely automated systems can be supplied. Price of 1680-A: $4975 in U.S.A.

For complete information, write General Radio Company, 22 Baker Avenue, W. Concord, Mass. 01781; telephone: (617) 369-4400; TWX: 710 347-1051.

GENERAL RADIO

Circle 6 on reader service card

later apparently became masked by other failure mechanisms, probably due to excessive dissipation during aging of the transistors under power at high temperatures. To date the results of the study have not been released by NASA and no further action has been taken on the program.

Commercial manufacturers were much more receptive to our philosophy because they found from actual experience that it could save them money. A major manufacturer of automobile radios reduced his in-plant and field failures from approximately 3% to far less than 0.1% by noise testing all transistors before assembly into the radios. A manufacturer of electronic organs, after having to recall a large percentage of his production due to transistor failure, instituted 100% noise screening of transistors before assembly, resulting in an equally impressive reduction in failures.

John M. van Beuren
President,
Quan-Tech Laboratories Inc.
Whippany, N.J.

Questioning low-cost voltmeter

To the Editor:

The article "Digital meters for under $100" [Nov. 28, p. 88] can lead users to believe that instrument manufacturers are pricing their equipment exorbitantly high and that they are not offering good dollar value.

The author is not being realistic in believing that the described voltmeter could be built to sell for less than $100. At today's prices, the cost alone for the decade counters and readout is in excess of $170. Based on best possible forecasts, this price can be expected to remain for some time in excess of $80. In addition, such items as power supplies, printed-circuit boards, package, switches, checkout, and wiring labor would realistically price the design as shown into a range of $600 to $800.

I have no quarrel with Schmid over circuit design or details, and I agree that multifunction IC's will bring prices down; however, believing that a greater-than-ten-to-one price reduction will be achievable in the near future is misleading and—at this point in time—wishful thinking.

James Nelson
Digital Voltmeter Project Manager
Dana Laboratories Inc.
Irvine, Calif.

▪ The article quite clearly stated that a $100 price depended on mass production and certain improvements and modifications of the prototype. Its purpose was to show the kind of savings that are possible with integrated electronics, not that voltmeter prices were out of line. Industry rumors hint that a $200 voltmeter with IC's will be introduced at the IEEE show in New York in March.

Enter the millishift

To the Editor:

The milliday [Nov. 14, 1966, p. 43] is an interesting concept. But why not a millishift? Assume an 8-hour shift plus 10 minutes grace for getting from parking lot, plus 10 more for return.

Thus a millishift is .00833 ⅓ hours. And conveniently it is half a minute.

Otis N. Minot
Lexington Research
Lexington, Mass.

People

In his three years at NASA, **James C. Elms** has been far from the basic research laboratories; he guided operational manned flight programs. Now he's been appointed to direct NASA's Electronics Research Center in Cambridge, Mass., and he will use this experience to guide the development of much of the equipment that's used for space flight.

James C. Elms

The 50-year-old physicist succeeds Winston Kock, who recently returned to the Bendix Corp. as director of research.

Prior to his appointment as overseer of the agency's diversified and expanding research program, Elms served in Washington as NASA's deputy associate administrator for manned space flight, and earlier in Houston as deputy director of the Manned Spacecraft Center.

Tour of labs. When Elms was appointed to the Cambridge post, he arranged to visit other Government laboratories to catch up with research programs, particularly in bionics—a favorite of his—and in related areas such as real-time monitoring of medical data and the contributions of aerospace medicine to general medicine.

Elms thinks the product fallout from the space program is overstressed. He is more enthusiastic about the over-all impetus the space program has given the nation's industrial progress.

Along with his boss, NASA administrator James E. Webb, Elms looks upon the Cambridge center as an experiment in coordinating the efforts of universities, industry and Government. New procedures must constantly be worked out there to handle the flow of information from these three sources.

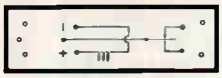
Differing views. Elms sees the center as experimental in another sense. "We will do research and development on the facility itself, as well as on devices and systems. It's hard to build a flexible facility and keep it flexible, but we'll try," he reports.

Adlake Mercury Wetted Relay — Application Data

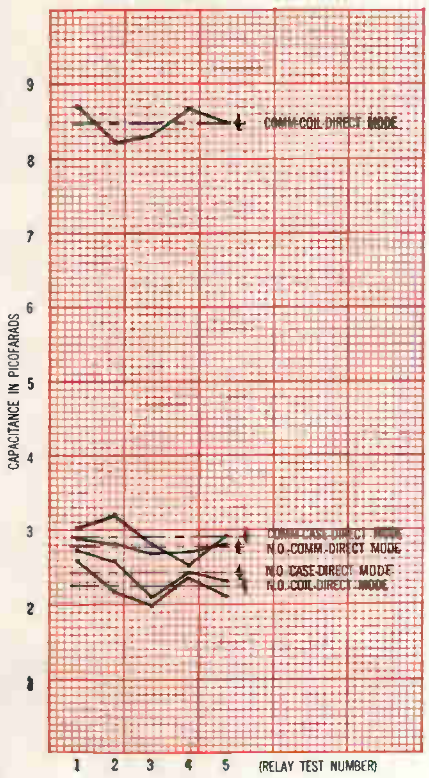
Capacitance of Adlake Mercury Wetted Contact Relays Applicable for Low Signal Applications

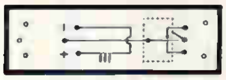
Typical Capacitance in Picofarads — Graphs illustrate typical capacitance values for Adlake AWCA-16000 series relays. Fig. I is for unshielded relays. Fig. 2: Electro-statically shielded switch brought out to a separate pin. Fig. 3: Electro-statically shielded switch with case and shield tied together at a common pin. Interelectrode capacitance across contacts of a bare switch, without external wires, is less than 1.0 picofarad.

Abbreviation COMM. stands for the Combination of the Armature and Normally Closed Contact. N.O. is the abbreviation for Normally Open Contact; whereas the symbol # is the mean average for the 5 relays. Graphs are available on other styles of Adlake Mercury Wetted Contact Relays upon request. (Please state wiring configuration.)

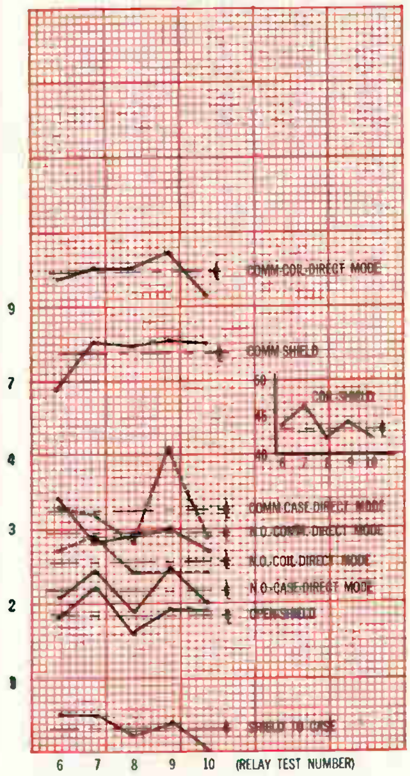


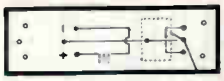
AWCA 16011-S
Fig. 1



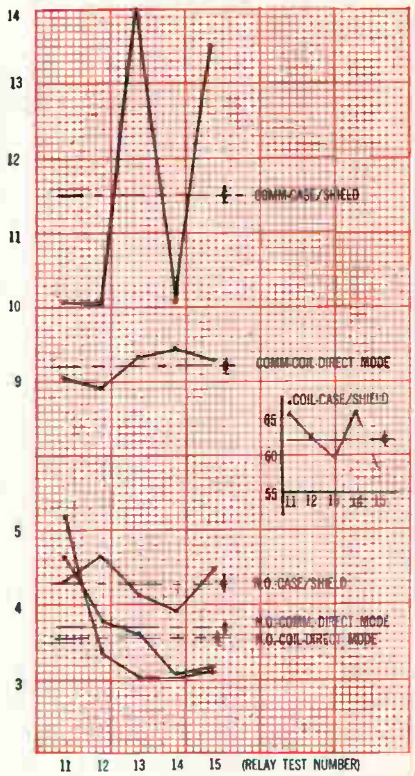


AWCA 16016
Fig. 2





AWCA 16018
Fig. 3



Data was obtained using a Boonton Electronics Corporation Capacitance Bridge, Model 75-A-S8 at 1MHz

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Circle 9 on reader service card

People

The American Telephone & Telegraph Co. has named a 60-year-old electrical engineer to its top job—chairman and chief executive officer. **H.I. Romnes** will succeed Frederick Kappel on Feb. 1.


H.I. Romnes

In his 40-year career with AT&T, Romnes was active in management and research operations. In 1927 he joined Bell Telephone Laboratories, AT&T's research arm, to work on circuit design. Eight years later he transferred to the parent company and advanced through a number of engineering management jobs. In 1950 he became director of operations of the long lines department and two years later was named chief engineer of the company. Four years later he was elected president of the Western Electric Co., the manufacturing subsidiary. He returned to AT&T as vice-chairman in 1964 and a year later was elected president.

Romnes was the driving force behind AT&T's decision to install a direct dialing network. He is also credited with strengthening the ties between Western Electric and Bell Labs.

Ralph S. Holmes has been named division vice president of a new medical electronics group at the Radio Corp. of America. His appointment, in effect, implements RCA's recent agreement with Hoffmann-La Roche Inc., a pharmaceutical company. Under the agreement, RCA will manufacture and service electronic gear developed by the two companies and Hoffmann-La Roche will do the clinical testing and marketing.


Ralph S. Holmes

Holmes has directed several special projects for RCA in a career that spans more than 40 years.

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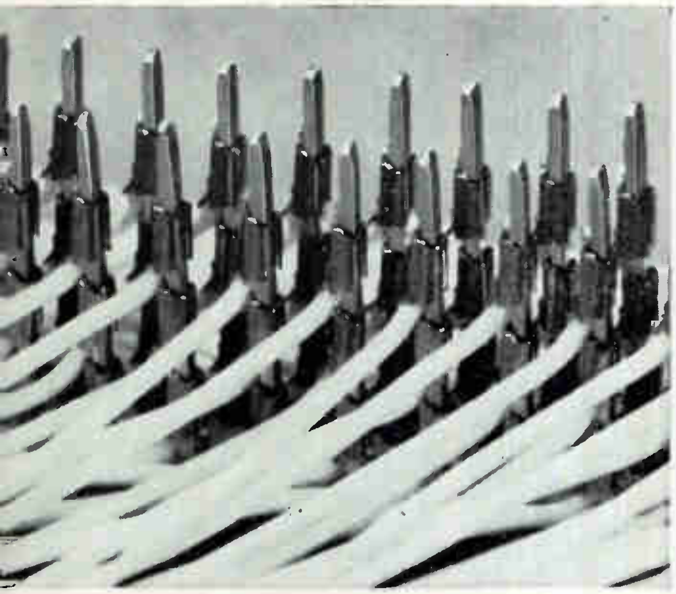

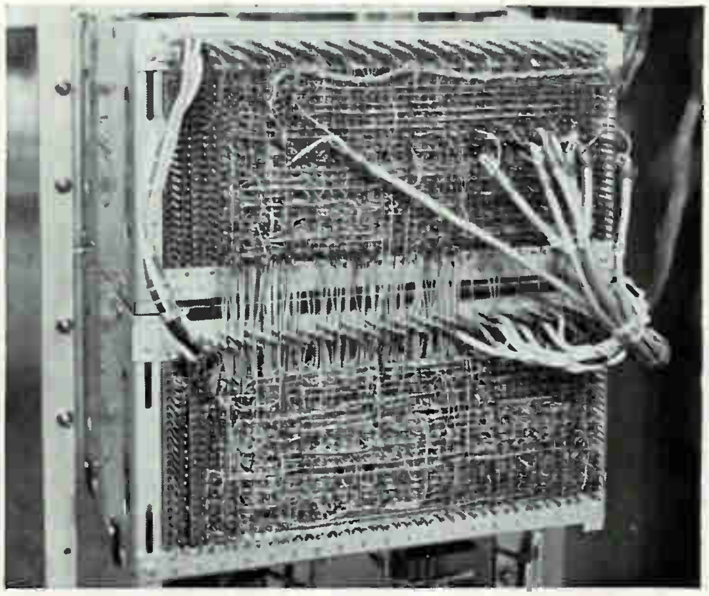

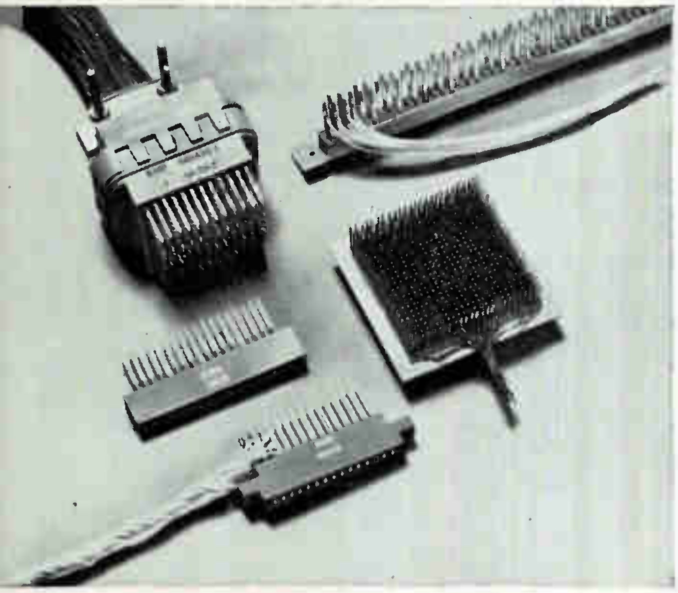

blocks, bus bars, cable connectors, junction blocks, relay blocks, and other devices. Furthermore, large-scale wiring of these products may be accomplished by mounting them on a panel and programming the TERMI-POINT machine for high-speed automatic wiring.

Besides the speed, density, and versatility of this wiring method, it offers an unusual degree of reliability. The reason for this is AMP's special post presents relatively large contact surfaces which are wiped clean by the wire held by the TERMI-POINT clip as the post is terminated. The resulting connection is highly resistant to the effects of corrosion, vibration, and temperature extremes. It is held with a high retention force which exceeds the yield strength of the wire itself, yet the post plating remains undamaged and the wire may be used again.

No other wiring method offers this combination of advantages!

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If you plan to enlarge or improve your present wiring facilities, we suggest a comparative study of this new technique at your earliest convenience. Write or call today for a demonstration; or ask for information about the TERMI-POINT products which interest you most. Find out how this versatile new method can boost your future production!

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Meetings

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

Computer-Aided Circuit Design Conference, Engineering Institutes; University of Wisconsin, Madison, Wis., **Jan. 16-18.**

Computer Aid For Reliability Analysis of Electronics Conference, Engineering Institutes; University of Wisconsin, Madison, Wis., **Jan. 19-20.**

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

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

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

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

Conference on Color Television Broadcasting, Society of Motion Picture and Television Engineers; Park Shelton Hotel, Detroit, **Jan. 27-28.**

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

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

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

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

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

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

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

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

Numerical Control Society Conference, Statler Hilton Hotel, Detroit, **March 1-3.***

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

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

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

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

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

Call for papers

Biomedical Sciences Instrumentation Symposium, Instrument Society of America; Albuquerque, N.M.; May 15-17. **Jan. 15** is deadline for submission of abstracts to Robert Allison, director, Vascular Laboratories, Scott and White Clinic, Temple, Texas 76501.

Symposium on Microwave Power, International Microwave Power Institute; Stanford University, Stanford, Calif., March 29-31. **Jan. 16** is deadline for submission of abstracts to Donald Dunn, chairman, 1967 Symposium on Microwave Power, International Microwave Power Institute, P.O. Box 2335, Stanford, Calif.

Conference on Nuclear and Space Radiation Effects, IEEE; Ohio State University, Columbus, Ohio, July 10-14. **March 1** is deadline for submission of abstracts to John Wirth, Organization 5212, Sandia Corp., Sandia Base, Albuquerque, N.M.

* Meeting preview on page 16

THE Connector Thing

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

MICRODOT WELCOMES AMPHENOL

!!!

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

IN HONOR OF THIS GREAT EVENT, MICRODOT IS HOLDING THREE

(count 'em, three)

CONTESTS

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

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

...AND ABOUT AMPHENOL.

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

CONTEST #1

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

WIN A REVELL SCALE MODEL KIT OF THE GEMINI SPACE CAPSULE

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

CONTEST #2

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

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

CONTEST #3

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

WIN A MODEL! SHE'S YOURS...

in perfect ⅛ scale, 8 x 10 glossy, perfect for your office wall, workshop or pool hall...inscribed "With Love and You Know What to____________ (your name here) from Marcia".

All you have to do is write, in twenty-five words or more a description of your application for the MARC 53. You notice how fast we forget the competition when we get down to business. Remember...everybody who enters Contest #3 wins!

MICRODOT INC.

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

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

Name____________

Title____________

Company____________

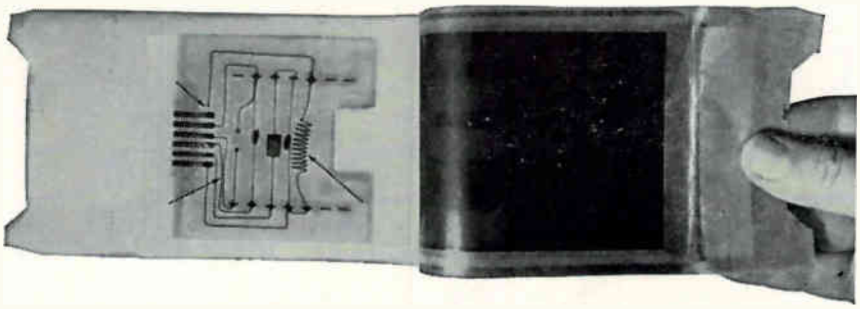
Address____________

City____________

State____________ Zip______

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

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



Meeting preview

NC by computer

Techniques for applying the computer to numerical control will highlight the Numerical Control Society's technical conference, which will be held in Detroit, March 1 to 3.

Bertram Herzog, a professor at the University of Michigan, will discuss computer-aided design, particularly the relationship of computer graphics to numerical control. Jay Bender of the General Electric Co. will analyze time sharing for programing and engineering and will give a demonstration of the technique. Other speakers will discuss the languages, such as APT and ADAPT, used to make computer commands understandable to machinery that is operated by numerical controls.

Big and small. Generally, initial equipment costs limit the use of numerical control to large companies. However, Charles Hutchins, executive vice president of the Pontiac Paint & Varnish Co., will present a case study of computer-aided programing for a small firm, and a second session will feature a case history of applications of numerical control machinery in a small shop.

On the second day of the conference, metalworking experts will examine the state of the numerical control art in Europe. Harold Burton, editor of the British magazine Metalworking Production, a McGraw-Hill publication, will handle the subject from the British viewpoint, while Ted Swanson of International General Electric, Frankfurt, West Germany, will discuss the same topic from the United States numerical control builder's viewpoint.

Inspection year. Another session will study inspection equipment needed for numerical control, and a panel will tackle the subject of training methods—what is being done at present and what is still required.

The final day will include a session on how to retrofit machinery for numerical control and how to adapt electronic equipment to NC applications.

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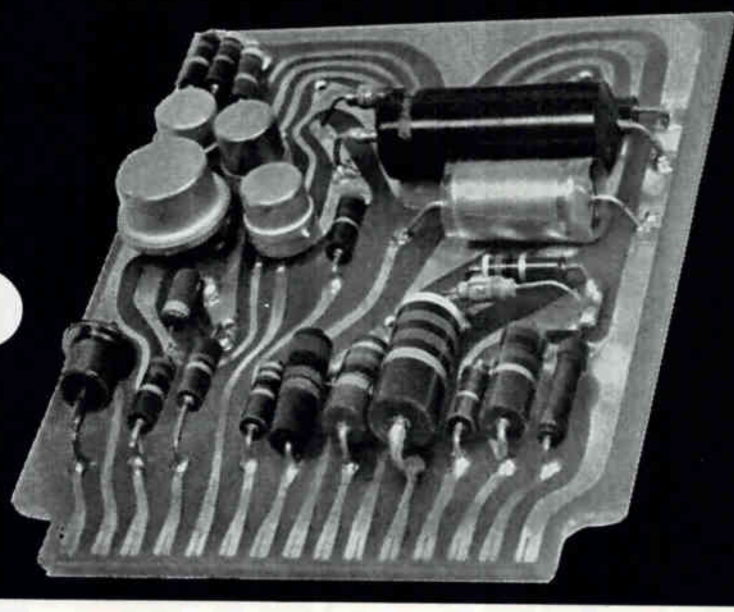
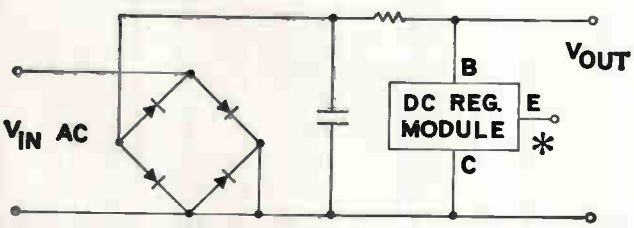
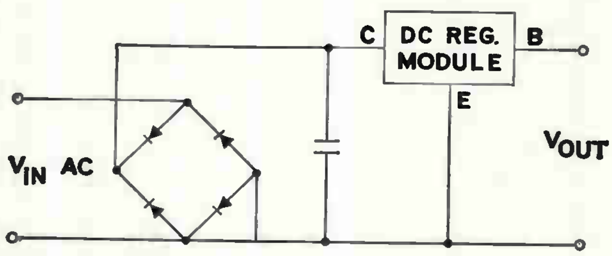


APPLICATION SCHEMATICS



*For external trim adjustment



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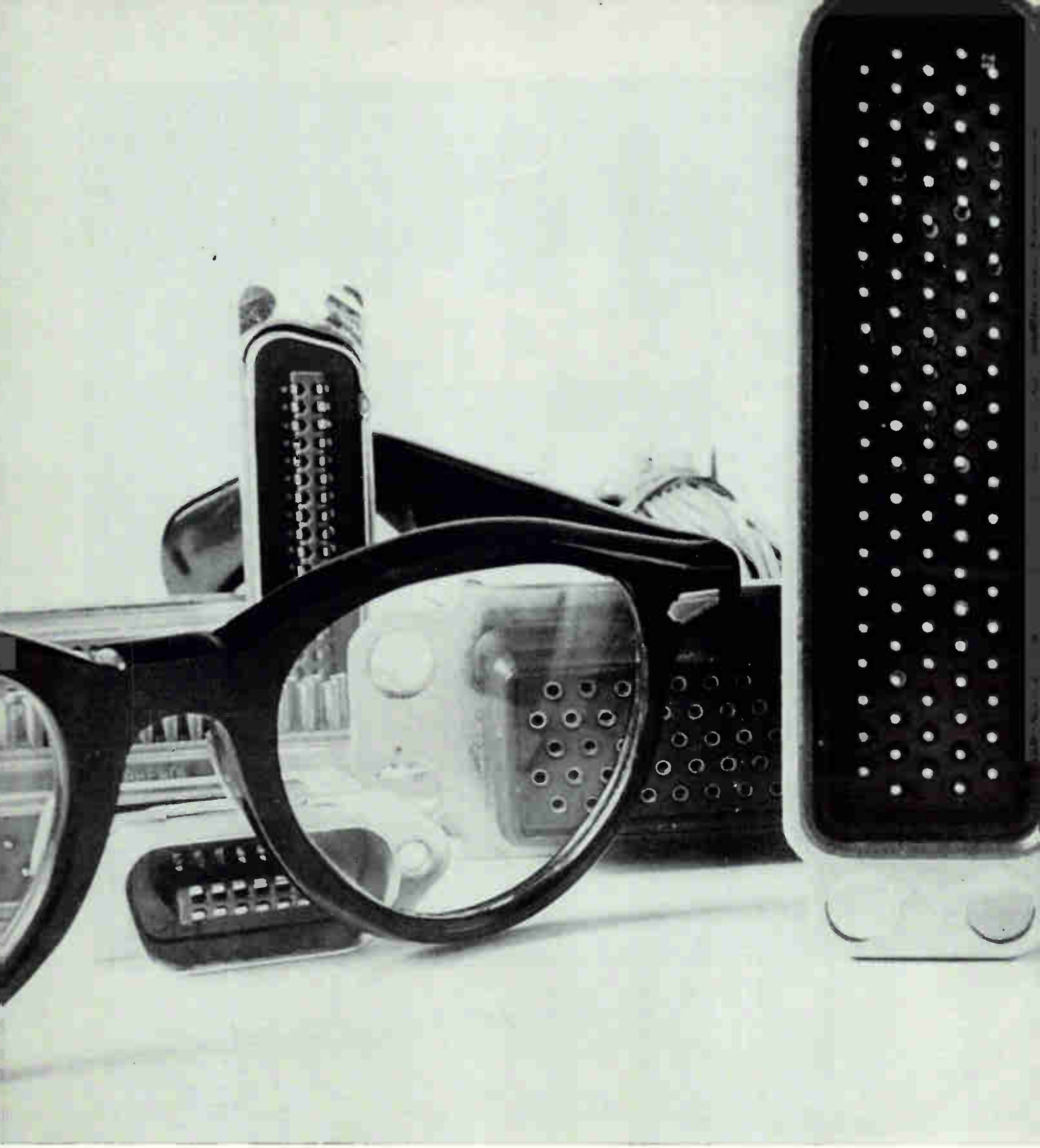
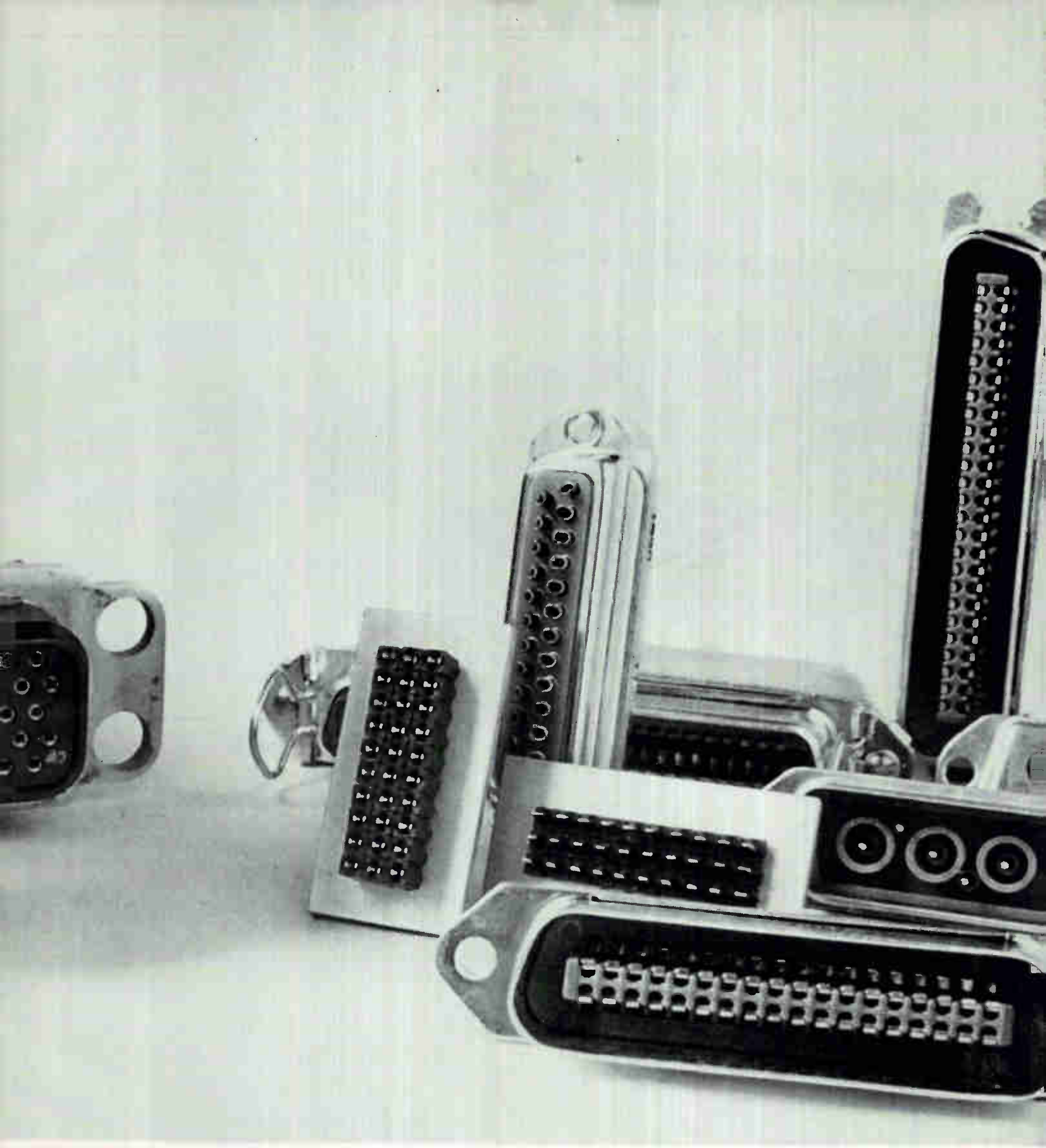


What to look for in a good miniature rack and panel connector.



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Circle 21 on reader service card

Circle 22 on reader service card

Editorial

Discovering technology

Technology, the oft-ignored stepchild of science, is coming into its own at last.

The nonengineering world has finally discovered it. Government leaders lament its lack, industrial management worries about understanding and using it, the financial community is anxious to make a profit from it. Technology is the hula hoop of 1967.

You can see this development in the profusion of meetings about technology and the proliferation of programs to spread it. In November, for example, at the dedication of the National Bureau of Standards' new facilities outside Washington, the Department of Commerce sponsored a two-day symposium on technology. While some technical men attended, the NBS's resplendent red auditorium was filled mainly with diplomats, Government observers and industrial executives.

Two weeks later, the management-oriented National Industrial Conference Board held a daylong meeting of top management men in New York City to examine what technology can do for the nation's industrial concerns. Earlier in the autumn, British Prime Minister Wilson proposed that Europe share its technology, and the president of Italy has proposed a Marshall Plan-type program to help expand technology in Europe.

None of Electronics magazine's readers, of course, are surprised to learn there is a technology. But ever since the first atom bomb was exploded in 1945, there's been a lot of talk about science and not much about technology. During descriptions of space shots on television, the "science" reporters for the networks wax rapturous about the scientific accomplishments that made it all possible. Yet there's very little science involved; it's almost entirely engineering. The weekly news magazines' science departments rarely write about science; nearly every week they write about technology and engineering and call it science.

In a recent Defense Department Report*, the myth of the importance of science in the economy has been laid to rest once and for all. A study of the development of a number of weapon systems estimates the scientific contribution at only 8% and the technological contribution at 92%. "Science" is defined in the report as theoretical and/or experimental studies of new, unexplored natural phenomena, and "technology" as the conception or demonstration of the capability of performing a specific function using new or untried theories, principles, techniques or materials.

Under the assumptions of the report, "new" means post-1945. And the report also concludes significantly that the technical contributions covered in the study began accumulating 20 years before the engineering design dates for the systems utilizing them.

Thus, much of the widely publicized new "science" is neither new nor science.

This is what has happened in military weapon systems, probably the most sophisticated and technically advanced area of electronics endeavor. Obviously, engineers in less developed fields, such as industrial or consumer electronics, are using technology that is even older.

All this would be just an argument about semantics if the mistaken reverence for science weren't having a deleterious effect on companies and countries. The public overplaying of science has often led to the wasting of funds on basic research at the expense of sorely needed development work, and has lured a lot of young people to pure science and away from engineering. It has even encouraged some engineering schools to urge the abandonment of the study of engineering for a concentration on physics and mathematics.

Yet, time after time, the evidence clearly shows the most progress stems from the unique and creative application of some old technical idea or scientific principle. As we've pointed out before on this page, the celebrated technology gap in Europe is not really a lag in technology at all, but in application.

The overemphasis on science and theory is starting to hurt the U.S. electronics industry in another way: too many young engineers feel theoretical work in the research laboratory or the university is the only suitable employment for a college-trained engineer. So most young engineers will not work as production engineers or as designers of the complex and ingenious equipment required to manufacture electronic products automatically. Yet some of the most challenging technical problems are in this apparently prosaic area.

Over the next 10 years, the greatest growth in electronics will come from the creative application to new areas of some developments that are now well established, such as integrated electronics, lasers, systems engineering, computers and communications—not from radical new developments that no one can now envision. Some very prosaic electronics will be applied to education and medicine. Systems engineering may show the way to solving a lot of nonmilitary problems, among them automotive traffic control, air pollution, juvenile delinquency and highway planning.

The key man in such developments will be the engineer, not the scientist. These are jobs for technology, not science.

* First interim report on Project Hindsight, by C.W. Sherwin, et al. 30 June 1966; revised 13 October 1966. Office of the Director of Defense Research and Engineering; Washington, D.C.

Electronics Newsletter

January 9, 1967

Time-sharing—is it private?

Are the memory banks of time-shared computers really secure? Or can one customer look into the memory banks of another customer—either accidentally or deliberately?

Although the operators of time-shared systems are reluctant to discuss such matters publicly, there has been evidence of breaches in security.

The home of time-sharing, the Massachusetts Institute of Technology, has been having trouble with students who break the elaborate codes that are supposed to insure the privacy of the users of its Project MAC (machine-aided cognition) computers. On one occasion, it's been reported, students tapped into lines carrying Government data, including information from the Strategic Air Command at Omaha. Some of this tinkering has had the effect of jamming the lines.

Last fall, the Federal Communications Commission established a panel to explore the question of Federal controls on time-shared operations; one of the questions to be examined is the privacy afforded users.

On-line circuit design at MIT

Computer-aided design of electronic circuits today is almost exclusively a matter of batch-processing. At the Massachusetts Institute of Technology, however, a program is under way to leapfrog to on-line circuit design in a classroom environment. By next fall, says Richard D. Thornton, an associate professor, work will start on an on-line classroom design of integrated circuits.

By then a joint program of MIT and the Bell Telephone Laboratories, called Multics (multiplexed information and computing service), will be in operation. Both Bells Labs and MIT are installing General Electric 645 computers for the timed-shared network.

Bell Labs is also moving in the direction of on-line circuit simulation for its own engineering laboratories, and several areas of cooperative effort by Bell and MIT have been opened.

One of the most pressing needs in this field is for a versatile, low-cost terminal capable of generating lines, curves and vectors in addition to numbers and letters. And one of the most promising designs under development is Bell Labs' Glance, a terminal driven by a local disk memory and using a direct-view cathode-ray tube.

Firms ready bids to supply avionics for Boeing SST

Although the Boeing Co. has won the competition to build the U.S. supersonic transport, many of the electronics designs for the plane haven't been specified. Four systems to be included are still in the development stage for commercial aircraft: a collision-avoidance system, clear air turbulence detectors, all-weather landing equipment and fault-locating gear.

Several manufacturers are preparing to bid on the avionics systems. The Airborne Instruments Laboratory has proposed an all-weather landing system, while the Bendix Corp. has offered a complete avionics package, including an automatic pilot, data instrument display and computer, integrated flight instrument display, inertial navigation and all-weather landing equipment. The Sperry Rand Corp.'s Sperry Gyroscope division has proposed an inertial navigation system and its Sperry Phoenix division expects to bid on an automatic flight control system.

←Circle 24 on reader service card

Electronics Newsletter

NASA consolidates support contracts at Cape Kennedy

The National Aeronautics and Space Administration is consolidating its support-services contracts at Cape Kennedy in an attempt to reduce the number of companies it has to deal with and; as a result, several major electronics and aerospace concerns may be squeezed out.

The two major support contracts that will be combined by Jan. 1, 1968, are those held by Trans World Airlines for general support and Ling-Temco-Vought Inc. for information services. TWA's contract is valued at $23 million a year and LTV's at $10 million. The new consolidated contract will cover five years and be on a cost-plus-incentive-fee basis.

Also, requests for competitive proposals have already been issued for a single contractor to combine the instrumentation support currently being provided by the Radio Corp. of America and the communications support provided by the Federal Electric subsidiary of the International Telephone and Telegraph Corp.

Surveyor will try to upstage Luna 13

The United States will try to outdo the Soviet Union's Luna 13 in testing the lunar soil when it launches Surveyor 3 to the moon this spring. The soft lander will carry a surface sampler to dig a 17-inch-deep trench in the lunar soil. One of the spacecraft's television cameras will transmit pictures of the scooped up material to earth for analysis. The Luna 13 can only stick a probe into the moon to check soil firmness.

The next Surveyor is scheduled to be launched by March, but a busy flight schedule at Cape Kennedy may force a delay.

Plans are made to live with CAT, or perhaps bell it

Research into clear air turbulence, or CAT, has largely been a hit-or-miss affair, with work by universities, industry and the Government conducted without coordination. Now the Commerce Department has set up a committee to give some direction to these efforts.

The Government is taking two approaches in its war on CAT, which has been blamed for a dozen crashes or near-crashes over the past few years.

The Commerce Department panel will sponsor the development of CAT detectors, and the Air Force, apparently prepared to live with the menace, has awarded the Boeing Co. a $6 million contract to develop an automatic flight controller that would sense the turbulence and adjust a plane's control gain to withstand it. With aircraft flying higher and faster, the effects of CAT are becoming more pronounced and planes' structural metal more quickly fatigued.

Addenda

Airborne Instruments Laboratory is developing an uncooled parametric amplifier that will have a noise temperature of 50°K, a level nearly equivalent to that produced by amplifiers operating at cryogenic temperatures. The critical elements of the paramps are varactor diodes with a 0 bias cutoff frequency in excess of 400 gigahertz, and improved millimeter wave klystrons. . . . The Stewart Warner Corp. plans to introduce a new desk-top facsimile machine within the next three months. . . . The Federal Aviation Administration is weighing proposals to buy solid state equipment for its 900 navigational ground stations around the country. The very-high-frequency-omnirange (VOR) stations currently use 200-watt tube transmitters.

Component and Circuit Design

IDEAS

from SYLVANIA Electronic Components Group

READOUTS

Breakthrough in EL panel design permits greater display flexibility

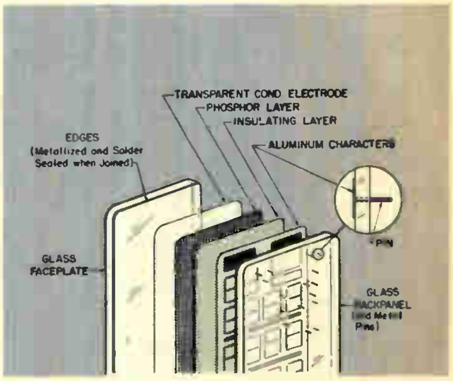
The newest advancement in electroluminescent readouts is a panel design of all-glass construction. Display designers and users now have a solid-state readout with higher reliability than ever before which lends itself to even greater design flexibility than previously possible with EL.

Completely engineered by Sylvania, this new concept actually allows both a decrease in readout character size (to ⅜-inch) as well as increased panel size. This means more characters per panel are possible than before in hermetically sealed EL designs.

Designers still get all the inherent advantages associated with Sylvania EL readouts: solid-state reliability, low-power consumption, wide viewing angle, light weight, low reflection, variety of characters, stable performance, no catastrophic failure, clear readability and rapid information display. Performance of the all-glass units is judged by the same standards as the metal-glass devices: brightness, spectral emission, contrast, life, etc.

What does "all-glass" really mean in this sense? While metal-glass EL panels use metal contact pins and metal sealing frames, this new design concept is completely of glass construction, with the only metal present being the connector pins. Eliminated also are conductive rubber contacts.

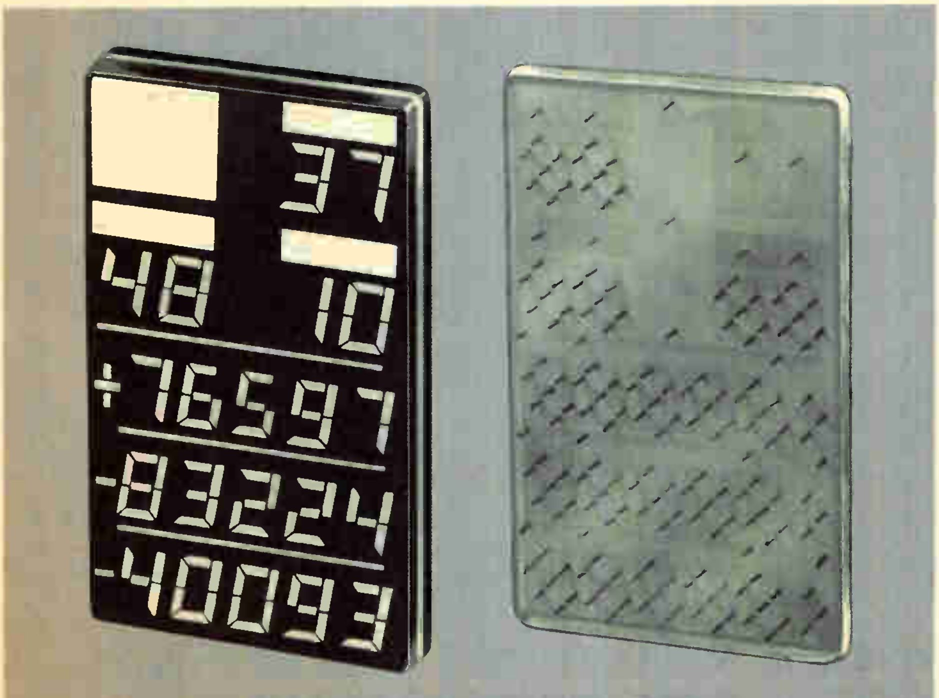
The user-benefit of this new construction is a higher degree of lamp



reliability for the demanding environmental and operational conditions encountered in severe aerospace applications.

The panels are designed to rigid specifications. The glass contact panel is molded as a single piece with the connector pins in place as integral parts of the panel. Combined with

(continued)



ALL-GLASS EL PANEL, FRONT AND REAR VIEWS.

This issue in capsule

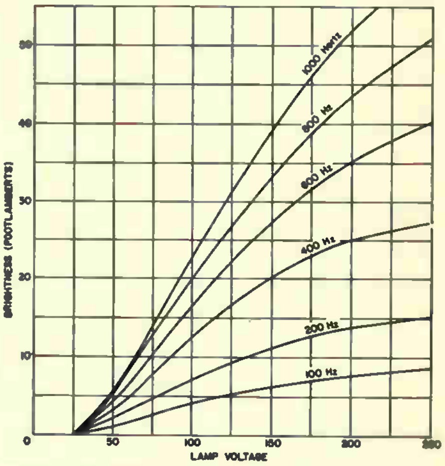
READOUTS *(continued from page 1)*
true hermeticity, the result is panels which perform reliably at extreme changes in altitude, temperature and humidity. They are also highly resistant to shocks and vibrations.

In the new construction, the glass contact panel containing sealed connector pins is ground flat on one side. The patterned back metallic electrode is applied to this glass surface. Thus, each active area becomes an integral part of its own connector pin, eliminating any possibility of registration problems. An electrical insulating layer is then applied over the back electrode and covered by a phosphor. A transparent conducting electrode put over the entire phosphor surface is the last electrical layer.

To protect the whole assembly, a glass front panel is placed on the transparent conductor and sealed to the contact panel, using a metal-solder technique. For less critical applications, an epoxy sealant may be used.

This simple construction process makes it easy to mass produce reliable and reproducible devices. The excellent match of expansion characteristics of faceplate and contact plate assemblies minimizes stress on the hermetic seal during temperature variations. Elimination of conductive rubber contacts provides a significant improvement in lamp reliability.

Standard all-glass units are available in 115 V and 250 V versions. The lower operating level is achieved by appropriate reductions in thickness of the EL and dielectric strata. Initial brightness is on the order of 25-30 FL at room temperature and 250 volts, 400 Hz. Spectral emission, contrast, life and half life are comparable to that of conventional EL panel design.



CIRCLE NUMBER 300

INTEGRATED CIRCUITS

How 4-bit array registers reduce IC package count, speed storage and transfer

Each of Sylvania's integrated four-bit binary register arrays contains the equivalent of at least 87 discrete components and the equivalent of 25 IC gates used in conventional integrated circuits. These monolithic digital functional arrays implement parallel storage or transfer of four binary bits every 15 nanoseconds. Here's how they work and how they can be used to build a temporary storage memory using only five IC packages.

Series SM-60 and SM-70 four-bit storage registers are for use as high-speed storage elements in control and arithmetic sections of digital computers. The SM-60 series has clocked inputs and clocked outputs. Further, the SM-60 output has wired OR capability which means outputs can be tied together to provide the logic OR function. The SM-70 series is operationally identical to the SM-60 except that it has a SUHL type output network and is not clocked with an enable signal. This means information set in the device is available at the output after a propagation delay of 20 nanoseconds.

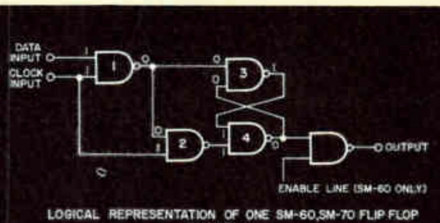
Figure 1 shows the logical operation of one of the four flip-flops in a storage register. With the data and clock inputs both at high (Logic "1"), the output of gate 1 is low (Logic "0"). This low condition appears at the input to gate 3 and forces the output of gate 3 to go high. The low output of gate 1 also appears at the input of gate 2, forcing the output of gate 2 to go high. Thus, both inputs to gate 4 are in the high condition. This means output of gate 4 is low. This low output appears at the input of gate 3, forcing the output of gate 3 high. The circuit is now latched with the output high. Once the circuit is latched, the clock input can be removed without disturbing the flip-flop.

Where data input is low (Logic "0") and clock input is high (Logic "1"), the circuit latches the flip-flop with its output in the low condition. If the clock input is low, no data is accepted.

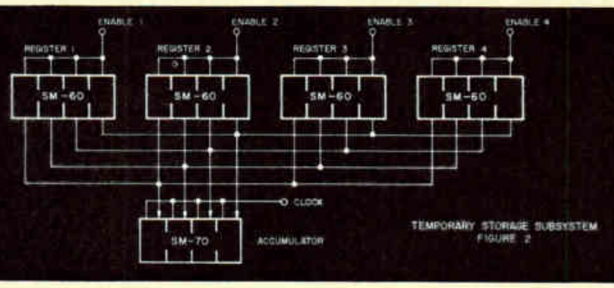
Figure 2 illustrates how to form a temporary storage register subsystem with common accumulator. Here, registers 1 through 4 can be enabled either separately or jointly. In the latter case, a logical OR is performed allowing masking techniques to be used. The SM-70 gives the accumulator a high fan-out. Only five packages are required and the number of external connections are cut to ⅛ of those required when conventional integrated circuits are used.

The SM-60 and SM-70 series operate over a temperature range of –55° to +125°C. Both these monolithic digital functional arrays are available in Sylvania's standard 14-lead dual in-line plug-in package and the TO-85 flat pack. They are completely compatible with the SUHL line of integrated circuits.

CIRCLE NUMBER 301

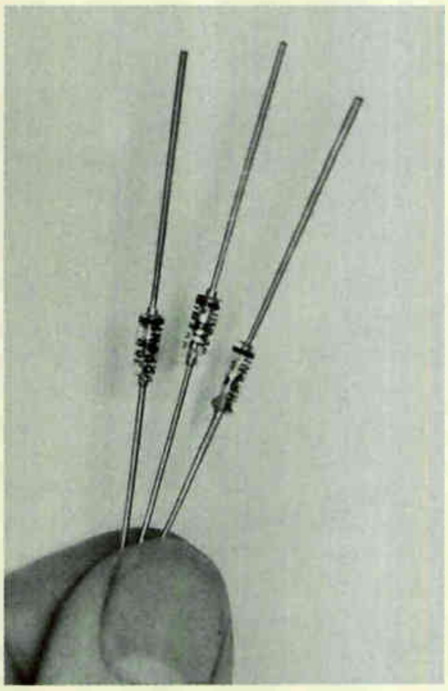


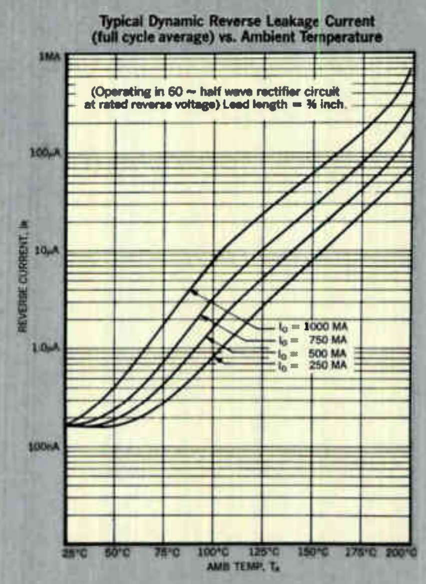
LOGICAL REPRESENTATION OF ONE SM-60,SM-70 FLIP FLOP
FIGURE 1

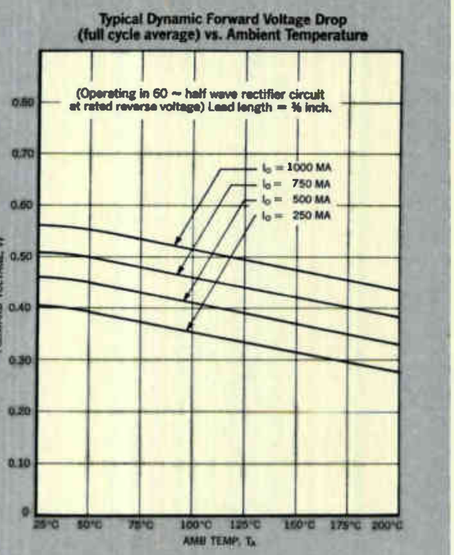


TEMPORARY STORAGE SUBSYSTEM
FIGURE 2

Absorb 1000-watt reverse transients with Sylvania's glass devices







Circuit designers are finding that Sylvania's glass rectifiers are better than other glass rectifiers. In this instance, the improved characteristics result in enhanced circuit performance and increased device reliability. Sylvania has coupled the inherent advantages of glass encapsulation with superior device design to make these glass diodes rugged enough for military applications. This designed-in dependability also makes this line of glass units an excellent choice for many other uses in computer, industrial and communications equipment. It is the improvements in device design that make Sylvania's glass silicon rectifier line stand out from other glass units.

In the improved devices, a large double diffused junction allows handling of 1000-watt reverse power transients while still maintaining the standard 50-amp forward surge capability. Sylvania's first glass rectifiers, can take outputs of up to 1 amp at reverse working voltage of 1000 volts without damage.

Heat dissipation is aided by welding a solid high conduction power lead to an oversized heat conduction stud. This enhances power handling capability while extending device life by keeping the unit cooler. The glass package is electrically neutral and smaller than many metal rectifiers, thus permitting greater stacking and card densities. With Sylvania's sealing techniques, the designer gets the benefits of improved device design without sacrificing any of the advantages of glass encapsulation. Use of a glass package means not only improved insulating characteristics but units that can be hermetically sealed. Radiflo leakage rate for these devices is less than 1×10^{-10} cc/sec. Low leak rates extend life and increase reliability. The glass body also enhances the thoroughness of in-process quality control by allowing visual inspection during production.

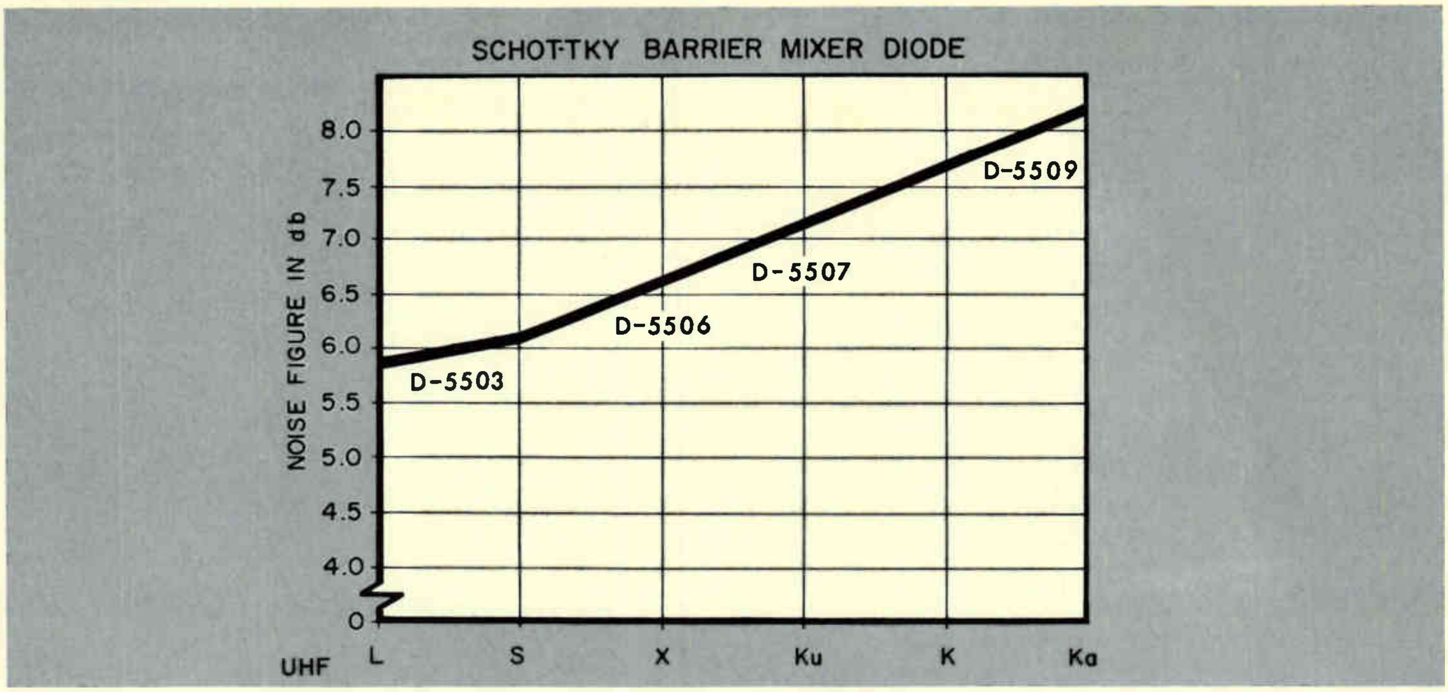
In addition to the ability to handle high reverse pulses, these rectifiers have low reverse leakage current. Typical rating is 10 na at 25°C ambient and rated reverse voltage. The high voltage rating and wide temperature operating range (−65°C to 175°C) capability of these units can't be matched by ordinary non-hermetically sealed devices.

All units in the Sylvania series are packaged in the conventional DO-29 outline. They are replacing existing glass, epoxy or top hat types in applications which demand higher reliability levels. These devices meet or exceed all the standard life and design requirements of MIL-S-19500.

CIRCLE NUMBER 302

ABSOLUTE MAXIMUM RATINGS:
−65°C to + 175°C — Resistive and Inductive Loads — Single Phase, half wave at 60 cps.

	Units	1N4383	1N4384	1N4385	1N4585	1N4586
Continuous Reverse Working Voltage, V_R	volts	200	400	600	800	1000
RMS Input Voltage, V_{rms}	volts	140	280	420	560	710
Average Forward Current, I_o	amps					
@ 50°C		1.0	1.0	1.0	1.0	1.0
@ 100°C		1.0	1.0	1.0	0.6	0.6
@ 150°C		0.3	0.3	0.3	0.2	0.2
Forward Surge Current, 1 cycle — $I_{F\,sur}$	amps	50	50	50	50	50
Forward Surge Current, Recurrent, $I_{F\,sur}$	amps	6	6	6	6	6
ELECTRICAL CHARACTERISTICS:						
Typ. Dynamic Forward Voltage Drop, V_F @ 1.0 amp	volts					
@ 50°C					.56	.56
@ 100°C		.52	.52	.52		
Typ. Dynamic Reverse Current, I_R @ V_R	μa @ 1.0 amps					
@ 50°C					.55	.55
@ 100°C		8	8	8		
Typ. Reverse Current, I_R @ V_R and +25°C	na	10	10	10	10	10
Typical Junction Capacitance — All Types — @ 0 V 80 picofarads; @ 10 V 21 picofarads						



Sylvania's Schottkys can take your designs through Ka-band...reliably

In last November's IDEAS, we announced MQM-packaged Schottky Barrier diodes that operate at frequencies through X-band. We have now extended the operating range of available Schottky Barrier diodes to include Ku-, K-, and even Ka-band. These newest diodes are also in the MQM package, and feature an even lower junction capacitance than their L-, S-, and X-band counterparts.

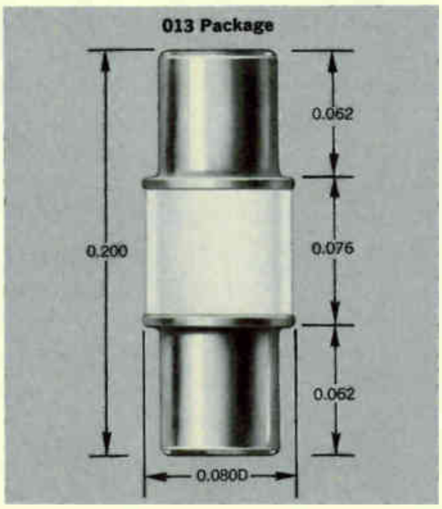
Effective coverage through the Ka-band (26.5 to 40.0 GHz) is only one of the outstanding features of Sylvania's Series D-5509 Schottky Barrier mixer diodes. To fully describe these new devices, one must combine the operating frequency performance with the extreme broadband capability having good burnout characteristics, and with an inherently low 1/F noise characteristic.

To get all this improved performance in one device means there must be not only an optimized semiconductor, but also an optimized package. The performance level of the D-5509 units shows they have both.

Sylvania's MQM package is the key to the broadband capability of these new units. Measuring only 0.08" x 0.20" overall, this package utilizes a low dielectric glass body hermetically sealed to precision mounting pins. The result is a package capacitance of only 0.08 pf allowing operation of a wide frequency spectrum.

In addition to its low capacitance, the MQM package features precise axial alignment of the mounting pins allowing precision design of miniature holders. Easy insertion and positive RF contact in holders are assured by a package design which has over 50% of its length devoted to circuit contact area.

Low junction capacitance of the diode permits operation in the Ka region. This low junction capacitance is the result of the superior alignment methods used in new Schottky Barrier diode processing techniques. The process employs epitaxial silicon to make devices with precisely controlled impurity distribution. In this improved method, a thin insulating layer and a relatively thick metallic contact layer over the barrier are used. The insulating layer and the superior mask alignment methods combine to produce the precise etching needed to make barrier regions of low capacitance. The metallic contact and pinpoint mask alignment maintain tight registration during metallization to give a reliable contact without increasing barrier region capacitance.



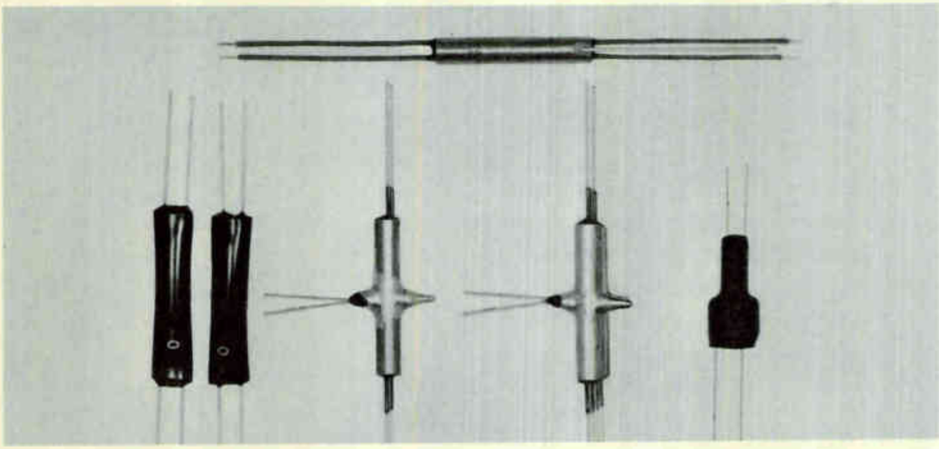
The low noise figures exhibited by the units in the D-5509 series (D-5509 = 10.0 db, D-5509A = 9.0 db, D-5509C = 8.0 db) result from the low series resistance of the diode. This low series resistance is obtained by keeping the epitaxial layer extremely thin, on the order of 1 micron. Because of the low 1/F noise characteristics of these units, they are ideal for doppler applications including police radar, proximity fusing, and traffic monitoring systems.

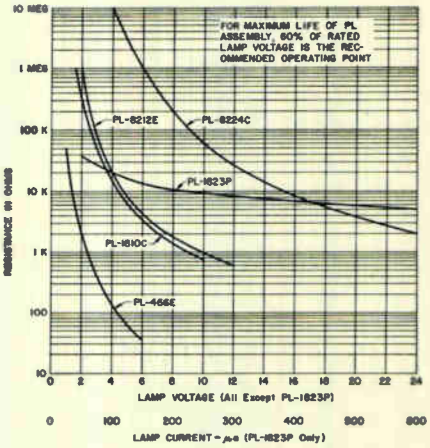
SYLVANIA'S SCHOTTKY BARRIER MIXER DIODES IN MQM PACKAGE

Frequency Band	S & C	X	Ku	K	Ka
Sylvania Series	D-5503 C	D-5506 C	D-5507 C	D-5508 B	D-5509 B
Minimum ONF	6.0 db	6.5 db	7.0 db	7.5 db	8.0 db

CIRCLE NUMBER 303

Combine lamps and photoconductors to get the function you need





Perhaps none of Sylvania's standard photoconductor-lamp (PL) assemblies fills your specific circuit requirement. Perhaps the new units that are coming don't include one that's just the right device. What do you do? Look for Sylvania's custom PL capability to get what you need, whether it be a simple detector unit or a combination of PL devices in one package.

Custom PL assemblies from Sylvania now allow circuit designers to implement many additional potential applications of photoconductor-lamp assemblies. A wide variety of possible photoconductor and lamp combinations means special assemblies can be designed to meet the most exacting requirements.

These custom assemblies take designers beyond the standard single-throw single-pole or double-pole types. Typical of one such custom design is an assembly containing two NE23 neon lamps optically coupled to three cadmium sulfide photoconductors. The photoconductors are enclosed in a lightproof metal cylinder and mounted perpendicular to the neon lamps.

Because Sylvania custom-designs, the company can offer PL combinations which more closely match the impedance level of the circuit they will be used in. For instance, with many entertainment manufacturers now becoming interested in all solid-state construction, Sylvania can deliver PL units that match impedance levels of solid-state circuits.

Availability of a wide variety of standard (shown in the table) and custom units erases limitations on the applications of PL assemblies. Because they have the characteristics of both a switch and a potentiometer and a response time in the millisecond range, they are unrivaled in many areas of remote control, low-level switching or potentiometry.

For example, for minimum hum pickup, the photoconductor can be soldered directly into an audio circuit to be controlled. Control can be achieved by varying PL lamp voltage from a remote location. PLs can directly replace switches and relays in any application within their power handling capabilities. Indirectly they can be used as triggering devices for higher power components.

Because of their time delay, PL assemblies are used extensively in the entertainment field to produce special musical effects such as tremolo and vibrato. Also, they may be used to regulate high voltage in color television receivers and for remote volume control in broadcast studio consoles. Industrial applications include performing AND and OR logic functions and the voltage control of time delay and frequency in monostable and astable multivibrators. Used with silicon controlled rectifiers, they can provide low-voltage isolated control for high-voltage loads.

CIRCLE NUMBER 304

	PHOTOCONDUCTOR								LAMP	
	Voltage (Volts)1,2	Dissipation at 25°C (MW)1	Light Resistance (Ohms)3	Dark Resistance (Megohms)4	Ascent Time (MS)3,5	Descent Time (MS)4,6	Shunt Capacitance (pf)7	Coupling Capacitance (pf)8	Rated Voltage (Volts)	Rated Current (MA)
PL-466E	400	300	35	0.3	55	17	4.944	0.433	6	35–45
PL-1810C	300	75	800	10.0	75	20	0.550	0.264	10	15–20
PL-8212E	300	75	700	10.0	55	17	0.960	0.229	12	35–45
PL-8224C	300	75	1500	10.0	55	17	0.740 (case grounded) 1.141 (case not grounded)	0.017 (case grounded) 1.070 (case not grounded)	24	15–20
PL-1823P	300	75	2750	10.0	50	12	0.700 (case grounded) 1.030 (case not grounded)	0.025 (case grounded) 0.905 (case not grounded)	90 (Breakdown), 59 (Operating)	0.3

AMBIENT OPERATING TEMPERATURE RANGE: —40° to +70°C

NOTES:
1. Absolute maximum rating system.
2. Measured with photoconductor in complete darkness at a pulse rate of 120 pps, 50 μs duration. Voltage in excess of rated may damage the photoconductor. Maximum DC voltage is limited by maximum dissipation and minimum dark resistance rating.
3. Measured at rated lamp voltage.
4. Measured 10 seconds after removal of rated lamp voltage.
5. Time to reach 63.2% of illuminated photoconductor current after application of rated lamp voltage.
6. Time to reach 36.8% of illuminated photoconductor current after removal of rated lamp voltage.
7. Measured across photoconductor leads (leads parallel to major axis) at frequency of 456 kc.
8. Measured between photoconductor and lamp leads (photoconductor leads tied together—lamp leads tied together) at frequency of 456 kc.

How a philosophy breeds IC reliability

As an engineering manager on the production side of integrated circuits, I'm necessarily involved in every facet of IC manufacturing and quality control. Occasionally, though, I'm asked to squeeze extra time into the day's occupation for, what is to me, an enjoyable diversion—showing and explaining our Woburn, Massachusetts, facilities to people who have a professional interest in ICs.

I'd like to comment on a couple of points that frequently come up in our discussions. The first is on reliability through hermeticity, especially as it relates to the dual in-line plug-in package. The second point deals with what we at Sylvania feel is a unique IC manufacturing philosophy.

The Sylvania dual in-line plug-in package was designed and constructed with the same reliability criteria in mind as the Sylvania flat pack. It is understood, then, that the cross-sectional appearance of the dual in-line package is very similar (except in size) to the flat pack.

The dual in-line (DIP) features a kovar bottom sealed to an alumina-filled glass construction in which the kovar leads have also been sealed. All of these seals take advantage of the technology gained from the kovar-to-glass seal originally developed for transistors. This is the classic kovar-oxide-glass combination. The package integrity that is achievable with this technology has been an established fact for many years.

The high degree of hermeticity that has become standard in the industry for such older packages as the TO-18 and TO-5, is now being achieved with the Sylvania DIP construction. The one significant difference between the older transistor metal packages and the DIP is the fact that the seal length (a possible leak path) is much longer than that encountered in the metal package. If anything, this would seem to lead to an even greater hermeticity capability.

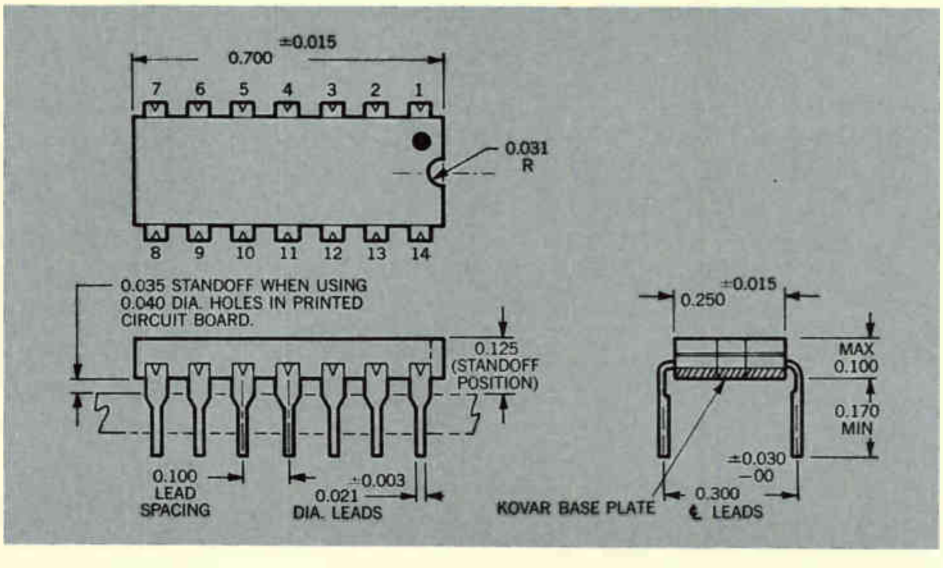
The cover of the DIP is made out of the same material as the body with the seal being a pyroceram frit. As a result of the use of these materials, the Sylvania dual in-line package is composed of thermally matched seals throughout its construction.

The integrated circuits manufacturing philosophy at Sylvania has always been to manufacture all circuits with identical care and a high degree of workmanship. Therefore, in the final analysis, Sylvania circuits need only be graded by their industrial or military capabilities as determined in the 100% final test. All Sylvania integrated circuits go through a sequence of reliability tests during their manufacture. These tests are applied after sealing the package in the following order.

First, each IC package is subjected to five cycles of –65°C to +200°C thermal cycling with fifteen-minute soak times at each of the temperature extremes. This test is assurance to both Sylvania and its customers that the package will withstand demanding stresses after sealing. Second, all packages are subjected to a 20,000 G centrifuge test while they are in the Y_1 plane. This test insures that the wire bonds have also been subjected to a mechanical stress test. Third, all packages are bubble-tested in 150°C glycerine for any leaks that might have come about as a result of deficient sealing or due to the package stress tests discussed above. Fourth, all integrated circuits are stabilization-baked at 300°C for 48 to 60 hours. Fifth, all Sylvania circuits are subjected to the worst-case DC tests at the temperature extremes guaranteed and also for all parameters which are called for on the Sylvania data sheet or in the customer's specifications. The ultimate electrical capability of each and every integrated circuit is tested at 75°C, 125°C, –55°C and 0°C for DC parameters. Following that, every unit is tested for all dynamic characteristics at switching. This is done in Sylvania's fully automatic test equipment at the rate of one circuit every two seconds. This equipment has been dubbed "Mr. Atomic" Multiple Rapid Automatic Test Of Monolithic Integrated Circuits). It is only as a result of the test performance in "Mr. Atomic" that any differentiation between military and industrial capability is made.

Each lot of integrated circuits is then held in quarantine for quality audit of the capability of the lot. During this audit, random samples are drawn for electrical parameter check and also for a hermeticity check. The latter is performed with Sylvania's radiflo equipment. This equipment uses radioactive krypton for a tracer gas and is the most efficient means available today for determining the fine leak rate of hermetically sealed packages with sensitivity to at least $1x10^{-12}$ cc/sec/standard atmosphere.

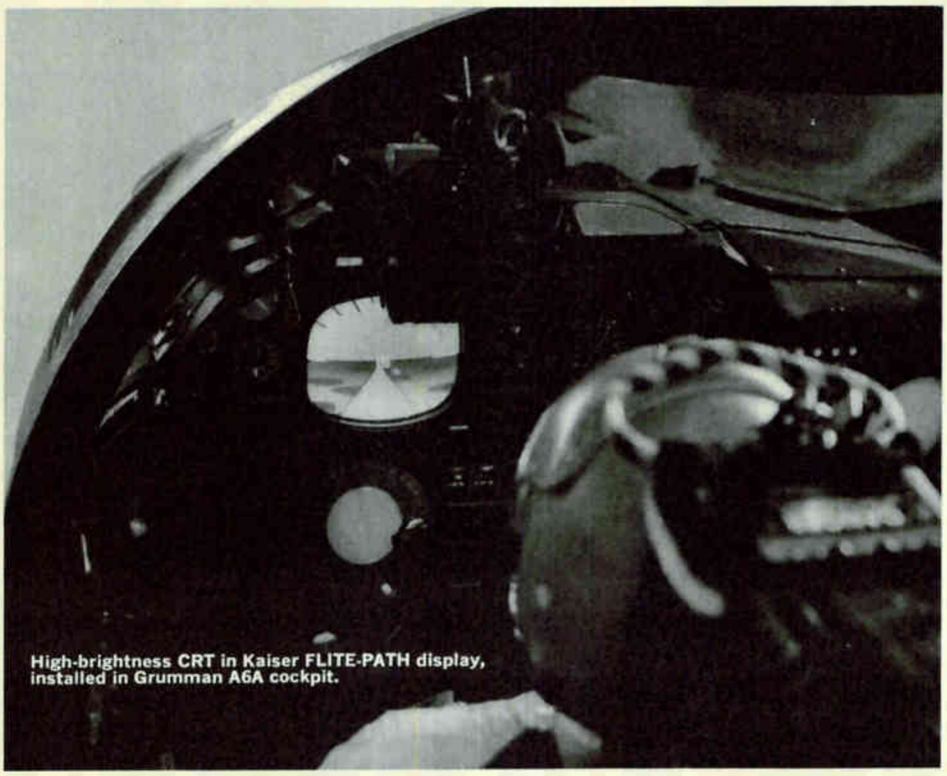
It is only after the complete circuit tests and package mechanical and hermeticity tests described above have been performed that Sylvania integrated circuits are shipped to our customers.



Henry Styskal

HENRY STYSKAL

New high-brightness, high-resolution tubes customed to your needs



High-brightness CRT in Kaiser FLITE-PATH display, installed in Grumman A6A cockpit.

What size high-brightness, high-resolution CRTs do you require for your aerospace equipment? Now, chances are you can get precisely the right devices to fulfill this need. You can, that is, if you consider Sylvania's new family of customized high-brightness, high-resolution CRTs. We've already made many variations of the basic unit. Each still retains the superior performance characteristics of the basic design. We'll use this same custom capability to build you a CRT tailored to meet your specific needs.

Sylvania's new family of custom high-resolution, high-brightness CRTs makes possible displays which are clearly visible even in ambients of high light levels. Combine this high-brightness, high-resolution capability with the ability to stand high altitudes and you get an ideal aerospace display device.

Other high-brightness tubes in this line can enhance quality of displays used in shipboard command systems, battlefield surveillance equipment, tv monitors or just about anywhere conventional CRT displays are washed out by high reflected or direct ambient light.

One important use of this new type tube has been in fighter aircraft for Vietnam. In the aircraft, a high-brightness cockpit display uses an 8" version of the tube to get an electronic photograph of the horizon. The picture the pilot sees is computer-generated by radar to give him a fix on the terrain.

Other customized versions of this tube may be the answer to your display problems. While usual applications for this family range from 3" to 8" screens, Sylvania will design and build tubes to your specific requirement.

Typical of these new tubes is type SC-4649A, with a rectangular screen having useful dimensions of 4⅜ x 5¾ inches. Key features of this unit include a high voltage gun of improved design and a neck diameter of 0.870 inches. Encapsulated leads insure reliable operation at high altitudes. Typical operating conditions show a brightness of 1.000 foot-lamberts minimum at 225 μa of anode current.

The SC-4649 series uses high voltage electrostatic focus and magnetic deflection with deflection angles of 70 degrees. An aluminized P31 phosphor gives a green fluorescence with a medium short persistence.

In addition to the SC-4649A, other versions of this series (SC-4649B through F) are available with various combinations of faceplates and bonded shield cover panel.

CIRCLE NUMBER 305

SEE OUR SPECIFICATIONS IN VSMF MICROFILM CATALOG FILE

Use Sylvania's "Hot Line" inquiry service, especially if you require full particulars on any item in a hurry. It's easy and it's free. Circle the reader service number(s) you're most interested in; then fill in your name, title, company and address. We'll do the rest and see you get further information almost by return mail.

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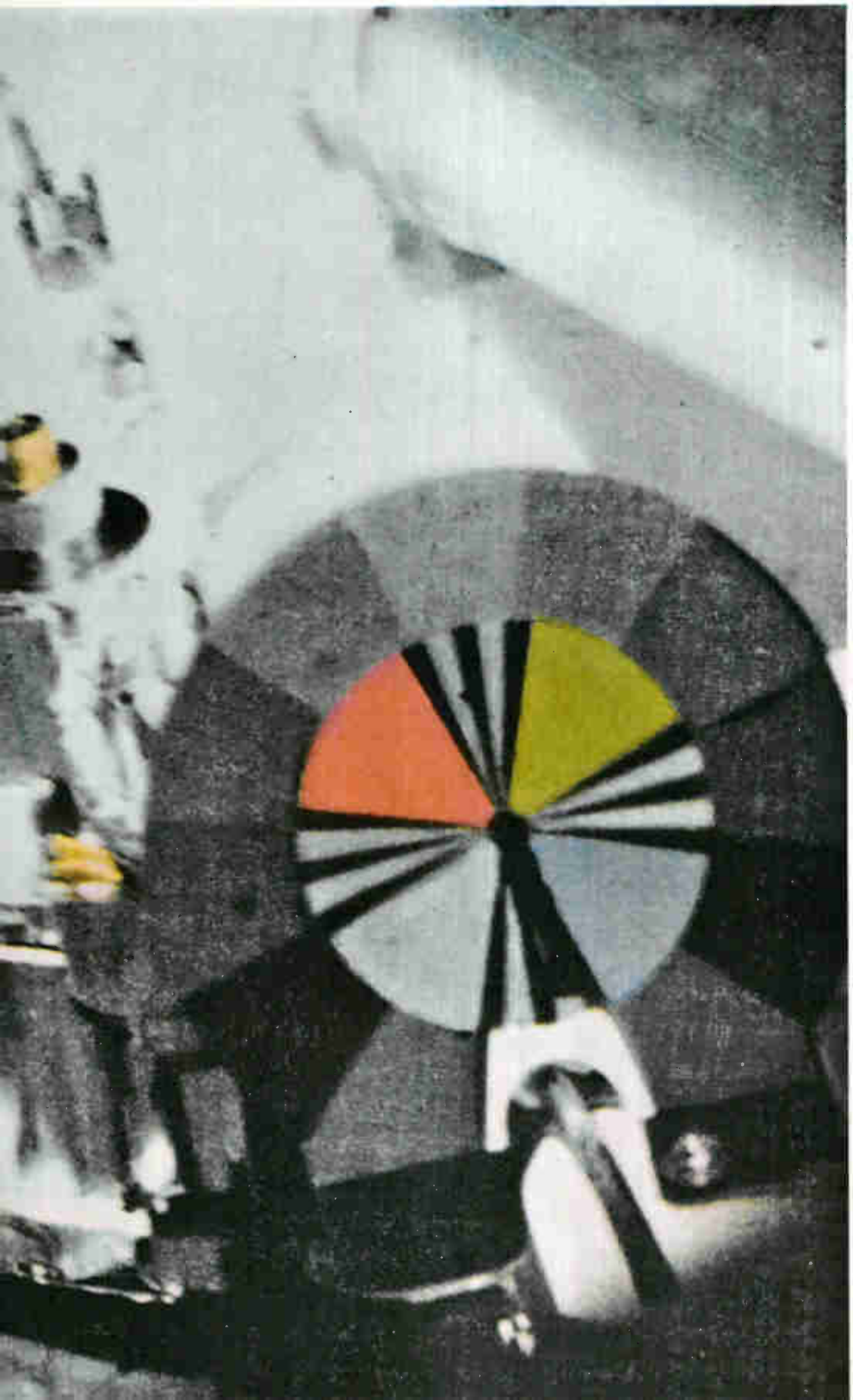

Our Kemet solid tantalum capacitors were among the least delicate components to soft-land on the moon. And, though the lunar night is −254° F. . . we survived.

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Circle 35 on reader service card

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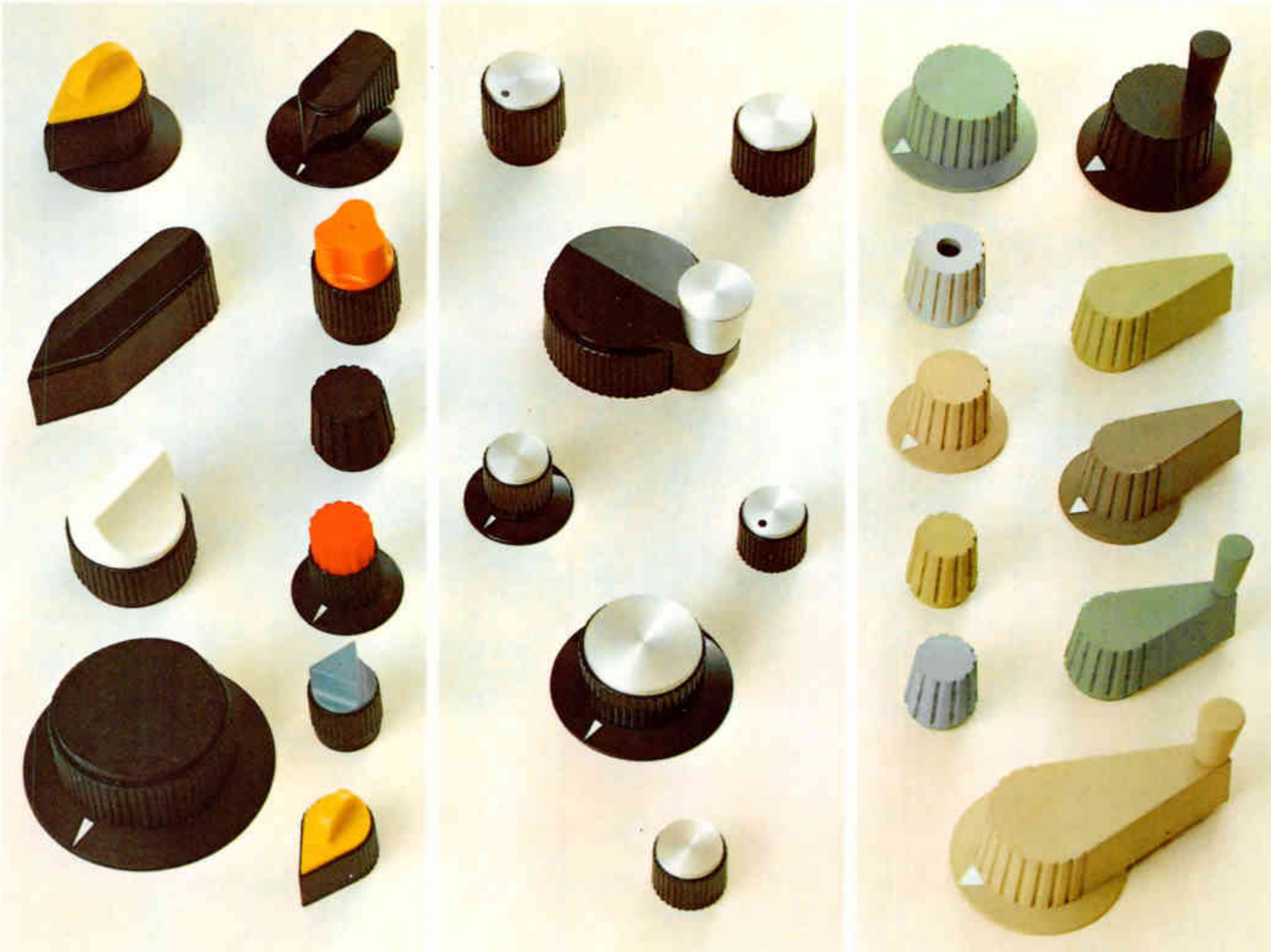

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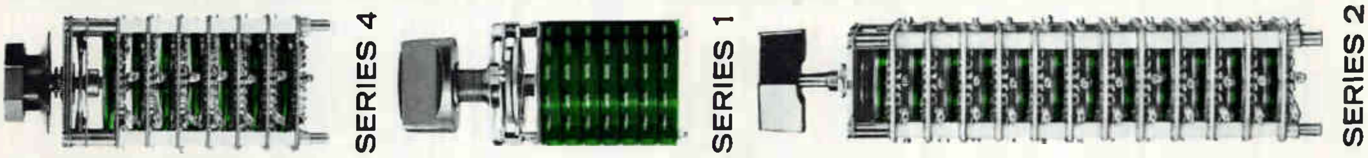

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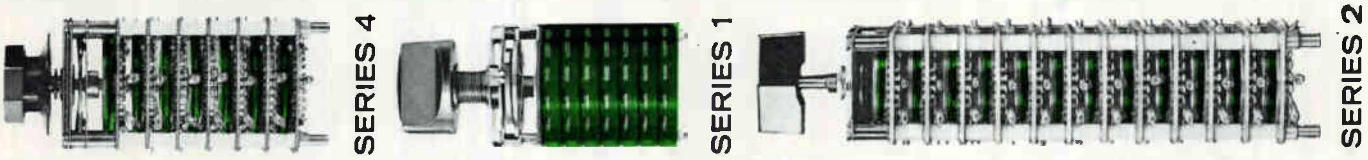

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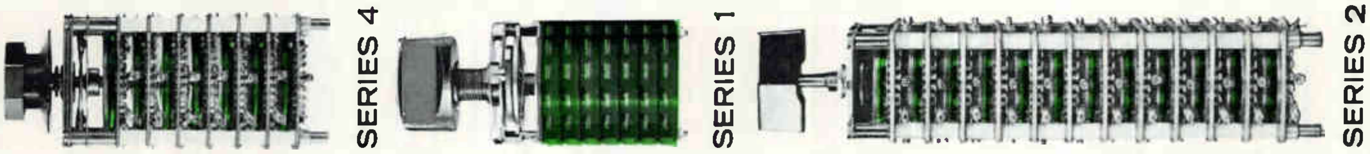

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Circle 263 on reader service card

Electronics Review

Volume 40
Number 1

Manufacturing

The perfect bond

Three years ago, Honeywell Inc. tantalized other producers of integrated electronics systems by claiming it could get perfect molecular-diffusion bonds between an integrated-circuit chip and its leads. But Honeywell wouldn't say how it performed the trick [Electronics, Feb. 14, 1964, p. 70].

Now, one of Honeywell's rivals in aerospace electronics, Westinghouse Electric Corp., shares the secret and plans to use it to prepare multifunction assemblies of IC chips for military systems.

Whether Westinghouse puts the technique into production depends on whether it receives military funding for further development, according to Charles Denton, manager of the mechanical design group of the Westinghouse Aerospace division in Baltimore. He says that a proposal for a military contract has not yet been made, but that discussions are being held with the Naval Air Development Center in Johnsville, Pa., and with the Rome Air Development Center, Rome, N.Y.

The bonding method eliminates the usual interface between chip and lead materials and allows face bonding without the usual raised bump, ball or pad contacts. Any IC chip can be used, as long as the thin-film terminals on the chip are aluminum. The leads applied to the chip are fingers of nickel, coated with an aluminum film that fuses into the film on the chip.

Finger frame. The nickel fingers, 2 mils thick, support a 10,000-angstrom aluminum film that is the actual lead conductor.

To make them, sulfomate nickel is deposited 2 mils thick on a polished plate of stainless steel and then etched into the desired lead pattern held together by a frame of nickel. After the aluminum is deposited on the nickel and heat-treated to make it adhere, the fingers and frame are stripped off the plate.

The fingers are positioned on the chip and bonded with a special parallel-gap welder. The assembly is heated to 300° C. Current from a programed welding supply is passed through a fingertip, heating the joint to 600° C as the welding electrodes press the two aluminum surfaces together. A 2-millisecond surge of current heats the joint above 600° C and the bond is made. Finally, the current is gradually eased down until the assembly has cooled to 300° C again. It all takes 150 milliseconds.

To make the bonding electrodes, a thoriated tungsten rod is ground into two identical halves with a tip radius of 2 to 6 mils. The gap between the electrodes is set by inserting a sheet of split mica, about ½ mil thick, between the two halves.

Bonds as small as 2 mils in diameter have been made, and because the bond has no interface, the fingers will break before the bonds fail. One reason the bonds are so effective is the half-moon cross-

A paper loss

A technical paper on Honeywell Inc.'s diffusion-bonding process was to have been a star attraction at the Society of Automotive Engineers' Electronic Packaging Conference next month—but nowhere in the paper was Honeywell's name mentioned.

Suddenly last week, the picture changed.

The author, Fred Walton, a former Honeywell engineer currently employed by the Westinghouse Electric Corp., withdrew his paper. Recently Walton published—despite Honeywell's protests—a paper describing a packaging system. The system turned out to be Honeywell's Micpak.

In publicizing the technical session, the society issued this description: "A unique specific technique for producing highly localized monometallic monolithic diffusion bonds suitable for microelectronic interconnection and packaging techniques will be described by Fred Walton of Westinghouse Defense and Space Center, Baltimore. This highly localized diffusion bond approach provides a bond reliability at the subsystem level comparable to that formerly available at the component level."

Honeywell, a spokesman has indicated, is displeased by Walton's actions. Walton's rejoinder is that his work on the techniques was funded by military contracts—the Air Force's Rome Air Development Center, Rome, N.Y., paid for the bonding work, he says, and the Naval Air Development Center, in Johnsville, Pa., sponsored Micpak. Honeywell funded the silicon multilayer board work.

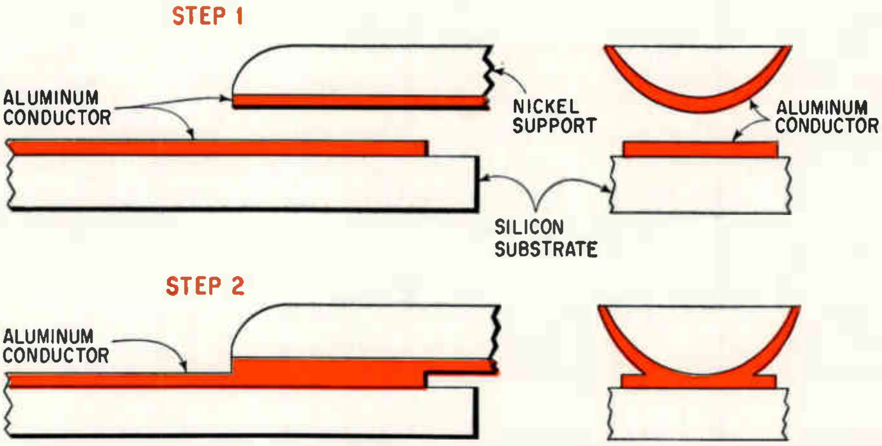
Walton says he left Honeywell after working three and a half years on the processes at Honeywell's Aeronautical division in St. Petersburg, Fla. He left because he was convinced Honeywell would not put Micpak into production, after some $400,000 had been spent. Westinghouse, he adds, does plan to use the process, and may invest up to $700,000 on its version of the packaging technique.

In rebuttal, Honeywell says that while the Micpaks "will probably not be used as such, the techniques gained will probably be employed in the future." While the spokesman confirms that it has not authorized detailed reports, Honeywell has submitted a report to the military. Honeywell began work on the processes before it got the contracts, the spokesman continued, and both company and military funds went into the research and development.

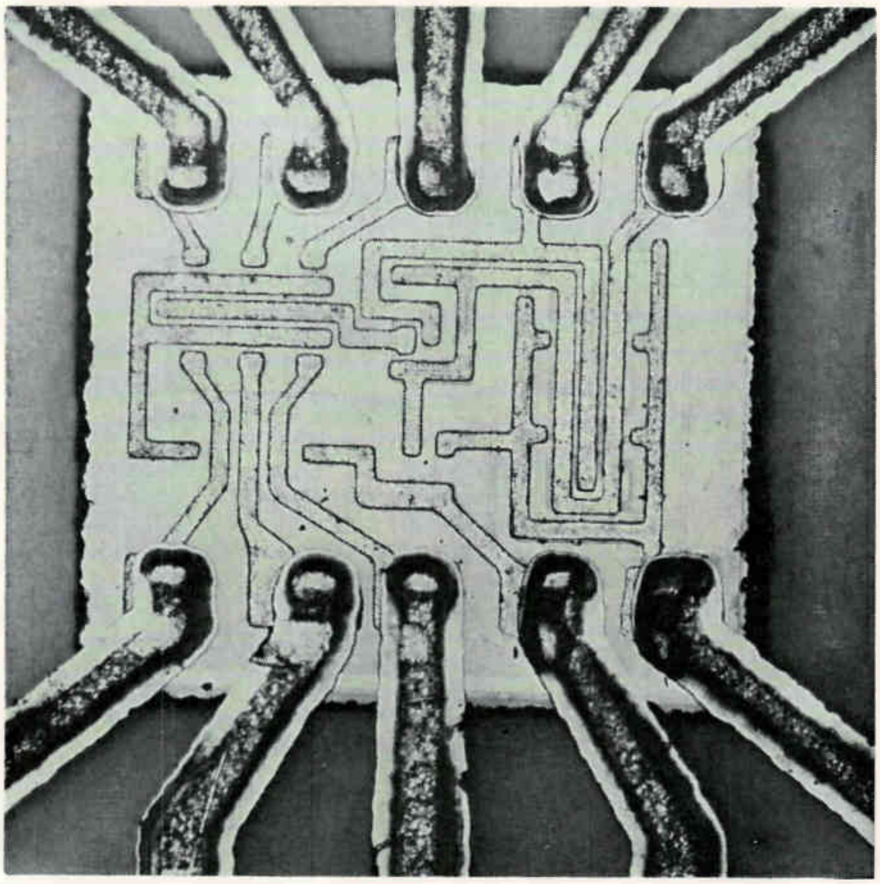
section of the fingers, seen in the diagram. As the round side presses down, surface gases and oxides are squeezed aside while diffusion of the aluminum is aided by plastic flow and some evaporation and condensation.

Silicon wiring. After the fingers are bonded to the chip, the other ends of the fingers can be bonded to aluminum wiring on a substrate that interconnects many such chips. The chips can be placed face-down on a flat substrate, or into channels in the substrate alongside the wiring.

Such assemblies are used by Honeywell in its Micpak packaging system. Honeywell has also demonstrated the bonding of groups of chips to a silicon-crystal equivalent of a multilayer circuit board. The substrate, processed like an IC but without devices, contains a low-resistivity ground plane of p-type silicon, a high-resistivity p-type epitaxial layer with n-type diffused crossover conductors and thin-film surface bonding pads and conductors joined to the crossovers through windows in an oxide layer.



Interface-free bond is formed when molecules of aluminum film on the chip diffuse with those in the film on the substrate. The diagrams are before (top) and after views and cross-sections along the finger (left) and through the fingertip.



Chip and finger subassembly, ready for bonding the finger ends to an interconnecting substrate. The chip can be bonded face-down to the substrate or be inserted in channels in the substrate.

Big little packages. Westinghouse plans to use miniature multilayer ceramic boards for IC interconnection. These will be sealed, along with discrete devices, in a 1-inch-square package with 68 leads. The bonding is being done one finger at a time on a pilot line, but Westinghouse plans to qualify the process for military systems and install automatic production equipment. It hopes to develop simultaneous bonding of many leads.

The two companies are not alone on the chip and finger trail. International Telephone and Telegraph Corp. has been developing a similar lead-bonding technique [Electronics, July 12, 1965, p. 98]. And Bell Telephone Laboratories Inc.'s beam-lead technique fabricates lead fingers as part of the chip-metallization process [Electronics, June 28, 1965, p. 68, Nov. 16, 1964, p. 114, and Dec. 26, 1966, p. 111]. Bell's technique is being adopted by several firms.

Military electronics

Litton's loss

A nearly $20 million program to modernize the Air Force's ground-to-air communications network, 495L, has been terminated suddenly and without explanation. Late in December the Air Force said that as of Nov. 9, 1966, the contract with the Westrex Communications division of Litton Industries Inc. had been ended "by default."

The move apparently didn't catch Westrex by surprise. Only a month earlier, the division underwent a major overhaul: the top man, general manager Charles T.

Johnson, left the company. Litton brought in a new man, Joseph Smith, and upgraded the post to president of the division.

No details. Smith himself declines to elaborate on the reason for the contract cancellation, explaining that it would be inappropriate to discuss the details prior to an appeal that Litton has filed.

The cancellation is the second within three months involving a major contract for an L program—the designation given to command and control systems under development. The earlier termination involved the 473L program, an Air Force command information system [Electronics, Sept. 19, 1966, p. 201].

The decision to junk the 495L program reportedly wasn't made by the program director, Electronic Systems Division at Hanscom Field, Mass., but at a high Pentagon level. According to one industry source, the Air Force division commander, Gen. John W. O'Neill, was ordered to cut off the program.

Apparently by coincidence, the Westrex cancellation occurred at about the same time an Air Force evaluation team at Hanscom Field was completing work on contract-definition proposals of Litton and the Hughes Aircraft Co. for data-collection centers to be used in the tactical air control system, the 407L. Hughes eventually won the $68.5 million production contract [Electronics, Dec. 26, 1966, p. 26].

On schedule. Smith said Westtrex has an $12 million contract with the Army for delivery of equipment similar to that of the 495L and that this job is proceeding "pretty much on schedule."

Westrex's president conceded that during the negotiations for the data centers the "495L question was raised," but he asserted that the military "specifically assured Litton that there was no prejudice" in the case.

The 495L program relies heavily on high-frequency, single-sideband as a primary mode of air-to-ground links. The original order, placed with Westrex two years ago, was for about $9 million. This was subsequently raised to about $15.5 million and would have gone to more than $19 million, Smith explained.

The goal of the 495L program was to upgrade the technical capability of the existing communications system, particularly for better control of the worldwide airborne fleet and to provide digital data communications. Also included were plans to extend coverage of the network to additional military users and expand the number of stations to serve additional areas of the world. The prime contractor was to equip at least one new ground station for the network, install additional equipment at existing stations and provide for integration of the existing and new subsystems.

A spokesman for Hanscom Field declined to disclose how much money has been paid to Westrex under the program.

The information officer for the user command, the Air Force Communications Service at Scott Field, Illinois, said that none of the systems developed under 495L has been turned over for operational use. He said the Air Force now plans to upgrade the worldwide ground-air system by procuring off-the-shelf hardware as needed.

Inventory gear. Westrex president Smith said he understood the Air Force will use "inventory gear" and this, he said, will mean "less capability by a long shot in sensitivity, tuning and in overcoming intermodulation loss."

According to Smith, the Air Force is buying some of the materials, such as antennas, from system subcontractors.

Smith said the first of 20 subsystems was to have been delivered in March with deliveries of two per month after that, and contract completion by the spring of 1968. In each case, he said, the equipment would have been unique.

Service rivalry

Ask an Air Force electronics procurement officer what he thinks of TX, or "testing extra," and he no doubt will tell you it's one of the most efficient and economical procedures around for assuring semiconductor reliability. Ask his Army or Navy counterpart the same question and he'll probably say, "It's ok, but . . ."

The Air Force, which has been pushing the concept of TX for the past four years, maintains that it provides a tenfold improvement over conventional sample-testing methods and costs only a little bit more.

Reluctant move. At the persistent urging of the Air Force, the other two military services have reluctantly gone along with TX, but only for a few selected orders for transistors, diodes and rectifiers. The Air Force, on the other hand, has applied the testing technique to major orders: the F-111 and G-5A aircraft and the 487L communications system. (For more on the history of TX, see the panel below.)

Tx specs, the Air Force says, fill the gap between the loosely regulated but inexpensive sample-testing procedures, and the expen-

A slow start

Since the early 1950's, the Air Force has mulled a plan to test all components of new systems under full power, measuring the variations to screen out defects. But it was not until the F-111 program got under way three years ago that the idea was put into effect.

Engineers at the General Dynamics Corp., F-111's prime contractor, at that time drew up specifications for the aircraft around the testing-extra concept, and W.F. Stevens and his staff at the Air Force System Command's technical requirements and standards office, edited these specs only slightly before adopting them for Air Force-wide use.

Tx standards have since been applied to the Mark 2 avionics system for the F-111, the C-5A transport plane and the 457L Strategic Air Command communications system; next on the list is the new short-range attack missile (SRAM).

Air Force officials are already considering TX testing of integrated circuits; they maintain that such testing would be valid if IC designs were ever frozen. However, the other services oppose the idea on the ground that the setting of TX standards for IC's could stifle technical progress in the field.

TX versus ER

The present ER, or established reliability, standards for components haven't been basically altered since they were developed four years ago for the Minuteman missile program.

They differ from TX standards principally in that they require serialization of each component, a system involving extensive, and expensive paperwork. This procedure allows the user to trace a faulty component's full history back to its manufacturer.

Another difference is that ER standards require lifetime testing of samples before components are shipped so that a mean-time-between-failure can be figured. Components covered by TX standards can be supplied to users immediately after a burn-in lasting from 72 hours to a week. In addition to the burn-in, TX components are tested before and after high-temperature storage and high-temperature cycling.

sive ER, or established reliability, method. Tx standards require that all components survive from 72 hours to a week of burn-in before shipment, while ER standards provide for a complex series of trials, including lifetime sample tests that may last as long as three months. Under the TX procedure, an entire batch of components is thrown out if 10% or more fail the "infant mortality" burn-in.

The Army and the Navy generally view the TX concept as just another test procedure in a field already crowded with some 213,000 reliability specs. But proponents of TX contend that the method is more logical than ER because components are most likely to fail in the early stages of use. Generally, reliability statistics bear out this contention.

Dollars and cents. The most striking argument offered by TX supporters is the Air Force's experience with it on the F-111 program. Conventional testing of a resistor for this program would have cost 53 cents, they say, whereas TX testing produced a reliability level nearly on a par with ER at a cost of 4 cents a component.

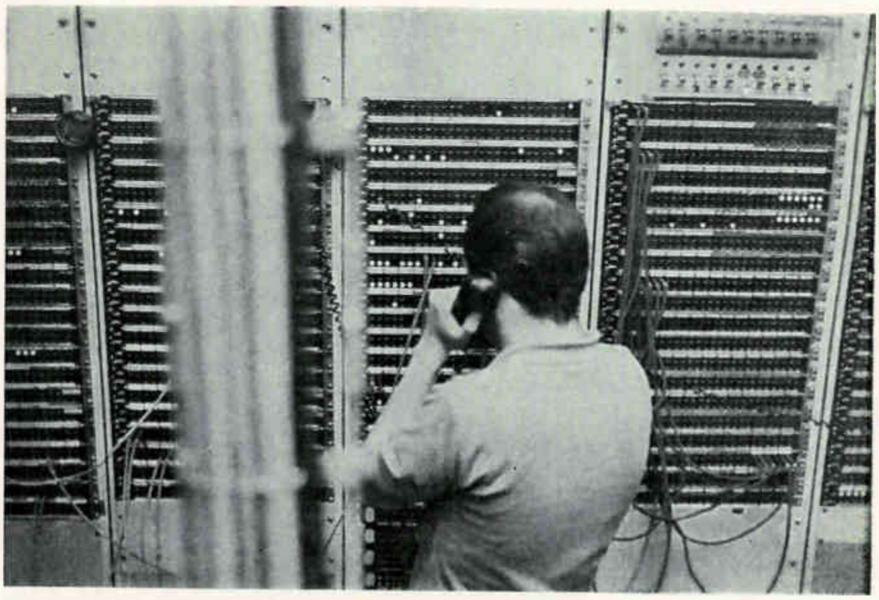
Further, says the Air Force, one subsystem in the F-111 has already exceeded a mean-time-between-failure of more than 4,000 hours, though the specs called for only 150 hours.

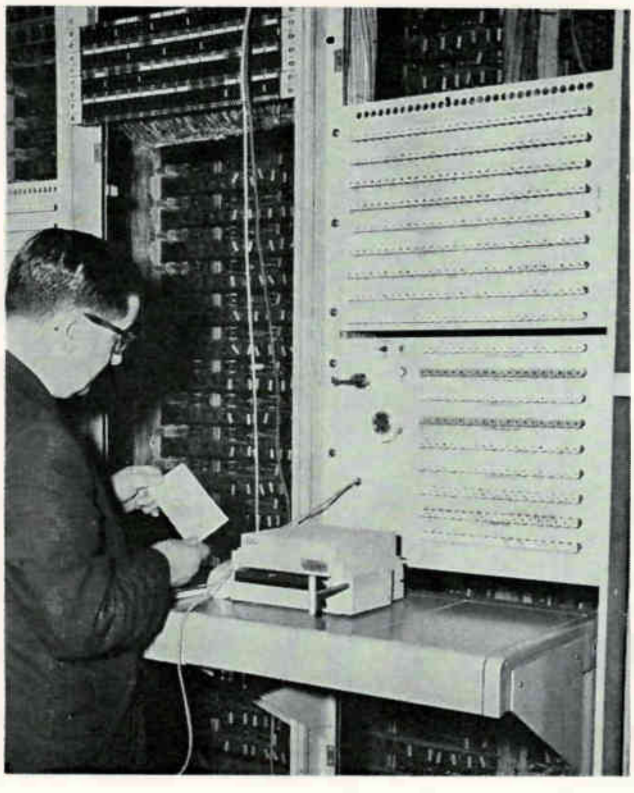
The Air Force wants to establish TX not just to assert itself but to cut costs. It holds that if all the services adopt TX standards, dropping many of the other specs, manufacturers will be able to plan longer production runs, reduce inventories and, therefore, sharply cut component prices.

Communications

Touch and go

The major obstacle to rapid consecutive missile launches has been the tangle in communications. It takes several technicians four or five hours to manually patch circuits for communications between the control center and different launch pads. Now, the Air Force has installed a push-button switch-





Manually patching complex communication lines for a missile launch is tedious. A technician (above) spends hours connecting circuits to establish communications between a launch control center and a launch pad. However, in a system designed by Western Electric (left), push buttons and punch cards switch all communications in less than five minutes.

ing system at the Western Test Range at Vandenberg Air Force Base, that cuts the time between shots to under 5 minutes.

Eventually the switching system, built by the Western Electric Co. for $6 million, will enable the range to monitor simultaneously four countdowns instead of the two it can handle at present. "The rapid turnaround and improved communications osc department.

The system consists of five switching matrixes that link the control center to 30 launch pads, radio facilities, telephone lines and range instrumentation. This is in addition to existing telephone communications and data links. Lines are immediately ready to use when switched. For every link there are alternate routes.

Far ranging. Two sets of 260-line switches provide separate voice links for controllers and such range users as the Air Force Systems Command, the Strategic Air Command and the National Aeronautics and Space Administration. Another 100-line switch connects radio links, establishing communications with downrange sites on Hawaii and ships and planes in the South Pacific. One switch interconnects about 30 sky screens to monitor the initial phases of liftoff.

All switches are controlled by push buttons at the control center. Telephone communications can also be switched by inserting a prepunched IBM card into a desk-top multiple contact reader. Holes in the card permit contacts to close various points on the switching matrix, making the desired connections. These telephone switches can make 40 connections at one time—either point-to-point or conference calls. If necessary, all 260 lines can be linked in a conference call. Because technicians don't patch manually, communications are more reliable. "The costs of a missile program make it imperative to have satisfactory communications," says Charles Edmondson, an engineering supervisor at the Vandenberg range. "It doesn't matter how good the missile is, if you can't talk, you're dead," he asserts.

No punch. A similar system—built by the Westrex Communications division of Litton Industries Inc.—is in operation at Cape Kennedy. The system consists of two switching matrixes—one 300-line matrix for two-wire communications and a 600-line matrix for four-wire communications. The matrixes are independent and cannot be interconnected. The 600-line matrix contains provisions for conference calls and is completely nonblocking, that is, a connection can always be made. Punched cards can switch the entire system in about 30 minutes.

However, Robert Smith, project manager in Westrex's systems engineering department, says that in a typical launch it would take about 10 minutes to switch the lines since only 200 to 300 lines have to be connected.

In the Westrex system, the 300-line matrix is used for base communications and also serves as an emergency backup if regular communications fail. The 600-line phone system is the normal equipment for range and down-range communications.

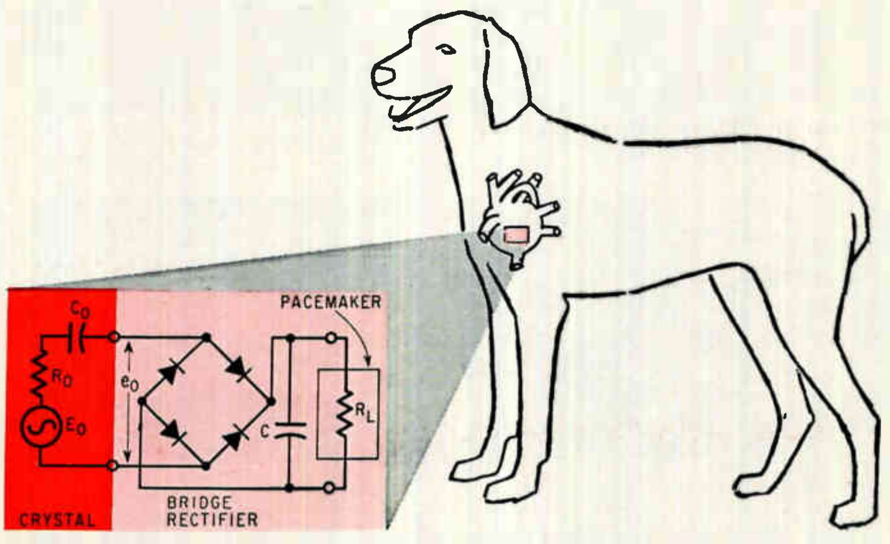
Medical electronics

Heartfelt power

Were it not for the fact that the batteries of cardiac pacemakers require replacement every few months, the tiny implanted instruments could go on steadily triggering the beat of a sick heart for years without adjustment. To get around the power-source problem, researchers have experimented with a dozen or so techniques to convert kinetic energy—of either the lungs or the heart itself—into electricity to run the pacemaker, but each attempt has run into fundamental problems. Now two researchers at the Case Institute of Technology in Cleveland have developed a technique that appears to sidestep these problems.

Power converter. The medical electronics engineers, Wen H. Ko and Michael Neuman, have borrowed one of the basic elements of the motion-to-electricity conversion technique: the piezoelectric wafer. But instead of physically attaching one end of the wafer to the moving heart, they have simply placed it near the organ. In essence, the wafer, built into an enclosure, forms a resonant chamber much like the inside of a drum. Hence, steady motions of the heart are converted into sound waves that drive the wafer and produce a small current. The technique has already been successfully tested in two dogs.

What is particularly attractive about this process is that the wafer doesn't make contact with the heart. In earlier experiments in which contact was made, the heart



Sound waves generated by the beating heart provide enough power to generate a current to operate a cardiac pacemaker.

eventually adjusted itself at the point of contact until the wafer was no longer deflected. In the Ko-Neuman technique, the natural movement of the organ isn't affected. In addition, the instrument used can be made so small that it can be implanted directly inside the heart, the researchers say.

Beam shaped. In the unit, a ceramic wafer shaped like a cantilever beam is housed in a small enclosure. The enclosure prevents body fluids from shorting out the high-impedance crystal; the beam is weighted at one end and anchored at the other. The impact of the heartbeat causes the weighted beam to resonate, or vibrate, at a frequency that corresponds to the mechanical driving source, producing a train of electrical pulses.

The researchers have made use of the crystal's capacitance by adding a voltage doubler circuit externally. The energy converter, constructed of Clevite PZT-5H crystal, measures only 2 by 5 by 1 centimeters. At a 80 pulse-per-minute-rate, the maximum output is 4 volts into a 10^5-ohm load. This power—160 microwatts—is more than enough to drive a pacemaker.

Avionics

Only make believe

The obvious way to test the experimental design of an airplane is to build a prototype and fly it. That's the expensive way. A much cheaper method is to work out a mathematical model of the design and crank the information into a computer for simulation. The one drawback here is that the results are totally dependent on the assumptions made in the mathematical model. North American Aviation Inc. has just won a $5.6 million Air Force contract for a design that combines the two techniques: it will develop what's called a variable stability system (VSS) for a test plane that, in effect, makes it act like any other.

Specifically, the North American contract calls for a control system for a vertical takeoff and landing (VTOL) aircraft, a modified Hummingbird 2. About 250 controls in the system will be adjustable, so that by flipping a few switches and dials, the Hummingbird can be converted into any number of other experimental planes. Further, any combination of designs for such parts as wings, tails, or fuselage can be tested in flight.

Changing response. According to William T. Barker, program manager at the Los Angeles division of North American, the 250 adjustable variables will integrate 5° of freedom: roll, yaw, pitch, lift and thrust. Adjusting the variables alters the response of the aircraft, causing the handling characteristics to change.

The ultimate purpose of the VSS installation in the Hummingbird is to generate data for writing a comprehensive military specification for VTOL aircraft, provide a test bed for design theories and to provide design information on aerodynamics and controls. The VTOL specification will describe flight characteristics and define the limiting design.

It looks like a Hummingbird but it'll act like any VTOL plane.

Fly by wire. The modified Hummingbird is a two-pilot airplane. The evaluation pilot will always "fly by wire"—that is, he will control the aircraft through the VSS with no mechanical connection to the controls. The other pilot, for the sake of safety, will have direct access to the controls in the conventional manner and will be able to take over in the event of VSS failure.

With more than 250 variable flight parameters, and with many additional fixed parameters, managing the interaction among these obviously will require a computer. North American engineers have not yet decided on the type of computer they will develop for the VSS, but it will probably be an analog-digital design.

Collision course

A multimillion-dollar contest is shaping up as several avionics companies compete to build collision avoidance systems for commercial airlines. Experimental systems have already been built by the Collins Radio Co., the Bendix Corp. and the McDonnell Co. And two other avionics concerns—TRG Inc. and the National Co.—are working on collision avoidance systems. None of the systems are compatible.

In an effort to pressure the competing avionics companies to either redesign their systems, or to find ways to make them compatible, the airlines' industry group, the Air Transport Association, is trying to establish standards for the design of the avionics gear. A technical committee of the association, set up for that purpose, will begin a series of meetings this month.

Time basis. Both the Collins and the McDonnell systems use time-frequency as the basis for warning pilots that they are approaching another craft and what evasive action should be taken. McDonnell's design uses ground stations.

But in the Collins system, air-to-air synchronization and time-averaging techniques, using accurate atomic clocks, eliminate the need for the ground stations.

Both the Collins and the McDon-

nell designs have been outlined before the industry group. The Bendix system hasn't been presented and little is known about how it operates, except it's a cooperative system and it needs neither atomic clocks nor ground stations.

After the industry group decides on a standard, the Federal Aviation Administration gets into the act. It's the FAA which makes the final ruling on what systems can be installed in airlines, and a spokesman for the agency concedes that will probably take years before agreement will be reached.

Computer-aided design

Circuit course

The infant field of computer-aided design (CAD) is beginning to generate broad interest among electronics engineers. This is evidenced by the number of public and private courses, workshops and symposiums listed for this year.

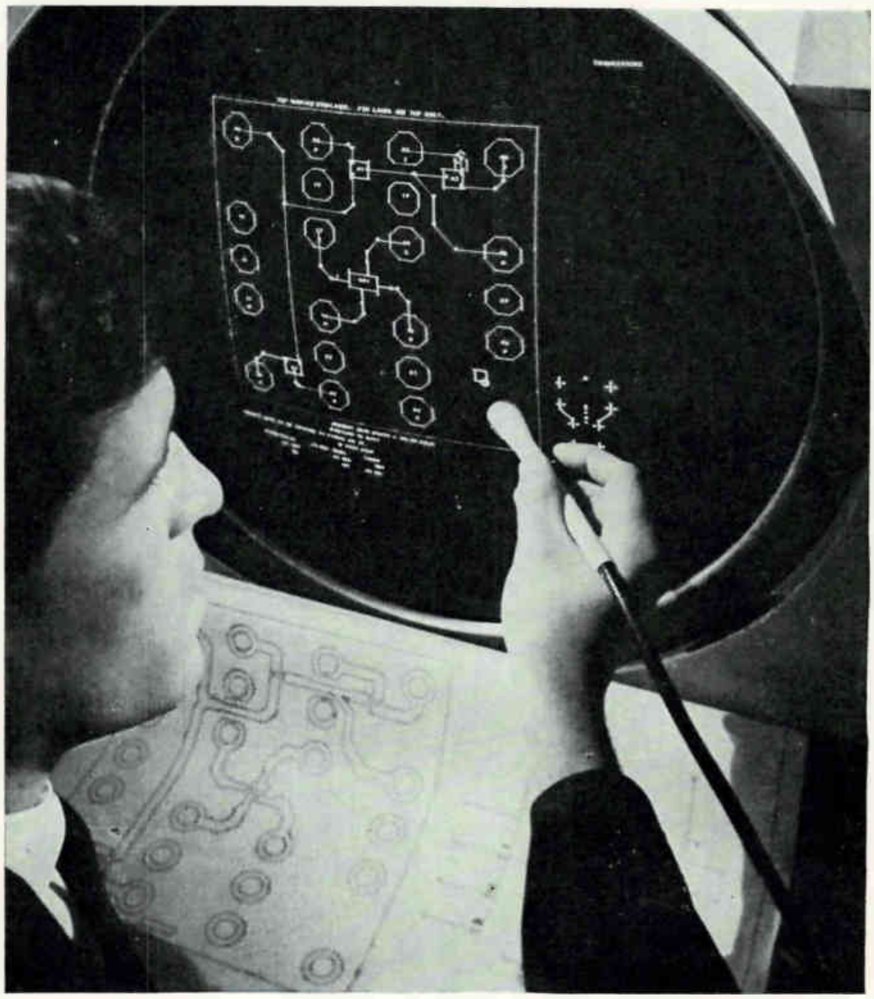
Last month three CAD sessions were announced, one by a private consultant and two by schools. This brings to almost a dozen the number of technical sessions already scheduled.

From Jan. 24 to 26 Design Automation Inc. of Lexington, Mass., will give a course in Palo Alto, Calif., on computer-aided analysis of circuits. Specifically, it will cover the use of the NET-1 computer program. The course will be repeated in Los Angeles, starting on Jan. 31. Tuition is $275. The company, headed by Nathan O. Sokal, was the first to be established for CAD consulting.

Cosponsors. At New York University's School of Engineering and Science, a three-day class on circuit design by computer will be held from Jan. 31 to Feb. 2. The program is cosponsored by the National Aeronautics and Space Administration and the Office of Naval Research.

And at the University of Missouri, College of Engineering, a summer institute is planned that will devote time to CAD. The workshop program will be in three sections. The first, from Aug. 7 to 12, will include an intensive course in Fortran 4 programing, with emphasis on electronic circuit design. The second, from Aug. 14 to 18, will deal with analysis and design of electronic circuits by computer. And the third, from Aug. 21 to 25, will consist of eight concurrent sessions: time domain techniques, optimization techniques, filter design, nonlinear circuits, biomedical data processing, biomedical transducer design, digital logic design and digital simulation.

At the University of Missouri the fee per workshop is $150.



Designing circuits by computer. Engineer at IBM lab experiments with various patterns for a circuit.

Instrumentation

Giant capacitors for Apollo

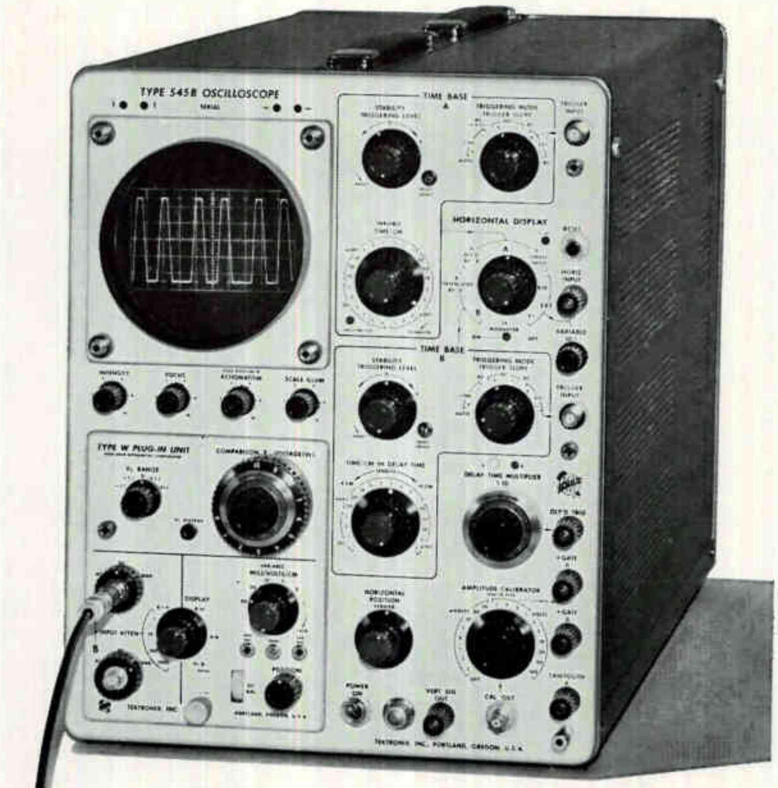
The National Aeronautics and Space Administration will use the world's largest balanced capacitance bridges to monitor fuel consumption during the 1½-minute flight of the Apollo launch vehicle's initial Saturn stage. During that period, liquid oxygen and propellant fuel will slosh back and forth in the craft's tanks, with waves reaching four feet at times.

To cope with this sloshing, four 49-foot-long capacitance bridges are to be installed in the Saturn vehicle at a cost of $10,000 each, including associated electronics. Built by Trans-Sonics Inc. of Burlington, Mass., the capacitors will each consist of 12 segments of aluminum tubing functioning as electrodes; the liquid flowing between the tubing will act as a dielectric.

Finding its level. Each segment of tubing is a 49-inch continuous

A Tektronix High Resolution Measurement Package:

- *Type 545B Oscilloscope with Advanced CRT*
- *Accurate Horizontal Delayed Sweep*
- *Type W Plug-In for Accurate Voltage Measurements*



Small spot size — uniform focus
The waveform demonstrates the small spot size and uniform focus which provides fine trace definition.

The cathode ray tube and the delayed sweep of the Tektronix Type 545B Oscilloscope, plus the voltage measurement capabilities of the Type W Plug-In Unit, combine to make an ideal package for high resolution measurements. Even greater versatility is then available because the Type 545B is compatible with all Tektronix letter and 1-series plug-ins.

Precision CRT

The Type 545B uses the advanced T5470 cathode ray tube that provides small spot size and permits uniform focus over its entire 6 x 10 cm display area. The illuminated, no-parallax internal graticule lets the operator make full use of the measurement capabilities of the oscilloscope. Risetime and falltime measurements (10 to 90%) are made using the dashed graticule lines, and the illuminated graticule simplifies photographic recording.

Horizontal Delayed Sweep

The delayed sweep capability of the Type 545B gives you the ability to make very accurate time measurements. The incremental accuracy (0.2%) of the delay-time multiplier provides a calibrated delay range which is continuously variable from 1 μs to 10 s with an accuracy within 1%. The Type 545B provides stable triggering on small signals. It triggers internally with AC coupling from 150 Hz to 10 MHz on 2-mm deflection, increasing to 1 cm at 30 MHz.

Accurate Voltage Measurements— DC to 23 MHz

The high resolution Type W Plug-In Unit (illustrated) can measure voltages with an accuracy of $\pm 0.2\%$ V_C. It provides an effective CRT height of $\pm 11{,}000$ cm, permitting evaluation of 1 mV pulses riding on signals up to ± 11 V (10 mV evaluation to ± 110V). The common mode rejection ratio of the Type 545B is at least 20,000:1 on signals from DC to 20 kHz. Bandwidth of the instrument is DC to 23 MHz at 50 mV/cm and DC to 8 MHz at 1 mV/cm.

The Type 545B vertical amplifier is easy to maintain and calibrate with a hybrid circuit design and a compact delay line that requires no adjustments. Among the letter and 1-series plug-ins available for use with the Type 545B are spectrum analyzer units covering the spectrum from 50 Hz to 10.5 GHz, and sampling units with 90 ps risetime and TDR capabilities. With the Type 1A2 Dual Trace Plug-In, DC to 33 MHz measurements may be made with 10.5 ns T_r and 50 mV/cm deflection factor.

Type 545B (complete with probes and accessories)	$1550
Type W Plug-In Unit	575
Type 1A2 Dual Trace Plug-In Unit .	325

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measuring sensor and each has a discrete sensor. The segments are designed so that alternate sensors are connected to the opposite phase of the drive signal. The capacitance bridge is maintained at null by a 10-bit digital servo system. As liquid fills the first sensing unit, the output increases in value until the second sensor is reached. When the liquid is at the second sensor, the output decreases until the third is reached and so on. Discrete sensors at the interfaces identify the segment being reached. The continuous output increases on all odd-numbered segments and decreases on even-numbered segments.

The lightweight, rugged, self-calibrating system measures the liquid level to a resolution of 0.1 inch over a height of 588 inches.

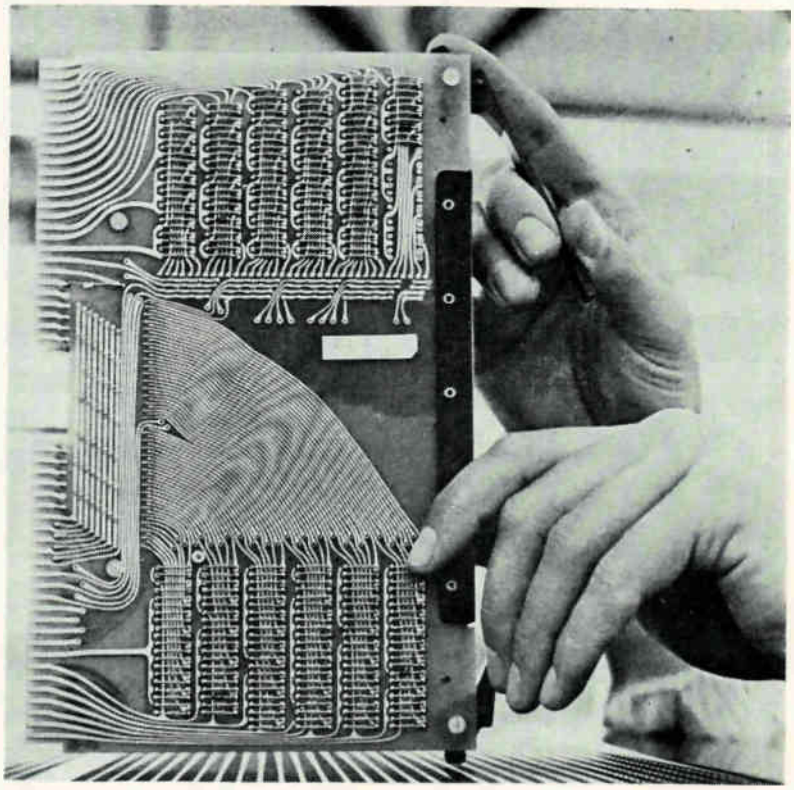
The electronic unit provides a digital output with an updating time of 280 microseconds. The level, and thereby the remaining quantity of propellant, is monitored continuously from the loading of the fuel until burnout and stage separation. The information is gathered in digital form, updated 3,600 times per second and transmitted to the ground via the launch vehicle's telemetry system.

Computers

Another Sigma

The first computer with a memory cycle of less than one microsecond that sells for below $500,000 was announced last week. The computer, the Sigma 5, has a memory cycle of 850 nanoseconds and a typical configuration costs about $300,000.

The computer is the third in the Sigma series built by Scientific Data Systems Inc. Its predecessors are the Sigma 7, announced last March, and the Sigma 2, which came out in September. Bryan Middleditch, manager of product marketing, says the new computer is designed primarily for scientific applications; it can also be used for commercial data processing, but decimal arithmetic is more awkward to handle and therefore requires more time than on the Sigma 7.



Memory module containing 4.096 eight-bit bytes. Up to 32 of these modules may be installed in the new Sigma 5 computer.

Speed second. Except for time-sharing ability, the Sigma 5 is identical to the Sigma 7 from the programer's point of view. "In the Sigma 5, when trade offs were made, the designers favored cost rather than speed," says Dan Cota, a member of the product planning staff at SDS. The Sigma 7 required additional hardware for efficient decimal arithmetic, for juggling many time-sharing inputs at high speed and for other tasks.

The Sigma 5 can execute several programs at once; it works on a high-priority foreground program as long as possible, then switches to a background program kept in its memory until it is interrupted by another foreground task.

The fast 850-μsec memory cycle is possible because the memory organization is 2½-dimensional, as in the other Sigmas. The 2½-dimensional organization uses only three wires threading each ferrite core instead of four, reducing propagation delay and noise [Electronics, Oct. 31, 1966, p. 83].

Interleaving. One feature of the new machine, common in larger and more expensive systems, is the modular organization of the memory, with interleaving. Modular organization permits overlapping of memory cycles; a memory cycle may be started in one module while a cycle is under way in another. This results in an effective cycle time of 600 nsec. With interleaving, one module may contain only odd-numbered addresses and another only even-numbered addresses. Hence operations that refer to sequential locations in conventional memories refer instead to alternate modules whose cycles may be overlapped. Groups of four or eight modules may also be interleaved in the Sigma 5.

The low price was attained, says Paul Lebowitz, product manager for the Sigma 5 and 7, by keeping down the total number of basic components. Only 437 different parts are used, compared with about 1,000 for comparable machines. This permits the company to buy fewer parts in higher volume at lower cost. Software development cost also was low because the

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Circle 51 on reader service card

Sigma 5 is program-compatible with the Sigma 7.

Space electronics

High marks for ATS

Except for a few minor hitches, the first Applications Technology Satellite (ATS-1) and its ground stations are performing to specifications. The "engineer's satellite" is already proving several design concepts that will go into future hardware such as the Communications Satellite Corp.'s proposed Aeronautical Services Satellite.

Built by the Hughes Aircraft Co. [Electronics, Nov. 28, 1966, p. 121], the spin-stabilized, stationary satellite was launched on schedule Dec. 6 and is now on station over the equator east of Christmas Island in the Pacific.

It has relayed very-high-frequency voice transmissions from aircraft in flight to ground stations with fair success; it has successfully despun its phased-array antennas to put more energy into ground receivers; it has relayed color television via its wideband frequency-modulation circuitry, and it has sent back pictures of one-third of the earth's surface over a new spin-scan tv system.

Still to be accomplished, however, is a single-sideband multiple-access experiment to enable several ground stations to transmit through the satellite simultaneously.

On schedule. Operation of ATS-1 is going "pretty much on schedule, although we would like to get back a little more data," says one engineer at the Goddard Space Flight Center, Greenbelt, Md., which is running the project for the National Aeronautics and Space Administration.

The satellite's 6-gigahertz antenna is passing its first flight test with high marks, putting out about 10 decibels more gain than possible with a spun array.

The multiple-access experiment, in which the satellite receives frequency-division SSB transmissions from ground stations and transmits them as a single phase-modulated carrier, is scheduled for this month.

Relay test. The preliminary tests of voice relay from aircraft to ground were generally successful although they did show some signal fading. They were performed with makeshift vhf aircraft antennas designed for vertically polarized line-of-sight signals.

Circularly polarized aircraft antennas, insensitive to the signal polarization resulting from such phenomena as Faraday rotation, are currently being built at Dorne & Margolin Inc. and the Bendix Corp. They will be installed on commercial planes from seven airlines for further ATS experiments. Originally slated to begin this month, these tests may not get under way until next spring—or February at the very earliest.

Industrial electronics

Market view

About 18 months ago a Dallas company, Recognition Equipment Inc., developed a 45-foot-long electronic panel for the New York Stock Exchange for displaying market transactions. Now, Trans-Lux Corp. of New York has relied heavily on semiconductors to shrink the panel down to eight feet—a more convenient size for most stock brokerage houses [Electronics, Sept. 6, 1965, p. 36]. Both designs use a continuous belt of plastic disks that are flipped into position by jets of air to spell out the numbers and letters reporting market movement.

Called Trans-Jet, the system is tied to the Big Board's nationwide stock exchange communications network to display market quotations instantly. It would replace the displays found in most brokers' offices which project the market ticker tape onto a viewing screen. The new display requires considerably less maintenance and can be placed overhead in the center of a room instead of against a wall.

Time circuits. The moving belt of the quote board is made up of

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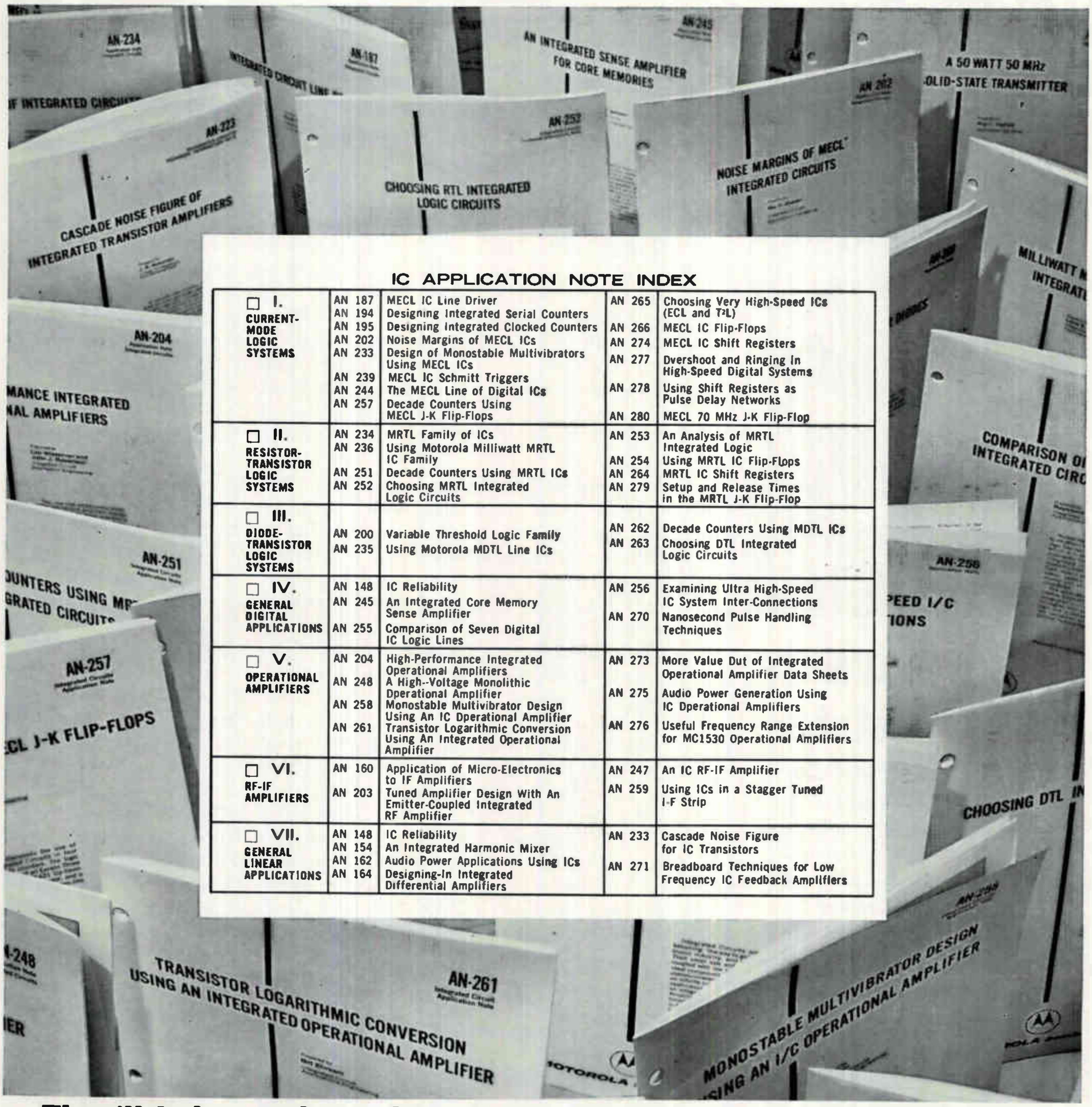

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MOTOROLA Semiconductors

Circle 53 on reader service card

¼-inch panels, luminescent plastic disks that are black on one side and yellow on the other. Semiconductor timing circuits synchronize the belt's speed with actual market activity. Other circuits convert the serial signals coming from the stock exchange into a parallel digital code and also set up logic "quotation commands" for the 23 air jets, which control a single vertical column of disks. Each column is eight inches high.

According to the commands, the disks are flipped from their black to their colored sides. Up to 900 characters per minute can be displayed.

In developing the display, Trans-Lux used nearly every type of solid state component:

- **Integrated circuits** decode the input from the ticker tape and synchronize its speed to the speed of the display.
- **Small-signal discrete transistors** drive ferrite core pulse transformers used for buffering.
- **Silicon controlled rectifiers** and power transistors control the air jets and drive the d-c motors which move the display.
- **Photocells** help synchronize the mechanical position of the moving frame to the electrical position signals.
- **Diodes and unijunction transistors** receive the signals from the ticker tape and act as a master clock for the system.

These components are all from Texas Instruments Incorporated's Silect line—plastic packaged low-priced units for industrial applications. The IC's are series 73 units in dual-inline packages. An order for more than $1 million worth of semiconductors has already been placed, according to Trans-Lux.

The over-all size reduction of the electronics obtained by Trans-Lux is impressive. The earlier 45-foot display required 75 plug-in printed-circuit boards housed in a separate cabinet. Trans-Lux's display needs only five plug-in boards and a motor-control board placed at one end of the moving belt. Additional size reduction is probable in the next few years when the electronics is redesigned to use metal-oxide semiconductor arrays.

For the record

Profit sharing. The Radio Corp. of America says sales and profits rose to a record in 1966. The company reports that sales will surpass $2.5 billion and profits $130 million. Color television manufacturing and broadcasting contributed the lion's share to the company's over-all gains. For 1967 RCA anticipates more of the same. On the other hand, the Westinghouse Electric Corp. reports that fourth quarter earnings will fall below the figures for the like period a year ago despite an increase in sales. Widespread strikes caused the decline. Nevertheless, the company expects the earnings for the entire year to top those of 1965. And the General Electric Co. expects 1966 earnings to be less than 1965's because of strikes during the final quarter.

Tape measure. The Nortronics division of the Northrop Corp. is selling a crash recorder that can record a 10-hour plane flight. Present recorders generally record only the last 15 minutes. The new unit weighs 2½ pounds and occupies less than 61 cubic inches; its outside diameter is slightly more than 4 inches. Compressed time-recording techniques result in smaller tape reel requirements. It is believed that the amount of data recorded depends on the speed of the tape. Inputs include flight crew intercom conversations, instrumentation data and a time signal code. Frequency response is in the 400-hertz to 3-kilohertz range.

Split decision. By a close vote of four to three, the Federal Communications Commission has approved the merger of the American Broadcasting Co. and the International Telephone and Telegraph Corp. The Justice Department warned of possible antitrust violations but said it planned no move to block the merger.

Ersatz quartz. The Bell Telephone Laboratories and the Western Electric Co. have developed a way to grow quartz crystals that will replace natural quartz crystals in stable, high-frequency applica-

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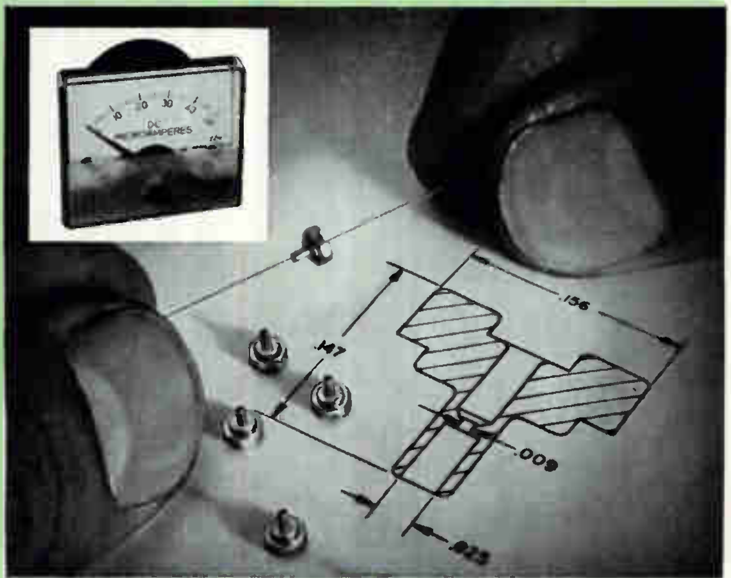

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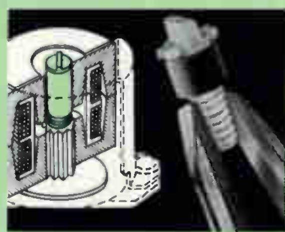
and this...

Willson eyeglass hinges diecast in a single automatic operation. Moveable elements cast assembled by Gries high speed, low cost "Intercast" method.

and this...



Indiana General's cup core has #1-64 polypropylene screws automatically insert-molded into delicate ferrite tubes by GRC's exclusive process.

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Circle 55 on reader service card

tions. Synthetic quartz crystals are cheaper and can be used in virtually all communications devices. By adding lithium nitrite to sodium hydroxide, researchers found they could increase the Q of the crystals 10 times to about 1 million. Lithium nitrite is believed to keep water from forming in the grown crystal. Under certain conditions quartz crystals with Q's of 2 million have been grown, making them equivalent in Q value to natural quartz crystals.

Data key. The Keydata Corp., a Cambridge, Mass., company that offered one of the first commercial time-sharing services, [Electronics, Feb. 22, 1965, p. 17] will soon buy 20 DDF-516 computers from the Computer Control division of Honeywell Inc.

Sound technique. West Virginia University researchers have developed a method using sound waves to dry fine particles of coal that were formerly discarded because conventional drying techniques were considered uneconomical and dangerous. The high temperatures required to remove moisture from coal particles increased the threat of coal dust explosion or fire.

Bit by bit. The Western Union Telegraph Co. will soon be using the Milgo Electronics Corp.'s narrow-band modem to send 2,400 bits per second over an 800-hertz bandwidth [Electronics, Nov. 28, 1966, p. 46]. Milgo expects to deliver more than $600,000 in modems to Western Union by mid-year but will not say how many modems are involved in the two-year contract. The manufacturer says the modem will transmit digital data from computers or related devices at high speed over Western Union's expanding communications network. [Electronics, Nov. 28, 1966, pp. 128-131].

System link. The Collins Radio Co. has completed the first step in the construction of a $9.5 million communications network for the Air Force. Voice communications via the new high-frequency link were established recently between Clark Air Force Base in the Philippines, Scott Air Force Base in Illinois and the Pentagon.

The only test a Unitrode diode

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can't pass.

of the reasons Unitrode components can do all the things mentioned above.

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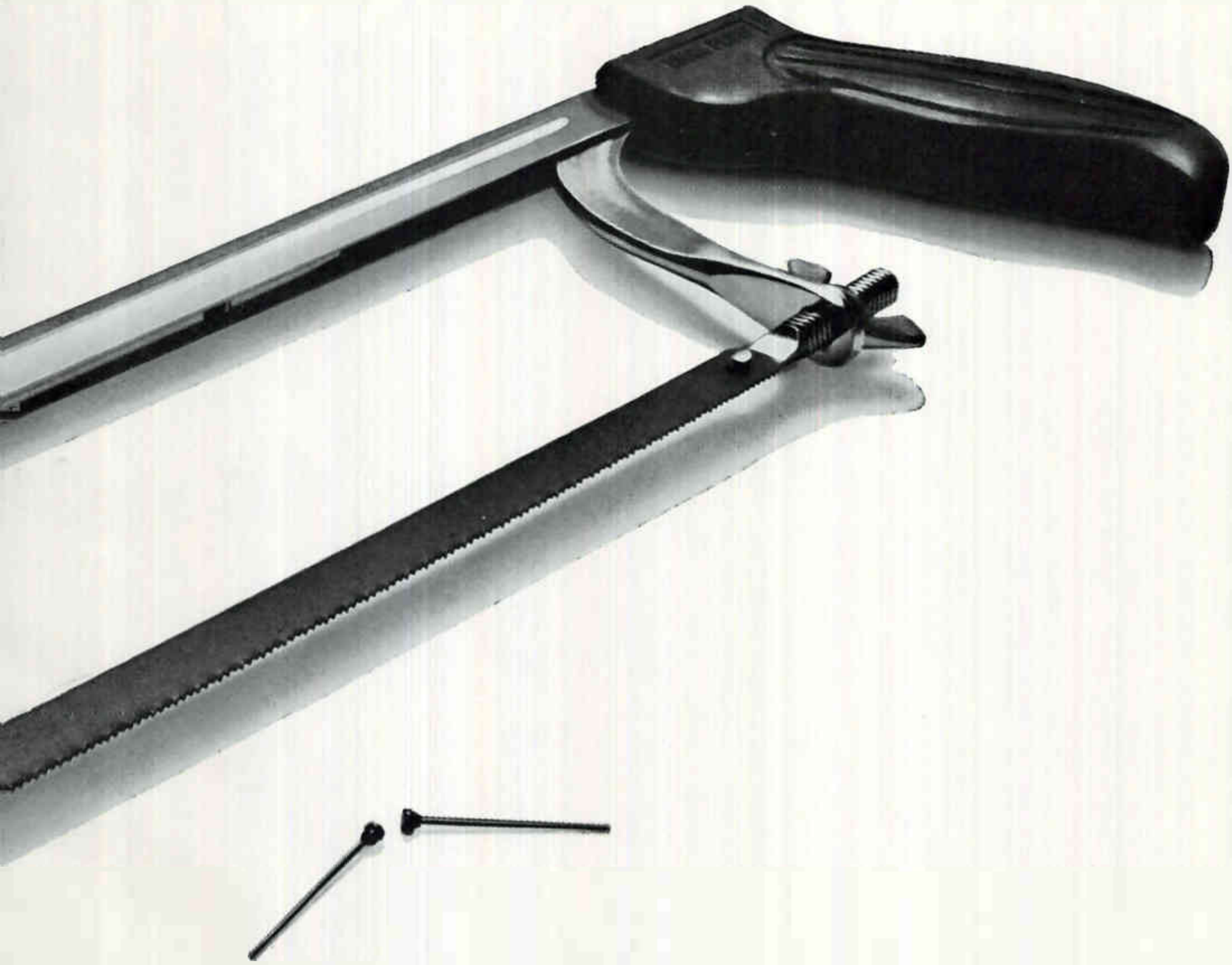


Circle 60 on reader service card→

It used to be a nagging pain figuring out how much resistor precision to buy.

Washington Newsletter

January 9, 1967

Webb brings back $5 billion budget from Texas . . .

The National Aeronautics and Space Administration's chief, James E. Webb, made a profitable trip to the LBJ Ranch last month. What he brought back from Texas was a $5 billion NASA budget for the year ending June 30, 1968. Webb did better than many people, including some at NASA, had expected. Some had predicted a drop from the current fiscal year's $5 billion to $4.7 billion or even $4 billion.

Included in the NASA budget to be sent to Congress this month will be $400 million to start the Apollo applications program, but the fate of the space agency's request for funds to start the Voyager unmanned planetary exploration program remains extremely doubtful.

. . . that boosts electronics center's fiscal '68 outlay . . .

Getting a bigger piece of the NASA budget in fiscal 1968 is the Electronics Research Center in Cambridge, Mass. This outlay is expected to rise 67% in fiscal 1968 to $20 million from this year's $12 million. The total staff at one center is slated to reach 750 by mid-June and nearly 1,000 in fiscal 1968. Heading the center's priority list of research projects are laser and optical systems for communications and astronomy. An expanded effort to develop transmitter arrays radiating 10 to 20 kilowatts for such applications as direct broadcast satellites is also in the works.

. . . and includes added space shots

Additional space flights are also covered by the new NASA budget. Two more Applications Technology Satellites equipped with 30-foot antennas [Electronics, Nov. 28, 1966, p. 52] are to be added to the currently approved program of five flights. Spacecraft shots to be added to the Mariner program include missions to Mars in 1971 [Electronics, Aug. 22, 1966, p. 69] and to Venus in 1970 and possibly 1972, all carrying probes to launch into the planets' atmospheres.

Avionics contracts for manned bomber

The Air Force continues to back research and development on the avionics for its proposed advanced manned strategic aircraft, although Defense Secretary Robert S. McNamara has refused to give the program a green light. The Aerospace Systems division of General Precision Inc. is getting $2 million to evaluate techniques for obtaining precise navigation fixes and transferring this data to the inertial systems of the plane's weapons.

Also, the Autonetics division of North American Aviation Inc. has a $1.1 million contract to develop an advanced forward-looking radar to locate and identify ground targets under varying conditions.

Independence of new Congress will affect electronics

President Johnson's unchallenged rule in Washington seems ended and the change will affect many of the programs in which electronics companies are involved, from space exploration to Government efforts in the fields of medicine, education and air and water pollution control.

The President is on the defensive. His leadership is being questioned within his own party. This new atmosphere in the Capital will be most apparent in the new Congress convening this week.

The 90th Congress will be more conservative than its predecessor and far more difficult for Johnson to work with. Committee chairmen and senior members, whose authority was undermined in the 89th session by the voting strength of freshmen Democrats loyal to the President, are back in their traditional positions of power and influence. This will all have its effect as Congress considers, and possibly reshapes, programs critical to the electronics industry.

Additionally, there is a growing belief among Congressmen that the Government must seek more help and suggestions from industry in undertaking such massive projects as improving the quality of the natural environment, providing adequate housing and waging its war on poverty.

Senate to study spinoff of Federal research data

The Senate Small Business Committee's subcommittee on science and technology will hold hearings on the effectiveness of the Government's efforts to disseminate research and development information to industry and schools. One possibility that will be discussed is the establishment of a Federally chartered corporation similar to the Communications Satellite Corp. to coordinate these efforts. Another will be the feasibility of combining the technological information centers now operated by NASA, the Atomic Energy Commission and the Commerce Department.

Switch to Centaur means more NASA electronics spending

A decision by NASA to switch to the Atlas-Centaur launch vehicle after 1968 means more dollars for electronics subsystems. The electronics for each Centaur will cost approximately $6 million, equal to the total cost of the Agena stage of the agency's present launch vehicle, the Atlas-Agena.

Dividing up the contracts for the Centaur second stage will be the prime contractor, the General Dynamics Corp.'s Convair division, the guidance contractor, Honeywell Inc.'s Aeronautical division, and the computer subcontractor, General Precision Inc.'s Librascope group.

The change to the powerful Atlas-Centaur was dictated by NASA's plans for heavier satellites. For instance, the Centaur will launch the sixth and seventh Advanced Technological Satellites, each weighing about 1,200 pounds, or about 50% more than the first ATS satellite.

Cost of world weather watch put at $1 billion

Interest is increasing in the effort to establish a worldwide network of weather stations compatible with a computerized reporting, analysis and forecast system. To meet the cost—estimated at $1 billion by some sources—the United States in April will seek a financial commitment for each nation of the World Meteorological Organization sponsored by the United Nations.

Construction and installation of the system is scheduled for the period from 1968 to 1971. Much of the outlay will go for electronics gear on ships, buoys, anchored barges, balloons and second-generation meteorological satellites.

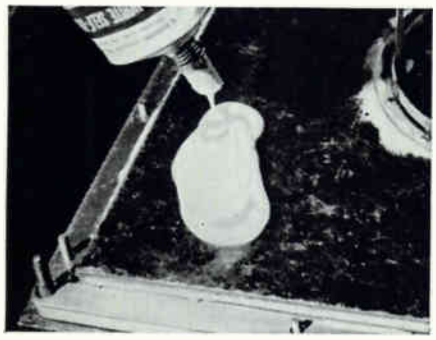
Robert M. White, the administrator of the Environmental Science Services Administration, refuses to comment on initial cost of the network. But he points out that the present world weather system costs $1 billion a year to run, and that it will cost each participating nation another $150 million annually to operate the expanded system.

The goal of a world weather watch is to provide daily weather forecasts with 90% accuracy two weeks in advance.

Circle 65 on reader service card

There's a G-E silicone

Bonding

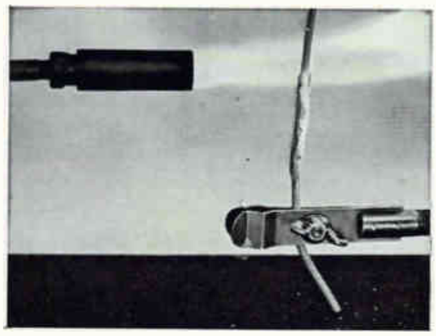


Laminated layers of mica sheeting are securely bonded with G-E RTV silicone sealant. Ready to use, it bonds to most materials, forming heat-resistant rubber.

Screws and drilling are eliminated by adhering identification plates with RTV adhesive sealant. It won't harden, soften, crack or shrink.

Insulating

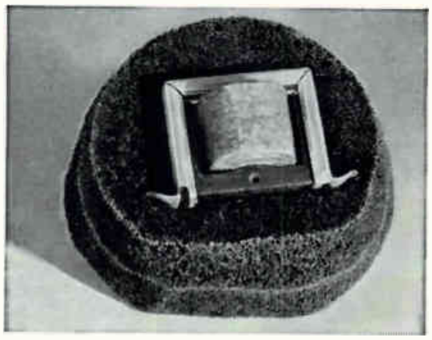
G-E RTV translucent sealant provides excellent see-thru insulation instantly. UL-recognized, the sealant also comes in colors.



Silicone rubber wire and cable insulation passes UL vertical flame tests and is frequently used in high-voltage circuits.

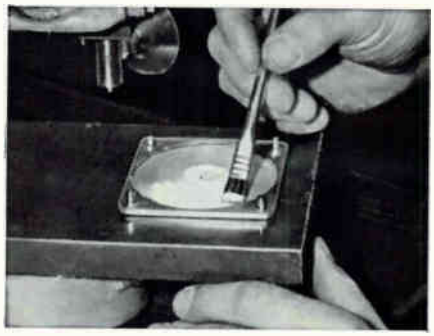
G-E silicone dielectric greases, ideal heat transfer media, are easily brushed, painted, sprayed, dip-coated or applied directly from tube.

Damping

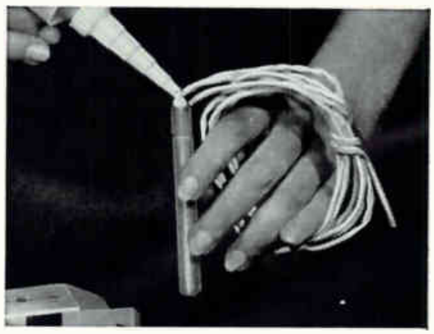


G-E RTV-7 silicone rubber foams on the spot to provide mechanical support, shock and vibration damping, and light weight electrical insulation.

Sealing



G-E two-part RTV, available in a range of viscosities, seals filament condenser plate in dielectric heater. Also protects against vibration.

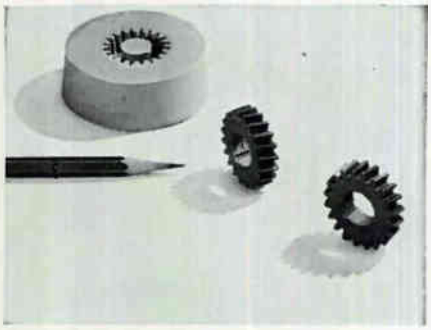


G-E RTV is ideal for high temperature moisture sealing of heating elements. It withstands temperatures as high as 600°F, as low as —75°F.

design solution for:

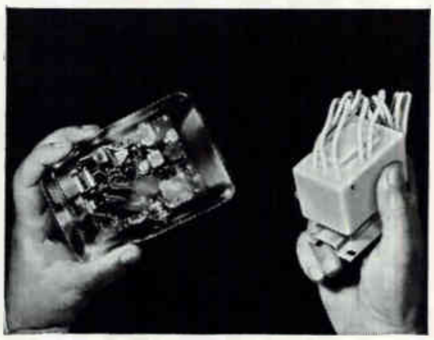
Moldmaking

Tough, flexible G-E RTV silicone for moldmaking reproduces detail accurately and minimizes tooling costs.

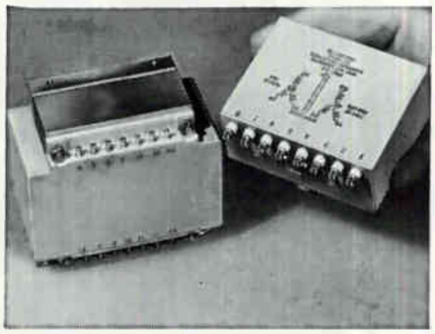


For prototypes or short-run parts production, G-E RTV is an excellent flexible moldmaking material. And it needs no release agent.

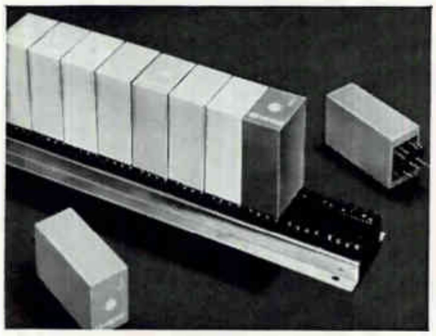
Potting and Encapsulating



Many G-E RTV silicone compounds are available—all with good strength, outstanding electrical properties and resistance to temperature extremes.



Impregnation of transformer coils with G-E RTV provides electrical insulation and environmental protection at high temperatures.



G-E RTV provides attractive, protective packaging for components. Each unit is encapsulated in a different color RTV for easy identification.

Fluids Applications

G-E silicone dielectric fluids provide excellent electrical properties and thermal stability for many types of components.

Fabricating

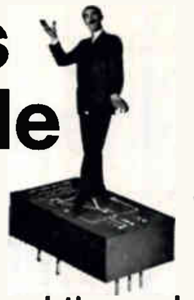
G-E silicone elastomers are easily used to make numerous silicone rubber parts by standard rubber fabricating techniques.

If you can't find it here, write for our Silicone Selector Guide:

Section N1254R Silicone Products Dept., General Electric Company, Waterford, New York 12188.

GENERAL ELECTRIC

the Nexus ultra-stable USL-1



An unprecedented breakthrough in operational amplifier technology

The USL-1 is a designer's dream . . . a high-performance operational amplifier which can operate from almost any existing power source, and which provides stability and common mode rejection orders of magnitude better than any prior state-of-the-art amplifier.

Because this new unit provides virtual immunity from input power variations, it can be operated from dry or wet batteries, automobile or aircraft electrical systems, digital equipment and computer power supplies, or any other convenient source of power providing between −8 and −25 Volts and +8 and +25 Volts. It is not even necessary that the two input voltages track each other.

The USL-1 is so nearly universal in application that it could readily replace over 70% of the operational amplifiers currently in use . . . and do a better job. It frees the designer from the power supply restrictions normally imposed by conventional amplifiers, and offers him greatly improved performance in many applications. For example, because of its extremely high common mode rejection, it functions more accurately than other op amps when used as a voltage follower, subtractor, non-inverting amplifier, etc.

The USL-1 is a premium, encapsulated unit, incorporating high-reliability military-type components and all-silicon semiconductors. A lower-cost commercial version (ESL-1) is also available for shipment. The latter, developed for use in less demanding applications, also uses all-silicon semiconductors, and provides specifications which are extraordinary compared with conventional units.

USL-1 & ESL-1 TYPICAL SPECIFICATIONS

Supply voltage (USL-1)	±8 to ±25 volts
Supply voltage (ESL-1)	±8 to ±16 volts
Output voltage & common-mode voltage (USL-1)	±20 volts from ±25 V supply ±10 volts from ±15 V supply ± 3 volts from ± 8 V supply
Output current	±5 mA at any supply voltage within range
Overload protection	Fully protected against short-circuits, overload, overdrive
Common-mode rejection	130dB
Input impedance	0.3 megohm
Power supply rejection	3µV/Volt (0.3 na/V)
Gain (into 10K load) (USL-1)	100,000
Gain (into 10K load) (ESL-1)	50,000
Temperature coefficient (USL-1)	3 µV/°C
Temperature coefficient (ESL-1)	10 µV/°C
Slewing rate	1.5 V/µsec.
Common-mode stability	3µV/Volt (0.3 na/V)
Case size	2.02" (l) x 1.14" (w) x 0.62" (h)
Price (USL-1)	$75 (1-9)
Price (ESL-1)	$35 (1-9)

Send today for full details on this exciting new operational amplifier

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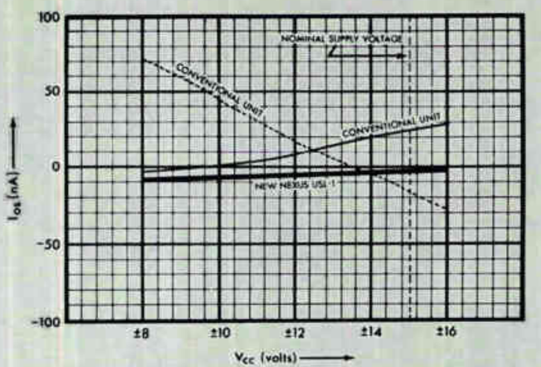
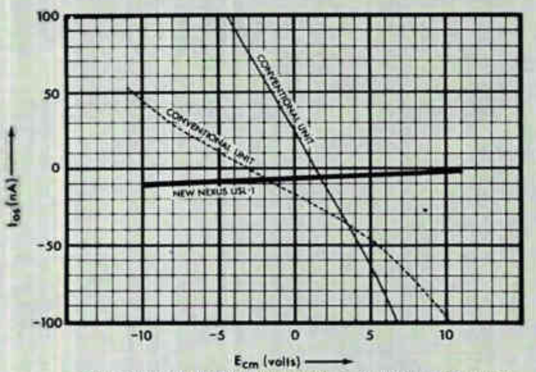
Prices F.O.B. Canton, Massachusetts.
Prices slightly higher outside North America.

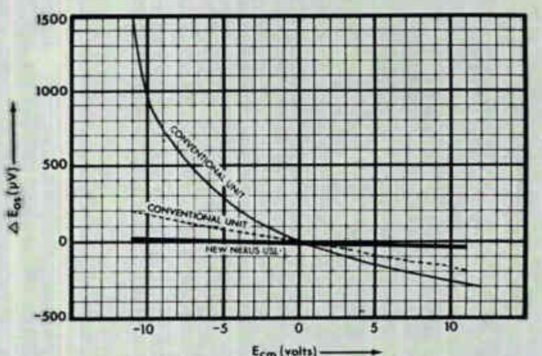
Circl 69 on rea er service card



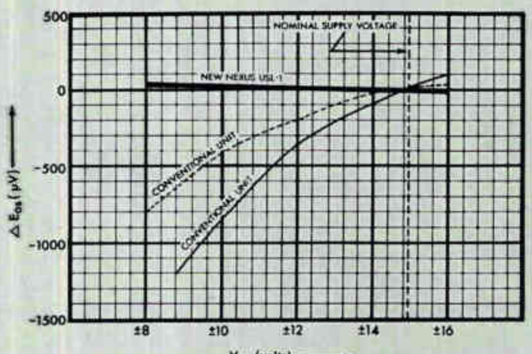
OFFSET CURRENT (EITHER INPUT) VS. POWER SUPPLY VOLTAGE



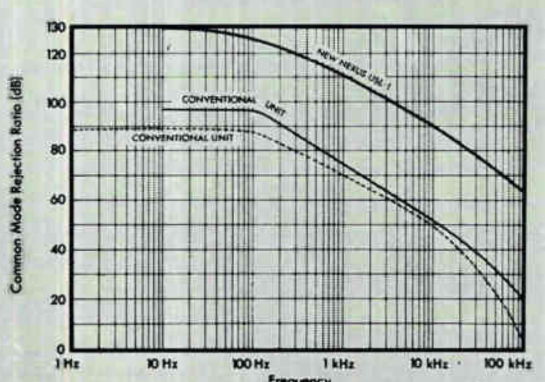
OFFSET CURRENT (REFERENCE INPUT ONLY) VS. COMMON MODE VOLTAGE



OFFSET VOLTAGE VS. COMMON MODE VOLTAGE



OFFSET VOLTAGE VS. POWER SUPPLY VOLTAGE



COMMON MODE REJECTION RATIO VS. FREQUENCY

WIRE HARNESS LACING, like most manual jobs—costs money!

• Saving by using low cost lacing materia seems good economy...

• ...until production lags and rejects pile up

• For real economy you need the uniformity, th high quality of GUDEBROD LACING TAPE.

• That's why this guarantee can help you cut costs in cable harnessing!

You owe it to your zero defects program to investigate Gudebrod lacing tape. Its guaranteed quality and its constant uniformity are important to you—and to your harnessing operation. Why? Because Gudebrod smooths and speeds the hand operation of lacing and knot tying. There's no need for readjusting or retying. Rejects are minimal. The result? You save time—and that saves money and hastens delivery. Gudebrod sets its manufacturing standards high and adheres to them. When you use Gudebrod tapes you can set production goals and achieve them. This is the combination that saves you money in your harness department. Ask for the Gudebrod Product Data Book.

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The first hand tool engineered for wire harnessing. Handle holds bobbins, feeds tape as needed, grips tape for knotting. Speeds, eases harnessing. Pays for itself in time saving.

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Electronics Division

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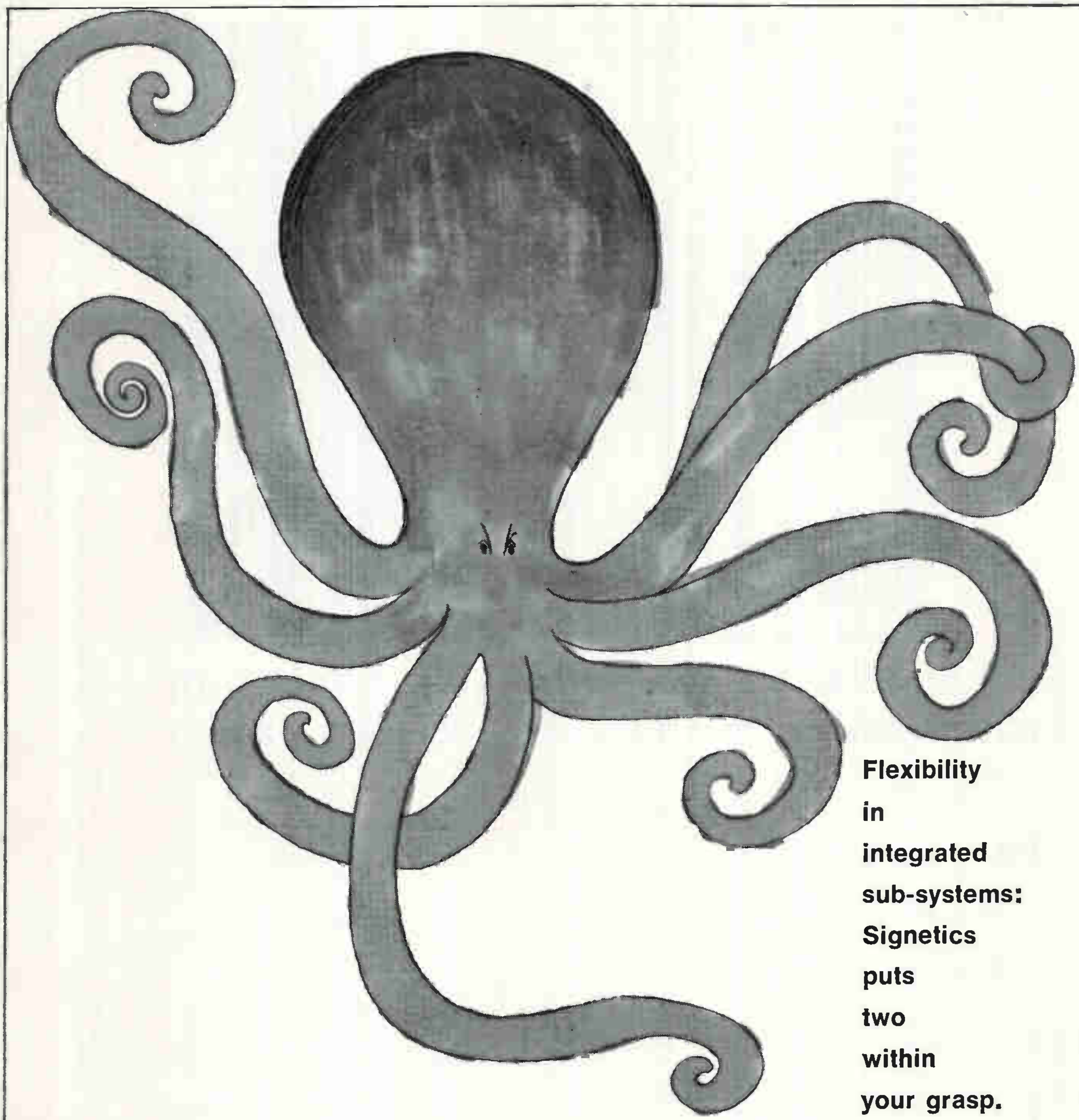

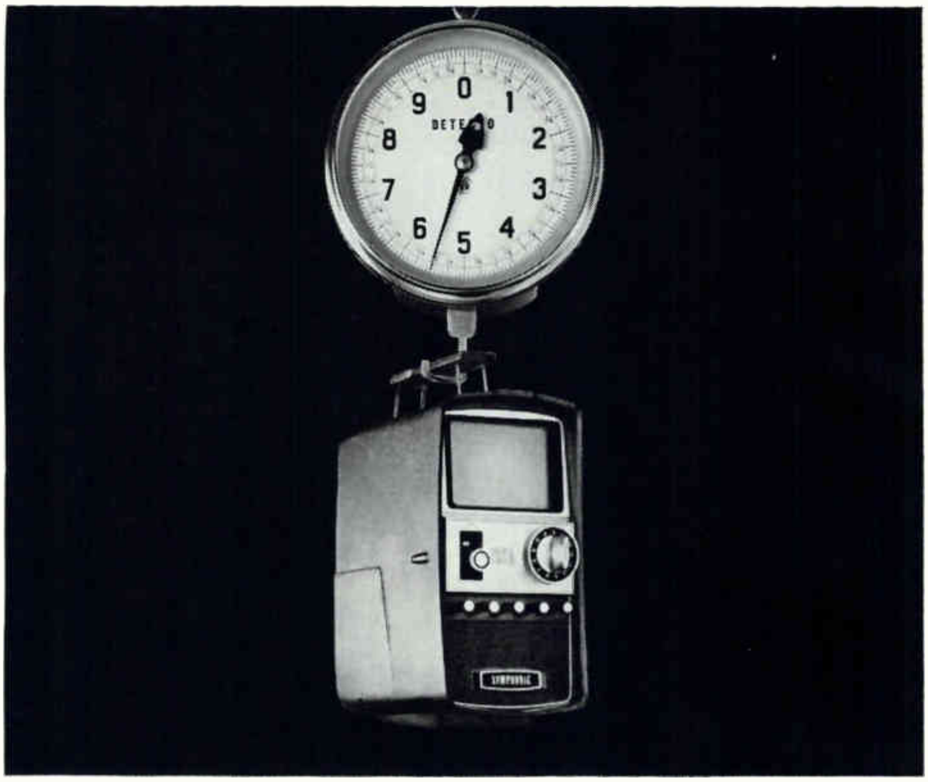

Symphonic Television needed a battery to trim pounds and dollars off its new portable "Minni TV."

Mallory made it.

What can we do for you?

Symphonic Television needed a battery. A battery for the world's smallest TV set with a self-contained, rechargeable power source. A battery so light you can hold the entire set—batteries and all—in one hand while you watch it. Yet a battery that would bring the price of the set well below that of other less-portable portables.

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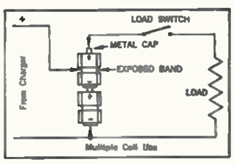
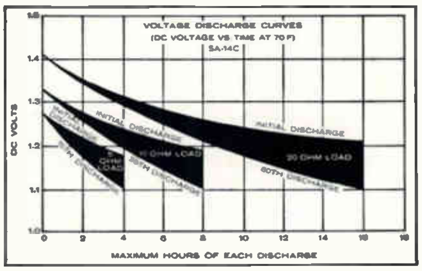
THE RECHARGEABLE BATTERIES YOU CAN AFFORD

Duracell rechargeable alkaline batteries. These are the batteries that will make a new generation of battery-operated devices practical: inexpensive TV sets; AC-DC radios; tape recorders; portable phonographs; transceivers.

The low initial cost of these batteries is one reason. The unique exposed band contact is another. It lets you design battery-operated equipment with built-in rechargers that automatically prevent charging when a primary cell is in the circuit. (See schematic)

That's not all. Duracell rechargeable alkaline batteries are lighter than most other rechargeables. They come fully charged. And one glance at the discharge-cycles graph tells you how little they cost to operate.





OVER 1000 DIFFERENT TYPES

Mallory currently makes over 1000 batteries of all sizes and capacities. If we're not actually producing the battery you need, we'll be happy to work with you in designing a new one. Please write the Technical Sales Department, Mallory Battery Company, a division of P. R. Mallory & Co. Inc., South Broadway, Tarrytown, New York 10591. Or call 914—591-7000. (In Canada: Mallory Battery Company of Canada Limited, Sheridan Park, Ontario.)

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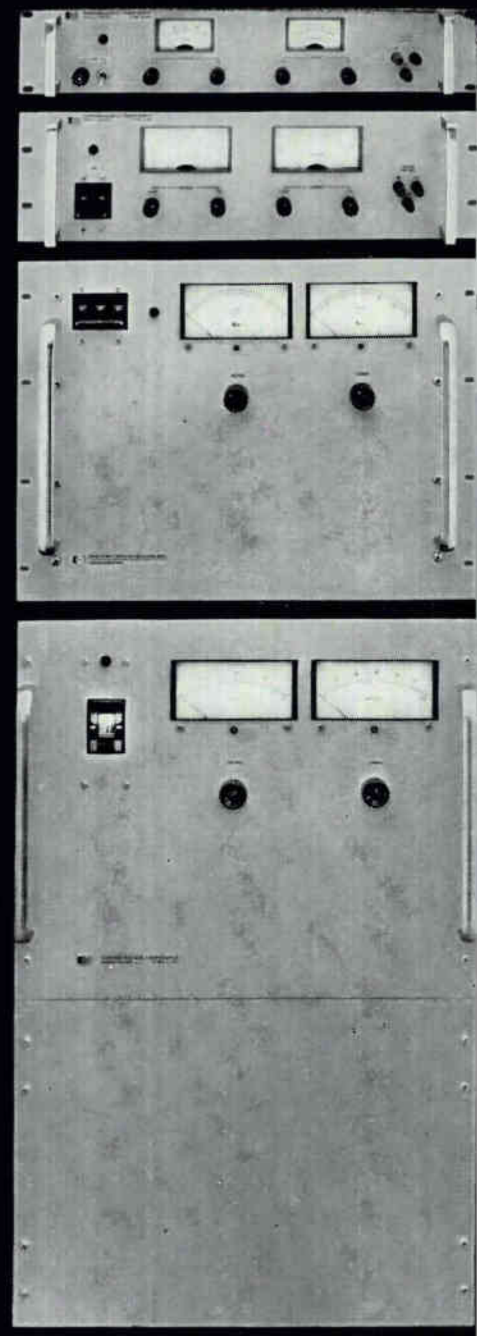
It's good business to do business with Mallory

new disciplines in DC

take the all-silicon models with more power, less weight & volume

20 SCR supplies provide Constant Voltage/Constant Current operation with automatic crossover



Many applications require a DC power source without needing full transistor regulation or laboratory-type performance. For such requirements, Hewlett-Packard/Harrison Division now offers an unusually wide selection of SCR regulated supplies. All are characterized by moderate regulation, high efficiency, low ripple, and size and weight smaller than competitive magamp and SCR supplies. All models are fully adjustable from zero to full rated output. Inherent protection assures that no damage will be caused by any overload, including a short circuit, regardless of how long imposed. Remote programming is accomplished using either resistance or voltage control.

Remote Error Sensing • No Overshoot on Turn-On, Turn-Off, or AC Power Removal • 50 MS Transient Load Recovery • Excellent Line Transient Immunity — No "Poke-Through" Lasting 5-10 Hz • AC Line Dropout Protection Circuit on Three-Phase Supplies Turns Off Unit if Any or All Input AC Lines Lose Voltage • Overvoltage "Crowbar" Protection Option Available on All Models • Auto-Series, -Parallel, -Tracking

DC Output	Panel Height	Model	Price
0- 4V, 0-2000A	26¼"	6463A	$3,500.
0- 8V, 0-1000A	26¼"	6464A	3,300.
0- 15V, 0- 200A	14"	6453A	1,375.
0- 16V, 0- 600A 0- 18V, 0- 500A	26¼"	6466A	2,600.
0- 20V, 0- 15A	3½"	6427B	380.
0- 20V, 0- 45A	5¼"	6428B	550.
0- 36V, 0- 10A	3½"	6433B	370.
0- 36V, 0- 25A	7"	520A	575.
0- 36V, 0- 100A	14"	6456B	1,275.
0- 36V, 0- 300A	26¼"	6469A	2,300.
0- 60V, 0- 5A	3½"	6438B	360.
0- 60V, 0- 15A	5¼"	6439B	550.
0- 64V, 0- 50A	14"	6459A	1,275.
0- 64V, 0- 150A	26¼"	6472A	2,600.
0-110V, 0- 100A	26¼"	6475A	2,600.
0-120V, 0- 2.5A	3½"	6443B	360.
0-220V, 0- 50A	26¼"	6477A	2,600.
0-300V, 0- 35A	26¼"	6479A	2,600.
0-440V, 0- 25A 0-500V, 0- 20A 0-600V, 0- 15A	26¼"	6483B	2,600.
0-600V, 0- 1.5A	5¼"	6448B	550.

Contact your nearest Hewlett-Packard Sales Office for full specifications.

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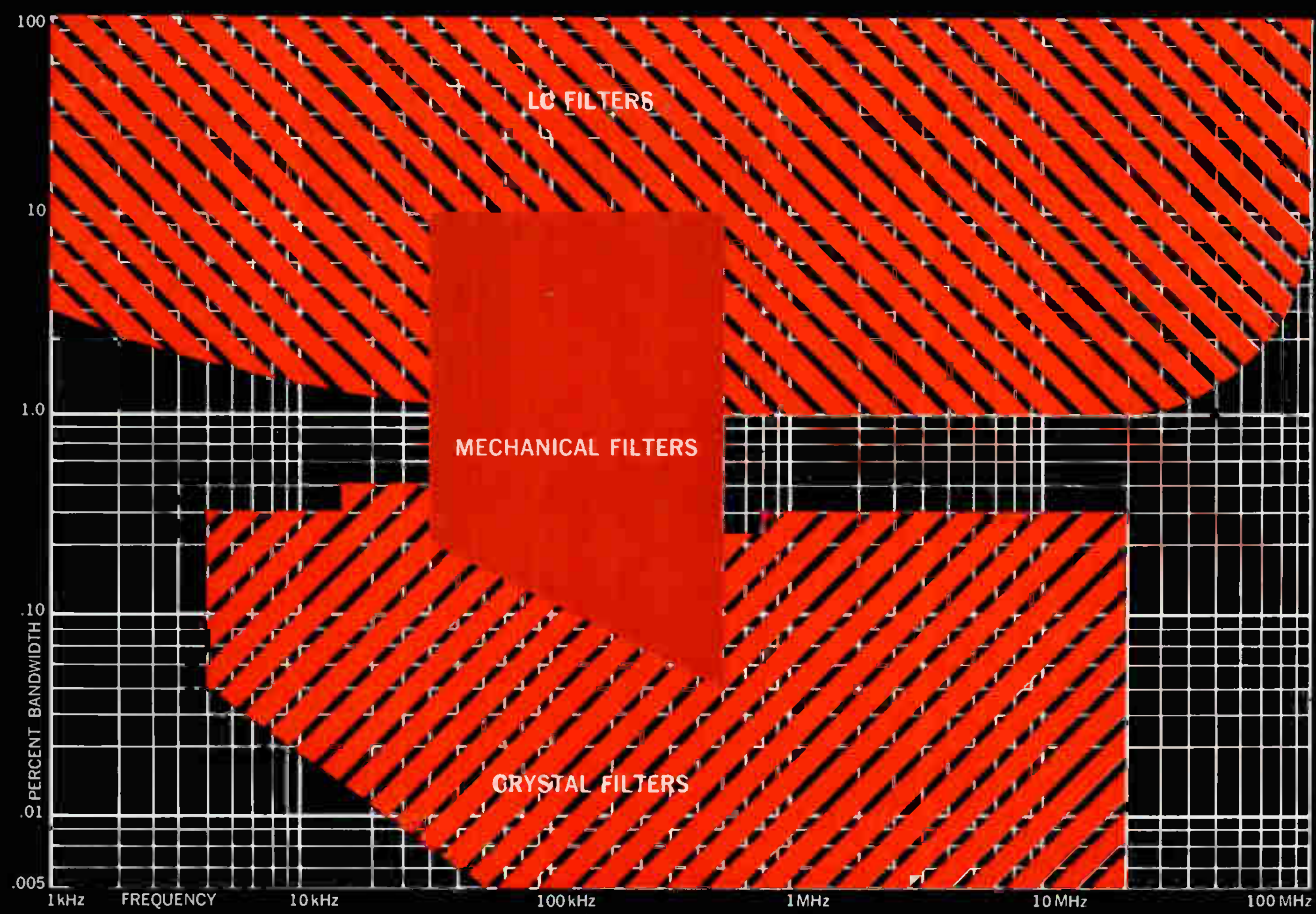
Circle 73 on reader service card



Across the spectrum . . . all your filter needs

Only Collins offers Mechanical, Crystal and LC Filters covering the practical spectrum from 1 kHz to 100 MHz. At Collins, you get the filter best suited to your need — you're not limited to the best available from a single product line. The diagram defines the areas served by Collins' computer-design program. This program means accelerated deliveries at product line prices. Hundreds of design combinations are available immediately. Take advantage of Collins' quality and reliability — and its capability of delivering large quantities on schedule.

Crystal Filters

Collins Crystal Filters meet most narrow band needs (from 5 kHz to 20 MHz) in designs such as Butterworth, Tchebycheff and Linear Phase. Prototypes to your specifications are generally available in four to six weeks. Collins Crystal Filter capability is expanding rapidly. Even if your requirement appears to fall outside the defined area, send your specifications for design analysis. As one of the largest suppliers, Collins satisfies delivery requirements for all major programs.

Mechanical Filters

Collins has sold more than a million Mechanical Filters since introducing them to the communications industry. Hundreds of designs are available from stock in frequencies from 60 to 600 kHz, and with 60-db to 6-db shape factors as low as 1.2 to 1. The filters tolerate extreme temperature changes and long, continuous service without ageing, breakdown or drift. They're smaller in size and less expensive than other filters covering their spectrum.

LC Filters

Collins toroidal coil capabilities led to development of an extensive line of LC Wave Filters covering the sub-audio to 100-MHz range. These include low-pass, high-pass, band-pass, band-rejection, and other phase or amplitude responsive networks. Modern synthesis design techniques produce high performance units in small packages. Collins is one of the world's largest suppliers of LC Filters and precision inductors.

Send or call your performance requirements to Components Division, Collins Radio Company, Newport Beach, California 92663. Phone: (714) 833-0600.

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Circle 75 on reader service card

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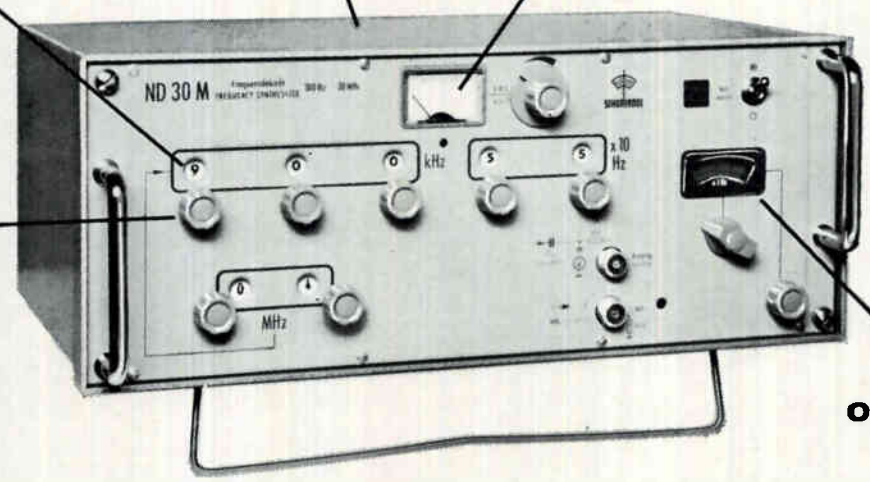


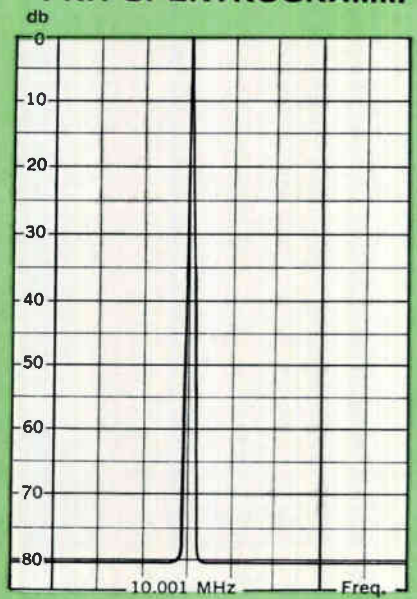
TYPE ND 30M

FREQUENCY SYNTHESIZER

FEATURES

- Built-in 1 MHz crystal has proportional oven and $5 \times 10^{-9}/°C$ stability
- Spurious and noise suppression better than 80 dB
- All solid state design
- Modular construction
- High resolution search oscillator . . . 130 divisions
- AC or battery operated

FNA-SPEKTROGRAMM



SPECTRAL PURITY OF ND 30M
FREQUENCY SYNTHESIZER
200 Hz per division Measured at BW of 10 Hz

Type ND 30M is the latest in a line of Frequency Synthesizers providing unusually high accuracy and ease of operation. Continuously variable over its range, each model provides a direct digital readout, with no tuning required. Perfect for bridge measurement, work with filters, networks, nuclear magnetic resonance, and as a source of reference frequencies for standards labs. These units can also be supplied in 19" rack mountings.

*Type ND 30M without crystal $5,290

Other ranges start at $3,180
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Type ND99K (0 to 110kHz)

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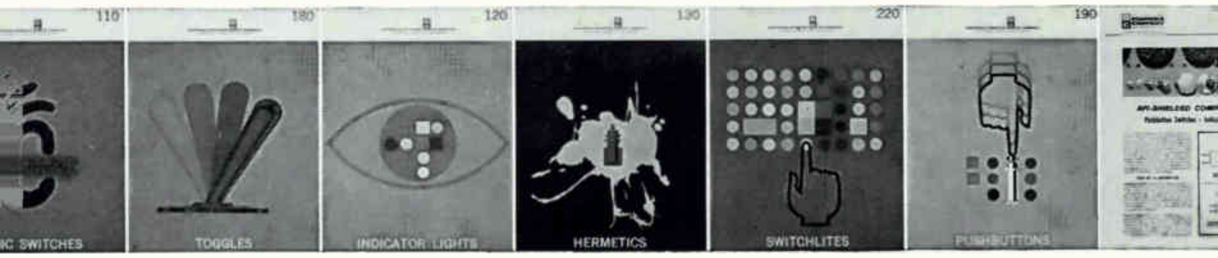

We have news for you!

Control Switch makes:

1. More types of switches than any other manufacturer. Including those mentioned above, plus RFI-shielded types, Switchlites with 1 to 4 lamps and colors, basic precision switches, as well as indicator lights.

2. Many switches that others don't make at all.

3. Many switches of advanced design. Like the world's smallest toggle switches. And the smallest indicator lights with RFI shielding.

4. Above all, quality switches. For application where a switch must not fail!

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#498 Toggle Switch Catalog 180
#499 Indicator Light Catalog 120
#500 Hermetically-Sealed Switch Catalog 130
#501 Switchlite Catalog 220
#502 Pushbutton Switch Catalog 190
#503 RFI-Shielded Component Bulletin 62

CONTROLS COMPANY OF AMERICA
CONTROL SWITCH DIVISION
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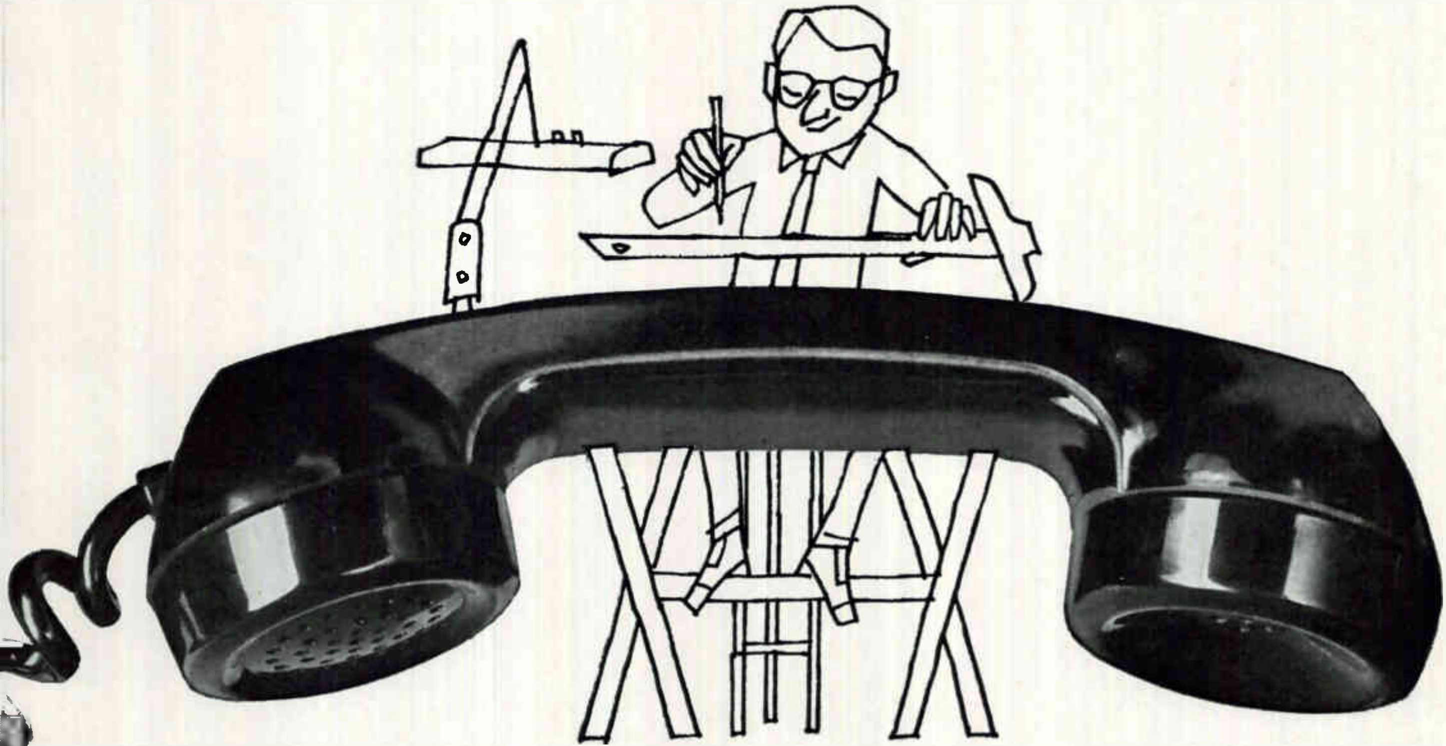
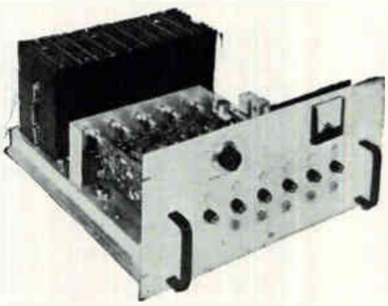
Circle 81 on reader service

want a custom-designed electronic power supply?



call 312 439-2800



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We're geared to handle them with a team of electronic engineers and volume production facilities. High- and low-voltage transistorized power supplies, or entire power systems. For electrostatic copiers to process control, optical readers to radar.

Tell us your specs; we'll design to meet them.

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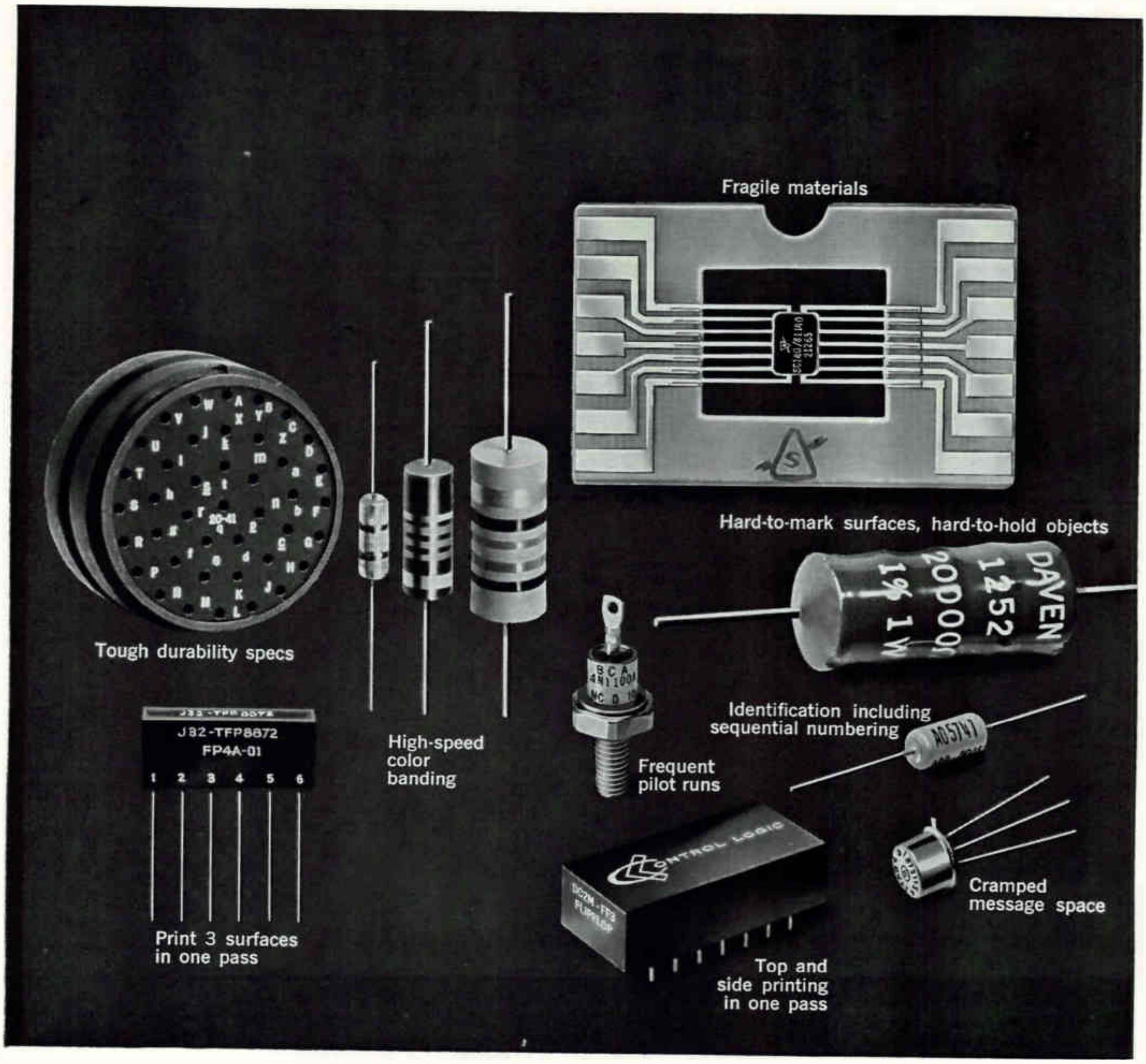

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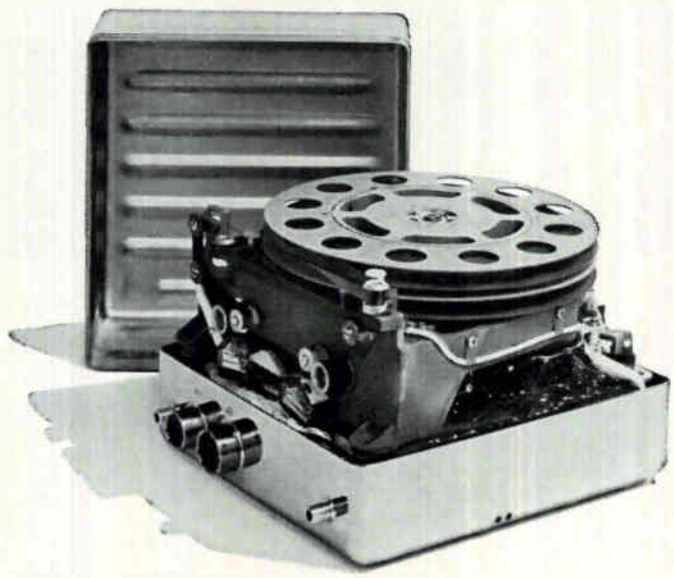

With our custom recording systems one of a kind beats a full house

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Technical Articles

Computer-aided design: part 4, Analyzing circuits with numbers page 88

In the end, the computer-aided designer has to put numbers and equations into the computer. The more complex the network the more data required and the more sets of simultaneous equations. To handle such data and equations as easily as possible, the engineer can use matrix algebra. In this article, an expert on numerical processing for computer-aided design explains how to get the most out of matrix algebra in the design process.

Electronic navigator charts man's path to the moon, page 109

When man embarks on the first truly extraterrestrial trip, the Apollo voyage to the moon, he will be guided by a box not much bigger than an unabridged dictionary. Its design, simplified to make it more reliable, is built around direct coupled transistor logic and a single integrated logic circuit.

1967 Electronics markets page 123

For 1967, marketing managers are optimistic after enjoying the best sales year in history. Electronics' annual survey predicts industry sales will rise a whopping 10% to $21.8 billion. Military spending, fueled by even larger increases for Vietnam will rise sharply. Vietnam may cost as much as $25 billion. On the technical front, the stream of integrated circuits into commercial products will turn into a flood. For the cover, art director Saul Sussman illustrated this trend by superimposing a silhouette of the United States on an integrated circuit background.

Coming January 23

- **Integrated electronics for microwaves**
- **Computer-aided design, part 5: modeling**
- **Radar sensor for Apollo**

Computer-aided design: part 4
Analyzing circuits by the numbers

Most computer-aided designs are accomplished numerically with matrix algebra, a technique still unsurpassed in solving complex network problems

By Frank Branin

International Business Machines Corp., Poughkeepsie, N.Y.

In the final analysis the computer-aided designer must feed numbers into the computer to check the performance of his design. These numbers are related to the equations that describe a given network. Since deriving the equations manually is tedious and error-prone, this approach has been abandoned in general purpose network analysis programs. Instead, the computer is exploited to derive the network equations automatically from simple input data that describes the network parameters and configuration.

Fortunately, matrix algebra, a technique which dates back to 1850, sets up these equations in a procedural form that is easy to program. With matrix algebra it is possible to handle d-c, a-c and transient network analysis problems, and the designer can derive the network equations according to the mesh, node, cutset and mixed (state-variable) methods of analysis.

Moreover, matrix algebra is a convenient shorthand that simplifies and organizes the mathematics of network analysis, making it easier to discern relationships that might otherwise be lost in details. Thus, matrix algebra is a valuable tool in computer-aided design.

A brief review of matrix algebra is given in "Understanding matrix notation" on p. 91. For clarity, the term "problem" refers to d-c, a-c or transient analysis, "method" refers to mesh, node, cutset or mixed approaches and "technique" refers to the specific steps that are applied to solve the problem such as Gaussian eliminations.

Forming a matrix of the network problem

Whether the designer must perform an a-c, d-c or transient analysis the problem is the same—to predict the behavior of a system of interconnected elements. The physical properties of a network are completely determined by the element characteristics and how the elements are connected. Mathematically, the network problem involves the properties of an underlying topological structure called a linear graph and a superimposed algebraic structure of variables associated with the nodes, branches and meshes of the graph. The linear graph for a Wheatstone bridge, as shown, top p. 90, represents its branch-node connection pattern. The direction chosen for each branch is arbitrary. The graph is formed by replacing each branch of the network with a line connecting the same nodes. These lines are numbered arbitrarily.

When the elements of a network are interconnected, its physical variables are constrained as described by Kirchhoff's current and voltage laws. These laws are conveniently expressed in terms of topological matrixes that specify how the network is connected.

ABCD's of network topology

Four different topological matrixes, designated A, B_T, C and D, are used for obtaining the network equations. Not all the matrixes need be derived for every problem since the matrixes required are dependent on the method of analysis chosen. The flow chart, bottom p. 89, makes clear how these matrixes may be derived in sequence, starting with a table of interconnections. The table is obtained from input data that describes the network configuration. For the Wheatstone bridge, the following table contains the information from which all four topological matrixes can be derived.

The computer first converts this connection table into a branch-node incidence matrix $\bar{A}$, as indicated. Each column of $\bar{A}$ indicates which branches are connected to a particular node—a +1 indicates that the node is an initial node, and a—1 identifies a final node. If the branch is not connected, a 0 is entered.

Connection table

Branch	Initial node	Final node
1	g	f
2	b	f
3	f	c
4	c	b
5	b	g
6	c	g

The distinctive feature of the $\bar{A}$ matrix is that each column is the negative sum of all the other columns. Hence, the matrix contains redundant information which can be removed by deleting the column corresponding to the ground or datum (reference) node. The matrix that results is called A, as shown on p. 90. In this example, node g is the reference node. Therefore, striking out column g in the $\bar{A}$ matrix results in the A matrix.

It is always possible for a designer to select a tree in the graph. A tree is a connected set of branches that includes all nodes of the graph and does not form any closed paths or meshes. There are many ways to choose such a tree; for example, branches 1, 2 and 3 in the Wheatstone bridge network represents one tree of the network. The remaining branches are called links; each link, when added to the tree, forms a unique closed path called a basic mesh or loop. An algorithm is available for classifying the branches as tree branches or links on the computer[1].

If the A matrix is then partitioned into submatrixes A_T and A_L that relate to tree-branches and links, respectively, as illustrated, the submatrix A_T is always square. The inverse of A_T is related to B_T, another topological matrix associated with the tree. Matrix B_T is called the node-to-datum path matrix.

Its columns show which branches are positively, negatively or not included in the corresponding node-to-datum path.

The relation between B_T and the inverse of A_T is given by

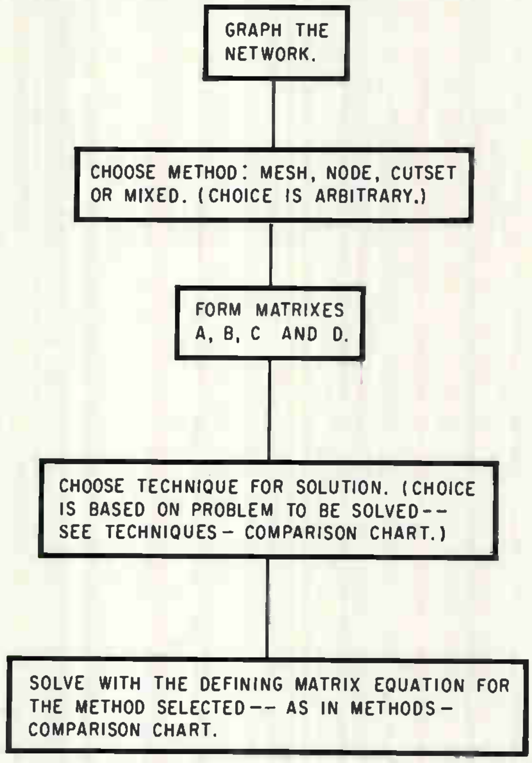
$$A_T^{-1} = B_T^t \tag{1}$$

where B_T^t is the transpose of B_T. An algorithm for determining the B_T matrix from the $\bar{A}$ matrix is available for the computer[1].

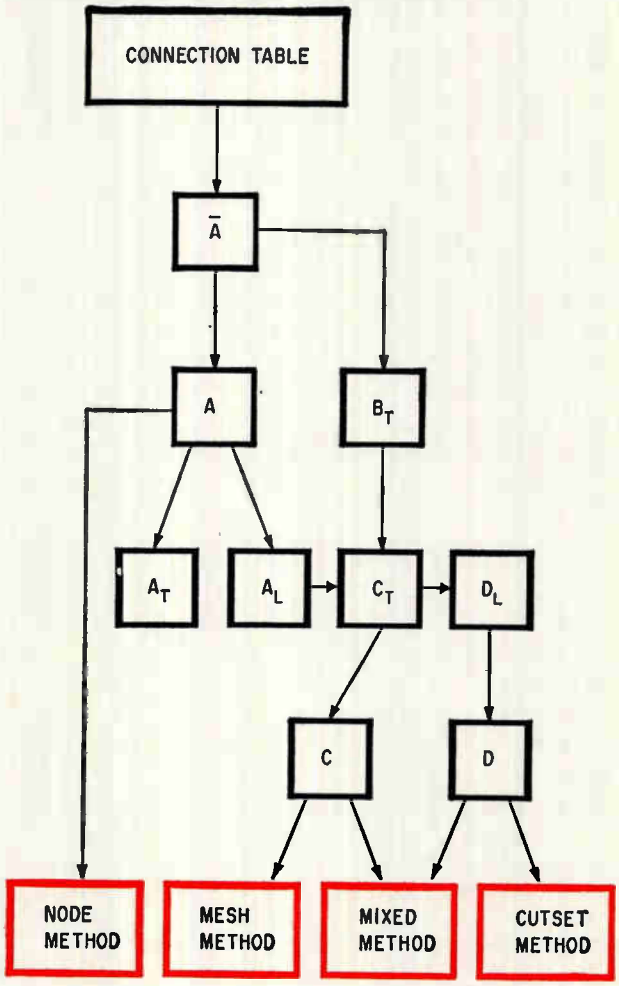
If the designer chooses to solve a network from mesh equations he will need C, the branch-mesh matrix, top p. 92. In forming the C matrix, the convention is adopted that each link together with the adjoining tree-branches defines a basic mesh. Thus, each basic mesh will contain only one link. The direction of each link defines the positive direction of the corresponding mesh.

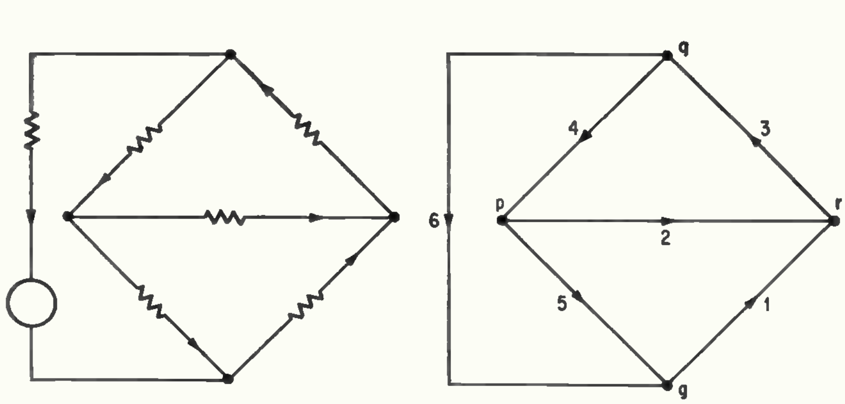
Mesh 4 is formed with link 4 and branches 2

Steps in numerical network analysis



Developing the major matrixes

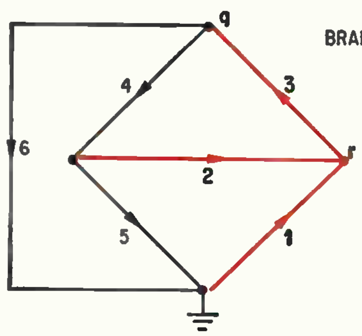




$\bar{A}$ MATRIX

BRANCH \ NODE	p	q	r	g
1	0	0	-1	1
2	1	0	-1	0
3	0	-1	1	0
4	-1	1	0	0
5	1	0	0	-1
6	0	1	0	-1

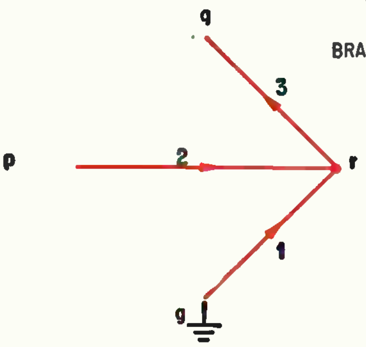
By replacing each of the elements in the circuit at the left with a line that connects between the same node points, a graph of the network is formed (center). To form the $\bar{A}$ matrix the branches are given arbitrary directions and sequential numbers. If the arrow leaves a node a +1 is entered in the column, if the arrow enters a node, a —1 is tabulated, and if a branch does not connect to a node a 0 is recorded.



A MATRIX

BRANCH \ NODE	p	q	r	
1	0	0	-1	A_T
2	1	0	-1	
3	0	-1	1	
4	-1	1	0	A_L
5	1	0	0	
6	0	1	0	

The A matrix is formed by selecting a reference node, in this case node g, and deleting that column from the $\bar{A}$ matrix. By selecting a tree of the graph, shown in color, the network can be resolved into two parts. The second part is the link structure of of graph, shown with black lines. Submatrixes A_T and A_L are then tabulated for the tree and links by relating the arrow directions for their respective branches to the nodes of the graph.



B MATRIX

BRANCH \ NODE	p	q	r	
1	-1	-1	-1	B_T
2	1	0	0	
3	0	-1	0	
4	1	0	0	B_L
5	0	1	0	
6	0	0	1	

Matrix B_T is related to the tree structure of the graph and is obtained from the $\bar{A}$ matrix. The transpose of $-B_T$ is equal to the inverse of A_T. Matrix B_T is called the node-to-datum path matrix. Its columns indicate how the branches are included in the node-to-datum path.

and 3 included positively; mesh 5 is formed with link 5 and branch 1 included positively and 2 included negatively; mesh 6 is formed with link 6 and branches 1 and 3 included positively. Thus, each column of the C matrix shows which branches are positively, negatively or not included in the corresponding mesh. The C matrix, like the A matrix, can be partitioned—in this case into C_T and C_L submatrixes, referring to the tree-branches and links, respectively. Submatrix C_L is a unit matrix and does not have to be stored explicitly in the computer. Only the submatrix C_T is needed and this may be obtained with the aid of a theorem which states that for any linear graph, the branch-node and branch-mesh matrixes obey the fundamental relations:

$$A^tC = 0 \qquad (2)$$

and

$$C^tA = 0$$

where the product is a null matrix; therefore, from the first of these expressions and with the aid of equation 1, the equation for computing C_T is

$$C_T = -B_TA_L^t \qquad (3)$$

If the designer chooses to analyze a network from the cutset equations he will need the basic cutset matrix, D. A cutset is any set of branches which, when removed, separates the graph into two disconnected subgraphs—one of which may consist of a single node. Each basic cutset is uniquely associated with a single tree-branch just as each basic mesh is uniquely associated with a single link. As illustrated, each basic cutset may be identified by passing a closed circular surface through the graph so as to cut a single tree branch.

Any link cut by the surface belongs to the same basic cutset. The link is oriented positively or negatively depending on whether it passes through this surface in the same direction as the tree-branch or in an opposite direction. The D matrix may also be partitioned into submatrixes D_T and D_L, referring to the tree branches and links. Each column of the D matrix shows which branches are

Understanding matrix notation

Matrix notation is a valuable tool for manipulating many variables without being swamped by clerical details. It enables the engineer to detect relationships between systems of equations which would be obscure in conventional notation.

The idea of representing an entire array or matrix of numbers by a single symbol leads to a shorthand notation even more powerful than ordinary algebra. This idea evolved from the study of simultaneous equations as outlined in the following three steps. Consider the equations:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 = b_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 = b_2$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 = b_3$$

Step 1. Since it is a nuisance to write the symbols x_1, x_2, x_3 and the arithmetic operators repeatedly, the designer may write these equations in the form of a tableau, thus:

$$[x_1 \quad x_2 \quad x_3]$$
$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

Step 2. The x's are written in a column to the right of the matrix of coefficients a_{ij}. The result resembles the format in which we write algebraic quantities to be multiplied.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

Step 3. Finally, the entire coefficient matrix and the columns of x's and b's are symbolized by the letters A, x, and b so that the matrix equation is expressed in shorthand form.

$$Ax = b$$

All these steps symbolize the original system of equations and the rule for multiplication of the matrix A by the vector x is expressed in steps 2 and 3. Thus, the equation $Ax = b$ can represent a system of any number of equations in any number of variables. Also, when the numbers of equations and variables are equal, x may be written as

$$x = A^{-1}b$$

Here, the symbol A^{-1} stands for another matrix—the inverse of A—which, when multiplied by the vector b, gives the unknown vector x. Standard procedures exist for computing such an inverse matrix.

The operations of addition, subtraction, multiplication and inversion of matrixes are well-defined, but division is not. Addition and subtraction require operations on corresponding terms of the matrixes that are involved and commutative. Multiplication, conversely, is not usually commutative. Hence, the order of multiplication of matrixes must be respected.

Two other operations peculiar to matrixes are transposition and partitioning. A matrix is transposed by interchanging its rows and columns and this operation is indicated on A by the symbol A^t. A matrix may be partitioned either horizontally or vertically or both, producing submatrixes in the process.

There are three special types of matrixes: the null matrix, all of whose elements are zero; the unit matrix, whose diagonal elements are all 1's and whose off-diagonal elements are zero; and the diagonal matrix, which has nonzero elements only on the diagonal. The null matrix is the counterpart of the algebraic zero (under addition) while the unit matrix is the counterpart of 1 (under multiplication).

The most difficult—and fundamental—problem in matrix theory is to compute the eigenvalues λ_i and eigenvectors χ_i of a matrix. The object of this particular game—called "solving the eigenproblem"—is to solve the equation

$$A\chi_i = \lambda_i\chi_i; \quad i = 1,2,\ldots,n$$

where n is the dimension of the (square) matrix A. That is, a vector χ_i is desired such that when multiplied by A, produces another vector λ_i times as large. Here λ_i is a scalar which may be real or complex and which multiplies each element of the vector χ_i Usually, there will be as many λ_i's as there are rows and columns in A, but sometimes, several of these λ_i's may have the same value.

Solving the eigenproblem may not interest all readers. However, the solution to this problem reveals much about the mathematical properties of the matrix A.

positively, negatively or not included in the corresponding basic cutset.

Since each tree-branch is assumed to be oriented positively in its own basic cutset, the submatrix D_T is a unit matrix. The submatrix D_L, which refers to the links, is the negative transpose of C_T. Thus,

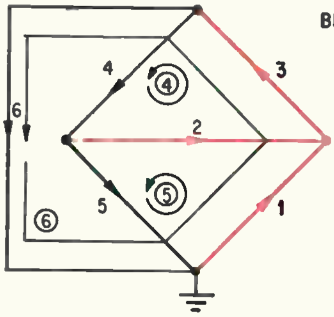
$$D_L = -C_T^t$$

Hence, all of the topological matrixes A, B_T, C, and D can be derived, step by step, starting with the connection table. These matrixes can now be used in expressing Kirchhoff's laws.

Electrical network laws

In addition to Kirchhoff's current and voltage laws, electrical networks obey Ohm's law—or a generalized version for nonlinear networks. Before programing the computer to derive these laws in equations, it is helpful to express these laws in matrix form. To accomplish this, it is necessary to identify certain current and voltage variables associated with a typical branch of an electrical network shown, bottom p. 92. The r^{th} branch is depicted as an impedance or admittance element Z_{rr} or Y_{rr} in series with a voltage source E_r and in parallel

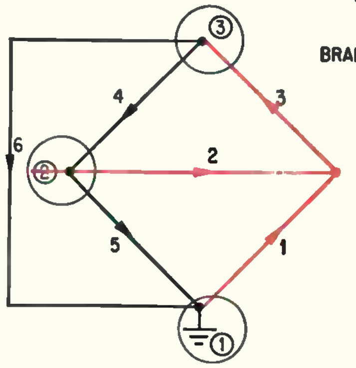
C MATRIX



$$\begin{array}{c|ccc} \text{BRANCH} \backslash \text{MESH} & 4 & 5 & 6 \\ \hline 1 & 0 & 1 & 1 \\ 2 & 1 & -1 & 0 \\ 3 & 1 & 0 & 1 \\ \hdashline 4 & 1 & 0 & 0 \\ 5 & 0 & 1 & 0 \\ 6 & 0 & 0 & 1 \end{array} \quad \begin{matrix} C_T \\ \\ C_L \end{matrix}$$

Basic meshes of the graph are selected by closing each link. The positive direction of the mesh is then determined by the direction of the link. Circled numbers inside of loops refer to the meshes. To form the C matrix the following convention is applied: a +1 is entered if the branch follows the same direction as a mesh, a —1 if it does not, and a 0 if a branch does not contact a mesh.

D MATRIX



$$\begin{array}{c|ccc} \text{BRANCH} \backslash \text{CUTSET} & 1 & 2 & 3 \\ \hline 1 & 1 & 0 & 0 \\ 2 & 0 & 1 & 0 \\ 3 & 0 & 0 & 1 \\ \hdashline 4 & 0 & -1 & -1 \\ 5 & -1 & 1 & 0 \\ 6 & -1 & 0 & -1 \end{array} \quad \begin{matrix} D_T \\ \\ D_L \end{matrix}$$

Cutsets of a graph are formed by circling a node to which at least one branch is connected. The circles are then numbered to indicate which branch has been cut. To form the D matrix a +1 is entered if the direction of the branch is away from a cutset, a —1 if toward the cutset, and a 0 if not in contact with the cutset. Submatrixes are then formed by partitioning the tree and links of the D matrix.

with a current source I_r. Either of the sources may have any value. There are three distinct current and voltage variables to identify in this branch. Branch current i_r enters at its initial node, but the element current J_r, that passes through Z_{rr}, is defined by,

$$J_r = I_r + i_r \qquad (5)$$

according to the sign conventions shown. Similarly, although the branch voltage, measured from initial to final node, is e_r, the element voltage V_r that actually appears across Z_{rr} is expressed by,

$$V_r = E_r + e_r \qquad (6)$$

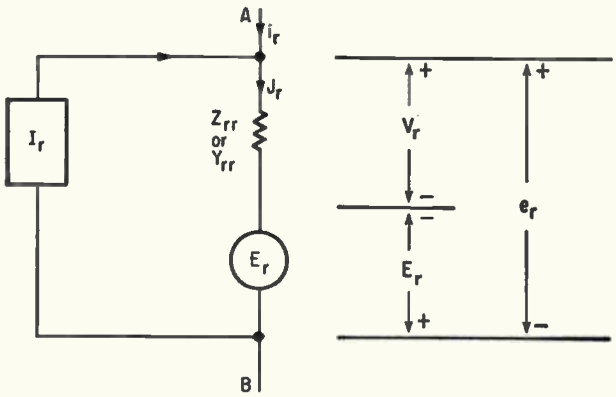
with the sign conventions taken as noted in the diagram.

Since E_r and I_r may be other than zero, Ohm's law for this branch must be written in terms of the element voltage and current variables V_r and J_r. Accordingly, Ohm's law for the entire network may be expressed in the shorthand notation provided by the matrix equations

$$V = ZJ \qquad (7)$$

or

$$J = YV \qquad (8)$$



To form a matrix that expresses both Ohm's and Kirchhoff's laws the branch element is employed.

where vectors V and J consist of the entire set of element voltage and current variables for the network, and where the admittance matrix Y is the inverse of the impedance matrix Z. The diagonal terms of Z (or Y) are the self-impedances (or self-admittances) of each branch, whereas the off-diagonal terms are the trans-impedances (or trans-admittances) between pairs of branches. If corresponding off-diagonal terms are equal they are mutual impedances (or admittances).

The dependent sources that describe the behavior of active devices such as transistors may be represented by off-diagonal terms in the Z or Y matrix. In the transistor amplifier and its equivalent circuit bottom p. 93, the T-equivalent for the transistor is represented with its amplifying effect accounted for by the dependent current generator αJ_e in parallel with the collector branch. But the amplification can also be considered as a transconductance that exists between the emitter and collector branches.

The following values are obtained from a handbook for a 2N190 transistor that operates at V_c = —5 volts and J_e = 1 milliampere: $\alpha = 0.979$, R_e = 0.0175 kilohm, R_b = 0.500 kilohm and R_c = 1,250 kilohms. If the 1-kilohm emitter resistor is combined with R_e to form a single branch having the value of 1.0175 kilohms and the numbering scheme on the diagram is applied, the following matrix equation expresses Ohm's law:

$$\begin{bmatrix} J_1 \\ J_2 \\ J_3 \\ J_4 \\ J_5 \\ J_6 \end{bmatrix} = \begin{bmatrix} 0.9828 & & & & & \\ & 2.00 & & & & \\ 0.9620 & & 0.0008 & & & \\ & & & 0.0200 & & \\ & & & & 0.1099 & \\ & & & & & 0.2000 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} \qquad (9)$$

where the element currents J are in milliamperes, the admittances (conductances) Y are in millimhos and the element voltages V are in volts. In this equation the transconductance $Y_{31} = 0.9620$ millimhos, which accounts for the dependent current source αJ_e in branch 3, has a value determined by $\alpha/1.0175$ since $J_1 = V_1/1.0175$. Thus the value of α can be determined for the dependent current source $\alpha\ J_1$ in branch 3.

Kirchhoff's current law for this network requires that $i_2 - i_4 + i_5 = 0$ at node b, $-i_3 + i_4 + i_6 = 0$ at note C, and $-i_1 - i_2 + i_3 = 0$ at node f. These relations can be combined into a single matrix

$$\begin{bmatrix} 0 & 1 & 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ i_5 \\ i_6 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad (10)$$

But the coefficient matrix in this equation is the transpose of A, the branch-node connection matrix. Hence equation 10 can be written

$$A^t i = 0 \qquad (11)$$

which represents an expansion of Kirchhoff's current law.

Similarly, the individual equations for Kirchhoff's voltage law can also be expressed in the matrix form

$$\begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \\ e_6 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad (12)$$

which requires that the sums of the branch voltage e around each of the three meshes equal zero. Here, the coefficient matrix is the transpose of the circuit matrix C so that Kirchhoff's voltage law can be written in the general form expressed by,

$$C^t e = 0 \qquad (13)$$

Corollary forms of Kirchhoff's current and voltage laws are embodied in the statements "the branch currents are a linear combination of the mesh currents" and "the branch voltages are a linear combination of the node-to-datum voltages." These statements can be written as the matrix equations

$$i = C\,i' \qquad (14)$$

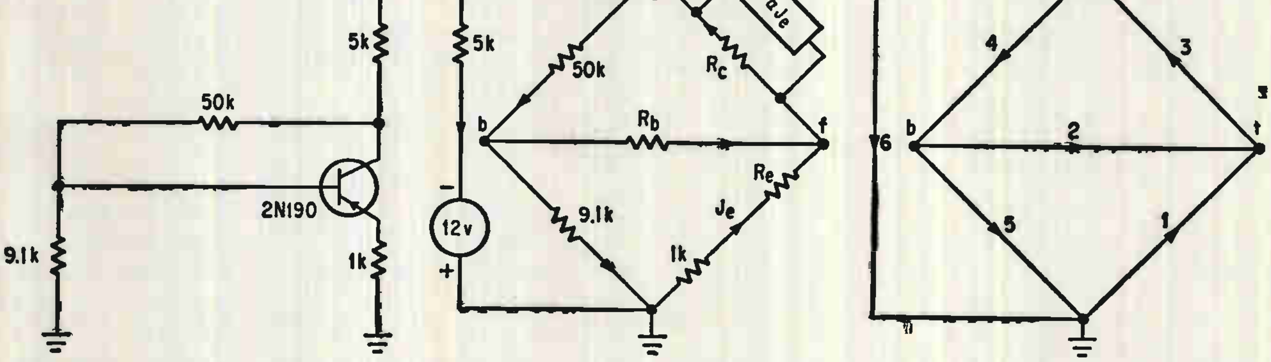
and

$$e = Ae' \qquad (15)$$

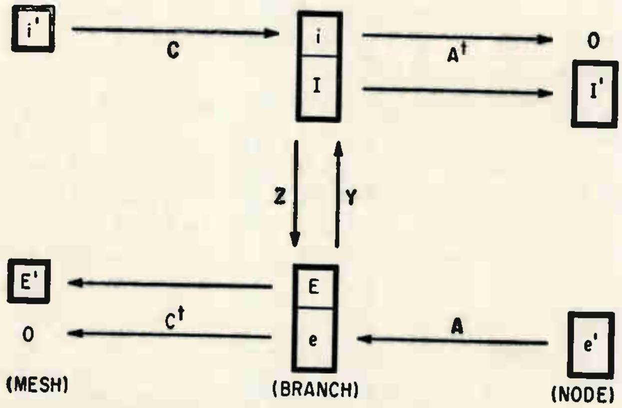
where i' is the vector of mesh currents and e' is the vector of node-to-datum voltages. Here, as in equations 11 and 13, the topological matrixes A and C automatically do the bookkeeping implied by Kirchhoff's laws, no matter how large the network or how complicated its interconnections. This demonstrates the power of matrix notation.

The three basic network laws can be summarized with a transformation diagram[2], top p. 94, which characterizes the algebraic structure that underlies the network problem and shows the interrelations between the variables expressed by equations 5 through 15. The diagram also depicts two additional relations: $C^tE = E'$, in which the sum of voltage sources E around each mesh gives rise to an equivalent mesh-voltage source E', and $A^tI = I'$, in which the sum of current sources I at each node gives rise to an equivalent nodal current source I'. (For nonlinear networks, the matrixes Z and Y symbolize nonlinear operators or transformations between V and J; this is the generalization of Ohm's law. Kirchhoff's laws are unaffected by nonlinearities.)

A variety of nonelectrical systems (mechanical, acoustical and structural[3, 4]) fit into this algebraic pattern and can be treated as network problems. Moreover, this pattern of algebraic-topological relations can be extended to characterize interconnected structures that consist of surface and volume elements as well as points and lines. From this extension, a direct correspondence with the operational structure that underlies vector calculus emerges and it then becomes possible to justify the application of network models (analogies) for a



The transistor amplifier at the left is represented by an equivalent circuit (center). Graph of the circuit appears at the right. Arrow directions and numbers on the graph are arbitrarily chosen.



The algebraic structure of the network problem is represented by the stages shown. These express the relationships of all the four matrixes and the interrelations of the circuit parameters.

wide class of partial differential equations—including Maxwell's equations[5].

Electrical network problem

Given the following, a network whose configuration determines the topological matrixes A and C; the impedance matrix Z (or admittance matrix Y) and the voltage and current source vectors E and I, the electrical network problem is to find the branch voltage vector e and the branch current vector i such that $E + e = Z(I + i)$ or $I + i = Y(E + e)$; $A^t i = 0$; $C^t e = 0$.

This problem may be handled with four different methods, three of which—the mesh, node, and cutset methods—are familiar. The fourth, the mixed method, though new, can be used like the others for d-c, a-c, or transient analysis. Moreover, it underlies the state-variable approach to transient analysis[1,6]. [See Electronics, Dec. 26, "Analyzing networks with state variables," page 63.] In all methods auxiliary variables, such as node-to-datum voltages e′ or mesh currents i′ must be used along with both of Kirchhoff's laws, and Ohm's law to solve the network problem.

Mesh method

If the impedance form of Ohm's law is slightly rearranged, the following relationship results,

$$(E - ZI) + e = Zi \tag{16}$$

Premultiplying by C^t and using equation 13 eliminates the vector e and results in the expression

$$C^t (E - ZI) = C^t Zi \tag{17}$$

By substituting equation 14 into equation 17 the matrix equivalent of the entire set of mesh equations is obtained. Thus,

$$C^t (E - ZI) = C^t Z C i' \tag{18}$$

Here, C^tZC is the mesh impedance matrix.

The solution for i′ is obtained from

$$i' = (C^t ZC)^{-1} C^t (E - ZI) \tag{19}$$

where $(C^tZC)^{-1}$ is the mesh solution matrix. The branch currents are computed from equation 14 and the branch voltages e from equation 16.

Node method

Applying equations 11 and 15 to the admittance form of Ohm's law yields the node equations

$$A^t (I - YE) = A^t YAe' \tag{20}$$

where A^tYA is the nodal admittance matrix. The solution for e′ is then expressed in the form

$$e' = (A^t YA)^{-1} A^t (I - YE) \tag{21}$$

where $(A^tYA)^{-1}$ is the nodal solution matrix. The computation of e and i is trivial.

Cutset (or tree) method

Instead of using the node-to-datum voltage e′ as auxiliary variables, the tree-branch voltages e_T may be used as a linearly independent set of voltages in terms of which all the branch voltages may be computed. Thus, in place of equation 15 the relation

$$e = De_T \tag{22}$$

may be applied, where D is the cutset matrix. The counterpart of equation 11 then becomes

$$D^t i = 0 \tag{23}$$

and these equations can be used to express Kirchhoff's voltage and current laws.

The cutset equations can then be expressed by

$$D^t (I - YE) = D^t YDe_T \tag{24}$$

where D^tYD is the cutset admittance matrix, and the solution for e_T can be expressed in the form

$$e_T = (D^tYD)^{-1} D^t (I - YE) \tag{25}$$

where $(D^tYD)^{-1}$ is the cutset solution matrix. Again, the computation of e and i is trivial.

Mixed method

The idea behind the mixed method is to express Ohm's law in a mixed form, with an admittance matrix for certain branches of the network and an impedance matrix for the remainder. Using the subscripts y and z to designate admittance-branches and impedance-branches, respectively, Ohm's law may be written in the form,

$$\begin{bmatrix} I_y + i_y \\ E_z + e_z \end{bmatrix} = \begin{bmatrix} Y_y & 0 \\ 0 & Z_z \end{bmatrix} \begin{bmatrix} E_y + e_y \\ I_z + i_z \end{bmatrix} \tag{26}$$

With this as a starting point, the y-branches are analyzed by the cutset method and the z-branches by the mesh method. The two types of branches are considered as separate subnetworks with the two resulting systems of equations coupled by an appropriate topological matrix using the following procedure.

Taking all the y-branches first a computer selects all the tree links. Any y-links thus identified will define basic meshes that contain only y-tree branches, since no z-branches have been considered up to this point. The paths-in-tree for these y-meshes are designated by the submatrix C_{Tyy}.

The tree-link sort is then resumed taking the z-branches into account. The z-links define basic meshes whose paths-in-tree may involve both y-tree and z-tree branches, designated by the submatrixes C_{Tyz} and C_{Tzz}, respectively. Thus, the C_T matrix for the entire network has the form

$$C_T = \begin{bmatrix} C_{Tyy} & C_{Tyz} \\ 0 & C_{Tzz} \end{bmatrix} \tag{27}$$

where the submatrix C_{Tzy} is zero.

If the y-branch voltages e_y are expressed in terms of the y-tree branch voltages, e_{Ty}, and equations 4 and 22 employed, the result is,

$$e_y = \begin{bmatrix} e_{Ty} \\ e_{Ly} \end{bmatrix} = \begin{bmatrix} U_{Ty} \\ -C^t_{Tyy} \end{bmatrix} e_{Ty} = D_y e_{Ty} \tag{28}$$

where D_y is the cutset matrix for the y-branches alone with the z-branches regarded as open circuited.

Similarly, the z-branch currents i_z may be expressed as a linear combination of the z-link currents i_{Lz} (which are identical with the mesh currents). This yields the relation

$$i_z = \begin{bmatrix} i_{Tz} \\ i_{Lz} \end{bmatrix} = \begin{bmatrix} C_{Tzz} \\ U_{Lz} \end{bmatrix} i_{Lz} = C_z i_{Lz} \tag{29}$$

Here C_z is the circuit matrix for the z-branches alone, with the y-branches regarded as short-circuited.

The terms of equation 26 may be rearranged in the form,

$$\begin{bmatrix} (I_y - Y_y E_y) \\ (E_z - Z_z I_z) \end{bmatrix} = \begin{bmatrix} Y_y & 0 \\ 0 & Z_z \end{bmatrix} \begin{bmatrix} e_y \\ i_z \end{bmatrix} - \begin{bmatrix} i_y \\ e_z \end{bmatrix} \tag{30}$$

The next step is to premultiply the first row of equation 30 by D_y^t and the second row by C_z^t and replace e_y and i_z by the expressions given in equations 28 and 29. The result thus obtained is,

$$\begin{bmatrix} D_y^t (I_y - Y_y E_y) \\ C_y^t (E_z - Z_z I_z) \end{bmatrix} = \begin{bmatrix} D_y^t Y_y D_y & 0 \\ 0 & C_z^t Z_z C_z \end{bmatrix} \begin{bmatrix} e_{Ty} \\ i_{Lz} \end{bmatrix} - \begin{bmatrix} D_y^t i_y \\ C_z^t e_z \end{bmatrix} \tag{31}$$

Except for the second term on the right, the result expressed by equation 31 is exactly what would follow from the tree method of analysis on the y-branches, with the z-branches open-circuited, and the mesh method of analysis on the z-branches, with the y-branches short-circuited.

Since it may be shown that

$$D_y^t i_y = C_{Tyz} i_{Lz} \tag{32}$$

and

$$C_z^t e_z = -C^t_{Tyz} e_{Ty} \tag{33}$$

these relations can be applied to produce the final result, namely,

$$\begin{bmatrix} D_y^t (I_y - Y_y E_y) \\ C_z^t (E_z - Z_z I_z) \end{bmatrix} = \begin{bmatrix} D_y^t Y_y D_y & -C_{Tyz} \\ C^t_{Tyz} & C_z^t Z_z C_z \end{bmatrix} \begin{bmatrix} e_{Ty} \\ i_{Lz} \end{bmatrix} \tag{34}$$

where the toplogical matrix C_{Tyz} effectively couples the two systems of cutset and mesh equations.

Numerical methods may be used for solving network problems of three main types: d-c, a-c and transient. These methods are detailed in the flow chart on page 101.

Solving the network problem

The most straight forward method for solving d-c network problems is conventional Gaussian elimination of variables in the mesh, nodal, cutset or mixed method equations. The amount of computation required is about $n^3/2$ operations (multiplications and additions), where n is the number of variables. If several solutions are desired for a given network with a succession of voltage and/or current sources, the procedure usually followed is to compute the mesh solution matrix or nodal solution matrix, at a cost of about n^3 operations, and then to multiply each different source vector by this matrix, at a cost of n^2 operations per vector.

However, the matrixes involved in most network problems are so sparse, (contain relatively few nonzero terms) that it is important to take full advantage of this sparsity when programing the actual method of solution. The Gaussian technique does not take advantage of the sparsity of the matrix. Techniques developed by Sato-Tinney[7] do exploit the sparsity of the nodal admittance matrix, so that both the number of computations and the requirements for computer memory are greatly reduced. They show that the order in which the variables are processed in the usual Gaussian elimination scheme strongly affects the number of computations involved in treating a sparse matrix. They also explain a special programing technique for storing a compact, coded form of the inverse of a sparse matrix that is more efficient to use computationally than the actual inverse.

In one piecewise analysis technique (developed by Kron[8, 9]) some tools are provided that enable the engineer to study the effect of varying a single resistance through a succession of values. This method, which is the basis of the MODIFY feature of ECAP[10], permits the nodal solution matrix for the original network to be updated with changes in one or more branch resistances. The amount of computation involved is trivial compared with that required for solving the nodal equations or reinverting the nodal admittance matrix.

An extension of the mesh method[9] leads to Kron's basic formula for updating the nodal solution matrix when one or more links are added to a given network. If Z_l designates the nodal solution matrix for the original network, Z_L represents the impedance matrix of the links to be added and A_L represents the corresponding branch-node connection matrix, then the basic formula is given by

$$(A^t YA)^{-1} = Z_l - Z_l A_L^t (A_L Z_l A_L^t + Z_L)^{-1} A_L Z_l \tag{35}$$

where $(A^+YA)^{-1}$ is the nodal solution matrix for the modified network. Equation 35 may be applied recursively to add one link-at-a-time until all links have been added or it may be used once to add all the links simultaneously. The latter method is more economical. Formulas similar to equation 35 update the mesh solution matrix or cutset solution matrix but Kron's technique **has not yet been applied** to the mixed method.

D-c problem tackled

Designer's frequently must analyze networks for different parameter values. To illustrate how Kron's method may be used to permit the designer to change parameter values without repeating each analysis from the start, consider the following example for a transistor amplifier. With the Y matrix given in equation 9 and the A matrix in equation 10 the nodal equations can be written numerically in the form

$$\begin{bmatrix} 2.1299 & -0.0200 & -2.0000 \\ -0.0200 & 0.2208 & 0.9612 \\ -2.0000 & -0.0008 & 2.0216 \end{bmatrix} \begin{bmatrix} e'_b \\ e'_c \\ e'_f \end{bmatrix} = \begin{bmatrix} 0 \\ -2.4 \\ 0 \end{bmatrix} \quad (36)$$

which can be verified by carrying out the matrix operations indicated in equation 20. By computing the inverse of the coefficient matrix, the solution is written in the form

$$\begin{bmatrix} e'_b \\ e'_c \\ e'_f \end{bmatrix} = \begin{bmatrix} 4.1880 & 0.3937 & 3.9561 \\ -17.6269 & 2.8642 & -18.8004 \\ 4.1363 & 0.3906 & 4.4010 \end{bmatrix} \begin{bmatrix} 0 \\ -2.4 \\ 0 \end{bmatrix} = \begin{bmatrix} -0.9449 \\ -6.8741 \\ -0.9375 \end{bmatrix} \quad (37)$$

Suppose that a particular value of emitter current for example, 1 milliampere is desired. This can be achieved by adjusting the bias resistor. This requires that $e'_f = -1.0175$ volts instead of -0.9375 volts as computed, and the change can be achieved by adjusting biasing resistors. If a resistor R_L is added in parallel with the 9.1-kilohm resistor in branch five, the corresponding A_L matrix is [1 0 0]. Accordingly, with the aid of equation 35

$$\begin{aligned} e' &= [Z_1 - Z_1A_L^t\,(A_LZ_1A_L^t + Z_L)^{-1}\,A_LZ_1]\,\bar{I} \\ &= Z_1\bar{I} - [Z_1A_L^t\,(A_LZ_1A_L^t + Z_L)^{-1}\,A_LZ_1]\,\bar{I} \end{aligned} \quad (38)$$

where $\bar{I} = A^t(I - YE)$. Since $Z_1\,\bar{I}$ has already been evaluated in equation 37, equation 38 may be written in the form

$$\begin{bmatrix} e'_b \\ e'_c \\ e'_f \end{bmatrix} = \begin{bmatrix} -0.9449 \\ -6.8741 \\ -0.9375 \end{bmatrix} - \begin{bmatrix} 4.1880 \\ -17.6269 \\ 4.1363 \end{bmatrix} [4.1880 + R_L]^{-1} [4.1880 \quad 0.3937 \quad 3.9561] \begin{bmatrix} 0 \\ -2.4 \\ 0 \end{bmatrix} \quad (39)$$

$$= \begin{bmatrix} -0.9449 \\ -6.8741 \\ -0.9375 \end{bmatrix} + \begin{bmatrix} 4.1880 \\ -17.6269 \\ 4.1363 \end{bmatrix} \left(\frac{0.9449}{4.1880 + R_L} \right)$$

Resistance R_L is chosen to decrease e'_f by 0.0800 volts thus bringing it to the desired value of -1.0175 volts. This requires that $(4.1363 \times 0.9449)/(4.1880 + R_L) = -0.0800$ or $R_L = -53.043$ kilohms. This negative resistance in parallel with branch five yields a net value of 10.983 kilohms in place of the original value of 9.1 kilohms. Thus, with Kron's method the exact value of biasing resistance required can be easily computed. Moreover, the nodel solution matrix does not require updating since the problem permits postmultiplying by $\bar{I}$. This technique of postmultiplying a matrix expression by a column vector is often an effective method of increasing computational efficiency and should be applied whenever appropriate to the problem.

By a suitable extension of equation 35, the sensitivity of the nodal solution matrix Z_1 with respect to any branch impedance Z_l may be computed as follows:

$$\frac{\partial Z_1}{\partial z_l} = \frac{1}{z_l^2}\,[Z_1A_L^t]\,[A_LZ_1] \quad (40)$$

where A_L is the connection matrix for the branch in question. (Second-order partial derivatives may also be computed.) Alternatively, the sensitivity of the node voltage e' to changes in E, I, or Y may be computed by differentiating the nodal equations. Thus, from equation 20 it can be shown that,

$$A^t\,(dI - dY\,E - Y\,dE) = A^t dY\,Ae' + A^tYA\,de' \quad (41)$$

and by rearranging,

$$de' = (A^tYA)^{-1}\,A^t\,[dI - dY\,(E+e) - Y\,dE] \quad (42)$$

Here, dI is the vector specifying the perturbations of all the current sources, dE of all the voltage sources and dY of all the admittances.

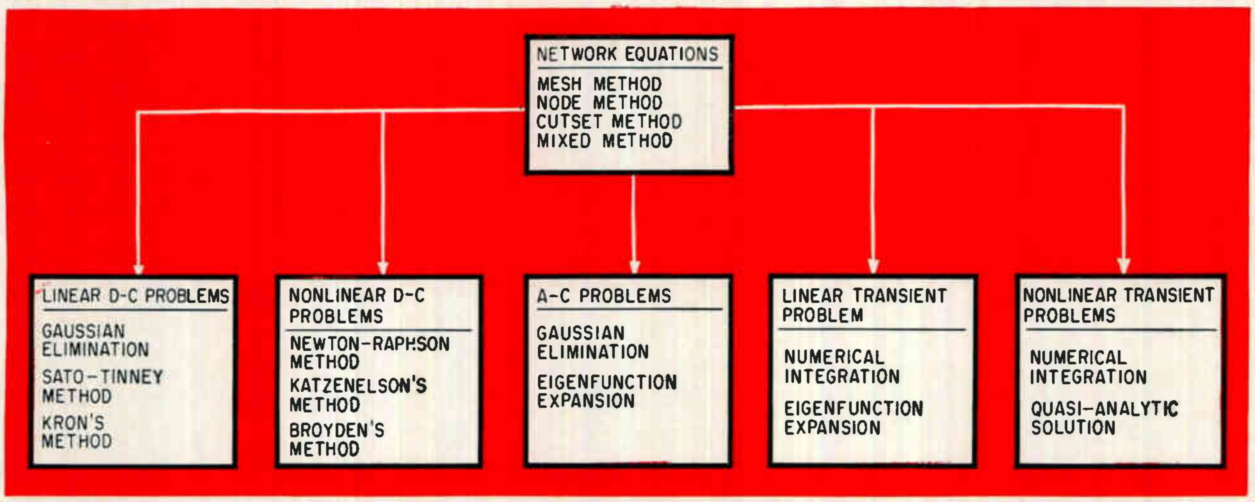
Performing a sensitivity analysis

When a current gain of a transistor drifts, the output of a circuit can fall outside the desired values. A good design accounts for this drift with a sensitivity analysis. For instance, if a 1% increase in α, the current gain, results in this circuit, a corresponding increase of 0.00962 in the transconductance Y_{31} results. Hence, the dY matrix in equation 42 would consist of 0.00962 in the (3,1) position and zero everywhere else while dI and dE would be zero. These values together with and the results already computed yield

$$\begin{bmatrix} de'_b \\ de'_c \\ de'_f \end{bmatrix} = \begin{bmatrix} 4.1880 & 0.3937 & 3.9561 \\ -17.6269 & 2.8642 & -18.8004 \\ 4.1363 & 0.3906 & 4.4010 \end{bmatrix} \begin{bmatrix} 0 \\ 0.009029 \\ 0.009029 \end{bmatrix} = \begin{bmatrix} -0.0321 \\ 0.1958 \\ -0.0004 \end{bmatrix} \quad (43)$$

The question of how to solve nonlinear d-c problems in an important one, but difficult to answer with complete assurance. One conventional technique is the Newton-Raphson[11] iteration method.

Techniques for network solution



For solving a single nonlinear equation $f(x) = 0$ this method applies the recursion formula $x_{i+1} = x_i - f(x_i)/f'(x_i)$ where $f'(x_i)$ is the value of the derivative df/dx at the point x_i.

For a system of nonlinear equations $f_j(x_1, x_2, \ldots, x_n) = 0$, with $j = 1,2, \ldots, n$, the notion of the derivative has to be generalized and for this purpose the Jacobian[11] matrix H is used. The jkth element of the Jacobian matrix is $H_{jk} = \partial f_j/\partial x_k$. The recursion formula now becomes $x_{i+1} = x_i - H^{-1}f(x_i)$ where x and f are vectors. An adaptation of this method has been successfully applied in TAP[1, 12] and in NET-1[13].

When the iteration converges, it does so quadratically. That is, at each iteration the error is proportional to the square of the previous error. However, the method may diverge under certain circumstances—for example, in some transistor switching circuits with positive feedback.

Methods have been developed to overcome two main drawbacks of the Newton-Rahphson method, namely: the need to repeatedly evaluate and invert the Jacobian matrix and the reliability of the method to diverge[14]. The remedy has not yet been applied to nonlinear network problems.

Another approach to solving the nonlinear network, has been described by Katzenelson[15]. It converges in a finite number of steps if the resistance characteristics are continuous, monotonically increasing and piecewise linear. Under these restrictions, the answer to the network problem is found by solving several linear problems, each approximating the nonlinear problem over a small range.

For each of these successive linear network problems the cutset solution matrix is slightly different. The key to the computational effectiveness of this algorithm is the application of Kron's method for updating the cutset solution matrix.

A-c network problems

Since the theoretical development given so far applies to complex numbers as well as real, the methods described may be used for a-c problems as well as d-c, but at approximately four times the computational cost of the latter. Moreover, since the coefficient matrix is frequency dependent in a-c problems, the equations must be solved (or the matrix inverted) at each new frequency. Thus computing frequency response curves is expensive.

A new approach to the a-c problem[6] that does not have the frequency limitation is based on the mixed method. It tackles the job of matrix inversion by first computing the eigenvalues and eigenvectors of the matrix and reduces the problem to the trivial task of inverting a diagonal matrix at each new frequency. [See "Understanding matrix notation" on p. 91.]

The method is better for computer-size problems than Laplace transform techniques that involve ratios of polynominals. The task of computing the coefficients of the polynomials is time-consuming and has serious numerical inaccuracies, especially when the polynomials are of high degree. Also, these roots may be extremely sensitive to errors in the coefficients. The eigenvalue[11] approach is more appropriate and gives all of the theoretical information that the Laplace transform method can provide. For example, the eigenvalues are identical with the poles of the network functions, the zeros of this equation can be computed by an iterative technique. Moreover, any network function desired may be computed directly and its sensitivity obtained, either with respect to frequency or with respect to any network parameter. Finally, even the pole sensitivities can be calculated.

The technique is based on equation 34, from which the differential equations for an RLC network can be derived in first-order form as follows:

All capacitors are treated as admittance branches and may have a nonzero conductance in parallel. Thus, the admittance matrix becomes $Y_y = pK + G$ where $p = d/dt$. The symbol K is used for capacitance so as not to conflict with the symbol C that designates the circuit matrix. Conversely, all inductors are regarded as impedance branches with a series resistance so that the impedance matrix is $Z_z = pL + R$.

With the definitions of Y_y and Z_z in equation 34, the differential equations (for constant K and L) can be written in the form

$$\begin{bmatrix} D^tKD & 0 \\ 0 & C^tLC \end{bmatrix}\begin{bmatrix} pe_T \\ pi_L \end{bmatrix} + \begin{bmatrix} D^tGD & -C_{Ty_2} \\ C^t{}_{Ty_2} & C^tRC \end{bmatrix}\begin{bmatrix} e_T \\ i_L \end{bmatrix} = \begin{bmatrix} I_T \\ E_L \end{bmatrix} \quad (44)$$

where the symbols I_T and E_L designate the driving currents and voltages. In more compact form, equation 44 is

$$P\dot{x} + Qx = f(t) \quad (45)$$

where $\dot{x} = dx/dt$ and x is the state-variable vector of capacitive tree-branch voltages and inductive

$$\dot{x} = Ax + g(t) \quad (46)$$

link currents. Solving this expression for $\dot{x}$ yields where $A = -P^{-1}Q$, corresponds to Bashkow's A-matrix[16] and $g = P^{-1}$ f. (This A matrix is not to be confused with the topological matrix A.)

For steady state a-c problems, the driving function may be written as $g(t) = g_o e^{st}$, with g_o a known vector and s a complex number. The steady state response is then $x(t) = x_o e^{st}$ with the vector x_o yet to be determined. With these relations substituted into equation 46, a linear system of equations $(sU - A)x_o = g_o$ is obtained for the formal solution. This is given by the relationship

$$x_o = (sU - A)^{-1} g_o \quad (47)$$

Solving for the eigenvalues λ_i and eigenvectors χ_i the matrix A allows the engineer to express $(sU - A)^{-1}$ in a very functional form. Let Λ a diagonal matrix, containing the λ_i on its diagonal, and let $\underline{X}$ be a matrix whose columns are the χ_i vectors. The eigenproblem can then be written as $A\underline{X} = \underline{X}\Lambda$ or

$$\underline{X}^{-1} A \underline{X} = \Lambda \quad (48)$$

This defines a transformation that diagonalizes the matrix A. But this same transformation also diagonalizes the matrix $(sU - A)$. As a consequence it can be shown that

$$(sU - A)^{-1} = \underline{X}(sU - \Lambda)^{-1}\underline{X}^{-1} \quad (49)$$

Accordingly equation 47 becomes

$$x_o = \underline{X}(sU - \Lambda)^{-1}\underline{X}^{-1} g_o \quad (50)$$

This is the basic relation of the new method, requiring the inversion of the diagonal matrix $(sU - \Lambda)$ at each frequency.

If $d = X^{-1} g_o$, then the i^{th} element of the x_o vector may be computed with the relation

$$x_i = \sum_{j=1}^{n} \frac{x_{ij}\, d_j}{s - \lambda j} \quad (51)$$

This partial fraction expansion of the state variable x_i may be evaluated at a computational cost of n operations per frequency as opposed to n^3 operations if the equation $(sU - A)\, x_o = g_o$ were solved by Gaussian elimination.

The cost of solving the eigenproblem is not negligible since it is equivalent to solving $(sU - A)x_o = g_o$ at roughly 10 frequencies. Accordingly, the present method would not pay off if solutions were required for only a few frequencies. But for a frequency response calculation this method is very effective. It is easy to derive sensitivity formulas with this method. For example, the frequency sensitivity of x_o is

$$\frac{dx_o}{ds} = -\underline{X}(sU - \Lambda)^{-2}\underline{X}^{-1} g_o \quad (52)$$

This method can also be extended to the computation of driving point and transfer functions and their sensitivities.

Large range of eigenvalues

The eigenvalue method is not free of all difficulties. It is possible that numerical errors of a crippling nature may arise when networks having large eigenvalue ratios are treated. The difficulty is that although the large eigenvalues can be computed accurately, the small ones cannot. But it is the small ones which are principally responsible for determining the behavior of the network.

One possible remedy is to solve the eigenvalue problem for the inverse matrix A^{-1}. Then the situation is reversed, the large eigenvalues of A^{-1} that are obtained accurately are the reciprocals of the small eigenvalues of A. Computing A^{-1} may be error-prone. But if the matrix Q in equation 45 is nonsingular, then the relation

$$A^{-1} = Q^{-1} P \quad (53)$$

may be applied to compute a more accurate inverse for A. A more accurate technique for computing small eigenvalues of the A matrix needs to be developed.

Transient network problems

With or without a computer, nonlinear transient problems are the hardest to solve. However, linear transient problems can be solved as easily as d-c and a-c problems. Nonlinear analysis of high order differential equations is often necessary. Solving these can be extremely slow when the network has a wide spread of eigenvalues.

An approach to linear transient analysis that yields an exact solution is obtained from linear network equations of the form, $\dot{x} = Ax + g(t)$. The solution for this system of differential equations may be expressed as

$$x(t+h) = e^{Ah}\, x(t) + \int_0^h e^{A(h-\tau)}\, g(t+\tau)\, d\tau \quad (54)$$

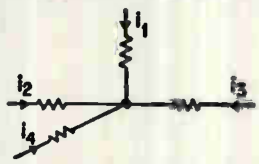
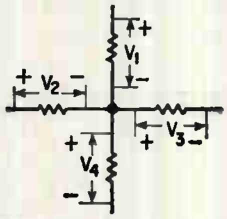
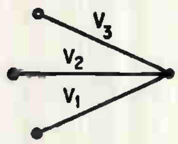
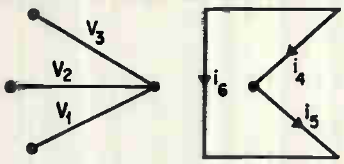
where e^{Ah} is a special matrix defined by the series

$$e^{Ah} = U + Ah + \frac{(Ah)^2}{2!} + \frac{(Ah)^3}{3!} + \ldots \quad (55)$$

This solution is exact, but its utility depends on the computation of e^{Ah}.

A finite number of terms may be used in the

Comparison of network analysis methods

METHOD	TERMS SOUGHT		MATRIXES REQUIRED	DEFINING EQUATION
MESH	i' (BRANCH CURRENTS)		C	$i' = (C^t Z C)^{-1} C^t (E - ZI)$
NODE	e' (BRANCH CURRENTS)		A	$e' = (A^t Y A)^{-1} A^t (I - YE)$
CUTSET	e_T (TREE-BRANCH VOLTAGES)		D	$e_T = (D^t Y D)^{-1} D^t (I - YE)$
MIXED	e_y, i_z (TREE-BRANCH VOLTAGES AND LINK CURRENTS)		C AND D	$e_y = D_y e_{Ty}$ $i_z = C_z i_{Lz}$

series expansion of e^{Ah}. But when the matrix A has a large eigenvalue, the integration step size h must be kept small (roughly less than the reciprocal of $|\lambda_{max}|$) to permit rapid convergence of equation 55. Precisely the same limitation arises in numerical integration with methods where h must be kept small to avoid numerical instability.

If, instead of avoiding the eigenvalue problem the designer solves it, then equation 54 becomes as practical as equations 50 and 51. The transformation that diagonalizes A also diagonalizes e^{Ah}, thus yielding the relation

$$\overline{X}^{-1} e^{Ah} \overline{X} = e^{\Lambda h} \tag{56}$$

where $e^{\Lambda h}$ is a diagonal matrix whose terms $e^{\lambda_i h}$ are trivial to compute. After solving this expression for e^{Ah}, equation 54 may be rewritten as

$$x(t+h) = \underline{X} e^{\Lambda h} x^{-1} x(t) + \int_0^h \underline{X} e^{\Lambda(h-\tau)} \underline{X}^{-1} g(t+\tau)\, d\tau \tag{57}$$

and all that is required is to compute the integral expression. If the driving function g $(t + \tau)$ is expressed as a polynomial in τ, however, the integration can be carried out exactly, term by term. This provides a very satisfactory way of evaluating the integral on a digital computer.

Numerical methods

Numerical methods of integration employ finite difference equations to approximate the actual differential equations to be solved. For a single differential equation of the form $dx/dt = f(x, t)$ a solution may be effected by the general finite difference expression

$$x_n = \sum_{i=1}^{M} a_i x_{n-i} + h \sum_{j=0}^{N} b_j f_{n-j} \tag{58}$$

where h is the integration interval, $x_n = x(nh)$ and f_{n-j} $(x_{n-j}, (n-j)h)$. The number and values of the coefficients a_i and b_i are determined by the number of terms of the Taylor expansion of x(nh) which are to be matched by the integration formula so defined.

If $b_o = 0$, the integration formula is called a predicator since the new value of x_n is predicted in terms of previous values (x_{n-1}) and previous derivatives (f_{n-j}) only. If $b_o \neq 0$, the formula is called a corrector since it provides a corrected value of x_n. This is accomplished using the predicted value of x_n, to compute an approximate value of the new derivative f_n which is then applied in equation 58.

For any integration scheme characterized by equation 58, there exists a characteristic polynomial whose roots p_k determine the solution of equation 58 in the form

$$x_n = \sum a_k p_k^n \tag{59}$$

where a_k are constants. Thus, x_n is a linear combination of terms p_k^n.

One of these roots p_k, lying near the point $1 + j0$

in the complex plane, will be the principal root since it primarily determines the desired approximation to the solution of the differential equation in question. All the other roots are parasitic roots and if any of these lies outside the unit circle, x_n will eventually diverge. This situation is called numerical instability and it invalidates the solution.

To prevent numerical instability, the integration step h must be kept small enough to insure that all of the parasitic roots of equation 59 remain inside the unit circle. In the case of a system of linear differential equations with constant coefficients, as typified by equation 46, the requisite condition on h for most integration formulas is

$$h|\lambda_{max}(A)| \leq c \qquad (60)$$

Here $\lambda_{max}(A)$ is the largest eigenvalue of the coefficient matrix A. The constant c is in the order of 1 or 2, depending on the integration method applied. Even in the case of nonlinear differential equations, an equivalent restriction, involving the (instantaneously) largest eigenvalue of the Jacobian matrix, must be imposed to prevent numerical instability.

It is just this constraint on the integration interval that makes most integration techniques so painfully slow for network problems that have a wide spread of eigenvalues. The largest eigenvalue—or, its reciprocal, the smallest time constant—controls the permissible size of the integration step. Conversely, the smallest eigenvalues (largest time constants) control the network response and so determine the total length of time over which the integration must be carried out. Thus, when the ratio of largest to smallest eigenvalues is large many very small integration steps are required to obtain the solutions. This is the biggest obstacle to be overcome in the transient analysis of networks.

There are, however, some integration formulas for which the constraint on h given in equation 60 does not apply; for example, $x_n = x_{n-1} + hf_n$ and $x_n = x_{n-1} + h/2\,(f_n + f_{n-1})$. Both of these have characteristic equations of the first degree and so have no parasitic roots. But the main disadvantage of these formulas is that they are inaccurate and the integration interval must often be shortened to insure sufficient correctness. Another disadvantage is that both methods require the solution of a system of linear equations at each integration step and this complicates their application.

Quasi-analytic methods

A quite different approach is needed for transient analysis of nonlinear networks. Although numerical integration can be used, the drawbacks cited above are overcome with quasi-analytic techniques. These techniques are applied for most nonlinear problems. Consider this problem: let A = D + B, where D contains all of the diagonal terms of A and B contains all the off-diagonal terms. Then equation 46 can be written as

$$\dot{x} = Dx + [Bx + g(t)] \qquad (61)$$

with Bx + g(t) a driving function. The analytic solution to equaiton 61 can be obtained by modifying equation (54) to read

$$x(t+h) = e^{Dh}x(t) + \int_0^h e^{D(h-\tau)}[Bx(t+\tau)+g(t+\tau)]\,d\tau \qquad (62)$$

Here, e^{Dh} is easy to compute since it is a diagonal matrix. Furthermore, the integration can be carried out with a polynomial approximation of any desired degree for Bx + g.

Equation 62 has an instability problem that is avoided by choosing the integration interval whose form obeys the relation $h|\lambda_{max}(B)| \leq c$, where c is a small constant. Thus, the largest eigenvalue of the off-diagonal matrix B controls the stability of this numerical integration process.

However, if a transformation on A is chosen having the form $T^{-1}AT = \bar{A} = \bar{D} + \bar{B}$ where $\lambda_{max}(\bar{B})$ is arbitrarily small, the integration interval can be increased without risking instability. Indeed, if T is so chosen that $\lambda_{max}(\bar{B})$ is zero, the eigenvalue problem is solved and the instability condition vanishes. In effect, the iterative process continually reduces $\lambda_{max}(\bar{B})$ until it vanishes. But the eigenproblem does not have to be solved to obtain a significant increase in the integration interval, as the following illustrates:

This type of transformation is tantamount to changing variables and then integrating the differential equations in the domain of the new variables. Specifically, the new variables are defined as $y = T^{-1}x$ so that equation 46 becomes $T\dot{y} = AT_y + g(t)$, or

$$\dot{y} = T^{-1}ATy + T^{-1}g(t) \qquad (63)$$

The solution, analogous to equation 62, is

$$\dot{y}(t+h) = e^{\bar{D}h}y(t) + \int_0^h e^{\bar{D}(h-\tau)}[\bar{B}y(t+\tau)+w(t+\tau)]\,d\tau \qquad (64)$$

where $w(t) = T^{-1}g(t)$

From this expression and the relation x = Ty, a solution to the original problem, equation 46, may be computed. Moreover, if T has been chosen so as to reduce $\lambda_{max}(B)$ sufficiently, a large integration step h may be used. The validity of this procedure has been verified in the following problem.

Consider an RC ladder network with five equal resistances and five equal shunt capacitors; the maximum integration step which could be taken safely with equation 62 was found to be equal to the time constant, RC. In the case of a modified network capacitor C_3 is split in half and the two halves connected by a resistor r has a very small value relative to any individual resistor R. Here, the integration step was found to be limited by the time constant rC.

Originally, the state-variable vector, for both networks, consisted of all the capacitor voltages. However, when a different combination of voltages

Network analysis techniques

Techniques	D-c problem	A-c problem	Transient problem
Gaussian elimination	Advantage: Most direct method Disadvantage: Usually does not take advantage of matrix sparsity For linear networks only	Advantage: Most direct method Disadvantage: Usually does not take advantage of matrix sparsity	
Sato-Tinney	Advantage: Gaussian elimination that takes advantage of sparsity Disadvantage: Requires special programing techniques For linear networks only	Advantage: Gaussian elimination that takes advantage of sparsity Disadvantage: Requires special programing techniques	
Kron's method	Advantage: Permits change of parameters for solution of a family of related problems. For example, in a sensitivity analysis there is no need to run the program from the start for each parameter change Disadvantage: For linear networks only	Advantage: Permits change of parameters for solution of a family of related problems. For example, in a sensitivity analysis there is no need to run the program from the start for each parameter change	
Newton-Raphson	Advantage: Converges quadratically Disadvantages: May diverge and the Jacobian matrix has to be computed and converted repeatedly For nonlinear networks only		
Katzenelson	Advantage: Technique is based on Kron's method. Guaranteed to converge for piece-wise linear monotonic functions Disadvantage: For nonlinear networks only		
Broyden	Advantage: Generalization of Newton-Raphson method that prevents divergence and does not require repeated computation and inversion of the Jacobian matrix Disadvantage: For nonlinear networks only		
Eigenfunction expansion		Advantage: gives driving-point and transfer function, poles and zeros, sensitivity and efficient calculation of frequency response Disadvantage: Requires solution of the eigenproblem	Advantage: Gives analytic solution that is free of time constant restrictions Disadvantage: For linear networks only
Numerical integration			Advantage: Most commonly used. Accurate. For linear and nonlinear networks Disadvantage: Very slow for networks with a wide spread of time constants
Quasi-analytic			Advantage: Treats diagonal terms of A-matrix analytically and off-diagonal terms by numerical integration. With modification time-constant restrictions are avoided. Disadvantage: For nonlinear networks only

was applied in treating the second network—namely, the voltage across capacitors C_1, C_2, C_4 and C_5 but the sum and difference of the voltages across the two half-size capacitors—it became possible to increase the integration step size until it was equal to that in the previous network. This simple change of variables defined a transformation which was sufficient to reduce the maximum eigenvalue of $\overline{B}$ significantly in equation 64, but far from adequate to solve the eigenproblem.

Thus, one key to the minimum time-constant problem lies in operating on the coefficient matrix A in some meaningful way. But if the A matrix is left intact, then the limitation implicit in equation 60 must be accepted. The simplest kind of operation on the A matrix is to extract its diagonal terms and handle them analytically, as in equation 62. A more difficult operation is to transform the matrix as in equation 63. Of course the ultimate is to solve the eigenproblem completely.

These are the guidelines for tackling the integration problem for nonlinear systems, where the Jacobian matrix plays the role of the A matrix. Obviously, solving the eigenproblem repeatedly for a Jacobian matrix, which changes during the course of the solution, is far too costly. However, finding a quick and dirty transformation T to be used in conjunction with equation 64 does seem plausible. Moreover, it should not be necessary to update T at each integration step since it is likely that a given transformation could be applied for many integrations before becoming degraded to the point of uselessness.

The feasibility of this approach will depend on keeping the average computational cost per integration step to a reasonable level. If this is accomplished, the minimum time constant barrier can be breached for both linear and nonlinear problems.

In the case of linear systems, the eigenvalue approach is clearly superior for both a-c and transient analysis since it goes directly to the heart of the problem. Fortunately, the advent of the digital computer brings this powerful theoretical tool to a practical working level.

What's ahead

Much unfinished work remains in upgrading network analysis programs. In addition to adding new and improved analytical techniques, programs must provide facilities for statistical analysis of circuits, storage and retrieval of device models, handling transmission lines and treating much larger problems. Graphical presentation of output variables in a variety of forms will be essential and a much closer degree of man-machine interaction will become possible with cathode-ray tube displays and remote access to the computer.

Also, there will be a need to handle integrated and monolithic circuits. This rapidly growing area places strong demands on current analytical, numerical and programing techniques. It will inevitably force the development of more powerful methods for solving partial differential equations.

A step beyond the production of more powerful and effective network analysis programs will be the development of optimization techniques—in which the analysis tasks will likely be relegated to subroutines. Significant steps have already been taken in this direction. Moreover, automatic network synthesis is also under investigation. It is probable, however, that for a long time computer-aided design will be based primarily on analysis and optimization techniques with the engineer playing an essential role in the design loop and controlling the entire process.

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Numbers vs symbols: battle lines are drawn

Frank Branin

Two techniques vying for application in computer-aided design are numerical and symbolic circuit analysis. Author Frank Branin, development engineer of the International Business Machines Corp., is a staunch advocate of the numerical approach. He tends to give short shrift to the symbolic method, possibly because over 75% of CAD is performed by numerical techniques. The symbolic technique was discussed in part 3 of the continuing series on computer-aided design [Electronics, Dec. 12, 1966, p. 92].

Branin thinks of the two techniques in relation to internal and external operations for the computer. In the symbolic technique, he says all operations (using both letters and numbers) are done inside the computer. But with the numerical technique the programer manually derives matrix expressions for those quantities that he desires to investigate on the computer. He then places numbers into these programs and feeds them into the computer so that the expressions may be evaluated. The computer then analyzes or designs the circuit with numerical techniques only.

Despite similarities in the two techniques some distinct points of difference are worth noting. In the symbolic approach the most critical parameters in a desired formula are highlighted because these appear as letters related to the circuit elements. In the simple expression for gain of an amplifier, $A_o = -g_m R_p / (1 + g_m R_k)$, the designer can tell at a glance that the stage gain depends on transconductance g_m, plate resistance R_p and cathode resistance R_k. Conversely, if he knows that $A_o = 50$, his knowledge is limited to how changes in circuit parameters can affect circuit performance.

Another advantage often stated for the symbolic technique is that it presents all circuit equations as polynomials of the complex frequency variable, s. This yields expressions with which the designer is familiar, delays the evaluation of complex variables until actually needed and offers convenient frequency information in terms of the poles and zeros of the circuit.

Too many trees

A clear advantage held by the numerical technique is that it eliminates listing topological trees for a network. Most symbolic techniques require such a listing. And for a network of 11 nodes and 21 branches it is possible to have over 13,000 different trees. Thus, much valuable time and storage space can be wasted by the computer in trying to find these.

It is too soon to effectively judge which technique will eventually dominate. For most circuit designers, even those using CAD, the lines of demarcation between the two techniques are still vague. Some experts claim that the difference is purely semantic —or at best, one of degree. Perhaps with improved programs or even with programs that are not presently available, sharper distinctions will emerge. As more engineers become familiar with a variety of computer-aided design programs, perhaps one technique will dominate.

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Circuit design

Designer's casebook

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

Quartz crystal synchronizes relaxation oscillator

By Roger G. Damaye

Fontenay aux Roses, France

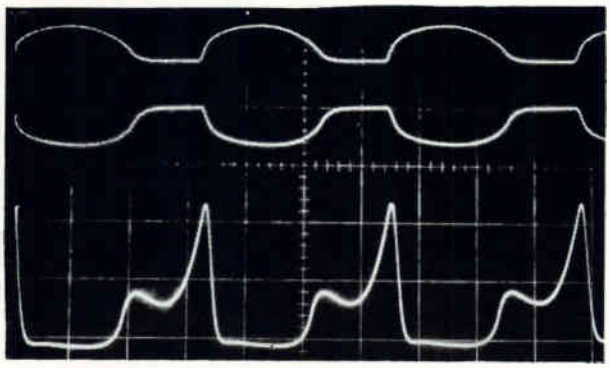
A simple and inexpensive clock for digital systems can be obtained with a quartz crystal and a unijunction transistor. The quartz crystal, when inserted between the emitter and base of the unijunction, oscillates in synchronism with the relaxation oscillator. Conventional unijunction relaxation oscillators are usually synchronized with a negative pulse applied to base 2 or a positive pulse applied to its emitter.

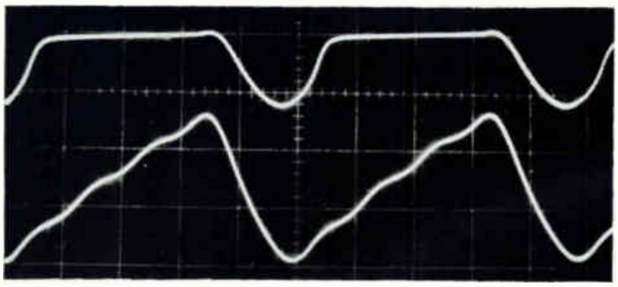
The electrical shocks created by the first few firings of the unijunction start the crystal oscillating and each subsequent firing of the transistor reinforces the oscillation. Adjustment of resistor R_1 is not critical and there is a margin of error of several degrees on either side of the optimum value. What is required is that the oscillating frequency of the crystal and circuit be close.

The frequency of oscillation remains stable despite voltage fluctuations of ±20% in the power supply and temperature variations of 0°C to 80°C. Synchronization of the oscillator is also possible at submultiples of the crystal's fundamental frequency but operation is sensitive to temperature variations. At half the fundamental frequency, f/2, the temperature stability is good, but falls off rapidly at f/3 and f/4.

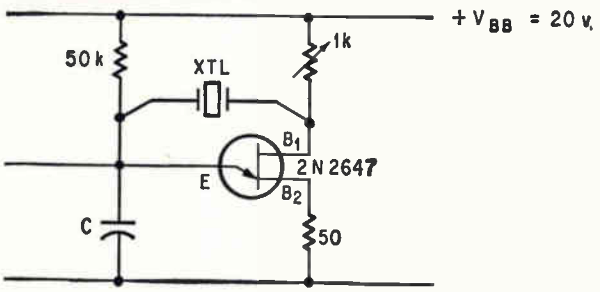
The circuit may be simplified by replacing capacitor, C, with a crystal. In the modified circuit a margin of adjustment is obtained for the 50 k resistor that is more than 15° on either side of the optimum.

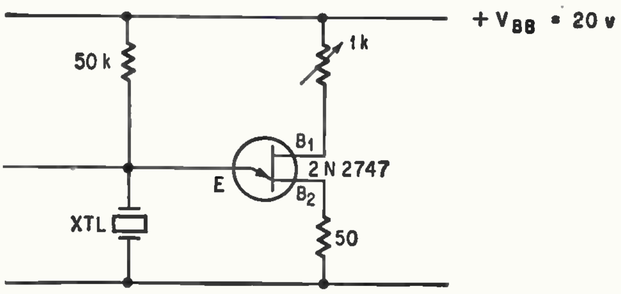
The oscillator can lock on the fundamental or half the fundamental crystal frequency. With a 100-kilohertz crystal stable oscillations of 100 and 50 khz are obtained. By shunting the crystal with a capacitor of several hundred picofarads, oscillations of 33.33 khz can be obtained. A modified circuit produced stable oscillations at 200 and 250 khz. Tests showed that good results were possible with 1 Mhz quartz crystals having fundamental frequencies ranging from 50 to 250 khz.





Different crystals change output waveshape. Waveshape at the left was obtained with a 60-khz crystal; and a 1-Mhz crystal above.





Quartz crystal inserted between emitter and base of unijunction transistor oscillator eliminates the need to apply external negative pulses to base 2 or positive pulses to the emitter for synchronization. In modified circuit at the right the capacitor C is replaced by the crystal.

Stable low frequencies with FET-bipolar pairs

By Gabriel Hanus and Yves Martinez

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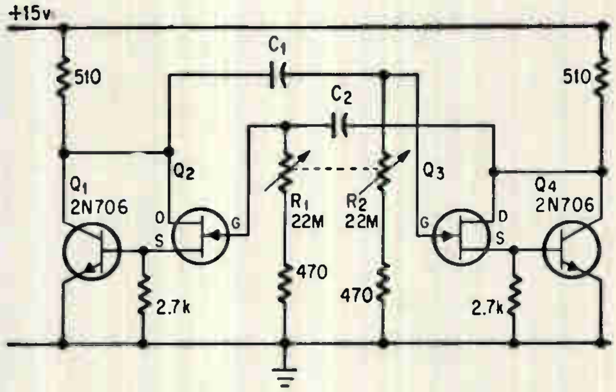

Time constants for the multivibrator are provided by the FET's and large resistance values.

Field effect transistors produce stable low frequencies in a multivibrator circuit because of their very high input impedance. Generators of very low frequencies require a long time-constant. However, if large electrolytic capacitors are used to obtain the time constant, stability is impossible to achieve. With FET's, however, their large resistances mean it's possible to obtain the long-time constant without large capacitors.

In the circuit, two n-channel FET's (2N3436) are connected as source followers and two npn transistors serve as switches. The principle of the circuit is similar to that of an ordinary multivibrator except that the bipolar-FET combinations are the active components. This introduces the FET's high input impedance and, at the same time, provides an overall gain that makes the bipolar's collector voltage independent of the current gain of the stage.

The 2N706 transistors do not saturate because their collector voltages supply the drains of the FET's. This arrangement makes the oscillator self-starting; since the transistors are biased in a linear region any change in input current causes a change in collector voltage. The circuit works equally well at high frequencies.

The duration of each state is determined by the discharge of either C_1 or C_2 into the gate resistance. When the voltage reaches pinchoff, the change in source current causes the circuit to change state.

If C_1 and C_2 are each 4 microfarads, increasing R_1 and R_2 can vary the multivibrator's period from 8 milliseconds to 6 minutes. If C_1 and C_2 are 100-picofarad capacitors, the frequency can be varied from 100 hertz to 3 megahertz.

Audio amplifier compresses input signal by 30 decibels

By David L. Pippen

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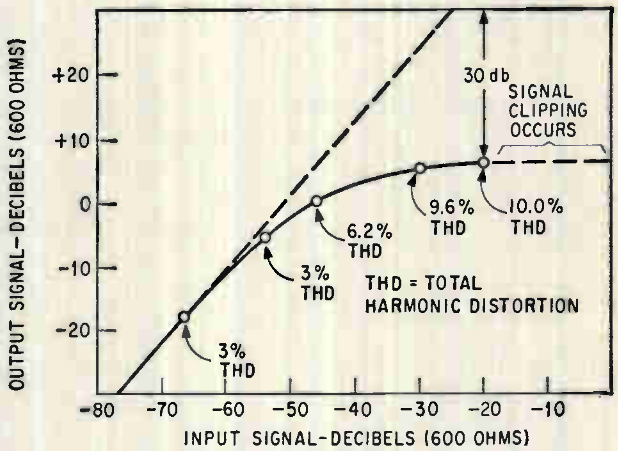
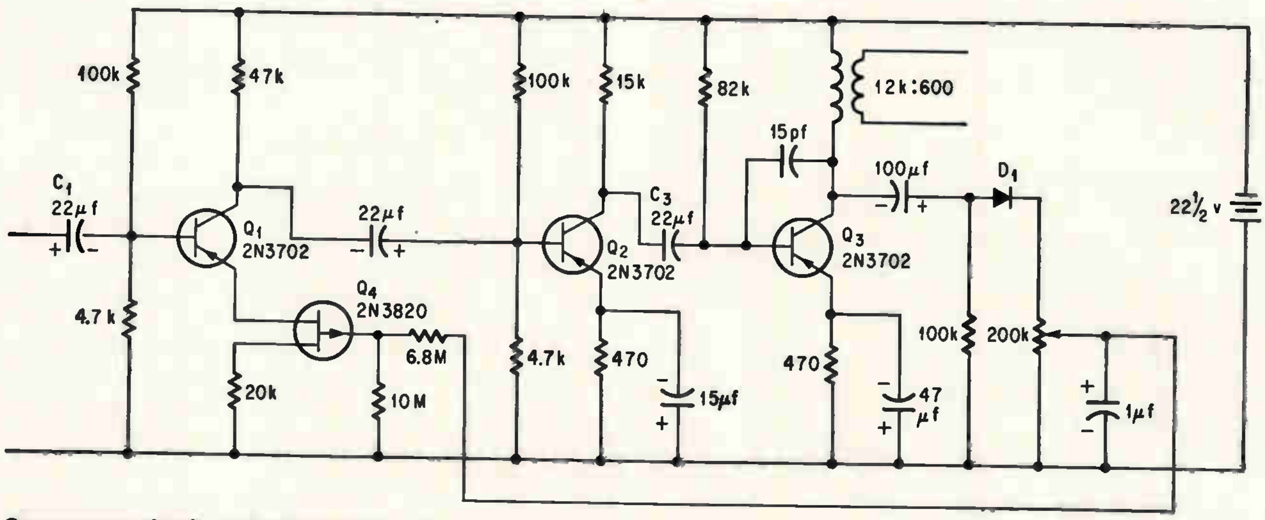


Compression response curve (solid line) tends toward a constant level as the input signal increases.

An amplitude compressor circuit that is inexpensive operates over a large dynamic input range by taking advantage of the characteristics of a field effect transistor. The circuit was designed to provide essentially constant amplification for a wide range of signals picked up by an acoustical transducer. The amplifier output feeds a 600 ohm line that handles maximum power levels of about 5 decibels. Because of the low distortion required at the maximum compression level and the wide dynamic range that must be accommodated, conventional compressor circuits are not suitable.

As indicated in the graph at the right, input signals can vary from 70 decibels below a milliwatt (—70 dbm) to —20 dbm and cause only 10% distortion at the output. At —20 dbm the signal is compressed 30 db below that of a linear amplifier. Input and output impedances are 600 ohms.

Transistors Q_1 and Q_4 are the controlled stages in this compressor. Field effect transistor Q_4 operates as a variable resistor in the emitter of Q_1. As the input signal increases, a d-c voltage on capacitor C_1 increases, biasing the gate circuit of Q_4 so that Q_4 is driven out of saturation and toward cut-off. When the d-c voltage reaches the knee of FET's saturation curve, the FET begins to cut off. This increases Q_4's source-to-drain resistance resulting in increased negative feedback from Q_1's base to its emitter. Because the feedback increases with input level, the over-all gain of the circuit is compressed and transistor Q_1 handles large input levels without large distortion. At input levels above —20 dbm, Q_1 clips the signal and the distortion rises.



Compressor circuit controls gain by varying the source drain resistance with input signal.

Diodes provide noise immunity for monostable multivibrators

By Radivoje Ilic

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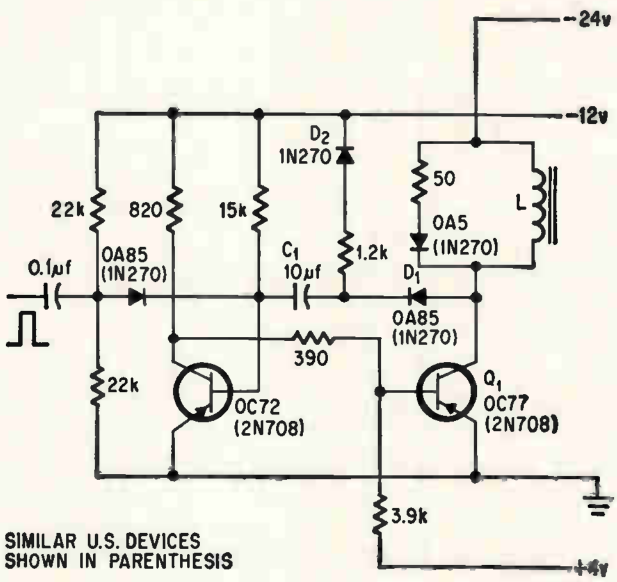
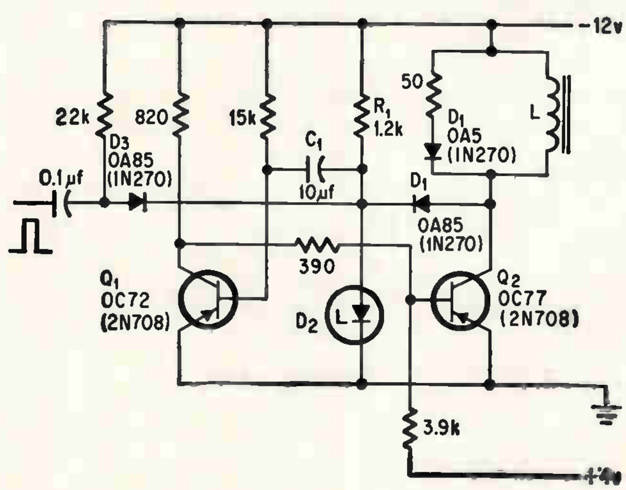
Diodes are handy components for eliminating undesired electrical pulses from multivibrators and other circuits that operate from a common power supply. The diodes are particularly effective in multivibrators with inductive loads in their collectors, such as relays.

Two multivibrator circuits have been modified with diodes to offer complete immunity to pulses that come from the power supply and to difficulties that arise from inductors in the transistor's collector. Diode D_1 in the circuit at the left prevents the inductive load from influencing the stability of the multivibrator. The diode is kept back biased at all times when transistor Q_1 is not conducting. Thus, it also acts to block extraneous pulses from triggering the multivibrator until the potential on



Diodes, added in both circuits, provide immunity to noise pulses from a common power supply and prevent interference from inductive loads.



the collector of Q_1 is higher than —12 volts. When the potential on the collector of Q_1 is greater than —12 volts diode D_1 is forward biased.

Diode D_2 is added to further prevent any undesired pulses that come from the power supply from having an effect on the stability of the circuit. It functions as does diode D_1.

In the modified circuit, right, page 106, a separate source is not needed for the electromagnet, and the circuit functions as the previous arrangement does against inductive load problems. Here, diode D_1 and zener diode D_2 prevent pulse penetration from the power supply and inductive load. The zener diode prevents D_1 from becoming back biased and also blocks noises and voltage functuations through Resistor R_1 and capacitor C_1.

Narrow-pulse one-shot recovers quickly

By John J. Moran* and Robert M. Gloriosco
University of Connecticut, Storrs

A one-shot multivibrator fits in computer and communications applications where the required pulse repetition rate is very high, dictating a rapid recovery time for the one-shot. The circuit will generate a 600-nanosecond pulse and will recover within 200 nsec. If the pulse width is increased, the recovery time is 200 nsec, or 3% of the output pulse width, whichever is greater. Circuit features low output impedance and low loss.

The short recovery time is obtained by discharging the timing capacitor C_1 through a low-impedance path formed by D_1 and Q_4.

When a negative pulse appears at the input, it turns Q_1 off and turns Q_2 on. Capacitor C_1 charges through Q_3, R_1 and the base of Q_2. The time constant of the charge path is R_1C_1. When Q_2 conducts, it holds Q_1 off. The recovery time—the time necessary to turn Q_2 off—is a function of the ratio $R_2/(R_1 + R_2)$ and varies with the type of transistor.

As Q_2 turns off, Q_1 turns on and the capacitor rapidly discharges through the low impedance path formed by D_1 and Q_4.

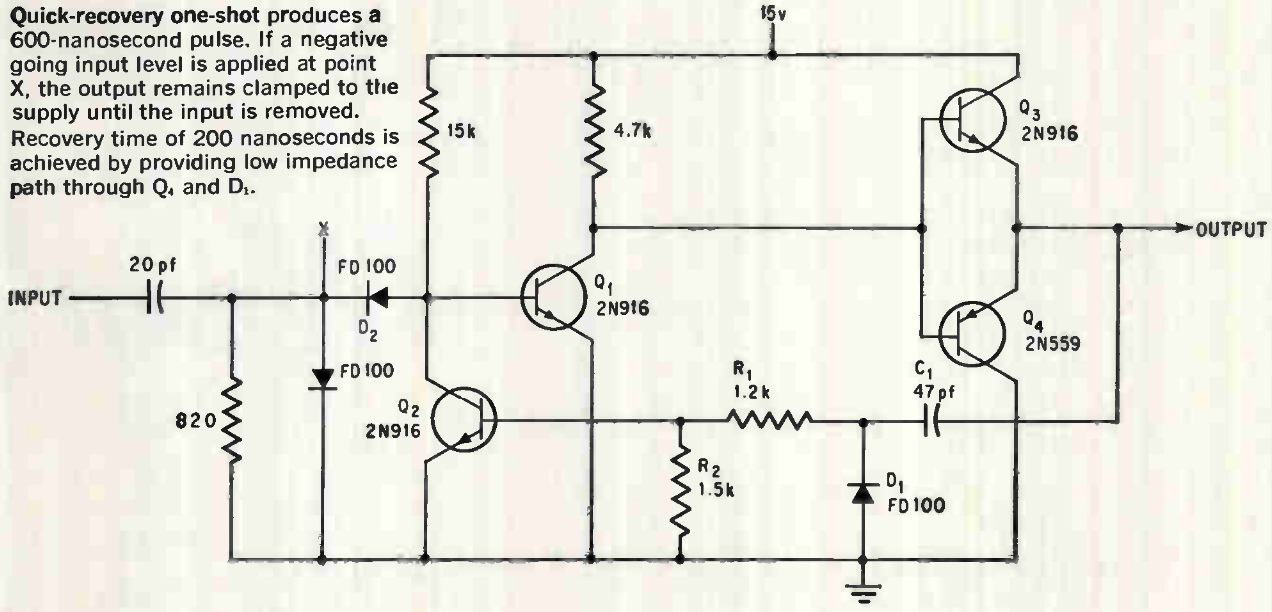
If the circuit is triggered rapidly so the output pulses have a large duty cycle, the pulse width might decrease slightly. To reduce this effect, resistor R_2 is made larger and connected to a negative supply. If C_1 is made larger than 0.05 microfarad, a series resistor is added to the discharge path to protect Q_4 by limiting the current.

The circuit has been applied as a pulse averaging discriminator in an f-m system with a carrier frequency of 1 megahertz, and a ±200-kilohertz deviation. With an f-m signal applied to the input, the integrated output is proportional to the frequency.

Another feature of the circuit is that an input applied at point X allows the output to remain clamped to the positive supply voltage for the duration of the pulse.

*Now with United Aircraft Research Laboratories, East Hartford, Conn.

Quick-recovery one-shot produces a 600-nanosecond pulse. If a negative going input level is applied at point X, the output remains clamped to the supply until the input is removed. Recovery time of 200 nanoseconds is achieved by providing low impedance path through Q_4 and D_1.



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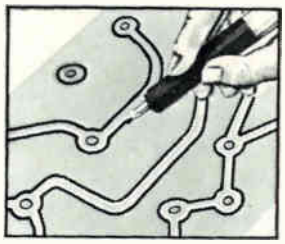

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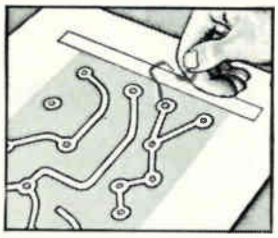

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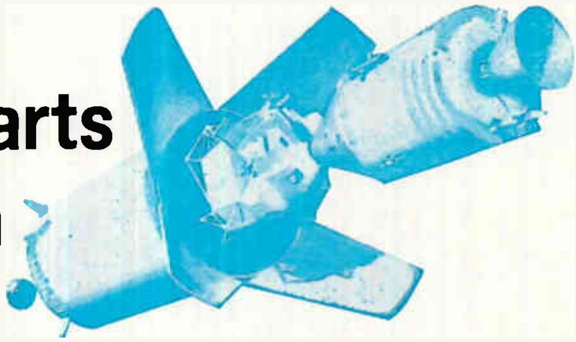


Electronic navigator charts man's path to the moon

Apollo, our boldest step into space, will be guided by a computer that is both elementary and advanced. Its memory holds a fixed program but its applications are diverse and flexible

By Albert L. Hopkins
Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

When man embarks on his first truly extraterrestrial adventure—a trip to the moon—he will be guided by a little box not much bigger than an unabridged dictionary, but much more versatile. The box is the Apollo guidance computer, which will determine whether the astronauts are on course and help them turn corners when the time comes. Prototypes of the integrated-circuit computer are now being tested on the ground.

The computer is part of the guidance and navigation system of the Apollo Command Module and the Lunar Module. The system performs different tasks during free-fall and powered flight.

In the free-fall phases—earth and lunar orbit, lunar descent coasting, and coasting through space between the earth and the moon—the system must determine the state of the vehicle—for example, orbital elements, position or velocity. These are part of an open-loop navigation process. The system is capable of performing the navigation itself but ground-based tracking stations duplicate the process simultaneously whenever possible.

Powered phases—boost, injection, ascent and entry—are short and critical. They require automatic steering for stability and accuracy, while the system directly controls the translation and rotation of the vehicle. These are closed-loop guidance functions. Each powered maneuver changes the velocity, as determined during navigation phases, until the guidance sensors indicate that the desired velocity is reached.

The guidance and navigation (G&N) system was designed by the Instrumentation Laboratory of the Massachusetts Institute of Technology and produced jointly by the AC Electronics division of the General Motors Corp., Kollsman Instrument Corp., a subsidiary of Standard Kollsman Industries, Inc., and the Raytheon Co. Its three major parts are:

- A three-gimbal inertial platform with three floated integrating gyros, each with a single degree of freedom, and three pulsed integrating pendulum accelerometers. The gyros and accelerometers continuously indicate changes in angular orientation (attitude) and translational velocity.
- An optical angle measuring unit—a sextant and scanning telescope in the Command Module, an alignment telescope in the Lunar Module.
- The guidance computer.

Some of the principal computer activities are correlated with navigation and guidance functions in the table on page 110. Critical phases are in color. These categories are interdependent because they share data, subroutines and interface activity. The computer's program has sections for executing dozens of jobs, but can do only about 10 at a time.

How it all began

The Apollo G&N system concept originated almost eight years ago, during a study for an unmanned space vehicle which would photograph Mars and return to Earth. The study concluded that the vehicle would require a navigation and guidance computer with inertial and optical sensors. The

The author

Albert L. Hopkins is the assistant director of MIT's Instrumentation Laboratory, where he specializes in the development of computers for inertial guidance and navigation systems.

computer logic and erasable memory would be built with core-transistor circuitry and the program would be stored in a wired-in read-only memory, called a core rope. Shortly afterward, MIT began designing the Apollo guidance computer with the same kind of circuitry plus a coincident-current ferrite-core erasable memory.

By late 1962, quantity production of monolithic integrated circuits had begun. The computer was redesigned to take advantage of the greater reliability, high speed, small size and packaging uniformity of IC's.[1] The direct-coupled transistor logic (DCTL) NOR gate was chosen as the basic circuit largely because of its simplicity. The designers chose only a single logic circuit type—a three-input NOR element, consisting of three transistors and four resistors on a monolithic silicon chip. The computer contains over 5,000 such circuits.

The decision to use the single logic circuit paid dividends for the Apollo project because microcircuit vendors could supply Apollo NOR gates some time before they overcame problems in producing more complex circuits. A family of specialized circuits might have saved space, but space was deemed less important than reducing the problems of specification, manufacture, and test of these relatively new circuits.[2]

It had long been known that all Boolean logic functions could be implemented with a single circuit [see "Single-circuit design," p. 115]. Several systems—MIT's Polaris guidance computer, a digital differential analyzer, for one—used a discrete-component NOR gate as its sole logic element type. But the concept has been applied rarely in general-purpose computers because specialized circuits required using fewer discrete components.

The core rope concept[3] was retained, because of the high density and the reliability advantages of nondestructive memory. The memory's main disadvantage is that it can be loaded only at the time of manufacture, but this was tolerable because program changes in any given computer are infrequent. However, each program must be completely debugged before assembling the rope.

When the decision was made to have a separate Lunar Module distinct from the Command Module, still another version of the G&N system was needed for both spacecraft. It was called Block 2 [Electronics, Dec. 12, p. 111]. The initial G&N system (Block 1) was put into production for the developmental command modules now being flown. The Block 2 guidance computer has twice the over-all speed of the Block 1, and has 50% more memory and consumes less power, with little change in size and weight.

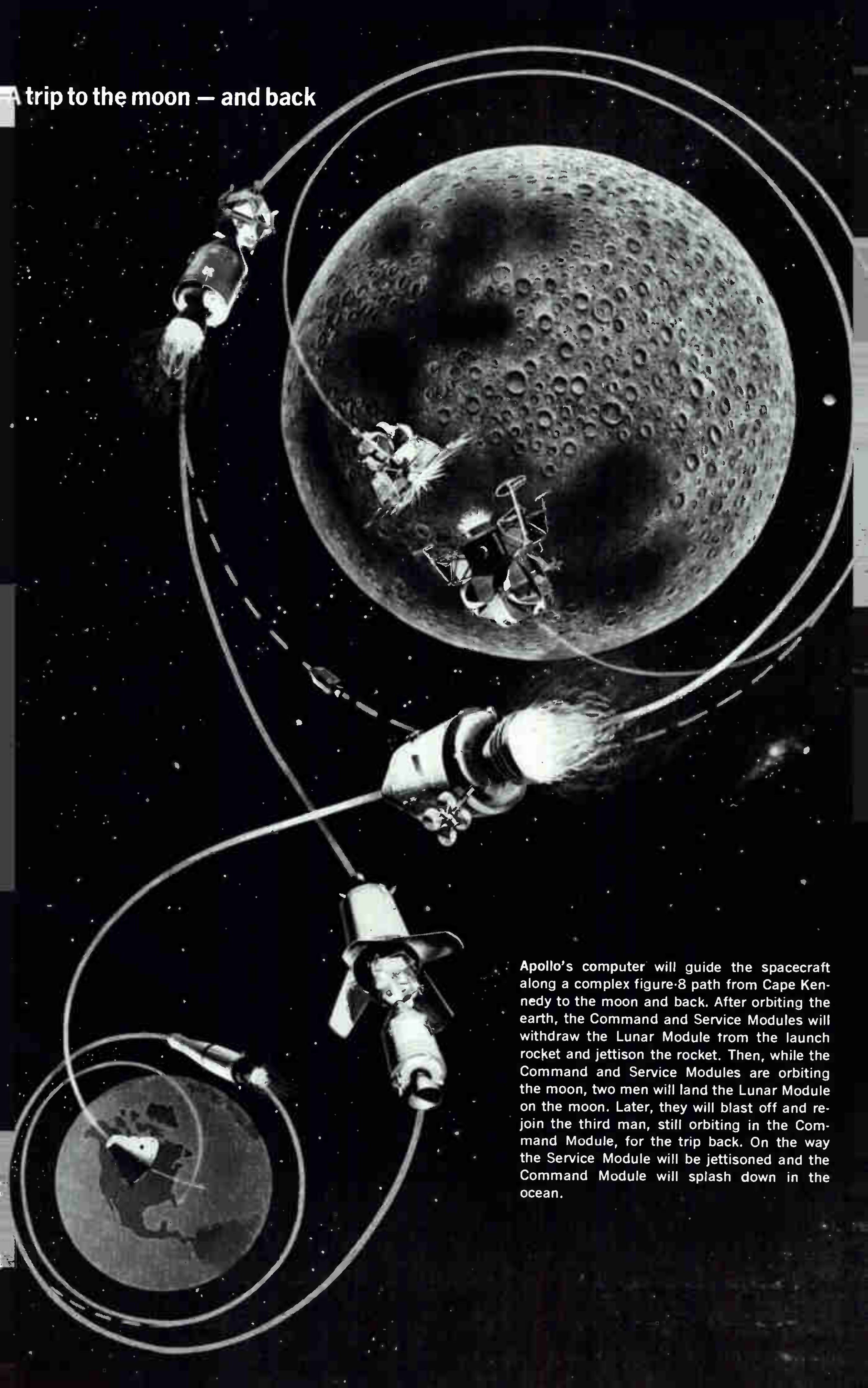
What's in the computer

Today's typical guidance computer is about a cubic foot in volume, and can do about the same job as large-scale central processors of ten years ago. The newer, larger, earth-based data processors can spread a work load over a period of time to balance

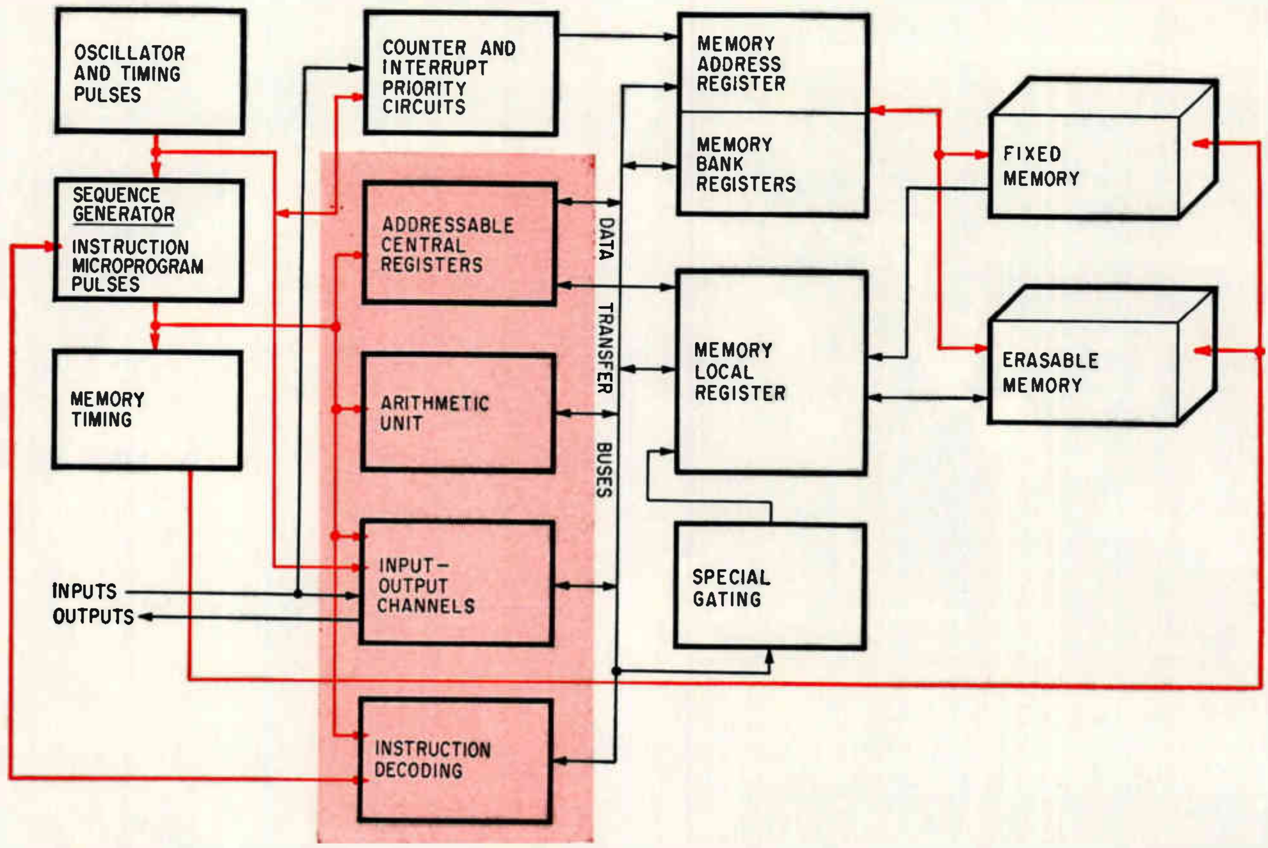
Phases of the moon shot and G&N activity

Phases	Alignment and system test	Inertial guidance	Optics sightings	Attitude control and small translations	Thrust control	Radar	Manual steering	Navigation measurements, calculations & display	Uplink navigation parameters
Prelaunch	*	*	*						*
First stage		*						*	
Second stage		*						*	
Third stage		*						*	
Earth orbit	*		*					*	*
Injection toward moon		*						*	
Module transposition				*			*		
Coasting toward moon	*		*	*				*	*
Midcourse corrections		*			*			*	
Lunar orbit insertion		*			*			*	
Lunar orbit	*		*					*	*
Lunar module descent injection		*		*	*			*	
LM descent coast	*			*				*	
LM powered descent		*		*	*	*		*	
LM final approach		*		*	*	*	*	*	
LM landing		*		*	*	*	*		
LM prelaunch	*		*			*			*
LM ascent		*		*	*			*	
Midcourse rendevous		*		*	*	*		*	
Terminal rendevous				*			*		
Injection toward earth		*			*			*	*
Coasting toward earth	*		*	*				*	*
Entry		*		*				*	

A trip to the moon — and back



Apollo's computer will guide the spacecraft along a complex figure-8 path from Cape Kennedy to the moon and back. After orbiting the earth, the Command and Service Modules will withdraw the Lunar Module from the launch rocket and jettison the rocket. Then, while the Command and Service Modules are orbiting the moon, two men will land the Lunar Module on the moon. Later, they will blast off and rejoin the third man, still orbiting in the Command Module, for the trip back. On the way the Service Module will be jettisoned and the Command Module will splash down in the ocean.



Organization of the Apollo computer shows the central processor (in tint block), the data paths (black lines) and control paths (colored lines). The data-transfer buses are the computer's backbone.

internal computing and input-output activity. For example, they can keep its various facilities busy by time-sharing. A guidance computer's central processor is also time-shared among numerous jobs, but must react to a large demand for input-output service in milliseconds rather than minutes. The Apollo computer can execute about 40,000 instructions per second.

It will be installed in the lower equipment bay of the Command Module, where the navigator will stand after his couch has been stowed. In the Lunar Module it will be behind the astronauts as they stand at their control stations. The crew can give commands to the computer and supply data and decisions when the computer requires it. The computer, in turn, supplies the crew with piloting data. The crew-computer interface is embodied in the display and keyboard unit, described later in this article. Interfacing circuits also connect the computer with other spacecraft systems.

Design of the computer

In addition to the memories, the computer has two other principal sections. The central section includes an adder, an instruction decoder, a memory address decoder and seven addressable registers. The sequence generator provides the basic memory timing and sequences of control pulses for each instruction; it also contains the interrupt priority circuitry.

The backbone of the computer is a set of 16 data-transfer buses, which interconnect the registers. Instructions can address registers in either memory, but the program cannot change the contents of the fixed part. Each memory word has 15 information bits and a parity bit. Data is stored as 14-bit words with a sign; instruction words have three order-code bits and 12 address-code bits.

Every instruction lasts an integral number of memory cycles. The normal sequence of instructions can be broken by a number of involuntary sequences, which are not under normal program control. These are triggered either by external events—an astronaut's entering data from the keyboard, for instance—or by certain overflows within the computer, such as a sum becoming too large for the register containing it. The breaks in sequence may occur between any two program steps and may be divided into two categories: counter incrementing and program interruption.

The shorter the better

Most guidance computers have word lengths of about 24 bits. The Apollo guidance computer is unique in having a 16-bit word. This short length was made possible by a decision to perform navigation calculations with multiple-precision arithmetic, in which a single quantity may occupy more than one computer word.

A guidance computer should have the shortest possible words to keep the circuitry simple, small and fast. Shorter words cut down on the number of memory sense amplifiers needed, for instance. One is needed for each bit in a word. These high-gain class A amplifiers are considerably harder to operate with wide margins of temperature, voltage or input signal than NOR gates are. Also, the time required for carry propagation in a parallel adder is proportional to word length.

The Apollo computer's data words are generally of two classes; those for navigational computations, and those for control. The first class requires a precision of 27 to 32 bits ($10^{8\pm1}$). The second class of variables can usually be represented with 15 bits. The precision required for navigational variables can be satisfied by using two words. Even if word lengths were 15 to 28 bits, two words still would have been required.

To accommodate both positive and negative numbers, the logic designer must choose among at least three possible number representations: one's complement, two's complement, and sign-and-magnitude. For a binary number such as 1110001011 (equivalent to +907 in decimal notation) the one's complement is simply the complement of each individual bit, or 0001110100; the two's complement is the same as the one's complement except that a 1 is added to the right-most bit position, or 0001110101. These complements represent —907. In sign-and-magnitude notation a bit is added to represent the sign, usually 0 for positive and 1 for negative; then +907 = 01110001011 and —907 = 11110001011.

The Apollo number system is a modified one's-complement scheme using two sign bits for overflow representation in the adder. This combines the advantages of the other two systems while sidestepping their disadvantages. The extra sign bit is available because the parity bit does not pass through the adder. In the conventional one's-complement representation, an overflow alters the sign bit. In the modified scheme the sign is not altered because of the double-bit representation. An independent sign representation for multiple-precision numbers is then possible. During operations such as multiplication, two's-complement arithmetic is used.

Sign-and-magnitude representation was rejected although it is the most straightforward for human inspection. However, it requires either a magnitude comparison or conversion to one of the complement representations when positive and negative numbers are added. In straight one's-complement notation, sign reversal is easy. However, zero is ambiguously represented by a word of all 0's or of all 1's, and addition may require an extra operation called end-around-carry. Two's complement notation avoids this and is convenient for input conversions from devices such as pattern generators, encoders, or scalers; but sign reversal is awkward.

Since the computer often would be using many multiple precision words for navigation, this was considered in the choice of number system and in the organization of the instruction set. Multiple-precision representation commonly requires the sign bits of all component words to agree; nevertheless, in the Apollo computer the signs of the components can be different [see "Multiple-precision arithmetic," p. 116].

The algorithm for double-precision multiplication is directly applicable to numbers with independent signs. A special double-precision add instruction simplifies the treatment of interflow. Independent signs are not permitted in double-precision division; both operands must be positive and the leftmost non-sign bit of the divisor must be 1.

Computer characteristics

Word transfers	Parallel
Word length	16 bits=15 data +1 parity
Number system	Modified one's complement
Memory cycle time	11.7 μsec
Fixed memory	36,864 words
Erasable memory	2,048 words
Normal instructions	34
Involuntary instructions (interrupt, increment, etc.)	10
Interrupt options	10
Addition time	23.4 μsec
Multiplication time: 14 x 14 bits	46.8 μsec
Double-precision addition time	35.1 μsec
Increment time	11.7 μsec
Number of counters	29
Power consumption	Less than 100 watts (including two DSKY's)
Weight	58 pounds (computer only)
Size	1.0 cubic foot (computer only)

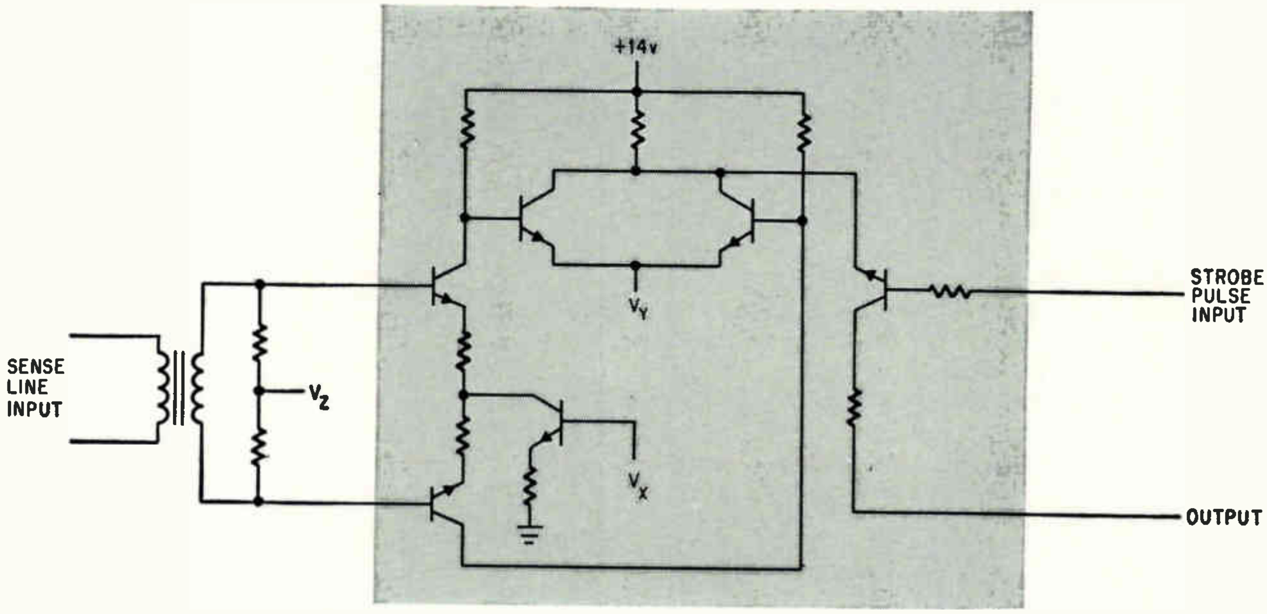
Two memories

The 2,048-word erasable memory is a conventional coincident-current, ferrite-core array. Nothing would be gained by using a faster memory organization, since the 36,864-word fixed memory requires a relatively long cycle. Both have a cycle time of 12 microseconds.

The array is wired in 32-by-64 planes which are folded to fit into a 9-cubic-inch module. A double-ended transistor switching network generates bi-directional currents in each selection wire. One wire in 32 is selected by switch circuits in an 8-by-4 array, and one wire in 64 is selected in an 8-by-8 array. The outputs of these silicon transistor drive circuits vary with temperature so that they match the requirements of the lithium-ferrite cores from 0°C to 70°C.

The integrated-circuit sense amplifiers are considerably more complex than the integrated NOR gates, but there are only 32 per computer. Each amplifier can be carefully selected. None have failed in several million device-hours of operation, although sense amplifiers have historically been the weak link of computer memory systems.

Large fixed memories are rarely used in ground computers, but guidance computer designers favor

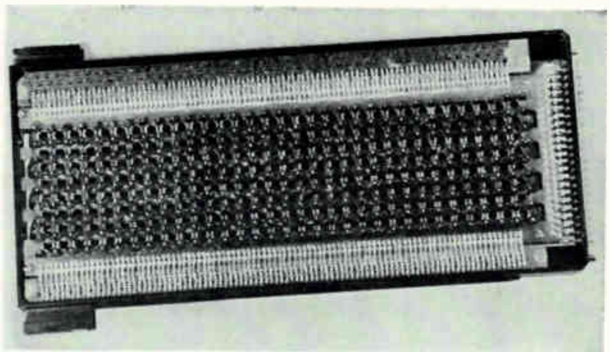


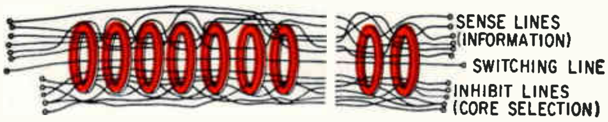
Sense amplifier circuit amplifies signals from both the fixedand the erasable memory in the Apollo computer. All components inside the tinted block are in an integrated circuit. Each computer has 32 of these amplifiers.

them. They occupy little space and are highly reliable. Fixed program and data limit alteration of mission plans, but help assure that the computer program is identical through all phases of testing and in flight. It also permits recovery from temporary malfunctions which would alter the contents of an erasable memory—as happened, for instance, during the flight of Gemini 4.

Early models of the MIT core rope memory actually resembled lengths of rope. Large numbers of wires thread through or bypass toroidal cores, as shown in sketch below, to create 1's and 0's.[5] Address decoding is also partly wired in. As a result, its cycle time is longer than that of some other transformer memories whose address decoding is external. However, bit density is extremely high—approximately 2,000 bits per cubic inch, including all driving and sensing circuits, interconnections, and packaging hardware.

High density is achieved by storing a large number of bits in each magnetic core. The total number of bits is the number of cores multiplied by the number of wires. Each of the Apollo memory's six modules contains 512 cores and 192 wires, or 98,304 bits of information.





Wires through a core store a 1 in a core-rope memory while wires bypassing the core store a 0. Magnetic switching of a core, triggered by currents in the switching and inhibit lines, generates pulses in those sense wires that thread that core; 16 wires at a time are gated to sense amplifiers to read one computer word. Each of the six core-rope modules in the Apollo computer contains 512 cores and 192 wires.

A link to ground

Computer words flow over prelaunch and inflight radio links between the computer and ground control. The upward and downward data rates are different; therefore the mechanizations differ considerably.

The downlink rate is 50 words or 800 bits per second. During one memory cycle the interface stores a full 16-bit word in a flip-flop register; then, upon command, it seems the bits serially in a burst to the communications system of the spacecraft.

Each bit received on the uplink requires a memory cycle; the maximum rate is 160 bits per second. Transfers from the computer to spacecraft display units also require one memory cycle per bit, as does data from the radar measurement subsystem. In these serial pulse trains two adjacent pulses differ in weight by a factor of two and positional notation is employed.

Information is also transferred incrementally. A sequence of pulses is transmitted over a single channel, but each pulse represents the same value, or weight. An incremental receiver counts pulses to form a word, where a serial receiver shifts pulses to form a word. The incremental transfer of information permits high precision and standardization in analog data transmission. For example, the

Single-circuit design

Computer logic circuits are all variations on three basic logic functions: AND, OR and NOT. These three basic functions in turn can be implemented with a single circuit, the NOR gate, shown at right; it has the logical function:

$$D = \overline{A + B + C}$$

read "NOT (A or B or C)." All four variables may have either of two voltage levels. If A, B, and C are all at the more negative level, the transistors are cut off and D is at the more positive level. But if one or more inputs rise, the corresponding transistor turns on and D drops to its more negative level.

When B and C are tied to ground, D is the inverse of A and the circuit is an inverter, or NOT circuit. If the output of the circuit shown is the input to such an inverter, then the inverter's output is:

$$E = \overline{D} = \overline{\overline{A + B + C}} = A + B + C$$

and the combination of two circuits is an OR gate. Likewise if A, B and C are the outputs of such inverters, whose inputs are F, G and H, then

$$D = \overline{A+B+C} = \overline{\overline{F}+\overline{G}+\overline{H}} = \overline{\overline{F}} \cdot \overline{\overline{G}} \cdot \overline{\overline{H}} = FGH$$

read F and G and H; the four circuits form an AND gate. Logically the inverse of an OR function is the AND function of the individual inverted variables.

Two-way functions simply require tying the unused input to ground. For functions of four or more variables, the outputs of additional circuits are connected to each other; only one of the circuits can be connected to the +4 volt supply. The ability to drive other logic circuits is increased by connecting NOR gates in parallel.

Complex logic functions are built up of alternate layers of AND and OR gates. Successive layers of NOR gates can be considered alternately as OR gates with positive inputs and AND gates with negative inputs. Thus the function:

$$E = D_1 \cdot D_2 \cdot D_3 = (A_1+B_1+C_1) \cdot (A_2+B_2+C_2) \cdot (A_3+B_3+C_3)$$

can be realized with exactly four NOR gates. The reason is that if

$$D = \overline{A + B + C}, \text{ then } \overline{D} = A + B + C$$

and that

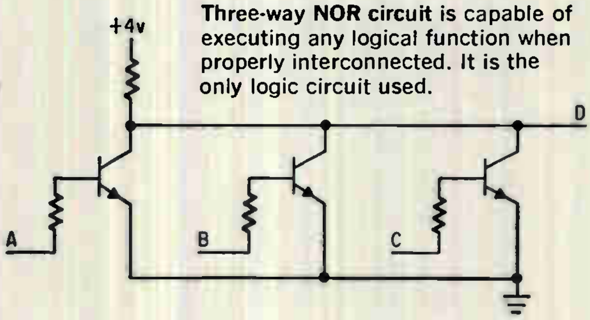
$$D = \overline{A + B + C} = \overline{A} \cdot \overline{B} \cdot \overline{C}$$

Therefore,

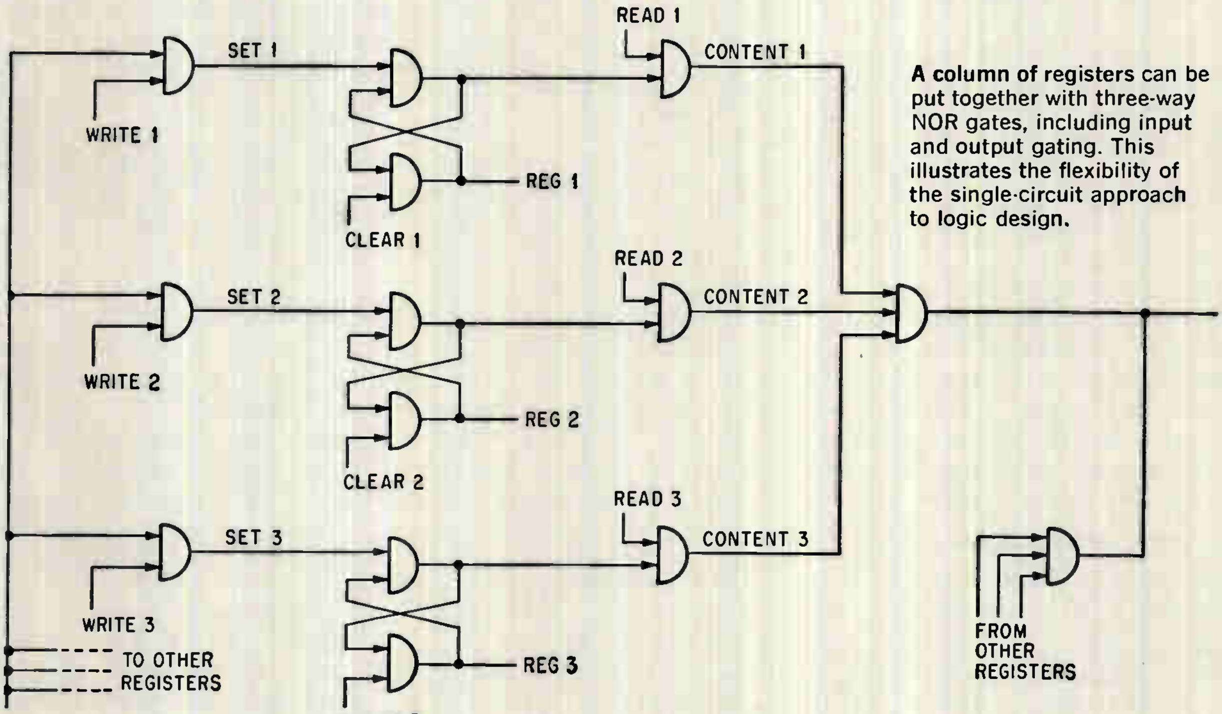
$$E = \overline{D_1} \cdot \overline{D_2} \cdot \overline{D_3} = (A_1+B_1+C_1) \cdot (A_2+B_2+C_2) \cdot (A_3+B_3+C_3)$$

If the intermediate variables D are needed, they must be inverted.

For example, the block diagram shows clearly how NOR gates can be interconnected to form a register or a single bit position in each of several registers without using multiple NOR gates for each logic function. Two gates cross connected form a latch or flip-flop; both the input and the output can be gated, or the ungated ON or OFF latch output is available. A six-way OR is at the extreme right.



Three-way NOR circuit is capable of executing any logical function when properly interconnected. It is the only logic circuit used.



A column of registers can be put together with three-way NOR gates, including input and output gating. This illustrates the flexibility of the single-circuit approach to logic design.

Apollo accelerometers are incremental, producing a pulse for each unit change in velocity. The computer uses incremental transfer for angle commands to the gyros and the gimbals in the inertial measuring unit, and for thrust control and certain display functions in the spacecraft. Pulses are sent in bursts at a fixed rate.

External requests for serial or incremental transfer are stored in a counter priority circuit. If at the end of an instruction no requests have been received, the next instruction is executed. If a request is present, the program is interrupted and an incrementing memory cycle is executed. Each counter is a specific word in erasable memory. During the incrementing cycle the computer reads the word, increments or shifts it, and stores the result in the original location. Overflows from one counter may be inputs to another. The computer processes all such requests before proceeding to the next instruction in the original program. This type of interrupt enters synchronous incremental or serial information into the working erasable memory.

Since counter words are in the erasable memory, any program always has ready access to them. Each increment or shift requires a memory cycle. To avoid taking too much time from guidance and navigation calculations, the aggregate counting rate is limited. This sometimes requires a logic circuit between the interface and the priority circuit to prevent the input pulse rate from exceeding a chosen level.

Commands or feedback for discrete actions are given by discrete signals—individual binary digits or small groups. These actions close switches, change mission phases, fire jets, start displays and control many other actions. Most discrete inputs to the computer are non-interrupting—that is, they are acted upon by the normal program. They are either d-c inputs through a filter to a logic gate, or a-c signals transformer-coupled to a flip-flop, which is reset after interrogation. A few special discrete inputs initiate a program interrupt—they announce their presence to the computer's sequence generator. Discrete outputs are controlled by the program.

During a program interrupt, the computer stores the contents of the program counter and transfers control to a program subroutine that processes the particular type of interrupt. When an interrupt is being processed no subsequent interrupts will be accepted, but all will be processed in turn.

The computer is the primary source of timing signals to about 20 spacecraft systems.

The man rules the machine

The crew-computer interface is the display and keyboard unit. It is abbreviated DSKY and pronounced "diskey." There are two DSKY's in the command module, one for the navigator and one on the pilot's main panel, for use during powered flight. One DSKY is installed in the lunar module.

Above the DSKY's keyboard is a numeric electroluminescent display of three 5-digit registers for data and three 2-digit registers for commands. The 15 bits of a computer word can be shown as 5 octal digits—the digits 0 through 7—in one register. The three registers can display the three components of a vector. Each register also includes a sign position; when a sign appears, the number is read as decimal; otherwise it is octal. The other digit displays are labeled verb, noun and program.

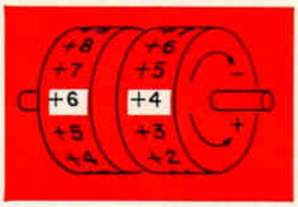
Each command is an imperative statement consisting of an action (verb) and an object of the action (noun). For example, "display" "time to ignition" is a request from the crew; or "load" "desired gimbal angles" is a request from the computer. These statements are expressed numerically;

Multiple-precision arithmetic

Independent signs arise naturally in multiple-precision addition and subtraction. Forcing signs to be identical would be costly because every operation may require sign reconciliation. For example, in decimal notation,

$$(+64) + (-46) = (+18)$$

Suppose the addition is done in one-digit decimal registers that indicate both positive and negative numbers in sign-and-magnitude form, like the mechanical registers below. In multiple precision, the left-hand register carries ten times the weight of the right-hand register, so that +64 would become (+6, +4) in the two registers, and −46 would become (−4, −6). The two registers operate independently so that the operation is



$$(+6, +4) + (-4, -6) = (+2, -2)$$

Considering the weight of the left-hand register, the result is clearly +20, −2. The sum of these is +18, but the signs are mixed unless corrected.

The same result can be obtained if operand signs are mixed. For example, +64 can be represented by either (+6, +4) or (+7, −6), so

$$(+7, -6) + (-5, +4) = (+2, -2)$$

The result again has mixed signs. On the other hand,

$$(+6, +4) + (-5, +4) = (+1, +8)$$

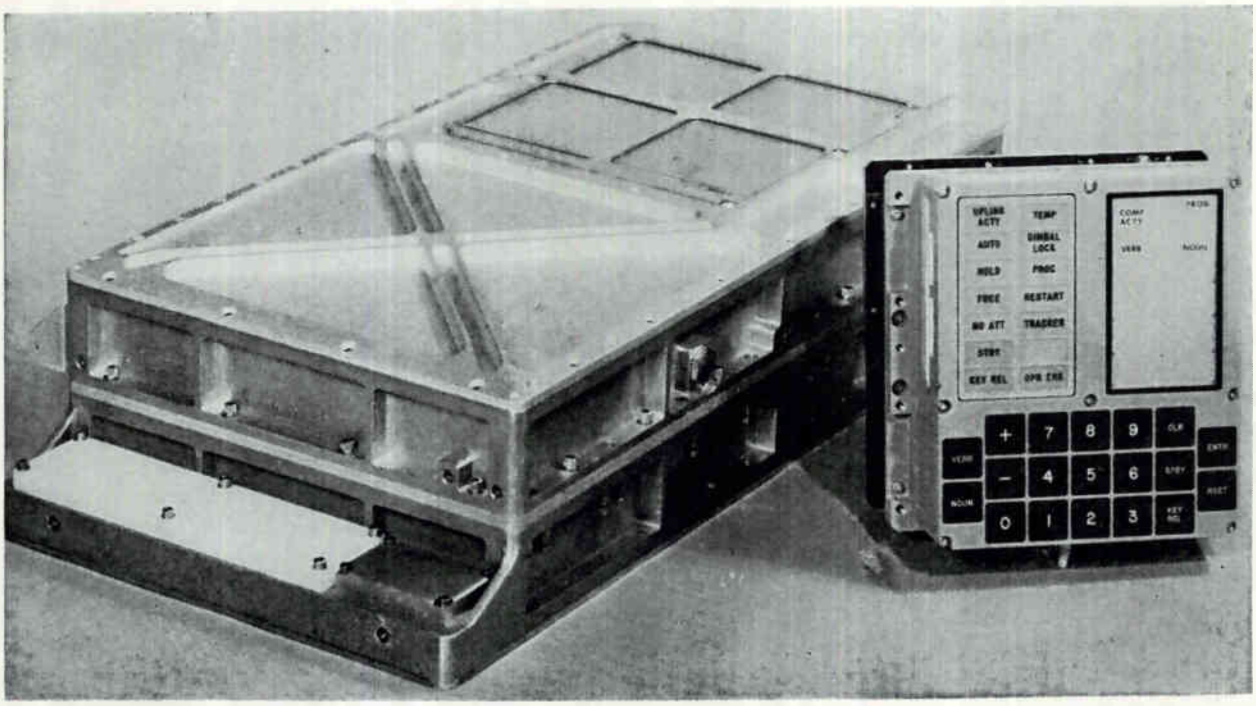
so that here correction is unnecessary. Still another possibility exists if the problem is stated:

$$(+7, -6) + (-4, -6) = (+3, -12)$$

The answer is still correct, but since one-digit registers contain the numbers an overflow has occurred in the right-hand register. In this case, the overflow is carried over into the left-hand register, with the proper sign:

$$(+3, -12) = (+2, -2)$$

In the Apollo computer this kind of overflow is called an interflow to distinguish it from an overflow in the left-hand register.



Apollo guidance computer, viewed from the rear, and its display and keyboard unit.

the crew looks up the verbs and nouns in a glossary. As a crewman keys in statements, they appear in the 2-digit registers of the display where they can be checked for accuracy. When the computer makes a request, the verb and noun display flashes on and off to indicate the computer origin of the command, and to attract the crew's attention.

Key code inputs interrupt the computer program. The keyboard's 19 pushbuttons include the 10 decimal digits, plus and minus signs, and 7 auxiliary keys. The 19 key functions are encoded into five binary signals by a diode matrix mounted directly behind the keyboard.

Program lights tell the operator what major programs the computer is running. The DSKY also has discrete alarm and condition lamps, a condition light reset key, and a key with which the operator relinquishes his use of the display lights to the computer—a function which permits the operator to decide whether his command has a higher priority than the computer's request. If a keyboard entry sequence is in progress when the computer program has a request or a result of display, a condition lamp notifies the operator of the fact. When he is ready to let the computer use the display, he depresses the release key.

Software

Guidance and navigation programs are executed under control of three special programs that ease the task of the human programer and insure that priorities are observed in the computer. These special programs are the interpreter, the executive, and the waitlist.

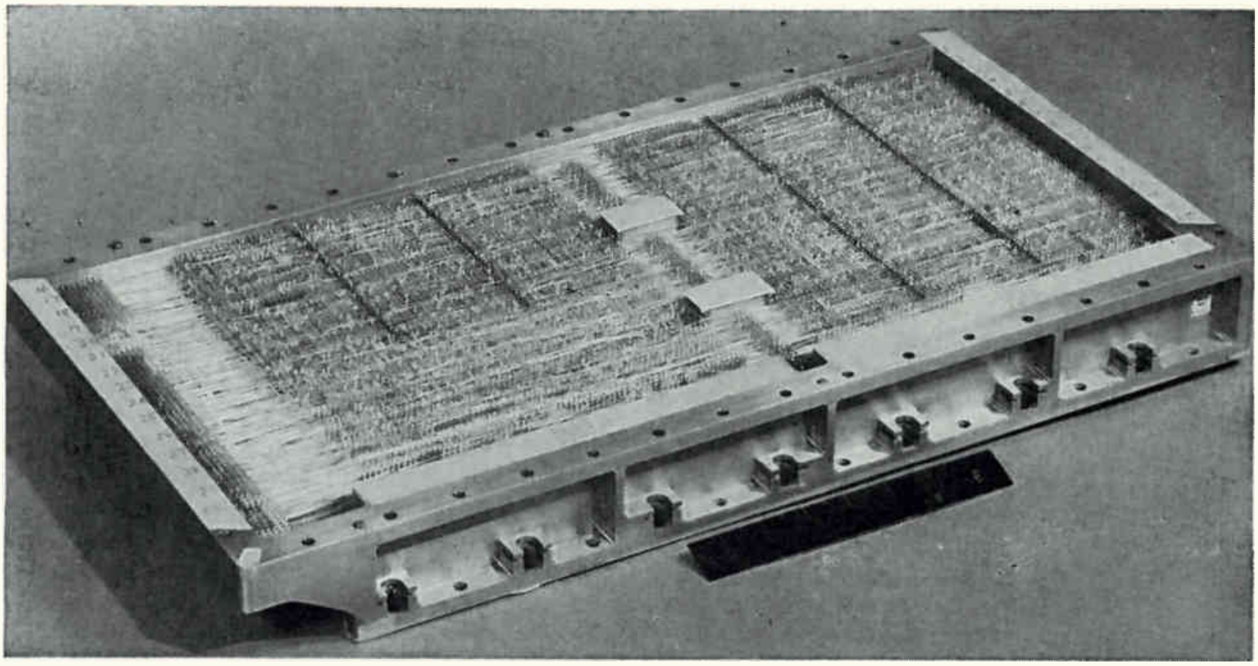
Most of the guidance and navigation programs are written in a special notation and stored directly in the fixed memory. The interpreter translates the notations into a sequence of subroutine linkages, which in turn execute the program. A program executed with the interpreter takes more time than would a machine-language program written with an automatic compiler; however, it occupies less storage space and saves the time of writing a program in basic machine language. The interpreter occupies only a few hundred words in fixed storage and requires only one instruction for relatively complex operations, whereas compiled programs would need several instructions.

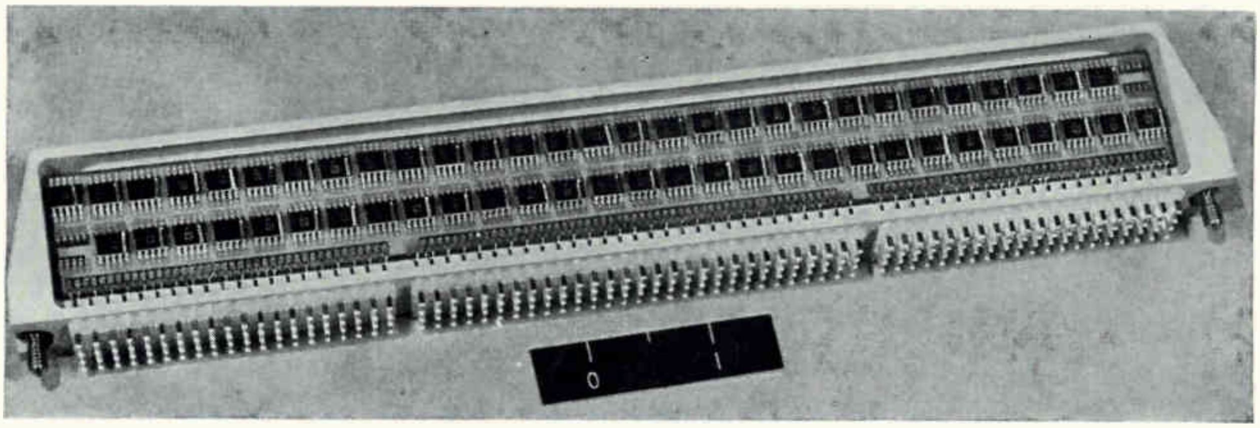
All programs except interrupt routines are controlled by the executive routine. Executive-controlled programs are called "jobs" to distinguish them from "tasks," controlled by the waitlist. The routine controls job priority, permits time-sharing of erasable storage, and displays computer activity on the DSKY. As one job runs, the executive checks at least once every 20 milliseconds to see if another job of higher priority is waiting to be executed. If so, control is transferred to the new job until the first job again becomes the one with highest priority.

When a job must wait until an external event occurs, such as the attainment of a specific velocity in powered flight, the executive may suspend it, or "put it to sleep." The job's temporary storage is left intact, so the executive can "awaken" the job when the event occurs.

When a job is finished the executive transfers control to a terminating sequence which releases the job's temporary storage to be used by another job. Approximately ten jobs may be scheduled for execution at one time.

Waitlist tasks are run in the interrupt mode, and must be no more than four milliseconds long. A longer program could cause excessive delay in





Logic module contains 120 monolithic integrated-circuit flatpacks, 60 on each side. These modules plug into a tray, whose wrapped wires interconnect the modules. A second tray holds the memory and its drive circuits.

other interrupts waiting to be serviced, since one interrupt program inhibits all others while it is running.

If the waitlist is to initiate a lengthy computation, it will call the executive routine so that the computation is performed as a job during non-interrupted time.

Modules and trays

Signal interconnections—the major mechanical problem in guidance computers—take up approximately three-quarters of the computer volume. The IC flatpacks are interconnected with multilayer boards, and wrapped wires connect the modules.

A basic design goal was small modules that could be easily installed and removed, for the sake of producibility, testing, diagnosis and maintenance. Another goal was to keep the computer's volume small. The goals were attained with 24 modules each containing two independent groups of 60 flatpacks with 72 connector pins. Two gates are on each flatpack; flatpacks and pins are connected to the board by spot welding.

All modules plug into two carriers called trays. One tray holds the logic, power supply and interface modules, and the other contains the memory, oscillator and alarm modules. The trays are magnesium alloy frames into which the modules are inserted by jacking screws. These provide a good thermal path between modules and tray, which in turn is screwed to a cold plate.

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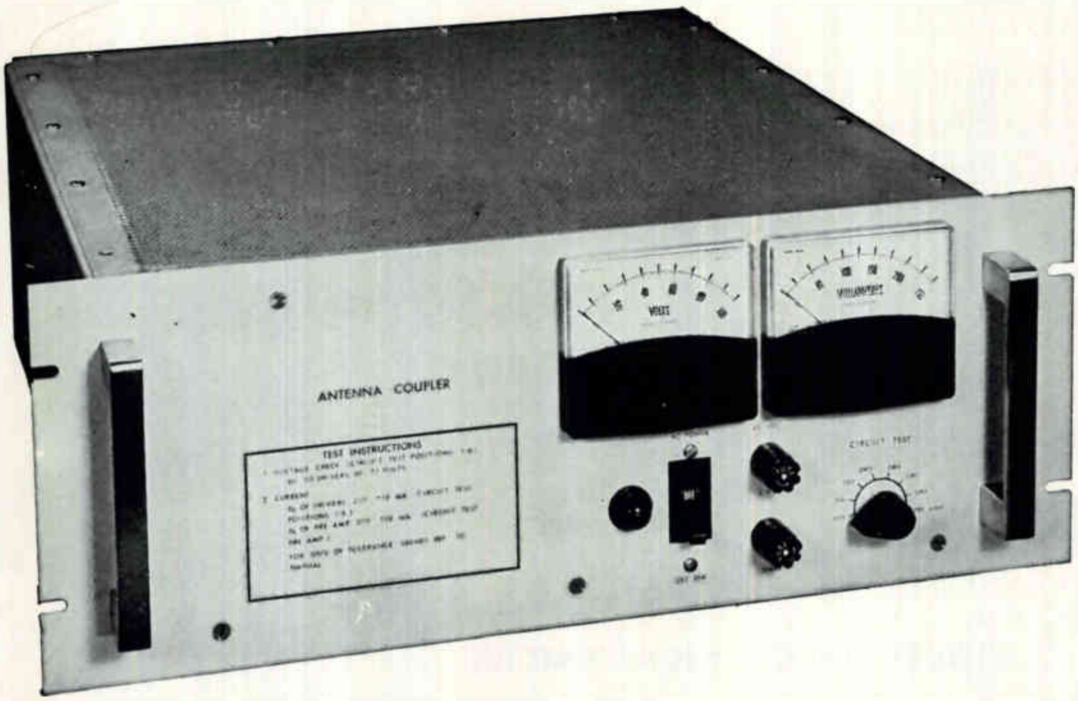

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		Power Required	115 V ± 10%, 50—60 cps or 48 V ± 3V, DC
Intermodulation Distortion	– 56.5 dB, 2nd order – 60 dB, 3rd order	Dimensions	19" wide x 20" deep x 7" high
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Inputs	1	MIL Qualified To	MIL-E-4158C, MIL-Q-9858A

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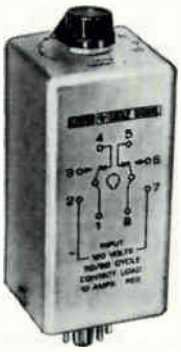

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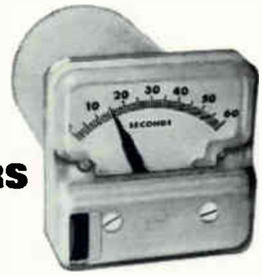

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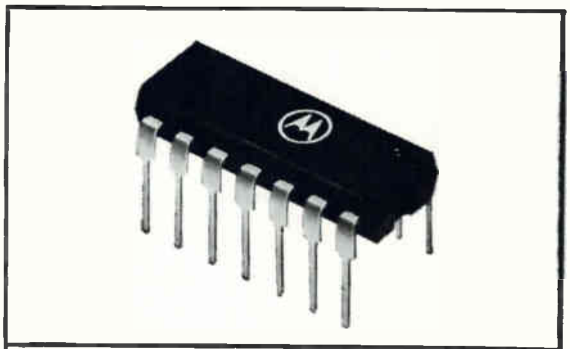

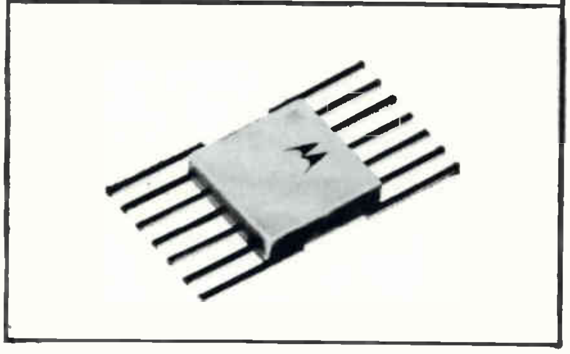

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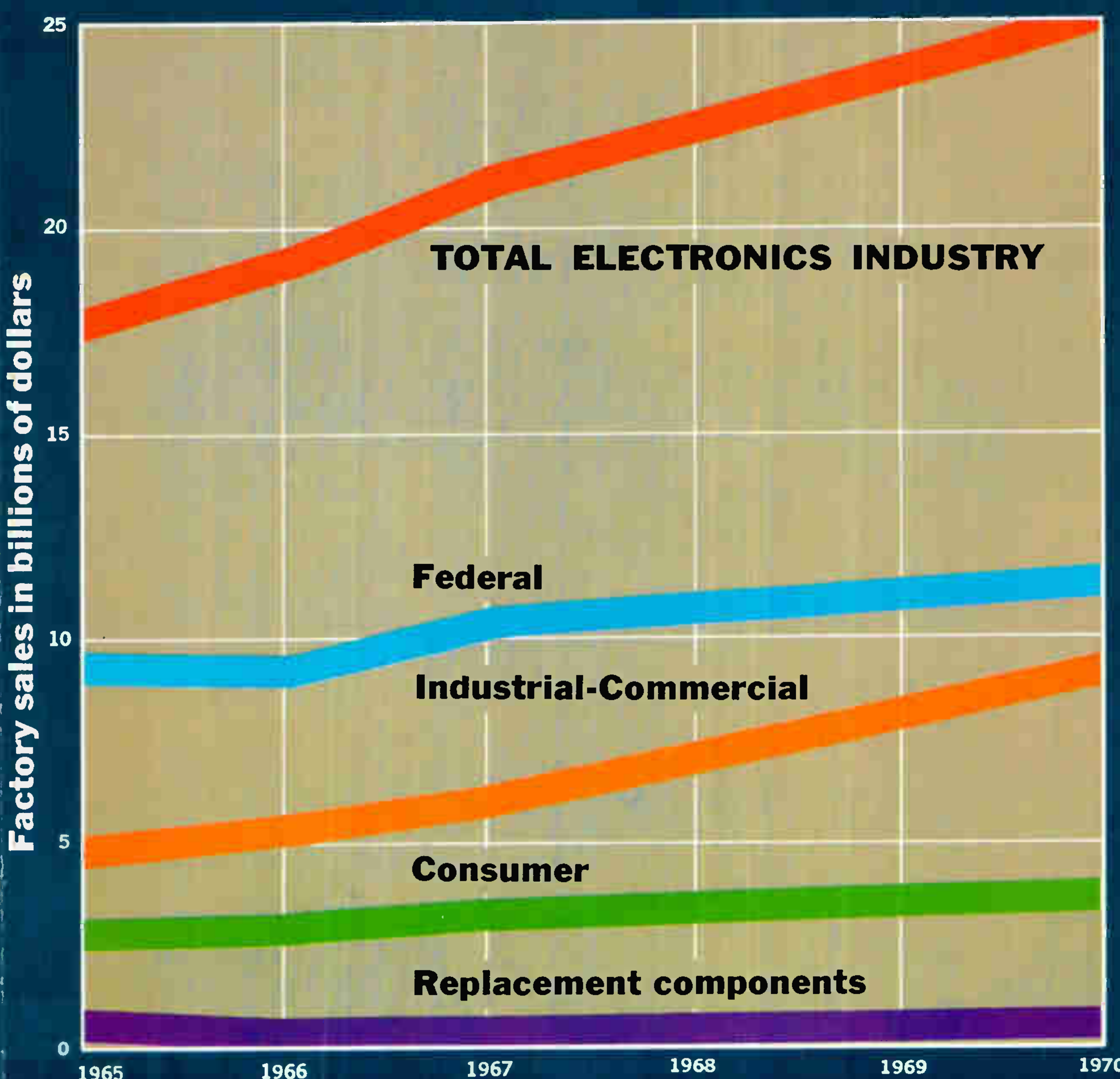
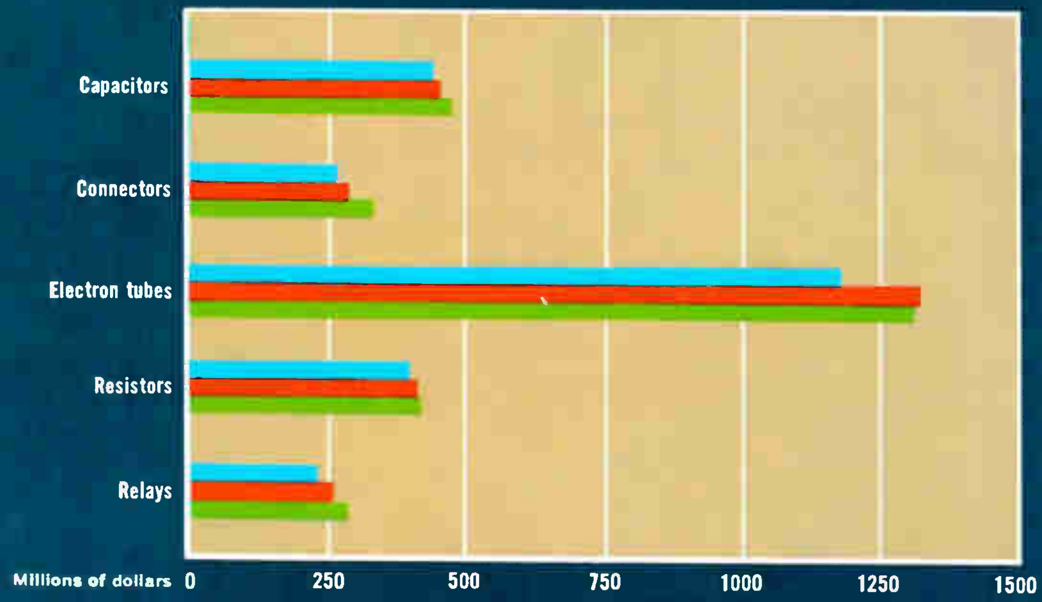
Electronics Markets 1967

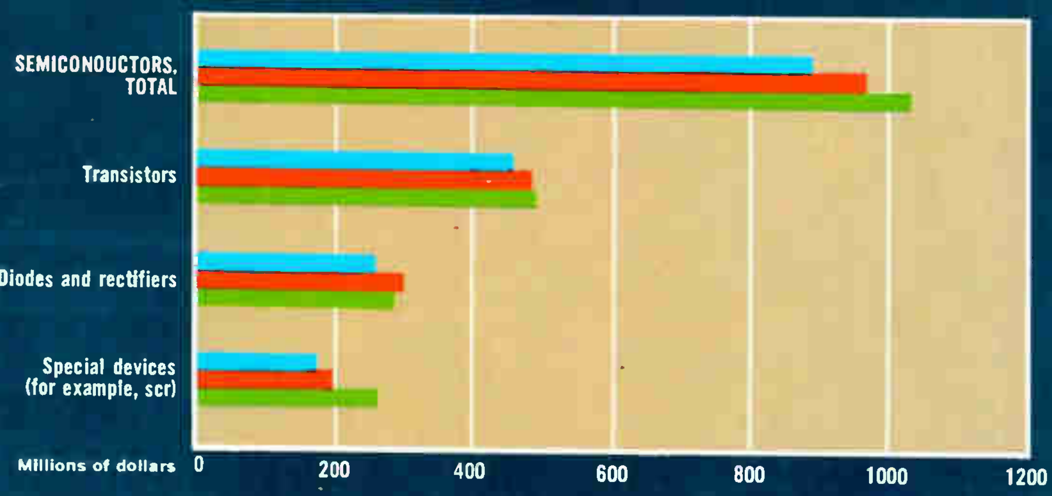
TOTAL ELECTRONICS INDUSTRY (millions of dollars)	1966	1967	1970
ELECTRONICS INDUSTRY, TOTAL	19,699.6	21,553.9	25,205.8
Consumer electronics	3,445.6	3,697.9	4,120.4
Industrial-commercial	5,734.0	6,420.0	8,629.4
Federal (including military and government nonmilitary, adjusted for calendar year)	9,810.0	10,719.0	11,731.0
Replacement components	710.0	717.0	725.0



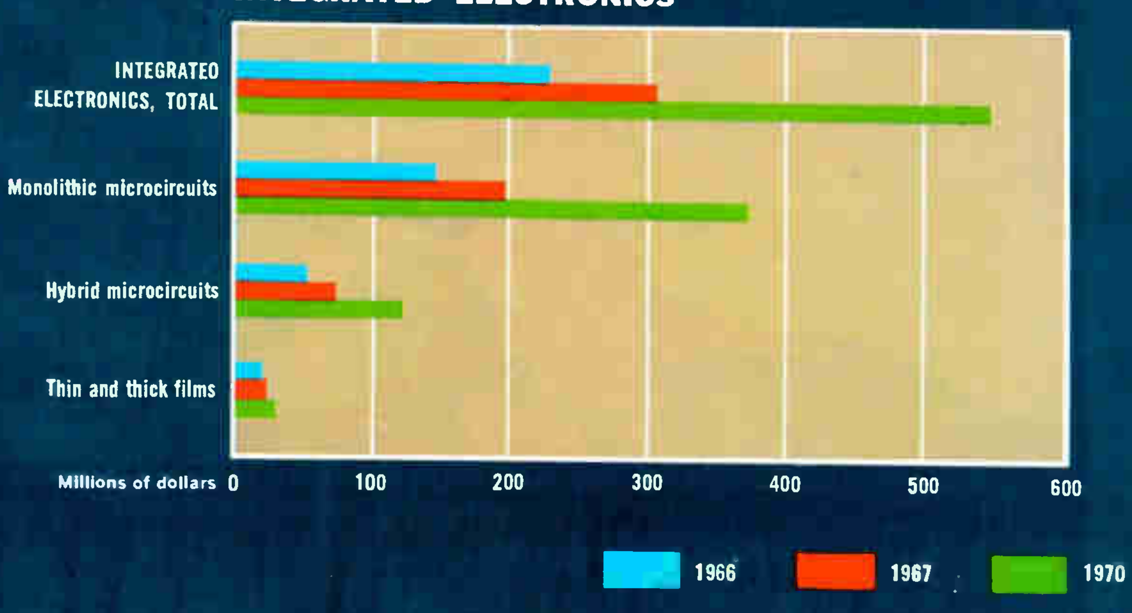
COMPONENTS



SEMICONDUCTORS, TOTAL



INTEGRATED ELECTRONICS



Electronics Markets 1967

Federal Electronics

	1966	1967	1970
	(millions of dollars)		
FEDERAL ELECTRONICS, TOTAL	9,810	10,719	11,731
Department of Defense, electronics portion, total	7,901	8,780	9,653
Procurement, total	4,462	4,973	5,449
Communications	1,136	1,274	1,386
Aircraft	1,283	1,420	1,561
Missiles	1,442	1,617	1,772
Mobile and ordnance	124	141	155
Ships	477	521	575
Research, development, test and evaluation	1,975	2,157	2,409
Operations and maintenance	1,464	1,650	1,795
NASA, electronics portion	1,745	1,776	1,868
Federal Aviation Agency, electronics portion	100	100	150
Atomic Energy Commission, electronics portion	64	63	60

Industrial Electronics

	1966	1967	1970
	(millions of dollars)		
INDUSTRIAL AND COMMERCIAL, TOTAL	5,734.0	6,420.0	8,629.4
Test and measuring instruments	576.0	650.8	799.5
Medical equipment	230.6	266.2	340.1
Nuclear instruments and equipment	138.2	158.6	214.6
Optoelectronic instruments and equipment	95.0	101.0	112.0
Computers and related equipment	2,145.1	2,426.8	3,534.2
Communications equipment	1,382.5	1,490.1	1,814.4
Laser equipment	33.6	49.8	99.9
Closed circuit television	30.6	42.0	59.4
Dictating devices	100.1	101.0	104.0
Power supplies	67.5	72.8	85.0
Industrial operations electronic equipment	934.8	1,060.9	1,466.3

Consumer Electronics

	1966	1967	1970
	(millions of dollars)		
CONSUMER ELECTRONICS, TOTAL	3,445.6	3,697.9	4,120.4
Television receivers, total	1,819.0	2,017.0	2,223.0
Monochrome tv receivers	729.0	667.0	473.0
Color tv receivers	1,090.0	1,350.0	1,750.0
Radios, total	389.9	396.7	435.6
A-m and f-m radios	177.5	182.3	208.6
Auto radios	212.4	214.4	227.0
Phonographs, total	470.2	470.8	483.3
Phonographs, monaural	120.5	116.0	115.0
Phonographs, stereo	349.7	354.8	368.3
Tape recorders	114.0	131.0	160.0
Phonograph records	420.5	431.7	500.0
Hi-fi components (including tuners, speakers, amplifiers, etc.)	81.5	87.5	115.0
Kits, except toys	42.5	46.0	56.5
Light dimmers	8.0	9.2	12.0
Musical instruments, electronic	100.0	108.0	135.0

(Based upon factory prices)

Industrial and Commercial Markets

	1966	1967	1970
	(millions of dollars)		
Test and measuring instruments, total	576.0	650.8	799.5
Spectrum analyzers, subaudio to 1 Ghz	14.5	15.3	17.0
Signal generators, up to 1 Ghz	14.3	16.1	19.0
Sweep generators, up to 1 Ghz	4.4	5.5	7.8
Pulse generators, up to 1 Ghz	5.5	6.5	8.5
Oscillators, subaudio through video	14.6	18.1	22.3
Waveform generators, all shapes	12.1	13.5	15.4
Waveform analyzers and distortion meters	4.0	4.6	5.6
Counters, time and frequency, up to 1 Ghz	30.3	33.4	37.0
Timers, electronic	72.3	79.6	108.4
Panel meters	30.1	32.3	34.1
Noise measuring equipment, up to 1 Ghz	11.4	12.6	14.5
Radio-frequency measuring instruments except counters	6.3	6.6	7.5
Voltmeters and ammeters, electronic, d-c to 1 Ghz, meter indicating	15.0	16.0	20.0
Digital voltmeters	25.0	26.5	30.0
Power meters, d-c to 1 Ghz	3.1	4.3	7.6
Impedance measuring equipment, up to 1 Ghz	14.3	17.5	18.0
Calibrators and standards, active and passive	14.1	16.0	20.3
Oscilloscopes, d-c to 1 Ghz	92.1	106.6	123.5
Recording instruments, digital and analog	41.5	47.7	66.5
Components testers (capacitor, transistor, tube, etc.)	21.0	22.5	27.0
Power supplies, lab type	43.0	49.0	60.5
Amplifiers, lab type	7.3	8.4	11.0
Microwave measuring equipment (above 1 Ghz) total	64.8	72.6	98.0
Oscilloscopes, above 1 Ghz	7.0	8.2	11.1
Microwave phase measuring equipment	5.4	5.7	8.0
Microwave impedance measuring equipment	12.0	13.5	18.0
Microwave power measuring equipment	3.7	4.4	6.3
Spectrum analyzers, above 1 Ghz	7.3	9.1	10.7
Frequency measuring and analysis, above 1 Ghz, other	7.0	8.5	11.2
Microwave noise measuring equipment	5.3	6.8	8.8
Signal generators, above 1 Ghz	7.5	8.3	9.0
Sweep generators, above 1 Ghz	6.1	7.2	8.7
Pulse generators, above 1 Ghz	3.5	4.5	6.2
Other test and measuring equipment, all frequencies	15.0	16.0	20.0
Medical equipment, total	230.6	266.2	340.1
Radioactive tracer equipment	12.4	15.3	22.6
X-ray equipment diagnostic	85.1	89.4	112.0
X-ray equipment, therapeutic	15.0	24.5	30.0
Patient-monitoring systems	10.7	15.4	25.6
Hearing aids	50.4	55.2	58.5
Electroencephalographs	2.9	3.7	5.3
Electrocardiographs	9.0	9.3	12.0
Electron microscopes	7.5	8.5	10.3
Analytical lab equipment, including blood colorimeters	13.2	15.0	20.4
Ultrasonic, diagnostic and therapeutic	5.8	7.7	12.2

	1966	1967	1970
	(millions of dollars)		
Diathermy, shortwave and microwave	2.0	2.1	3.2
Other medical electronic equipment	16.6	20.1	28.0
Nuclear instruments and equipment, total	138.2	158.6	214.6
Analyzers, pulse height	13.5	16.8	21.2
Other spectrometers for nuclear applications	4.0	4.3	5.6
Accelerators, linear	13.0	14.3	17.6
Accelerators, other	8.4	10.3	15.6
Power supplies for nuclear equipment	6.3	7.6	15.0
Amplifiers for nuclear equipment	4.1	5.5	9.5
Pulse generators for nuclear equipment	0.6	1.0	1.7
Personal dosimeters	0.7	0.8	1.0
Radiation monitoring, portable survey instruments	2.5	3.4	5.0
Radiation monitoring, fixed position	4.0	4.3	4.9
Detectors (all, separate unit or part of system), total	9.1	10.8	16.0
Semiconductors	3.0	3.7	5.1
Tubes (Geiger, gas flow, BG_3)	2.4	3.0	4.8
Scintillation, crystals and organic phosphors	3.0	3.3	5.1
Ionization chambers	0.7	0.8	1.0
Reactor controls	27.0	29.5	37.5
Nuclear instruments and equipment, other	45.0	50.0	64.0
Optoelectronic instruments and equipment	95.0	101.0	112.0
(including electronic densitometers, infrared generators and detectors, photoelectric template followers, etc.)			
Computers and related equipment, total	2,145.1	2,426.8	3,534.2
Digital computers, except process control	1,700.0	1,920.0	2,800.0
Analog computers, except process control	40.6	44.8	55.7
Hybrid computers, except process control	34.6	41.5	66.4
Peripheral equipment, total	299.9	338.0	437.1
Converters, A to D	9.6	11.3	16.8
Converters, D to A	4.9	5.8	8.5
Converters, card to tape	6.5	7.0	7.5
Readers, paper tape	21.5	24.2	29.0
Readout devices	150.0	166.8	210.5
Mass storage memories, total	107.4	122.9	164.8
Magnetic tape machinery	58.2	64.1	80.3
Magnetic drum memories	12.0	15.3	23.5
Magnetic disc memories	37.2	43.5	61.0
Data transmission equipment	70.0	82.5	175.0
Communications equipment, total	1,382.5	1,490.1	1,814.4
Land mobile	170.5	180.0	205.0
Microwave and radio relay	77.4	86.3	117.2
Terminal and switching	97.6	100.3	122.7
Radar	54.6	63.4	77.0
Other navigational aids	30.0	35.8	78.5

	1966	1967	1970
	(millions of dollars)		
Marine communications	17.6	19.6	25.6
Airborne, including ground links	165.7	170.6	210.0
Carrier current	16.3	18.6	27.2
Intercom	95.3	99.7	110.2
Commercial sound and public address	212.3	222.7	256.4
A-m station equipment	14.4	15.3	17.6
F-m station equipment	11.3	12.8	16.9
Tv station equipment	128.1	130.4	130.7
Amateur equipment	25.3	27.8	31.1
Citizens band equipment	35.9	40.5	48.7
Facsimile	22.0	25.5	30.5
Optical (light) communications (laser, infrared)	2.5	3.0	4.5
Telemetry	160.4	181.7	224.9
Communications equipment, other	45.3	56.1	79.7
Laser equipment, total	33.6	49.8	99.9
Welding and machining lasers	3.2	6.5	18.4
Measuring and surveying lasers	6.5	9.5	20.0
Medical lasers	1.0	1.3	3.0
Communications lasers	2.4	3.5	6.0
Other lasers	20.5	29.0	52.5
Closed circuit television, total	30.6	42.0	59.4
Industrial CCTV	14.4	20.1	26.6
Educational CCTV	10.0	13.4	19.5
Theater CCTV	2.2	2.8	4.4
Medical CCTV	4.0	5.7	8.9
Dictating devices (for business)	100.1	101.0	104.0
Power supplies, OEM type	67.5	72.8	85.0
Industrial operations electronic equipment, total	934.8	1,060.9	1,466.3
Motor speed controls	50.2	59.5	75.0
Welding	21.3	26.7	36.5
Power supplies (complete equipment)	95.0	104.7	132.0
Cryogenic equipment	55.4	66.1	90.0
Ultrasonic cleaning equipment	10.3	11.1	15.0
Other ultrasonic equipment	12.4	14.1	19.7
Infrared equipment	35.7	40.4	52.7
X-ray, industrial	23.2	26.7	49.1
Nuclear gauging and processing	65.4	76.3	110.0
Process control computer systems, total	202.2	235.8	350.3
Process control computer systems, analog	21.0	21.5	28.7
Process control computer systems, digital	75.6	103.8	185.0
Process control computer systems, hybrid	4.6	5.5	8.0
Other process controls	101.0	105.0	120.0
Machine tool controls, total	217.3	242.3	335.5
Point-to-point control systems	165.0	178.2	222.8
Continuous contouring systems	52.3	64.1	112.7
Controllers	29.2	31.2	38.5
Actuators, including valves	36.2	38.7	48.0
Indicators	3.7	4.4	6.2
Recorders	64.3	68.6	88.7
Other industrial electronic equipment	13.0	14.3	19.1

Components Markets

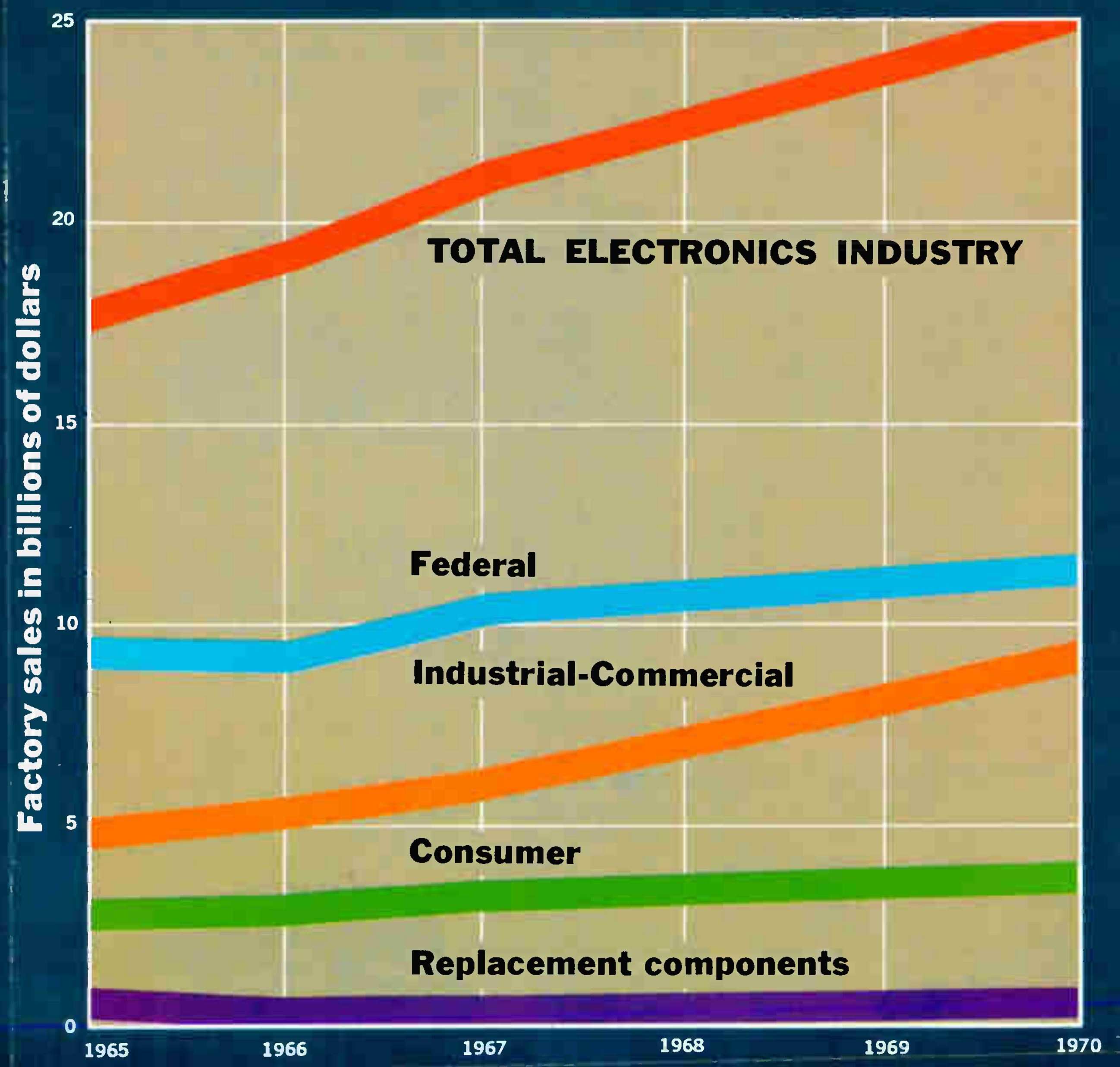
	1966	1967	1970
	(millions of dollars)		
ALL COMPONENTS, TOTAL	6,272.5	6,834.5	7,758.3
Antennas and antenna hardware	345.0	372.5	465.5
Batteries, total	80.8	88.1	113.8
Primary batteries	45.6	50.7	70.3
Secondary batteries	35.2	37.4	43.5
Capacitors, total	436.3	462.1	477.3
Paper and film capacitors	122.0	127.5	133.0
Electrolytic capacitors	192.8	210.8	215.5
Mica capacitors	30.0	31.0	32.0
Glass and vitreous enamel capacitors	9.0	9.0	8.0
Ceramic capacitors	53.9	55.0	59.3
Variable capacitors	28.6	28.8	29.5
Complex components (Multicomponent packages, two or more separate active or passive components in a single package)	202.5	220.0	280.0
Connectors, total	264.3	285.4	325.8
Coaxial connectors, standard size	24.5	26.3	25.7
Coaxial connectors, miniature	16.4	19.3	25.7
Cylindrical connectors	87.0	93.1	103.0
Rack and panel connectors	64.0	68.4	78.0
Printed circuit connectors	37.4	40.0	44.4
Special purpose and fused connectors	35.0	38.3	49.0
Delay lines	14.0	18.0	26.3
Electroluminescence	7.0	9.0	14.0
Electron tubes, total	1,178.2	1,319.8	1,308.9
Receiving tubes	274.5	283.0	250.0
Power and special purpose tubes, total	270.2	284.8	299.8
High-vacuum tubes	64.0	64.5	63.5
Gas and vapor tubes	20.3	20.1	19.3
Klystrons	36.3	41.0	37.5
Magnetrons	40.0	39.3	37.0
Twt's, including backward-wave types	40.0	43.0	45.6
Light-sensing tubes	35.0	38.0	50.0
Storage tubes	9.6	11.4	14.6
Light-emitting tubes	10.0	11.0	14.0
Display tubes, except cathode ray	3.0	4.0	5.3
Cathode-ray tubes, except tv	12.0	12.5	13.0
Tv picture tubes, black-and-white	157.5	147.5	124.4
Tv picture tubes, color	476.0	604.5	634.7

	1966	1967	1970
	(millions of dollars)		
Ferrite devices, total	288.1	305.6	361.5
Microwave ferrite devices	17.7	19.7	25.3
Computer cores	5.3	6.6	9.4
Transformers and chokes, except tv	230.4	236.7	267.4
Tv ferrite components, including yokes, flybacks	24.5	29.7	40.2
Other ferrite products	10.2	12.9	19.2
Filters, electronic	34.8	40.6	53.4
Integrated electronics, total	231.4	308.0	550.3
Integrated circuits, monolithic	145.0	198.0	379.0
Hybrid microcircuits (semiconductor and thin film components in combination)	55.9	75.5	125.0
Discrete chip components	7.0	8.7	14.0
Thin films	9.5	10.5	12.5
Thick films	14.0	15.3	19.8
Loudspeakers	105.0	115.0	128.0
Magnetic tape, total	143.5	170.3	221.4
Audio tape	41.5	48.8	65.0
Computer tape	51.7	59.6	71.2
Instrument tape	35.1	43.9	57.5
Video tape	15.2	18.0	27.7
Microwave components and hardware (not including tubes and antennas)	79.6	93.4	107.8
Printed circuits	102.7	106.5	142.2
Quartz crystals (including mounts and ovens)	50.0	58.0	68.5
Resistors, total	386.3	401.8	413.2
Fixed resistors, total	193.8	202.2	210.5
Composition resistors, fixed	82.0	87.1	88.6
Deposited carbon resistors, fixed	23.3	21.5	17.8
Metal film resistors, fixed	39.5	44.5	54.8
Wirewound resistors, fixed	49.0	49.1	49.3
Potentiometers, total	151.8	159.1	166.2
Wirewound potentiometers	76.0	78.3	76.5
Non-wirewound potentiometers	75.8	80.8	89.7
Other resistors (including varistors and thermistors)	42.7	40.5	36.5
Relays, total	237.5	254.1	277.1
Solid-state relays	3.2	4.3	9.7
Electromagnetic relays, total	95.3	104.2	112.5
Contact meter relays	3.6	4.6	4.6
Crystal can relays	22.2	24.2	26.3

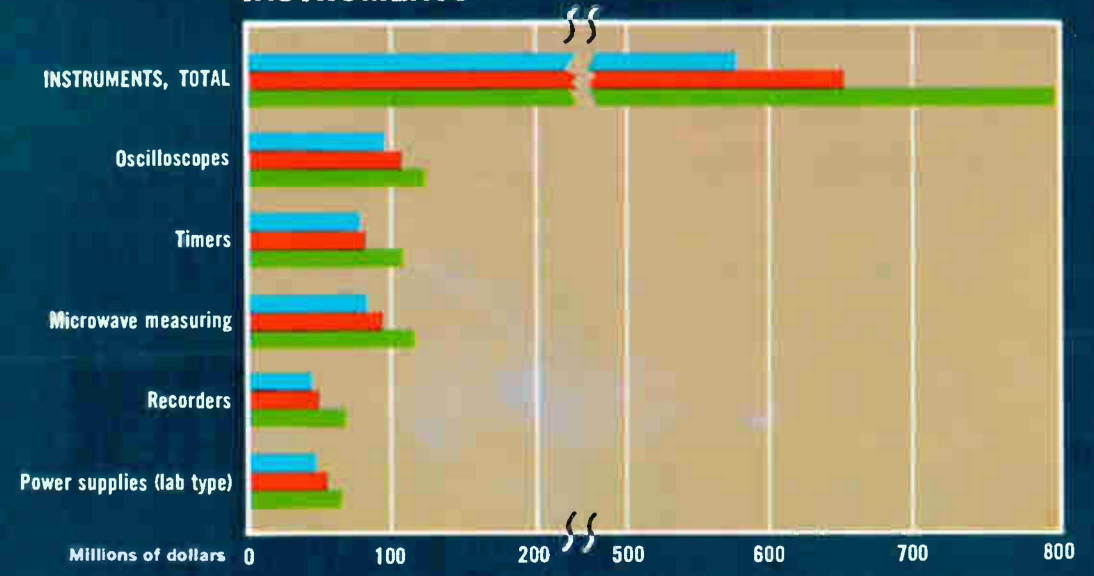
	1966	1967	1970
	(millions of dollars)		
Dry reed relays	19.0	22.6	25.4
Mercury wetted relays	12.5	14.4	16.0
Resonant reed relays	1.0	1.0	1.5
Stepping switches	12.6	12.6	11.7
Telephone type relays	20.3	20.6	21.4
Thermal relays	4.1	4.2	5.6
Other relays	139.0	145.6	154.9
Semiconductors, total	882.3	966.7	1,034.6
Transistors, total	453.8	480.4	483.7
Transistors, silicon	282.3	322.3	373.2
Transistors, germanium	171.5	158.1	110.5
Diodes and rectifiers, total	257.5	286.9	286.3
Diodes and rectifiers, silicon	200.2	230.3	241.5
Diodes and rectifiers, germanium	35.5	35.0	25.0
Rectifiers, selenium and copper oxide	21.8	21.6	19.8
Special semiconductor devices, total	171.0	199.4	264.6
Silicon controlled rectifiers	49.3	57.2	78.7
Microwave diodes, including varactors	21.2	26.3	30.3
Microwave transistors	11.1	12.1	14.3
Tunnel diodes	3.4	4.0	5.1
Light-sensitive semiconductors	21.2	23.5	31.0
Field effect transistors	7.6	12.0	30.0
Voltage reference and regulator diodes	57.2	64.3	75.2
Servos, synchros and motors, total	486.8	496.4	549.3
Resolvers	10.8	12.1	11.6
Servo motors	26.5	27.4	26.2
Synchros	29.3	30.2	30.2
Rate generators	3.5	4.3	5.1
Motor generators	11.4	11.7	11.3
Fractional horsepower motors	405.3	410.7	464.9
Solder	15.3	17.1	19.0
Switches, manual, total	143.0	155.1	199.6
Coaxial switches	20.3	22.5	28.4
Pressure switches	28.1	30.3	36.4
Rotary switches	19.5	22.9	31.5
Snap-action switches	50.0	52.1	70.3
Toggle, mercury, knife, misc.	25.1	27.3	33.0
Transducers, total	155.4	162.7	186.8
Pressure transducers	42.0	46.0	60.0
Position transducers	40.4	41.2	49.3
Strain transducers	28.0	28.5	30.0
Acceleration transducers	20.0	22.0	22.5
Other transducers	25.0	25.0	25.0
Wire and cable	400.7	408.3	434.0

Electronics Markets 1967

TOTAL ELECTRONICS INDUSTRY			
	(millions of dollars)		
	1966	1967	1970
ELECTRONICS INDUSTRY, TOTAL	19,699.6	21,553.9	25,205.8
Consumer electronics	3,445.6	3,697.9	4,120.4
Industrial-commercial	5,734.0	6,420.0	8,629.4
Federal (including military and government nonmilitary, adjusted for calendar year)	9,810.0	10,719.0	11,731.0
Replacement components	710.0	717.0	725.0



INSTRUMENTS

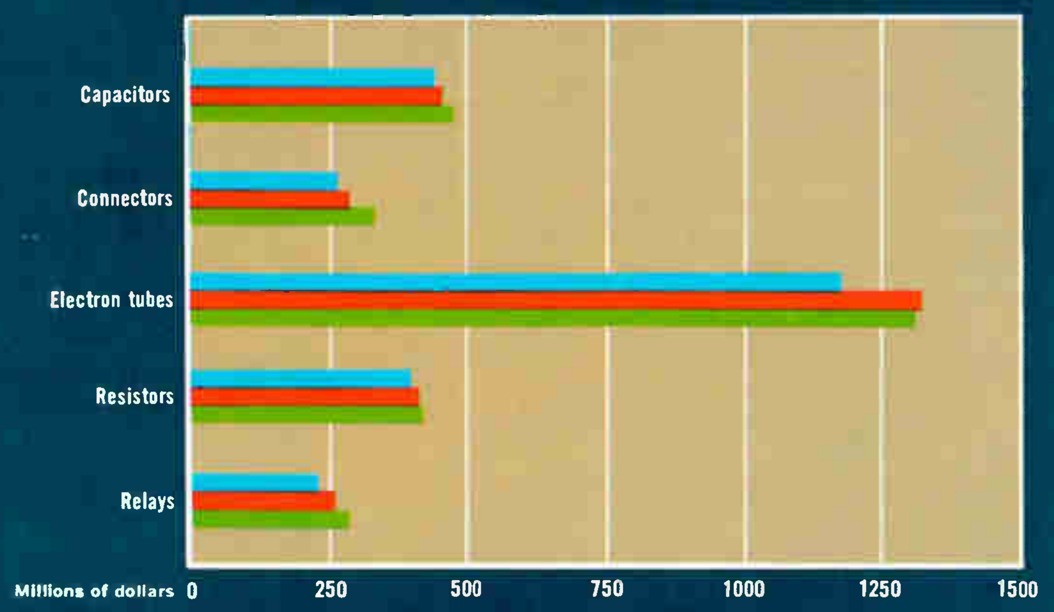


COMPUTERS AND PERIPHERAL EQUIPMENT, TOTAL

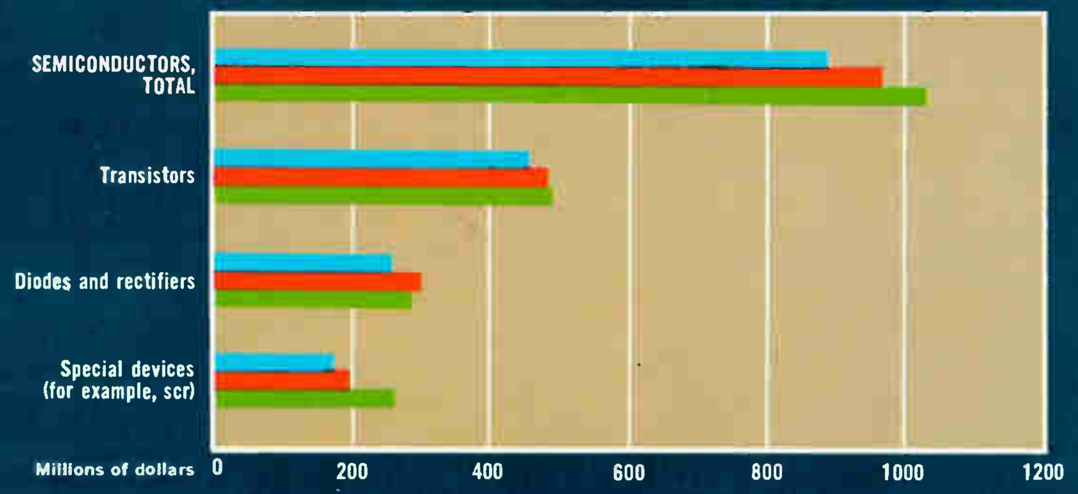
COMMUNICATIONS EQUIPMENT

1966 1967 1970

COMPONENTS



SEMICONDUCTORS, TOTAL



INTEGRATED ELECTRONICS

1966 1967 1970

Electronics firms will continue their vigorous growth in 1967; sales will hit \$21.5 billion, up 9.4% over 1966

The major reasons:

- Computer sales will climb by 13.2%
- Color television sales tabbed at 8 million units
- Military budget on the rise

Electronics markets: 1967

Spectacular rise continues

All segments of the industry are sharing in growth; television, computers and military spending are credited for the boom; integrated circuits remain major technological development

Rarely has there been such agreement on an industry's prospects. Economists, stock brokers, bankers and market analysts have chosen electronics as the golden girl of the year and Electronics magazine backs their judgment by predicting a total market of \$21.5 billion in 1967, up from \$19.6 billion in 1966. There are three reasons for the boom—television, computers and military spending.

While color-television firms have been racking up spectacular gains over the past couple of years, they've been moaning that they could have done even better if only they'd had the production capability. This finally seems to be their year. Most firms have completed broad expansion programs and, as a result, production estimates range as high as 8 million color sets. That's against a background of 4.7 million sets sold in 1966.

Computer manufacturers are on the same gravy train. They've been expanding facilities rapidly and view the sky as the limit as commercial and industrial firms snap up their output. Labor shortages and software snafus are a couple of the nagging problems that require solution.

The military budget keeps climbing, and spending for the war in Vietnam is making an impact on almost every sector of the industry, with communications, avionics and components showing marked gains.

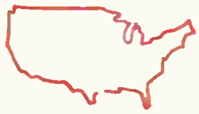
But the outlook for growth encompasses the entire industry. From instrument makers to medical electronics firms to components companies, there's nothing but good news.

Technically, the big story continues to be integrated circuits. They will continue to make inroads everywhere. Military equipment and computers will be using more and more IC's. In consumer areas, such as color television, IC's may continue to be a novelty, but some manufacturers are developing IC technology and say that only the requirements of the market are holding them back.

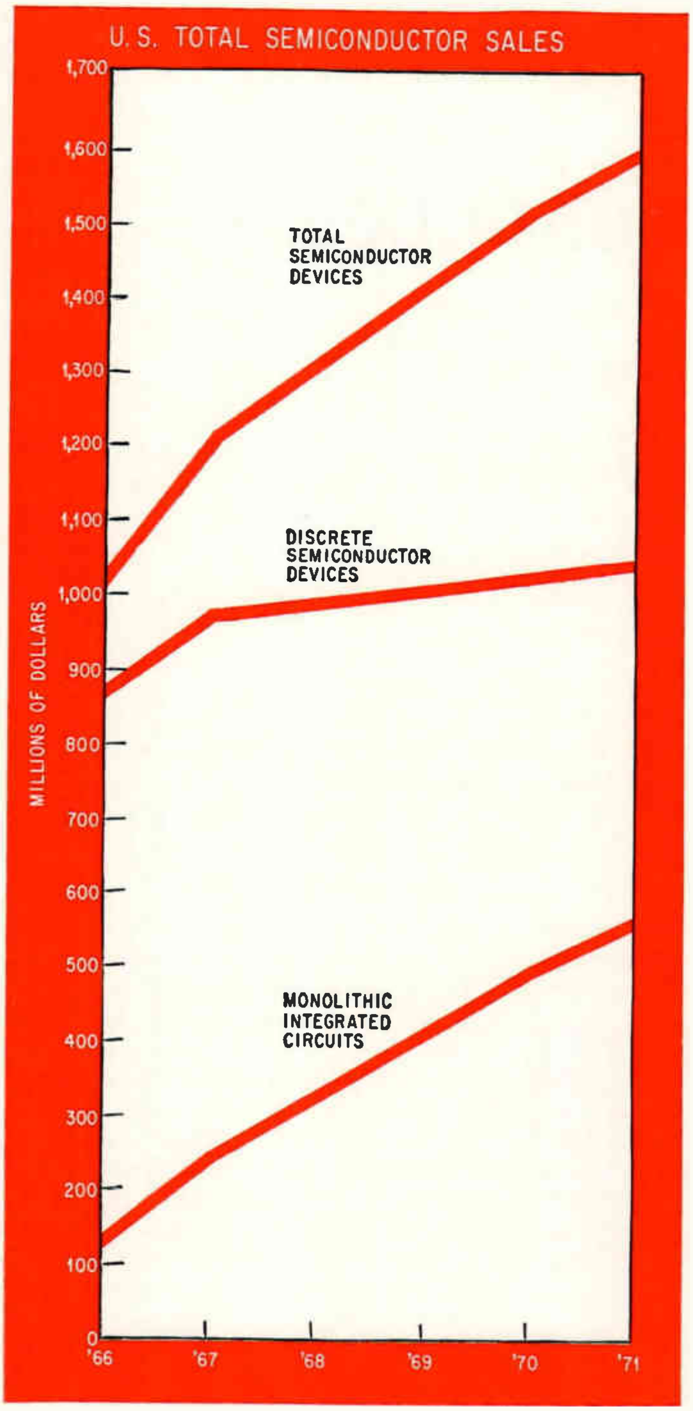
While they move ahead in developing new markets for IC's, many solid-state device manufacturers are casting uneasy glances over their shoulders at a brash newcomer—large-scale integration. Although LSI won't be much of a rival in 1967, it may pose a future threat. Many labs are now working to produce prototypes.

Contents:

Surge in semiconductors



'More and better' is the prognostication for both integrated circuits and discrete devices



Last year's boom in integrated circuits will continue this year, "only more so." This prediction by a major IC vendor reflects the unrestrained optimism that 1966 results have engendered in the industry.

Sales of IC's last year totaled about 32 million units, and the estimated dollar volume realized—around $145 million—was more than double the level forecast in 1965, despite a drop in the average selling price.

Electronics magazine's survey puts the 1967 IC market at about 100 million units, valued at $250 million. And should anyone think a slowdown is in sight, Radio Corp. of America officials project 1971 industry sales of 400 million units, of which, they add, about 150 million will be linear circuits.

The percentage of dollar sales to the military is expected to decline this year to about 40% of overall volume from the approximately 55% to 60% of 1966. However, sales to consumer-equipment makers will continue to represent a relatively insignificant part of the market, as the bulk of 1967 commercial IC volume will go for business machines and industrial computers.

An important factor in the expanded market is the plastic plug-in (dual in-line) package, which last year accounted for about 10% of dollar sales of IC's and this year may contribute as much as 30%.

The popularity of the dual in-line stems from its ease of handling and mounting in conventional printed circuit boards. It is in great demand for use in applications that don't require the highest volumetric efficiency. Some plastic dual in-lines have been tested by suppliers over the full temperature range specified by the military, and some may be used this year in limited-temperature-range military ground equipment.

Texas Instruments Incorporated, which last year entered the dual in-line market with a plastic version, may hedge its bet in the first quarter this year with a hermetic, hard-glass and Kovar-sealed dual in-line. The General Electric Co. expects plastic IC packages to be in short supply during the year, and consequently anticipates no significant price erosion. Prices will hover around an average of $1 a unit, according to GE, but because this year's circuits will be more complex than earlier versions they will yield "more circuit per dollar."

Large-scale integration—single wafers on substrates containing 100 or more circuits—probably won't make inroads in the market this year. But the major producers will undoubtedly invest much time and effort in studying lsi techniques and will develop some prototypes. Industry sources expect lsi devices to appear on the market by 1968 or early 1969, most likely in the form of custom or special circuits, such as decade counters and shift registers.

Fairchild Semiconductor, a division of Fairchild Camera & Instrument Corp., has slated relatively small quantities of medium-complexity (30 to 40 gates) arrays for mid-1967, and large arrays of up to 200 gates for late 1967. Complex arrays, Fairchild emphasizes, are still experimental and present problems in the areas of partitioning and packaging.

One question facing producers concerns whether discretionary wiring—the technique in which only good circuits on a chip are wired together with the aid of a computer—provides the most economical route to lsi. Both TI and the International Business Machines Corp. have programs using discretionary wiring, but neither is committed to the techniques.

C.F. O'Donnell, vice president for the Autonetics division of North American Aviation, Inc., holds that discretionary wiring may not be the most efficient and economical means of achieving lsi. With tongue in cheek, O'Donnell says discretionary wiring may "merely further IBM's plot to take over the entire world." Limiting the number of elements in an array to the amount consistent with very high yields may be more practical, he says. Concurring, Signetics Corp. finds it likely that face-bonded multi-chip assemblies will prove to be a far more practical approach to lsi than the "exotic notion" of discretionary wiring.

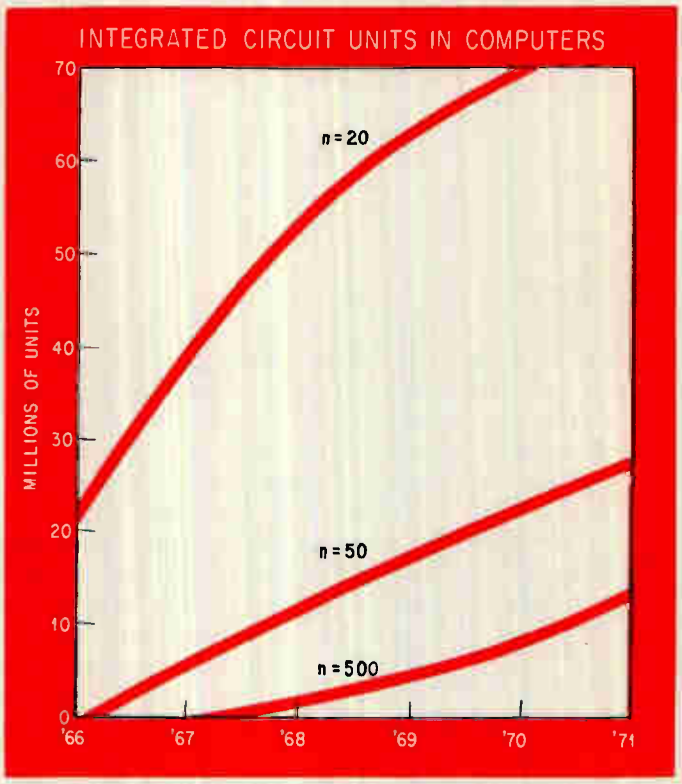
At a lower level of complexity, "complex-function" IC's, with 30 to 50 gates internally organized, may account for about 15% of the total 1967 IC market, according to TI.

MOS vs bipolar

Semiconductor and metal oxide semiconductor IC's continue to vie for position in the lsi contest. O.R. Baker, Signetics' vice president for product development, gives the edge to semiconductor IC technology from the viewpoint of cost and operating speed, but says MOS "may carve out a piece of the market in the low-speed, noncritical area of small desk calculators." Signetics has backed MOS programs for four years and indicates that it will continue to do so.

The General Instrument Corp. and the Philco-Ford Corp. have thus far expended the most effort in MOS technology, though their claim to this title may be challenged by others this year. Fairchild aims to put its scattered MOS efforts under central control and has hired Charles Sutcliffe, formerly of General Instrument, to head up its MOS IC operation [Electronics, Nov. 28, 1966, p. 8]. For its part, General Instrument has consolidated its MOS operations and has named J. Leland Seeley to direct them [Electronics, Nov. 14, 1966, p. 8]. Seeley expects MOS developments in three areas: multiphase computers, incremental computers and random-access memories. Mos chips for multiphase computers will feature power dissipation as low as 5 to 10 milliwatts at 1 to 2 megahertz, and clock rates up to 10 Mhz, according to Seeley. The low power dissipation will encourage larger logic arrays, and new processing methods will boost speeds and permit packing densities of up to 1 million devices per square inch, he says.

General Instrument is also developing an advanced digital integrating computer that performs calculations by summing increments. In such a computer, errors aren't cumulative.



In computers of the future, more circuit elements will be included in each IC chip. Autonetics forecasts these trends in use of 20, 50 and 500 element IC's.

Critics of MOS cite problem areas: low yields, erratic delivery and reported instability. Joseph van Poppelen, president of the semiconductor division of the International Telephone and Telegraph Corp., warns potential users not to believe today's "MOS story." ITT is concentrating on copying the Fairchild DTL (diode-transistor-logic) line of bipolar IC's, although its Palo Alto, Calif., laboratories are tackling surface problems related to MOS and other semiconductor devices. The company believes MOS may play a significant role in the future.

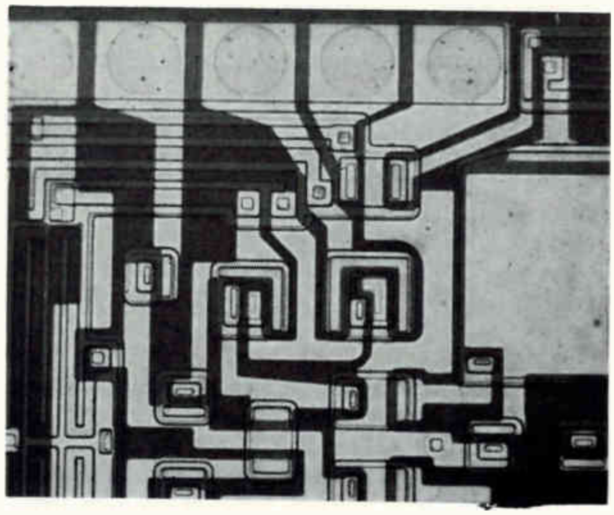
IC's under glass

Most proponents of complex integrated-circuit arrays agree that at the 100-circuit level of complexity, multilayer interconnections are needed.

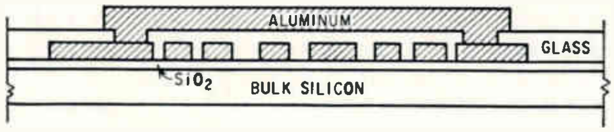
For simpler circuits, diffused crossovers may be satisfactory, but it seems inevitable that lsi devices will require layer-type insulation, such as glass [Electronics, Oct. 3, 1966, p. 108].

According to Signetics engineers, the vacuum deposition of glass over the aluminum and thermally grown oxide surfaces of integrated circuits offers advantages that will be exploited heavily this year. Aside from its use in fabricating crossovers within IC's, the glass layer protects a finished chip from scratching and gouging during assembly. Also, as shown in the top photograph, the glass coating can be selectively removed (note the circular pattern) from the aluminum bonding pads. This gives the operator a target for bonding; if the target is missed, the bond can easily be lifted from atop the glass without damage to the chip.

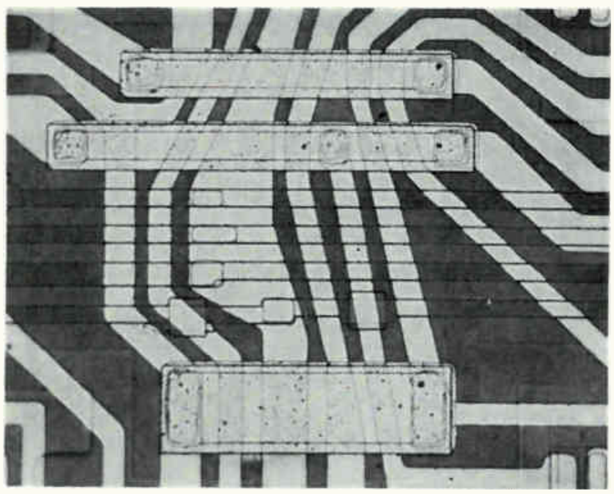
The bottom photograph shows several crossovers made by depositing glass over the aluminum in the area to be crossed and then depositing aluminum tie-bars over the glass. Such crossovers, notes Signetics, can be made directly over active devices, so that chip size is not affected as it is with diffused crossovers.



Glass layers protect IC from scratching and gouging. Circles are bonding targets from which glass has been removed.



Aluminum crossovers can be made easily above glass insulating layer, avoiding diffused IC



Glass islands in Signetics IC permit conducting tie-bars to be superimposed above substructure, including transistors.

Proprietary IC's

This year, more large industrial and military users can be expected to establish small in-house facilities for making prototype IC's, according to marketing specialists at GE's semiconductor products department. One consequence of this will be a demand for IC pellets, a market that GE sees as "small during 1967" but potentially important.

For instrument manufacturers and military-equipment makers, the establishment of in-house IC facilities seems natural. The former rely heavily on proprietary features, features that usually involve a very small percentage of the total circuitry in a device. Instrument makers are reluctant to risk loss of a proprietary design by turning it over to a device supplier to produce, and suppliers aren't anxious to become involved in developing a circuit that, at best, may represent a volume of only 3,000 to 4,000 units a year. In the case of military-equipment manufacturers, total dependence on IC suppliers can jeopardize defense orders if development delays occur. IC's developed by military houses are more likely to become high-volume items produced by vendors.

More testing

A sharp increase in the testing of integrated circuits is seen by both makers and users. Possibly because of competitive pressures, customers are insisting on more testing, although the added time and labor costs, plus the expenses stemming from lowered yields, are invariably passed along to them. Certainly the customer gets more testing for less money with today's sophisticated test equipment. For example, d-c and a-c tests can be performed on the same run with the device plugged into the same socket, and test programs can be easily changed by modifying a tape. Nevertheless, few observers are prepared to say exactly what the added testing is "buying" the customer.

One exception to the trend toward extra testing is a shift away from temperature testing—possibly as the result of lessened emphasis on the military market. Instead, most tests are performed at 25° C and sampling checks are made at the temperature extremes.

Material centers

Major IC vendors will intensify efforts this year to drive production costs down through the efficient utilization of "material centers"—plants at which wafer preparation, diffusion and epitaxy are carried out. To complement the material centers, additional assembly plants will be set up in regions of low-cost labor both here and abroad. Some domestic manufacturers already find Hong Kong losing its appeal as an assembly point, since, they believe, it won't remain an area of low labor costs for long.

A trend to contract purchasing may further influence the over-all IC pricing structure; a vendor can shave prices if it knows its shipping schedule over a long term. One example of contract purchasing is the recent agreement between Fairchild Semiconductor and the Burroughs Corp. Under its terms Fairchild will ship 20 million IC's, transistors and diodes over the next two years for use in Burroughs' general-purpose computers: the B2500, B3500, B6500 and B8500. Included in the gigantic procurement is the largest order for silicon monolithic IC's ever placed. The devices are complementary transistor logic (CTL). Fairchild predicts that 1967 will be the first year that almost every major computer house will be shipping an IC system.

Discrete semiconductors

Semiconductor concerns planning to compete at a profit in 1967 must be able to do so in the face of steadily decreasing selling prices. The trend is illustrated by the price curves at the right for silicon transistors. Despite the price decline, dollar sales of discrete semiconductor devices are expected to increase from about $950,000,000 in 1966 to about $1,025,000,000 this year.

For the customer, the picture is bright—not only regarding prices but availability, too. Some shortages experienced last year, particularly in military equipment, will be alleviated. And manufacturers will try hard this year to catch up with customer demand for devices in inexpensive plastic packages. The availability of all small signal silicon devices, notes TI, will be excellent.

A number of the new tested-extra transistors will reach the market in 1967. These devices result from the Pentagon-sponsored program to register transistors (under the designation JAN-TX) that have undergone tests over and above those required for regular mil specs.

Boom in plastic

Most broad-line producers agree that 1967 will be "the year of the package." Low-priced packaging —including transfer molded plastic, epoxy and ceramic—will be stressed. The biggest growth, TI predicts, will be in plastic-packaged economy devices, including field-effect transistors, power transistors, scr's and unijunction transistors.

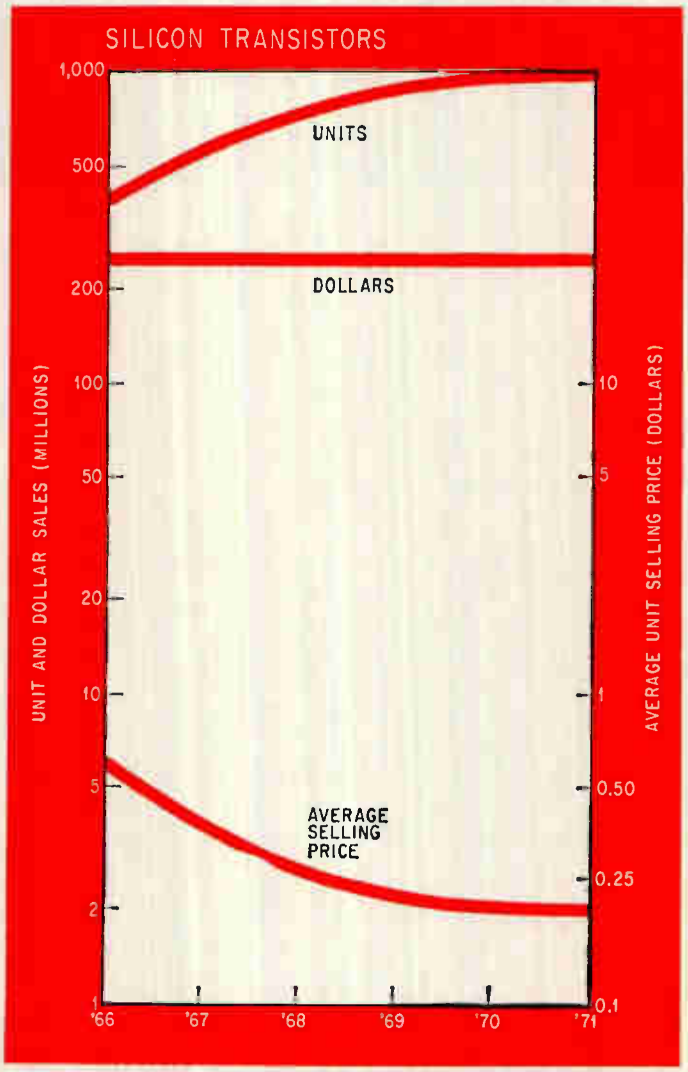
According to GE's Semiconductor Products department, 1967 will see a major breakthrough in the use of plastic-packaged devices in military and computer applications. GE itself is in the throes of a major change in its plastic "economy line" packaging, a change the company says will provide "dramatic improvement" in environmental capabilities and over-all reliability. Production will be completely converted to the new package early this year, GE adds.

Contributing heavily to the demand for inexpensive transistors will be the thriving entertainment electronics industry [see page 139]. According to GE, all-solid-state tv will grow in importance, as will hybrid tube-transistor sets. By the end of the year, the company says, almost all line-operated table radios will be solid state. GE is gearing for the anticipated transition with an audio-output family that will go into production this month; this line will be followed by several others later in the year.

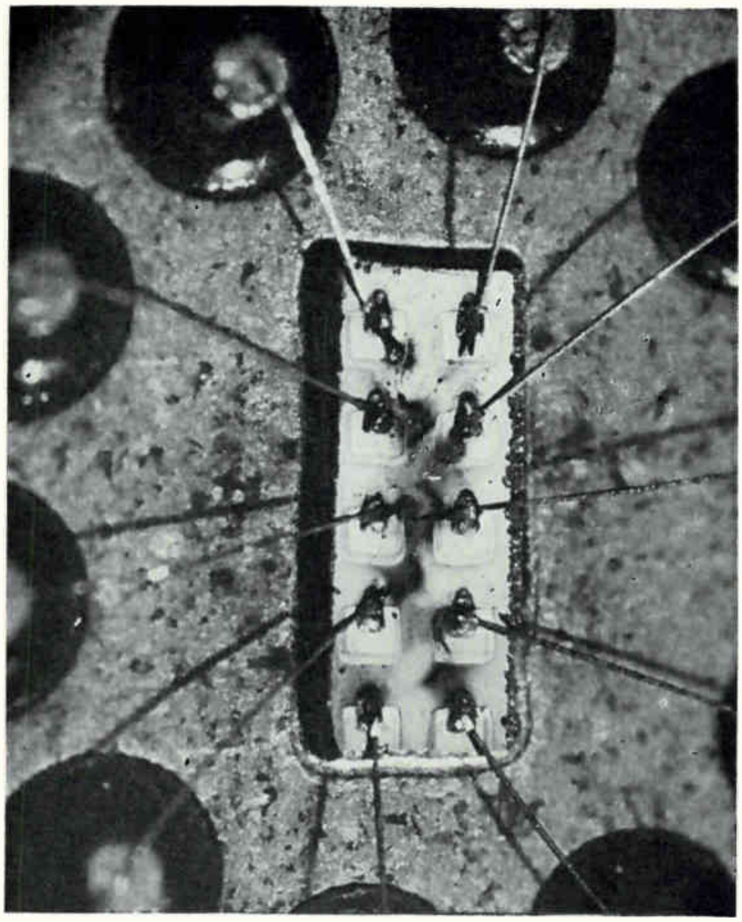
Power boost

The designer of rf amplifiers, servo-amplifiers, single sideband transmitters, two-way mobile radios and the like may find welcome relief in transistors with higher power and frequency capabilities. Fairchild, for one, predicts rf power transistors with a capability of 5 watts and 1 gigahertz in the near future.

Mos transistors, says Fairchild, will make inroads



Worldwide sales of silicon transistors rise as prices decline, resulting in a steady dollar volume. Chart based on figures from ITT.



Experimental array of "pseudo-planar" tunnel diodes made by GE. Technique may find role in future computers.

in higher voltage applications, handling up to 150 v. Uses will be found for them in tuners, military communications gear and such consumer products as hi-fi and television sets.

Tunnel diode revisited

The long-discussed application of the tunnel diode as a low-cost element of high-speed computers may be closer to realization because of a new GE technique [Electronics, Dec. 12, p. 210]. Most tunnel diode manufacturers have abandoned the computer market because TD's made by existing techniques can't be priced much below a few dollars—too high for computers. Vendors of TD's have, therefore, aimed mostly at the high-performance, high-price microwave market.

But GE has come up with a technique using what its engineers call a "pseudo-planar" process to make TD's at a price of less than 50 cents a unit in large quantities. Because of this development, logic designers may be taking another look this year at the variety of hybrid (transistor-tunnel diode) logic schemes that have been proposed over the past few years.

GE reports that clock rates up to 400 Mhz have been obtained with the new device in hybrid circuits. Furthermore, the new, inexpensive TD may find uses in integrated circuits or arrays. One experimental array containing ten of the GE devices is shown above/below.

Thyristor outlook

Chiefly because of thyristors' special switching capabilities, sales of these devices are expected to reach a record $67 million this year, up 35% from last year's $50 million. The workhorse of the thyristor family will continue to be the silicon controlled rectifier (scr).

As the technological and economic factors limiting the maximum current in a single scr pellet are pressed, says F.W. Gutzwiller, applications engineering manager for GE's semiconductor products department, one may expect ingenious arrays of parallel clustered devices in one assembly. The voltage blocking ability of scr's, highest of any solid state device, will put the scr in a position to displace gaseous tubes in high-power radar pulse modulators, nuclear particle accelerators and high-voltage d-c power HVDC transmission.

The possible future role of scr's in HVDC is being studied by engineers at Westinghouse, who have set up an experimental HVDC transmission simulator at the company's research laboratories at Youngwood, Pa. Hvdc scr systems complement the new methods of generating electricity by direct energy conversion. Most of these methods produce d-c power, and the scr's would be ideal for inverting this power to a-c.

One of the problems of using scr's in HVDC equipment, as well as in other applications requiring high-voltage capability, is series operation. But, says GE's Gutzwiller, 1967 may well prove to be the year in which the last reservations about using long series strings of scr's for severe switching duty are finally laid to rest.

Dynamic improvement

Improvements in switching speed and other dynamic characteristics of scr's, GE notes, should be even more significant than improvements in the devices' static characteristics. They're the key to successful parallel and series operation and are also the critical parameters for power converter and inverter uses. One goal of industry researchers has been, and continues to be, the development of an scr that can turn on and off in a few microseconds at ultrasonic frequencies while handling several hundred amperes at 1000 volts or more.

At the lower end of the power spectrum, scr's continue to wage a price and performance battle with power transistors in circuits operating from d-c power supplies. The place of scr's in such former sanctuaries as medium-power inverters and choppers is being challenged by transistors as the voltage and power-handling ability of the latter devices increase and their cost drops. But even here, GE says, big improvements in the speed and frequency characteristics of the scr will permit the device to retain its hold on these applications and even gain some places in other equipment.

Military electronics

Pentagon stresses tactical gear to meet needs of Vietnam conflict

With one major exception, the emphasis, dating from 1961, on development of tactical weapons at the expense of strategic programs will continue in 1967. The exception is the Poseidon, a submarine-launched ballistic missile that will go into production this year.

Military spending for electronics will reflect a rise in over-all Defense Department expenditures to about $80 billion this year from $72 billion in 1966. The electronics portion of this total, according to Electronics magazine's annual market survey, will be $8.7 billion, up from $7.9 billion last year.

Equipment applicable to the Vietnam war continues to top the Pentagon's buying list. The conflict costs more every month and drains off dollars from those projects unconnected with the war. Procurement of such Air Force and Navy fighter planes as McDonnell Aircraft Corp.'s F-4 and the Grumman Aircraft Engineering Corp.'s A-6 is being stepped up, and these orders mean further contracts for avionics, missile guidance systems and surface-based landing and navigation systems.

Priority will be given to electronic gear for helicopters, including fire-control systems, new armament, a stationkeeping system, air-traffic controls and navigation equipment. More money will be spent this year for communications gear—from portable radios for infantry patrols to big troposcatter terminals across the South Pacific.

Computers will be needed by all three services to handle logistics, keep personnel records and help direct battlefield operations. The military's demands for surveillance, reconnaissance and target-acquisition gear will strain the ingenuity of researchers in the fields of low-light-level television, lasers and infrared and ultraviolet light.

The Defense Department is encouraging the use of integrated circuits. According to a spokesman for the Pentagon's Director of Defense Research and Engineering, "We like to avoid as many connections as possible since they decrease reliability."

Extensive research will continue on avionics systems more advanced than such projects as the Mark 2, the Air Force system being built for the F-111A, and the Navy's integrated helicopter avionics system (IHAS) [Electronics, Nov. 14, p. 234.]

Strategic

Besides acquiring tactical gear, the Defense Department plans to beef up its force of submarine-launched ballistic missiles by ordering into production the Poseidon missile, the follow-on to Polaris. This move will open markets for inertial-guidance and fire-control systems and electronic components, markets amounting to hundreds of millions of dollars.

Also, studies on an improved ground-based ballistic missile will be accelerated and debates will continue on the merits and disadvantages of the Nike-X antimissile missile.

Air Force

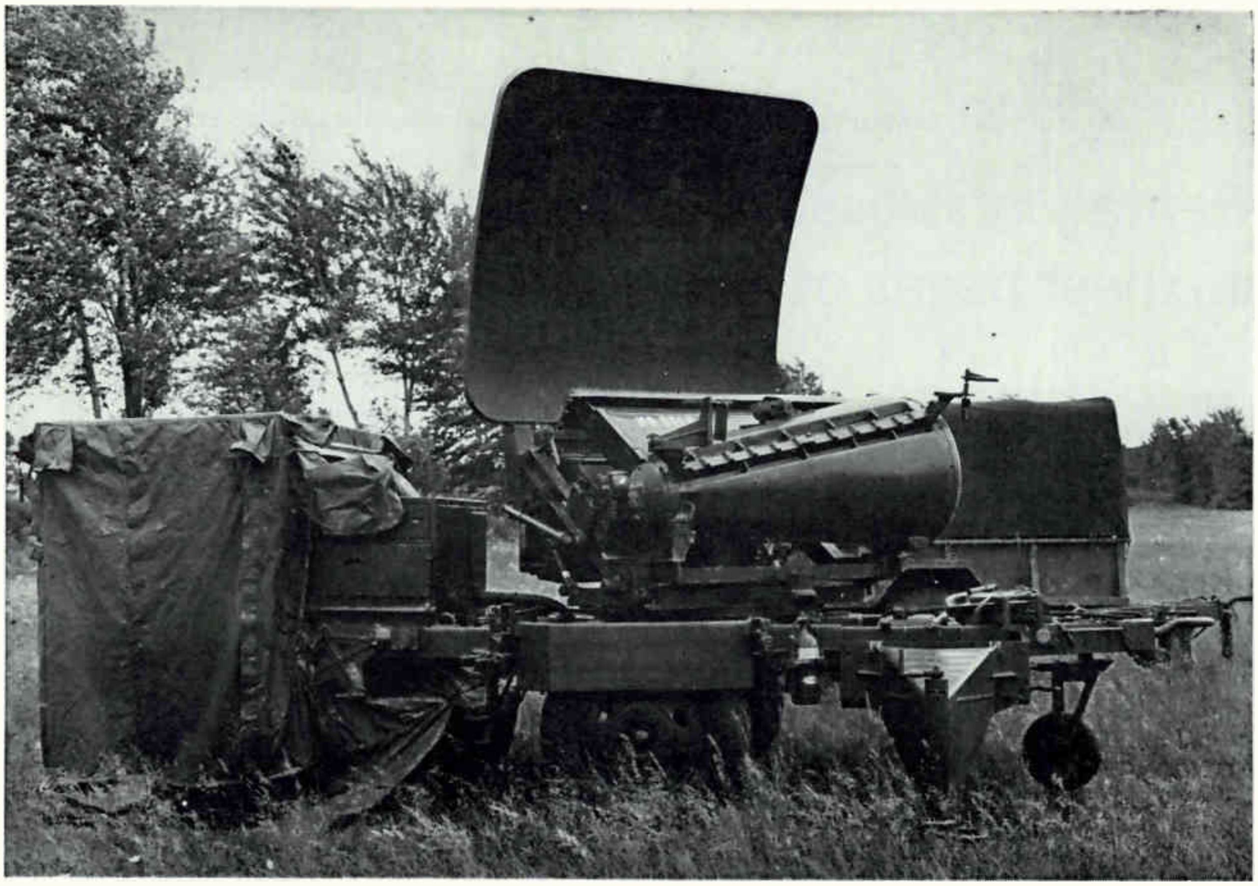
The 474-N project, a program to install radar sites along the nation's coastlines to detect sea-launched missiles will continue to provide a big market for electronics concerns. Also, research will begin on a new generation of large, phased-array radar to be used to monitor space.

The Air Force will continue to buy at least three fighters, the F-111A, A-7 and F-4, plus more C-141 cargo planes and the small OV-10 counterinsurgency aircraft. Development work on the giant C-5A cargo plane will continue.

The Air Force needs a self-contained (which usually means inertial) navigation set for tactical aircraft—the F-4 and F-105, for example. Obstacles here still involve weight, size and cost. Work will continue on an advanced instrument landing system for tactical planes.

New families of three-dimensional surveillance

Avionics for helicopters is a big market. The UH-1D troop transport (top) and UH-1B weapons escort ship (middle) are already in Vietnam. The HueyCobra will go over this year. All are built by Bell Helicopter Co.



Mortar-locator radar used in Vietnam is being updated by developer, GE, while a design competition is on to develop a more advanced unit that will scan in all directions.

radar, ground-controlled-approach radar for landing planes in poor visibility conditions, and automated data-gathering centers are in various stages of procurement; all are mobile, air-transportable and built in modular configurations. The GCA program to develop the first radar in this category since World War II, is expected to result in followup purchases of compact solid state scanning radars by commercial and overseas customers as well as the military.

Reflecting the increasing emphasis on tactical weapons, the Air Force Systems Command's Electronics Systems division at Hanscom Field, Mass., has created a separate organization strictly for tactical systems. At the same time, the Mitre Corp. —the engineering systems adviser to ESD—is planning a new tactical division.

Under consideration are programs for further development of solid state Tacan navigation systems, and in the advanced planning stage are proposed techniques to modify loran systems to serve tactical requirements.

To meet surveillance needs, more work on lasers and infrared sensors can be expected. And purchases of communications gear will include more lightweight, mobile equipment of tropospheric-scatter, single sideband, vhf and uhf types.

Army

For the Army, 1967 is the year of the computer. Besides buying a number of computers to process and distribute messages, the Army will continue three big programs to automate the battlefield—a move the service began preparing for 10 years ago. These programs are:

- The Tactical Operational System (TOS) to provide field commanders with quick intelligence and logistics information and to handle fire control. It will consist of computers and electronic displays tied in with a field army's organic communications. The Control Data Corp. will build a breadboard model of TOS from off-the-shelf equipment and this summer will deliver it to the Seventh Army in Europe for extensive testing.
- The Army's Combat Service Support System to test the feasibility of using an automated system on a time-sharing basis in the field to handle logistics and personnel records. The breadboard system will first go to Fort Hood, Texas, for tests, and then overseas. Industry bids on the breadboard model will be received some time this month.
- Tacfire, a research and development program aimed at automating combat artillery functions, including an entire artillery mission from receipt of target information from a forward controller to the firing of an artillery piece. Specifications will be released to the industry for bids before July.

Army officials consider this year's move toward automation very significant. Harold Silverstein, a special assistant to the Army's chief of communications-electronics, notes that in addition to increased use of computers there is a trend toward audio-visual presentation of data in command and control operations, management information and training.

Such equipment will one day be commonplace, Silverstein says. "The new generation of soldiers and officers being brought up on television and other electronic aids to education will find the audio-visual format more familiar and easier to grasp" than the technical-manual approach.

The official adds that "the big investment in strategic, long-haul communications in Southeast Asia and other areas will continue." Not only are more large terminals and new links being built in Thailand and South Vietnam, but the network in the South Pacific is being upgraded. Data terminals, switches and high-capacity radios will be frequent items on the Army's shopping list.

Tactical communications will be a big market as Vietnam war needs grow. There is also a push to improve air-ground communications in Vietnam [Electronics, May 16, p. 101].

Mortar-locator radar to calculate the source of enemy fire by monitoring the trajectory of shells represents a big effort this year. The General Electric Co.'s AN/MPQ-4A radar is being upgraded to improve performance and ease of maintenance, and a competition is under way among ITT-Gilfillan, Inc., a subsidiary of the International Telephone and Telegraph Corp., Emerson Electric Co. and GE to develop a radar that can scan in all directions.

More emphasis will be placed this year on tying in ground-based radar with computers and voice data links to direct air attacks when visibility is poor. Two such systems are being used successfully in Vietnam now and an improved model to replace both is in the works. The Marine Corps is using GE's AN/TPQ-10 and the Air Force is using the AN/MSQ-77, a modified version of the MSQ-35, which was originally built to score practice bomb runs for the Strategic Air Command by Reeves Instrument Co., a division of the Dynamics Corp. of America. The Marine Corps and the Air Force hope to come up with a single system, to be called the AN/TPQ-27, to satisfy the needs of both services.

Pilots of helicopters ferrying troops need devices to help them locate landing zones in poor visibility conditions. Among the approaches being tested are radio homing beacons to indicate to the pilots when they're over a landing zone, and beacons to indicate the perimeters of camps. Hyperbolic grid navigation systems such as loran C and D are also being considered.

Development of a new system to control air traffic over a field army will probably get started this year. Called Safoc, for semiautomatic flight observation center, the system will consist of four principal parts: radar or a hyperbolic navigation system to determine aircraft position, a data link between the aircraft and a ground station, a computer, and displays. Except for the data-link subsystem, the Safoc is almost identical to the Army's Missile Master fire-distribution system.

Designs for terminals for the tactical communications satellite now being developed by the Army Satellite Communications Agency are still being studied by a three-service executive group but should be given to industry next month. The terminals will take a number of forms; they will be used on aircraft, ships and ground vehicles, and will be carried and set up by three-man teams. The smaller the antennas, the more acceptable they will be; probably the biggest allowable will be six feet in diameter. They will operate in the ultrahigh-frequency or super high-frequency bands.

New ways will be considered this year to reduce equipment failure rates and maintenance costs. In this regard, the Defense Department will award contracts in May for the development of three items similar to, but sturdier than, existing equipment. The items are: a radio similar to the AN/VRC-12, the jeep-mounted vhf/f-m radio so popular in South Vietnam; a radio similar to the AN/ARC-34, a vhf command set used in several types of aircraft; and a personnel-detection radar similar to the AN/PPS-6 being developed for the Marine Corps.

Two types of manpack receivers for the loran C navigation system are being evaluated. The system is designed to help the foot soldier avoid getting lost or making dangerous excursions through enemy territory, and also to help a unit's forward air controller to get to the right spot to direct incoming planes.

The Army will continue to test every approach to improve surveillance techniques. A newly outfitted Mohawk surveillance plane that will carry side-looking radar and low-light-level television is in the works.

A prime contractor will be selected in May for SAM-D, an Army project to develop a surface-to-air missile to defend both civilian and military installations against low- and high-flying aircraft and short-range missiles.

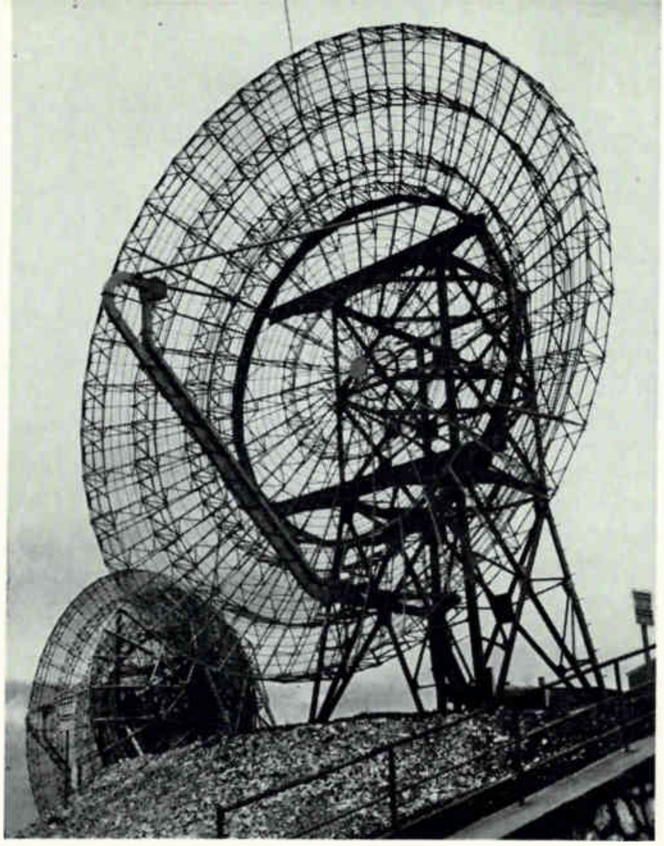
SAM-D batteries will be mounted on tracked or wheeled vehicles and will be accompanied by a multifunction phased-array radar.

Navy

Research, development, testing and evaluation of antisubmarine-warfare techniques and equipment have been costing the Navy about $330 million a year, and will, if anything, be expanded this year. Again the emphasis will be on improved sensors, weapons, and command and control systems. The trend toward using aircraft to search for enemy subs, rather than surface ships or submarines, will increase. Hardware procurement for the A-New command and control system, designed initially for use in the P-3 aircraft, will begin at the end of this year and reach a peak in early 1968 [Electronics, Dec. 12, p. 184].

One of the major decisions the Navy will make this spring concerns the number of F-111B's it will buy. Under its original contract with the General Dynamics Corp. the Navy is already committed to take 24. The plane is heavier than the Navy would like for carrier operations and costs are running far higher than originally expected.

Two new Navy planes are just getting into production: the Ling-Temco-Vought A-7 subsonic attack plane and North American Aviation, Inc.'s OV-10A, a prop-driven, "low-and-slow" ground-support and reconnaissance plane for use in anti-guerrilla warfare. Both aircraft are being bought by



Tropo terminals in Turkey, built by REL division of Dynamics Corp. of America, link Air Force operations in Europe and the Middle East with the rest of the world.

the Air Force, too. The Navy OV-10A order—for the Marines—is expected to amount to some 100 planes costing about $300,000 each.

In the design and development stage is the EA-6A electronic warfare aircraft. Grumman recently got a $12.4 million contract for the prototype, and Airborne Instrument Laboratory, a division of Cutler-Hammer, Inc., is contractor for the electronics.

Still in the in-house study phase is the VFAX, a new generation fighter-attack aircraft that would replace the F-4. The Navy would like to see contract definition work funded in the fiscal 1968 budget. The project, as with the F-111, probably will be subjected to an attempt to achieve commonality with the Air Force's FX studies, from which a multiservice, multimission plane would be expected to emerge.

The Navy also wants to push its VSX, an advanced antisubmarine aircraft, into contract definition in fiscal 1968, but this request is still unsettled. The Pentagon is making a cost-effectiveness study of all elements of the antisubmarine force, such as land-based patrol craft, hunter-killer submarines and fixed-base active and passive ranging and listening devices.

In the tactical-missile field, the Maxson Electronics Corp.'s Bullpup and Texas Instruments Incorporated's antiradar Shrike are being used extensively in Vietnam, and increased production of both can be expected. The Shrike, however, has not fully lived up to expectations, and the Pentagon has awarded General Dynamics a contract to develop a weapon called the interim ARM, or antiradiation missile.

The Navy is also moving into electro-optically guided air-to-ground weaponry. The Walleye, a 1,000-pound guided bomb, has recently gone into production at Martin Co., a division of the Martin-Marietta Corp. And North American Aviation is developing the Condor, a tv-guided missile with a standoff range of about 40 miles; it will be carried by the F-111B and the A-6.

Honeywell, Inc.'s Asroc is the Navy's principal surface-to-underwater antisubmarine weapon. Outlays will be continued for development of a follow-on antisubmarine missile compatible with Asroc's launching and fire-control systems.

The principal development in the surface-to-air-missile field is the General Dynamics Standard, which is to replace the Tartar and Terrier. The Standard MR, with a range of 10 nautical miles, will supplant the Tartar, and the Standard ER, with a range of 30 nautical miles, will replace the Terrier. First funding for production is contained in the fiscal 1967 budget. General Dynamics is providing its own semiactive homing guidance system for the weapons.

Another ship-defense system being developed with fiscal 1967 money is the point defense surface missile. Preliminary tests using the air-to-air Sparrow as a ship-based system have been successful, and the Navy thinks the Sea Sparrow air-defense system will be ready soon for its line ships as well as auxiliary craft. Existing Sparrows will be used with some components from the Army's defunct Mauler system.

Looking to the future, the Navy is carrying on research and development on an advanced surface-to-air missile system. Precontract definition work is being done by the Boeing Co., GE, Raytheon, the Radio Corp. of America, the Hughes Aircraft Co., the Sperry Rand Corp. and the Westinghouse Electric Co. However, this project called ASMS, will be kept in the design stage until it can be determined, probably in 1967, how much commonality it has with the Army's SAM-D antiaircraft missile. The Navy is also exploring possible shipboard mounting of the Army's surface-to-surface Lance to provide a new short-range bombardment capability.

In the ship field, there are these developments:

- Defense Secretary Robert S. McNamara's decision to move ahead with construction of a second nuclear carrier now that reactors are more economical. But the Secretary is holding back on nuclear-powered frigates and other support vessels.
- The Navy's decision to buy the fast-deployment logistics ship on a total package basis, farming out design and the entire production run to a single shipyard. The Lockheed Aircraft Corp., General Dynamics and Litton Industries, Inc., are competing in the contract definition phase for this award, which eventually may run to $1 billion.
- Just getting under way are plans to procure, on the same basis, the biggest thing yet in amphibious assault ships, a new type to be known as Lhas. This vessel will be able to put 1,800 troops ashore by both helicopter and landing craft.

Color tv projects a bright picture as capacity catches up with demand

Sales of color-television sets almost doubled in 1966 to provide a strong boost to the over-all consumer electronics market. However, with set makers plagued by shortages of components, material and labor, color-tv volume fell short of predictions for the year. Producers sold about 4.7 million sets in 1966, up from the 2.6 million units of 1965 but off from the 5.5 million forecast. Undaunted by this, however, the industry is back with even more optimistic predictions for 1967.

The most bullish sales forecast comes from the largest producer—the Radio Corp. of America. Delbert L. Mills, RCA's executive vice president for consumer products, puts the color-tv industry's volume this year at nearly 8 million sets. A more cautious forecast of 7 million unit sales comes from Walter C. Fisher, a Zenith Radio Corp. vice president, while Asher Cole, president of the National Video Corp., hedges a bit. "Only if the economy gets too heated up and there is a recession could the 7-million-to-8-million target be missed," he says.

For set makers, the major difference between 1967 prospects and 1966 results is one of capacity; these companies are in the final stages of the most ambitious expansion ever undertaken by a consumer industry. RCA says that with the completion of new facilities this year, its color-tv capacity will be triple what it was in 1966, while National Video expects to be able to produce 1.7 million color tubes this year, up sharply from about 1 million last year. National Video predicts that total 1967 industry production this year will climb to between 8.5 million and 9 million tubes from last year's 5 million.

Growing market

Color-television volume of $1.3 billion this year will help lift the over-all 1967 consumer electronics market to a $3.6 billion level from the estimated $3.4 billion of 1966, according to Electronics magazine's annual market survey.

Other segments of the consumer-products industry are also predicting 1967 sales gains. For example, Wybo Semmelink, assistant vice president of the North American Philips Co., forecasts a 20% rise in tape-recorder sales this year from the approximately 4 million units sold in 1966. He further asserts that the tape-recorder segment of the consumer market is second only to color television in current rate of growth.

Auto tape-cartridge stereo systems posted a $16 million sales increase last year from 1965 and, as home products, will make an even stronger advance this year. Electronics magazine's survey predicts that sales of these systems will surge to $131 million in 1967 from $114 million in 1966.

Although sales of black-and-white television sets have been declining, they are still the second most important factor in the consumer electronics market and are forecast at $667 million this year. Phonograph volume has leveled off; a $470.8 million total is expected this year, barely topping the $470.2 million of 1966.

Solid state slowdown

The advent of color tv has had one adverse effect: most observers agree that it has slowed the electronics industry's general shift to solid state components. Bernard T. Marren, manager of consumer products for the semiconductor division of the Fairchild Camera & Instrument Corp., attributes this slowing effect largely to the power requirements of color television. He explains that while there are power transistors available that can handle the 26,000 volts needed in a color-tv set, their prices aren't competitive with those of tubes.

Concurring in this observation that color tv has slowed the move to solid state, Clarence Bruce, manager of consumer marketing for Texas Instruments Incorporated's Semiconductor division, declares: "There's been a tremendous amount of engineering research but little conversion to solid state. We'll see some changes in 1967, but the full impact (of the trend to solid state) is some 18 months to two years off."

However, Bruce expects the marketing of more hybrid black-and-white tv sets this year, with makers introducing units with solid state tuners, picture i-f and automatic gain.

Mills of RCA says his company will soon introduce a completely transistorized, 9-inch black-and-white set and will also market a 15-inch color set containing a few transistors. The color set was originally slated for introduction last year. The executive adds that he expects to see many more hybrid sets in 1968.

The subject of integrated circuits in color tv is one that set makers approach with caution. Arthur L. Reese, executive vice president and general manager of the consumer products division of Motorola Inc., asserts that IC's are currently more of a promotional gimmick than anything else. Mills tends to agree, but holds that the use of IC's in color-tv equipment depends on marketplace requirements. "We have our homework finished and can put them in," he comments.

Bruce says TI expects to have IC's ready for color sets before the end of 1967 at prices equal to or under those of present components. Marren says Fairchild's semiconductor division this year will introduce a sound i-f integrated circuit and an amplifier circuit that makes it possible to integrate the whole sound stage of a tv set. (RCA put an i-f circuit in its top-priced color set of 1966.)

Used in only a handful of consumer products now, IC's will widen their penetration of this sector in 1967. The Westinghouse Electric Corp. will market a phonograph in which an integrated circuit replaces all electronic components. The General Electric Co. and the Philco-Ford Corp. already make radios containing IC's, and GE has also used the devices in the audio amplifiers of a phonograph, an eight-track cartridge tape player and a portable tv set. H.H. Scott, a producer of hi-fi equipment, recently introduced IC's in f-m tuner amplifiers.

Manufacturers of solid state components are making a big effort to develop products for the appliance market as well as for tv sets. Utilization of these devices in this area is still slight, but business is picking up in the small-appliance field and some solid state components are finding their way into large appliances.

Silicon control rectifiers are being used in such small appliances as power tools, home blenders and home light dimmers. As Marren notes, "Solid state is a natural for low-cost and low-power small appliances."

Philip Thomas, manager of TI's assembled functions unit, sees increased use of solid state components this year in food mixers, power tools and floor polishers. He further predicts the conversion to solid state of 50% of the speed controls for the appliance market by 1968.

Solid state devices are now being used as variable-speed controls in washers, electric timers in dishwashers, moisture sensors in dryers and ignition systems in gas ranges. Whirlpool Corp. is reportedly readying a washer using IC's for Sears, Roebuck and Co., and a solid state ignition system built by Wilcolator Co. is slated to appear in more range lines and in three manufacturers' water heaters. Scr's will be introduced in motor controls for air conditioners and refrigerators.

Over-all, manufacturers of solid state devices see rapid growth this year in all sectors of their consumer market. Fairchild estimates that 1966 industry sales of consumer solid state components came to $98 million, with silicon devices accounting for $45 million of the total and germanium devices the rest. Fairchild forecasts 1967 industry volume of $118 million, of which silicon components would have a $70 million share. Texas Instruments sets its sights a little lower, putting the 1966 market at $80 million and predicting a rise this year to $110 million.

Components

Demand continues strong

Business was so good for component manufacturers last year that at times they were hard put to keep track of the orders, which amounted to a total of $6.2 billion. And there's no slackening of pace in sight, with sales of $6.8 billion forecast for 1967.

The major markets have been created by the heavy demand emanating from the success of color television and computers, plus the rocketing military budget.

But component manufacturers have problems. They face shortages of materials such as copper that, along with the sheer volume of orders, have caused slowdowns in delivery of products. One sector of the market that has been affected is capacitors, with anticipated sales of $462.1 million this year. Customers have to wait for eight to 12 weeks for delivery on some types of capacitors.

The increased demand for high reliability has been another one of the major market factors, resulting in increased sales for items such as glass capacitors to the military, and opening up the computer market for products, expensive tantalum capacitors for example.

Tom Yost, manager of market planning for Corning Glass Works, says: "Computer manufacturers are using tantalum capacitors because they withstand high temperatures better than aluminum types previously used. They also withstand higher surge currents and higher ripple levels and work well in low-impedance transistor circuits."

Superior temperature performance, along with stability, is also giving a boost to metal films, one of the fastest growing segments of the resistor family. Joseph P. Coughlin, director of sales for IRC, Inc., says they are in demand for precision instrumentation and digital circuitry.

Resistors are a growing segment of the component market with sales of $401.8 million forecast by Electronics magazine for 1967, up from $388.3 million in 1966.

Along with films, another rapid growing area is cermet resistors. Sales, which were negligible a few years ago, climbed to about $25 million in 1966. The big demand is in the computer business, where their small size, stability and adequate tolerance, plus their compatibility in the processing of modules, makes them especially desirable.

One specter that confronts the component manufacturer is the integrated circuit. That this is a justifiable worry can be amply documented. For instance, most operational amplifier manufacturers are now recommending that designers consider IC's for circuit applications that don't have stringent requirements. The reason is price. In another case, IC's are not only replacing components in power supplies but are creating a demand for more accurate component tolerances. Says William McNeil, general manager of Micon Electronics, "Integrated circuits will be the death of subminiature radio-frequency connectors because the IC's will eventually replace the components that use this type of connector."

But component manufacturers only have to look as far as tubes to assuage some of their worries. Receiving tubes were replaced by transistors in many applications. Nevertheless, last year tube sales were higher than ever, at $274 million, and they will be up to $283 million in 1967. One big reason is a new market, color television.

Coughlin says continued gains in the over-all economy point to the continued growth of component sales.

Medical electronics

Heading for a $266-million year with basics and automated time-savers

The market for medical electronics will continue to grow in 1967 and, based on Electronics magazine's market survey, should increase about 13% to $266.2 million. Yet in an area of such vital concern and such potential for sophisticated electronics systems, it is noteworthy that the largest segment of the market is still maintained by X-ray equipment and hearing aids—two important, but less than revolutionary devices.

However, hospitals are seeking more modern electronics systems to help shoulder the increasing burden that Government programs such as medicare are placing on their facilities, and to help offset an acute shortage of trained medical personnel. Much of the electronic gear to be installed in hospitals this year will be aimed at relieving some of the work load on staffs.

Hospital test laboratories have long been a bottleneck but now the first wave of automated aids are being used to improve the efficiency of available personnel. Technicon Instruments Corp. has installed 80 of its 12-channel Autoanalyzers since last May, and Warner-Chilcott Laboratories Inc. is taking orders for its Robot Chemist, an automated chemical analyzer. Hycell Corp. reports that some 200 groups has shown interest in leasing Mark X automated analyzer.

X-rays televised

Radiologists, too, are seeking more efficient means of dealing with their procedures. Video tape recorders are being employed by some institutions for a rapid preview of X-rays before films are developed, and closed-circuit television is being

Automatic liquid sampling device provides test results in computer format for Technicon's Autoanalyzer. The reader in the system is built by IBM.

used to transmit X-rays. Tv monitors enable radiologists to tilt the patient's table and move the X-ray machine with remote control systems. "The coupling of television and radiology," says John A. Reynolds, vice-president and technical director of medical products for the Picker X-ray Corp., "has probably done as much as anything else to increase the speed in handling patients and the scope of diagnostic procedures."

Monitoring patients

Tools that extend the reach of doctors and nurses is, according to James Reeves, president of Spacelabs Inc., "creating a strong trend toward better mechanization in medical care." Reeves expects enormous expansion in the next five years as equipment becomes available for a market now ready for reliable and dependable equipment. Spacelabs will soon introduce intensive-care equipment for coronary patients based on experience gained on a job for the National Aeronautics and Space Administration. The monitoring equipment is being installed in two California institutions, Sherman Oaks Hospital and Valley Presbyterian Hospital.

Monitoring systems are also being built for hospital operating rooms. One large installation is being made by Statham Instruments Inc. with the National Institutes of Health for a cardiovascular research center at Methodist Hospital, Houston. The project, now in its initial stage, will ultimately include cardiovascular monitoring equipment for eight operating rooms and 50 intensive-care diagnostic units in the hospital. A set of analog and digital displays will assist the surgical team in making a rapid judgment of a patient's condition and also will supply predictive measurements.

Governing factor

The agencies of the Federal Government are central to the development of medical electronics. The military, the Public Health Service and the Food and Drug Administration are examples of Government organizations that not only purchase equipment but effect developments that stimulate purchases by others.

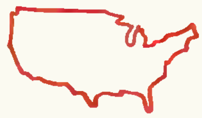
At the Public Health Service, engineers and doctors are working on computer analysis of electrocardiograms. Work has progressed to the point where the technique is acceptable for clinical use. "Eventually," declares Dr. C.A. Caceres, chief of the agency's Instrumentation Field Station, "the computer will bring the diagnostic abilities of specialist to the individual's bedside." Once the system goes into general use, physicians will be able to spend less time reviewing normal EKG's and be free to concentrate on the difficult ones.

The FDA feels that electronic instrumentation is a natural for insuring product quality and uniformity, according to Robert T. Myers, industrial product manager of Picker X-ray. He says the FDA is pushing such techniques and that this should foster rapid growth in the market.

The American Instrument Co. has developed a device for the CIBA Pharmaceutical Co., a division of the CIBA Corp., that automatically processes solid drug products into solution and analyzes them in an ultraviolet monochrometer. The instrument can perform up to 2,000 assays per day and is used to insure content uniformity.

Instrumentation

Widening range of applications boosts sales of instruments



Higher sales and wider applications in 1967 characterize the expanding perimeters of the test and measuring instrument market. The Electronics' survey envisions a \$80.8 million rise in the market to an estimated \$650.8 million in 1967.

The oscilloscope with its numerous uses will again lead the field in sales, and one manufacturer, Tektronix Inc., sees a better year in 1967 than last year when sales jumped 25% from 1965. Byron Broms, corporate planning manager for the firm, reports that the computer industry will again be the biggest customer for Tektronix oscilloscopes. Manufacturers of scopes will also benefit from the increased use of the instrument in automation, process and machine controls and color television.

Increased use of integrated circuits in the manufacture of counters will stimulate that growing market even more. Jack Salvador, engineering director at Computer Measurement Co., says, "All major counter manufacturers are planning to increase their use of IC's in the next 12 to 24 months. Integrated-circuit construction will make possible lower costs and the expansion of current market applications."

"In addition, the use of IC's will permit smaller instruments to do a better job than their big brothers," states Michael Dow, manager of Aerojet General Corp.'s Aerometrics division. Aerometrics is marketing a line of electronic counters measuring 9 by 3 by 9 inches, and weighing less than 7 pounds.

Ivan Easton, vice-president of the General Radio Co., reports, "People today want a complete package deal. They know what they want to measure and they say 'give us a system to do the whole business.' Now measuring systems costing $20,000 to $30,000 are being shipped. During 1967 we'll be shipping systems that will include small general-purpose computers as an integral part of the package."

The Vietnam war is, of course, having its effect on the instrument market. Many oscilloscopes, digital voltmeters and other test and measuring instruments have been sold for military applications. But, says Allan Dallas, director of marketing at Honeywell's Denver division, most instrumentation sales are to engineers, and it is hard to find out the actual use.

There are some drawbacks to the increased sales spurred by the war effort. "Government buying is now putting the pressure on the production area of the market at the expense of development," states Dallas. "We're getting orders for older equipment; we received one large order from the Army's Redstone Arsenal at Huntsville, Ala., for instruments that we had stopped making and a similar one from Kelly Air Force Base at San Antonio, Texas. If the Vietnam conflict ended tomorrow and the government put money into post-Apollo applications and research grants, we would be in a sounder position," Dallas says.

Manufacturers are also having problems because of material and component shortages.

Another development in counter technology is the push toward direct reading capabilities at 12.4 gigahertz and above. "This," says Salvador, "should make counters the primary source for radar communications work."

Buyer demands more

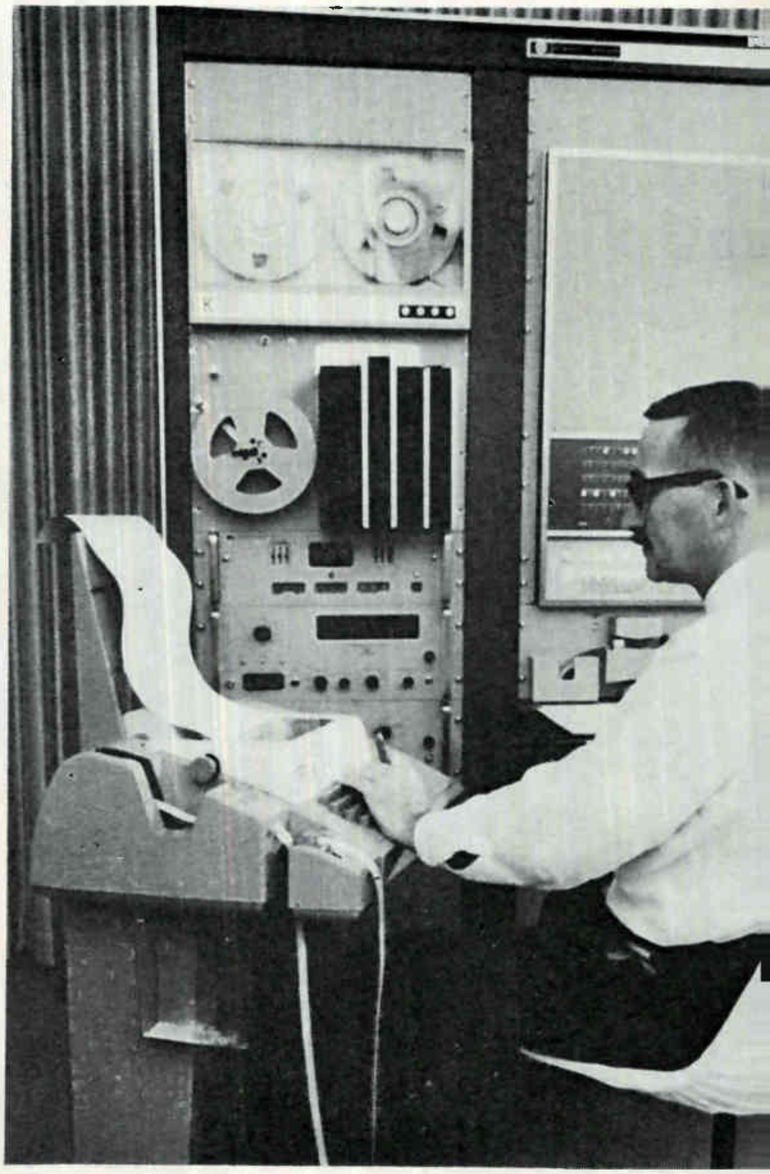
The instrument industry is getting a hand from a surprising new source—the discriminating buyer. The public's growing awareness of reliability, says Robert T. Myers, Picker X-ray Corp.'s industrial product manager, "has made it necessary for manufacturers to allocate much more money to provide the means for nondestructive testing. Prior to the public outcry for a quality product, capital appropriations for nondestructive testing devices was minimal." Myers sees a high growth rate in the coming years for the equipment because of the development of vast new markets.

Ultrasonic, X-ray and gamma-ray test and measuring instruments are finding their way into the tire, cigarette, consumer appliance and pharmaceutical industries as manufacturers see that product quality justifies spending money to buy sophisticated electronics equipment for nondestructive testing. For example, Picker recently installed X-ray inspection systems that enable tire manufacturers to detect voids and tears in treads and pipe makers to locate flaws in the welds on pipe sections.

Instrument companies are now eyeing the systems market. Honeywell Inc., for example, has combined individual products such as sensors, amplifiers and oscillographs into a complete measuring system for the diecasting industry.

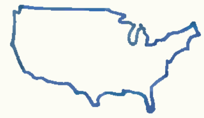
"The copper shortage has delayed the delivery of transformers," says Computer Measurement Co.'s marketing director, Nyal McMullin. "Deliveries are also being pushed back on computer-grade capacitors, and in some cases 40-week deliveries are being quoted for certain tantalum capacitors," he complains.

There are some who feel 1967 will bring tougher problems and that growth will be more difficult. John Fluke, president of John Fluke Manufacturing Co., says his firm shipped test and measuring instruments valued at $9 million in 1966, an increase of 50% from the previous year, but the company's backlog of orders changed very little over the year. "This, coupled with the tight money situation, will slow the rate of growth," Fluke asserts.



Computerized measurement systems, such as Hewlett-Packard's digital acquisition system, form a growing segment of the instrumentation market.

Stress is on safety as avionics sales continue to climb



In avionics, the accent this year is on greater safety and efficiency. The Federal Aviation Agency, which will spend an estimated $100 million on electronics equipment this year, is continuing to develop and install a national airspace semiautomated air-control system, though its efforts in 1967 will do little to clear the increasing congestion over airports. When finished in 1970, the system will include 21 centers, each costing between $12 and $16 million. Operational tests for the first center will begin in Jacksonville, Fla., in June.

In the landing-aids program, supported by the FAA, the airlines are installing Category II equipment, which allows commercial carriers to operate when runway visibility is only 1,500 feet and the ceiling a bare 100 feet.

Airlines are qualifying pilots for Category II and airports are being outfitted with the equipment. This means large outlays by the airlines for flight directors, radio altimeters, autopilots and related equipment. The FAA has not set the requirements for certification for Category III, the third and final stage of the program, but the airlines are buying Category II equipment in the belief that most of it can be expanded to meet Category III standards. Eventually landings will be made with runway visibility of only 150 feet.

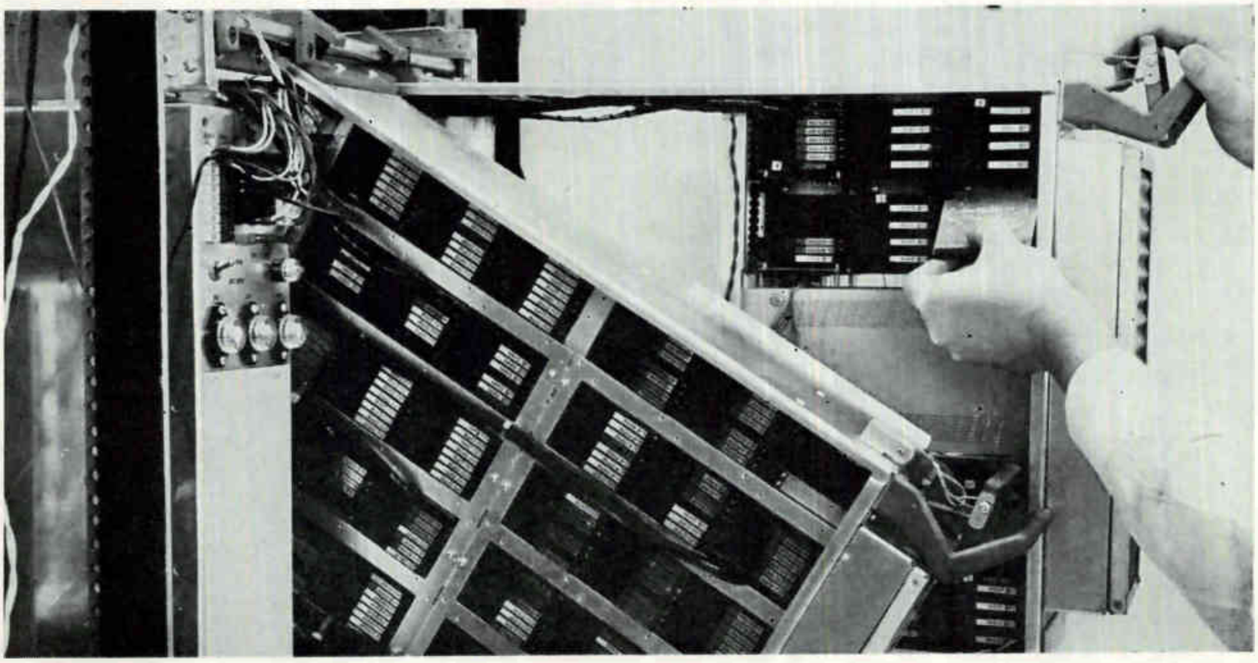
Efforts are also under way to find a solution to another problem—crowded skies. Several collision-avoidance systems are being developed, but only the McDonnell Aircraft Corp. has flight tested a model. The Bendix Radio division of the Bendix Corp. is working on another possible solution to air traffic congestion, an off-course analog computer navigation system. It would direct aircraft to very-high-frequency-omnirange phantom stations, thus relieving congestion among actual navigation stations. The phantom stations, in effect, would establish a parallel network to the present paths between omnirange stations.

Commercial aviation is also adopting inertial guidance navigation, long a favorite of the military. A digital computer navigation system with an inertial platform is being installed by Pan American World Airways Inc. to provide navigation and guidance information. The Sperry Rand Corp., which built the Pan American SGN-10 system, has an order from Italy's Alitalia Airlines, and other commercial and general aviation companies have expressed interest.

The development of airborne computer systems and the success of integrated circuits in military avionics have spurred the installation of IC's in commercial aviation avionics. The circuits are now extensively used in air-data computers, inertial platform control systems and radio receivers. This year, IC's will be introduced into ground support equipment by Bendix and the Radio Corp. of America, among others.

Military and space projects have long dominated the automatic test equipment market. But in 1967, large outlays will be made for commercial applications of automatic test equipment. The Boeing Co. recently issued a request for proposals for an automatic test equipment system for its own factory. The airlines are also a potential customer for automatic testers. Rapid, accurate testing at repair facilities means quicker turnarounds for aircraft and more time in the air. According to Jack Underwood, program manager for test equipment at the Aerospace division of RCA, "Boeing is the icebreaker; whoever gets this job will have an edge over the others in supplying test systems to all the airlines that buy Boeing jets."

Sperry's SGN-10 is the first inertial guidance system for airliners. Technician checks the gyro reference unit for flaws.



Tilt-out chassis units provide easy access to logic modules and wiring in Honeywell's new DDP-516 computer. The computer is built from integrated-circuit logic modules and uses Honeywell's standard IC core memory assembly.

Computers

Manufacturers scramble to expand as computer boom continues unabated

"A bottomless well," is the way one happy sales manager describes the demand for his company's new scientific computer. "We're making them as fast as we can, but if we had twice as many people in the plant it wouldn't be fast enough."

Nationally, the demand for computers may not be bottomless, but it is so great it has created an impressive growing market. Computers and related equipment are estimated at more than a $2.4 billion market in 1967 by Electronics—an increase of $281.5 million over 1966.

The Electronics survey also estimates that by 1970 the market will reach $3.5 billion even though a drop of 10% in Government buying is anticipated during the period. An agency is now required by Public Law 89-306—called the Brooks bill—to seek unused computer capability at another department before buying new equipment.

To keep up with the current demand, computer companies are expanding production and engineering facilities. Honeywell Inc., for example, is doubling the size of its engineering laboratory in Waltham, Mass.

Other expansions include the Univac division of the Sperry Rand Corp., the National Cash Register Co. and Scientific Data Systems Inc.

"We expect to be a solid number two in the computer market during 1967," says Robert P. Henderson, vice president for marketing in Honeywell's electronic data processing division. "But we are taking very little business from our competition. In fact we are often going in alongside his equipment—adding to it instead of replacing it." For the first time Honeywell is boasting that its data processing division is profitable.

The Hertz of the computer industry is, of course, the International Business Machines Corp., which has about 70% of the computer market. The company's multibillion dollar gamble—the IBM System 360—has already won about 30% of the market.

No one size of computer dominates the market—even the System 360 comes in nine sizes. Big businesses still favor large central processors, such as the Univac 1108 and General Electric Co.'s 635. Most large computers now can be time-shared by branch offices.

Time-sharing systems are usually private ones—the often-predicted huge-computer utility is still in its infancy. However, several companies—GE, for one—are servicing remote customers with present computers and RCA is planning a large, time-sharing version of its Spectra 70.

The newer computers perform so much better than their predecessors that many companies are finding the intermediate sizes adequate. If the company requires time sharing, however, it's more likely to need the greater capacity of a larger machine. Sales of desk-top scientific computers are skyrocketing. The Digital Equipment Corp., for instance, has sold about 300 of its new $10,000 PDP-8/S. And DEC says that the model has even increased its sales of larger computers. The potential customer, says DEC, finds that the small computer is not quite big enough and buys a larger model.

A time for consolidation

"Computer performance has increased 1,000 times over the past 10 years, but the next factor of 10 is nearly impossible," is the way computer technology is viewed by Max Palevsky, president of Scientific Data Systems.

"Computers today operate at speeds approaching the speed of light. To attain a small increment in performance now requires a great deal of work by many highly skilled people," he explains.

Evolution, not revolution, is expected by most system planners. For example, parallel processors —numerous small computers working together at a higher total speed than one big one—are too costly now for everyday use. Large-scale integration, an evolutionary step from present IC's, is expected to break the cost barrier. The multicircuit IC chips now in mass production are the first stepping stone.

"Hybrid IC's are dead in computers," says Donald Eckdahl, vice president and general manager of National Cash Register's electronics division. "And so are tunnel diodes and cryotrons. The semiconductor firms have left hybrids in their wake."

Hybrids, however, will be around for a while by sheer momentum. They are the basic ingredient, for example, in the System 360, which IBM isn't going to revamp overnight.

In high-speed memory technology, interest is increasing in thin films. Most thin-film memories contain only a few words for local high-speed access, but the Burroughs Corp.'s new D-830 and B-8500 models have thin films holding thousands of words. Large rod memories, a form of thin-film memory, are being used routinely by NCR, and Sperry Rand has big plated-wire memories for its new Univac 9000 series. Nonetheless, core memories continue to be lowest in cost and are continually getting faster, bigger and more compact per bit. They are still the dominant form of large memory.

Role growing

In the mid-1950's peripheral equipment was about 20% of system cost. Central processors have since become so much larger and able to service so many extra terminals that peripherals now exceed 50% of system cost. The card readers, tape drives and typewriters are being joined by visual displays, voice-response machines and other new classes of man-machine interfaces.

Electronic output may soon replace high-speed electromechanical printers and the filming of cathode-ray-tube-displays. Recently, the Xerox Corp. announced a low-speed electrostatic printer driven directly by a computer. One expert says such developments could in the next two or three years spell the doom of electromechanical printers.

Communications

Expanding markets seen for telemetry, mobile radio, microwave and tv gear

The electronic communications market will be marked this year by gains in sales of telemetry gear, mobile radios, broadcasting equipment and microwave systems. Another factor of increasing importance in this field is the vast data communications network taking shape in this country to link computers through common carrier facilities and private microwave systems.

Telemetry sales in 1967 will spurt to about $181.7 million from last year's estimated $160.4 million, according to Electronics magazine's survey, and the industry says the increase would be even greater were it not for Vietnam war costs.

Large amounts of telemetry equipment will be procured for the Apollo program as well as for the National Aeronautics and Space Administration's unmanned-satellite projects. In addition, the Air Force Systems Command's Space Systems division will be outfitting ranges for its Manned Orbital Laboratory project.

E. Wayne Copeland, marketing manager for the data communications section of the Bendix Corp.'s Electrodynamics division, estimates that ground equipment accounted for more than 60% of the 1966 telemetry market, with about 50% of this ground-gear outlay going for decommutators and discriminators and about 30% for such equipment as decoders, signal conditioners and buffers.

The use of pulse code modulation systems will continue to grow, though Jim Terry, senior applications engineer in the analog department of Electro-Mechanical Research Inc., Sarasota, Fla., notes that "if you need fewer than 100 channels, analog is still cheaper." For this reason, industrial telemetry presents a strong market for analog systems.

The armed services are proceeding, though slowly, with the shift in their air-to-ground telemetry systems from vhf to L band (1,435-1,535 megahertz) and S band (2,200-2,300 Mhz), a shift slated by the Defense Department for completion by Jan. 1, 1970. Officials of the Air Force Western Test Range say Vandenberg Air Force Base will have initial S-band capability by the end of this year. Rather than adding frequency-conversion gear, they say most of the vhf equipment at Vandenberg will be replaced by S-band equipment.

Mobile land radios

An increasing number of applications are being found for mobile radios, both vehicle-mounted and portable, in consumer fields, urban transportation, and police and other public-safety activities, despite the problem presented by a shortage of frequencies in major metropolitan areas. The 1967 market is expected to rise to $180 million from the $170.5 million of 1965.

In the field of urban transportation, efforts by cities to improve dispatching, to combat crime on public conveyances and to generally ensure passenger safety have sharply expanded the market for mobile radios. Last August, the Radio Corp. of America received a contract to equip more than 4,000 buses in New York City, and Motorola Inc. has orders for similar installations in Detroit, St. Louis, and Dallas.

Portable radios are being increasingly used in police operations and paging systems. New York, Detroit and Washington, D.C., among others, are outfitting police with walkie-talkie radios.

With all this, however, the persistent problem of frequency shortage in urban areas may be limiting sales of business, industrial and, to an extent, public-service land mobile equipment. Robert L. Casselberry, manager of product planning at the General Electric Co.'s communications products department, notes that Federal Communications Commission figures show that market growth in urban areas is proceeding at a pace 2% to 3% slower than in rural or suburban areas.

Less affected by this frequency problem are sales of Citizens Band equipment, for which more than 100,000 licenses are being issued annually. Manufacturers are hoping that experiments in the use of communications gear to aid drivers in distress will eventually lead to the installation of CB radios in every car.

The market for CB transceivers of 100 milliwatt power or less—units that don't require licensing—will probably be as big as that for licensed CB radios, says Robert Laub of the Lafayette Radio Electronics Corp., Syosset, N.Y. More than a million transceivers in this category are imported from Japan each year, Laub observes, many of these being toys for children (a far cry from the strung-together oatmeal containers that served as field phones for an earlier generation of kids).

Sales of cameras used in originating color tele-

Demand continues high for telemetry equipment such as the Mobile L and S land tracking system built for White Sands Missile Range by Canoga Electronics Corp.

vision programs and of recorders for color video tape will reflect the over-all color-tv boom. Andrew F. Inglis, a vice president of RCA's broadcast and communications products division, estimates that sales of "live" color cameras accounted for about 30% to 40% of total studio-equipment volume last year, and color video tape recorders about 20% to 30%, with switching equipment, audio amplifiers, monitors and other types of cameras contributing the rest.

"In the next five years," says Inglis, "most U.S. stations will be completely equipped for color." A color-tv studio usually needs two cameras for live programing, each costing about $70,000. There are about 600 tv stations in the U.S., and RCA says that only 150 of these are equipped to originate color programs.

The over-all market for television-studio gear this year is put at $130.4 million, up from $128.1 million in 1966.

The color-camera industry remains divided over the question of the number and types of tubes to be used. RCA produces a four-tube camera using both image-orthicon and vidicon tubes, while GE and the Marconi Co. of England make four-tube Plumbicon cameras, and North American Philips Inc. has a three-tube Plumbicon camera.

Philips claims that the three-tube Plumbicon unit is less expensive, easier to operate and less costly to maintain than any four-tube camera. Furthermore, says Robert Diamond, marketing manager for North American Philips' studio equipment division, a three-tube Plumbicon camera, with horizontal and vertical aperture correction, can produce pictures as sharp as those produced by image-orthicon equipment.

In the video tape recorder field, the trend is to the so-called high-band units, which record a signal modulated on a carrier that is about 4 magacycles from the color signal's subcarrier.

The Ampex Corp., Redwood City, Calif., is currently the leading manufacturer of high-band recorders, but RCA last November announced that it had units in the final test stage.

Microwave systems

The expansion of common carrier facilities provides a major market for microwave equipment, with the military, as always, a big customer, according to Kerry R. Fox, assistant vice president for microwave and scatter systems at the Collins Radio Co., Dallas, Texas.

Electronics magazine's survey indicates that sales of microwave gear are expected to climb to $86.3 million in 1967 from $77.4 million last year.

A trend to private microwave systems may be accelerated by the impending elimination, by Government order, of the American Telephone & Telegraph Co.'s Telpak A and B bulk communications lines, which provide voice-grade channels at economy rates. Users of these two lines are potential microwave-link customers, and AT&T has indicated that it may boost rates on other Telpak lines.

Utilities and railroads are already microwave customers, and a number of other industries are considering private systems to reduce costs or improve communications. For example, Aeronautical Radio Inc., the concern that handles communications for the airlines industry, is currently evaluating proposals for a private microwave system. The broadcasting industry, which has been pushing for a private space-satellite system for television distribution, is another potential customer.

Fixed systems owned by businesses can only operate at frequencies above 12 gigahertz, and Edward J. Hart, a department manager at RCA, notes that "with the increasing emphasis on data transmission, privately owned microwave systems in the 12-Ghz band should be a growing market."

Regarding data transmission, the linking of remote users to central computers through nationwide communications networks—exemplified by the recent establishment of a computer utility by the Western Union Telegraph Co.—portends greatly expanded markets for such interface equipment as high-speed teletypewriters, graphic displays and cathode-ray viewers.

Walter Bauer, president of Informatics Inc., Sherman Oaks, Calif., predicts that within 10 years a vast computer-utility system will include up to 95% of all computers in the U.S., and that eventually it will control switching, process messages and interconnect entire networks of computers.

James L. Hollis, president of Rixon Electronics Inc., Silver Spring, Md., notes that the computer-communications linkup is boosting sales of data modulators/demodulators, used to transmit and receive data, and says his company expects its 1967 sales of the devices to be at least double last year's.

Customers are still using modems transmitting at 1,200 to 2,400 bits per second, but Hollis indicates that the trend is to higher speeds.

Transmission by higher-speed data modems over the direct distance telephone dialing network is in the offing. Bell Telephone Laboratories Inc., will soon check out a new modem designed to transmit 3,600 bits per second over the direct-dialing network and more than 5,400 bits per second over leased lines.

Western Union expects to offer customers, on a limited basis, high-speed lines of 48,000-kilohertz bandwidth that they can dial into by request. Users will be charged only for time spent on the lines, rather than a monthly fee as with AT&T's Telpak C and D service.

Microwave

Industry seeks new markets as microwave sales climb

Comfortably counting profits after a banner year, microwave companies expect further growth this year although no one expects the boom to continue at the 1966 rate. The huge increase in defense orders that contributed heavily to last year's prosperity may be leveling off, but defense requirements are expected to remain high whether or not there is actual shooting in Vietnam.

"Microwave sales will continue to climb," says Lisle J. Smith, marketing manager of the Microwave Tube division of the Hughes Aircraft Co. "There seems to be a general upward sales trend in the making that should continue for two or three years. Then sales will flatten out, but at a higher plateau than that of several years ago."

The lessons of the military cutbacks of 1964 have been learned and manufacturers have diversified, thus reducing their dependence on the Pentagon [Electronics, Aug. 8, 1966, p. 108]. And in some special areas of the technology, particularly in the applications of microwave power, markets are beginning to jell.

"We've hit a pretty good level, and I don't expect it to drop," says Richard T. Orth, vice president in charge of Varian Associates' electron tube and device group. "A truce in Vietnam would have some impact on the microwave industry, but the reduction in orders would be small; money not going into bullets would go into surveillance and reconnaissance equipment."

Effects of Vietnam

Burton Silver, marketing manager of the Electron Tube division of Litton Industries Inc., says, "Vietnam is teaching some tactical lessons and we are getting a number of new requirements that stem from the fighting there."

Silver cites as examples the elimination of clutter in fire-control radar and the production of magnetrons with electronic frequency dithering.

"The military is throwing many requirements at us very fast," Silver says. "It wants radar to pick out slow targets in a jungle and air-to-air radar that can eliminate ocean clutter. It wants to collapse the reconnaissance time cycle, when 20 minutes from recon to air strike may be too slow.

"And the military is betting across the board. The services don't ask for just one system, they ask four or five primes to come up with perhaps three systems each. And some of the systems people are coming to us without even waiting for Government funding."

War or no war, a sizable market for microwave semiconductor technology is opening up in avionics systems such as those in the F-111, the A-7A and the F4 planes. Avionics packages, particularly those for tactical purposes such as terrain mapping and following, are getting closer to production.

Says Stephen DiBona, sales vice president of Microwave Associates, "Solid state signal generation and control for military avionics will be a heavy growth area in 1967." Even commercial airborne microwave, for weather radar and radar altimeters, is doing better than anticipated, according to DiBona.

Dean A. Watkins, president of the Watkins-Johnson Co., which makes devices for strategic reconnaissance systems, believes that the war has not materially affected W-J's fortunes. And he says a truce could only mean a shift in emphasis back to strategic weapons and thus boost sales. He lists three areas of interest: digital receivers, solid state devices with yttrium-iron-garnet tuned oscillators and telemetry; the latter is a field in which W-J is already active under contracts from the National Aeronautics and Space Administration.

Jackpot in sight

The research and development of the past few years is beginning to pay off with a stream of new microwave products, some of which may appear this year. Both Litton and Varian, for instance, are working on crossfield amplifiers, which Orth, of Varian Associates, thinks will eventually replace the traveling-wave tube. This is pleasing news to those electronic firms that find the traveling-wave tube too costly.

Len Bernier, sales and communications manager at Litton Electron Tube, says Litton will begin pilot production in 1967 of a crossfield amplifier built on what he calls an entirely different concept. It has only one electrode, a cathode, attached to a d-c power supply that amplifies a pulse produced by a radio-frequency trigger. The device can change its pulse repetition rate and even "chirp" (change the frequency within a pulse). It amplifies 20 times.

Litton is also working on electrostatically focused klystrons, such as the one Varian's Eimac division introduced last year. Electrostatic focusing eliminates the need for huge solenoids, which weigh over 100 pounds for a conventional S-band klystron delivering 1 megawatt.

Litton is not yet interested in solid state generation of microwaves. But, Bernier says, it does plan to demonstrate this year the feasibility of an electronically variable, solid-state delay line, in which a transducer changes a microwave signal to an acoustic signal. The conversion may be performed either by piezoelectric material, such as cadmium sulfide, or by a magnetostrictive YIG device, whose dimensions change in a magnetic field. Varying the spot at which the microwave signal is converted varies the delay; delay time can range from 1 microsecond to 1 millisecond. Acoustic delay lines take advantage of the much lower propagation velocity of acoustic waves compared with those of microwaves. The wavelength of biaudio energy in solids is about 10^5 times shorter than that of electromagnetic waves of the same frequency. This means it's possible to have a large time delay in a small volume and assures great compactness in delay lines.

New products on the way

Varian's new light-sensing and light-emitting division will introduce at least three product lines this year: low-light-level imaging tubes, X-ray imaging tubes and photomultipliers. Some of the products will be introduced at the annual Institute of Electrical and Electronics Engineers show.

DiBona of Microwave Associates sees microwave integrated circuits ringing up some volume sales in 1967 of airborne tactical radars. Switching devices are being designed into prototypes of such avionics packages as the MARK 2, and these may be forerunners of new families of microwave devices that eliminate interconnections and offer high reliability. Dana Atchley, president of Microwave Associates, sees significant advances this year for solid state devices in portable and manpack radars, in shipboard radars and in broadband devices for electronic countermeasures.

Judging from the widespread research in microwave, the design evolution may continue for some time. One intensive research area is in solid state oscillators. Leo Young of the Stanford Research Institute says the Gunn diode looks promising, but a serious problem is that the gallium-arsenide diodes have low resistivity and tend to burn out. The Stanford Institute is also working on very fast switches to produce pulses about ½-nanosecond long. One application could be short-range, high-resolution radar for nondestructive faultfinding.

Warming up

"The industrial microwave market is maturing nicely," says Carl Olsen, head of the Atherton division of Litton. Olsen expects the industry's approximate $3 million in sales in 1966 to increase 25% to 30% this year. "In five years, it could be $100 million—or it could be $10 million," Olsen says. One reason for the uncertainty is that microwave power is the most expensive kind of heating power to generate and, therefore, the applications tend to be specialized.

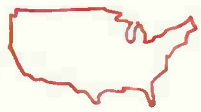
Present uses are in large-scale food preparation and in chemical drying operations. John E. Gerling, who was Olsen's predecessor at Litton and is now president of the International Microwave Power Institute, predicts that a $100-million market is 10 to 15 years away. Both Gerling and Olsen stress that microwave's advantages are in quality control. The reason: microwave heating is uniform throughout and is nondestructive to the material being heated.

Gerling says, however, that future applications of microwave may include such far-out possibilities as providing power to maintain a 50-mile-high broadcast antenna or cooking dough stretched into an endless canapé. Litton is working on microwave to generate plasmas—highly ionized gases—to make chemical solvents or stimulate processes.

An indication of microwave's maturity is the formation of IMPI last year. The user-oriented group attracted more than 100 manufacturers and customers to its meeting in Edmonton, Alberta, last spring. This year IMPI plans a technical conference March 29 to 31 at Stanford University, Palo Alto, Calif. Enthusiasm for microwave power is so great that IMPI is afraid it won't be able to handle the demand for attendance. That seems to be one of the few fears in the microwave industry at large.

Educational electronics

Growth to continue with Federal boost



The educational electronics market, supported by Federal aid to local school districts, will continue its gradual growth in 1967.

Much of the money now being spent for electronics hardware in education buys consumer-type equipment such as audio tape recorders for language laboratories and television receivers for closed-circuit systems. The size of the market is hard to determine; the Electronics Industry Association estimates that sales amounted to $115 million in 1965.

The total fiscal 1967 budget for the Office of Education's Bureau of Research is $103 million—about the same as last year; some $4 million of this is going for work on new educational media, including electronics.

The 1967 outlook is brightened by the expected impact of audio visual teaching machines and computer-aided instruction. Neither is much of a factor in current sales; only one local school district uses computer-aided instructions and few audio visual teaching machines are in operation. Several schools will get computer-aided systems this year; as many as 20 of the systems will be working by the end of 1968.

While this is far from a mass market, R. Louis Bright, associate commissioner for research in the Office of Education, predicts that sales of computer-aided instruction systems, including software, could reach $1.5 billion a year in five years.

Another expanding segment of the market is in equipment for educational tv broadcasting stations. These stations are growing in number as well as upgrading existing equipment. The National Association of Educational Broadcasters forecasts that capital costs for educational tv stations over the next five to six years will reach between $350 million and $400 million.

One small but fast growing segment of the educational electronics market is video tape recorders. One industry estimate places the size of this market at $15 million to $20 million in 1966, a figure which also includes related electronic equipment such as cameras and monitors when purchased as a system with video tape recorders. This portion will grow to approximately $30 million in 1967, it is estimated. By 1972, or in five years, this market will total in excess of $75 million,

Next year will see more VTR's sold with interchangeability—the tape from one machine can be played back on others—says John H. Trux, marketing manager for the Ampex Corp.'s Consumer and Educational Products division. Equipment will also be more flexible, including the capability of conversion to color and additional audio track. There will also be more units offered in the lower-cost field, that is, for less than $1,000 for a VTR of the quality needed for educational use.

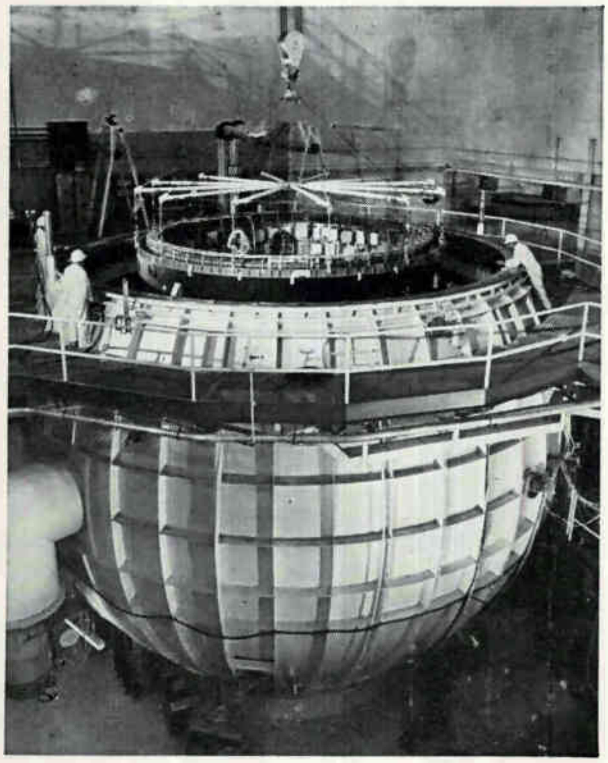
War budget squeezes space program but Apollo won't feel the pinch

Space spending, although restrained by military expenditures for the Vietnam war, will at least hold its own this year at $5 billion, the same as last year. Electronics magazine's annual market survey shows that the electronics industry will receive about $1.7 billion of space funds.

Apollo, as usual, will account for the bulk of space electronics spending in 1967. Virtually every electronics manufacturer in the country is on the list of 20,000 industrial companies working on Apollo. However, as the Saturn-Apollo system achieves operational status with the first manned flight this spring, contracts will be terminating. This, in turn, will reduce the flow of orders to subcontractors and vendors, particularly in the electronics industry, unless followup programs take up the slack.

Budget problems

At present, new programs are getting off to slow starts. The Apollo Applications Program gets under way this year with about $100 million, far below the $1 billion the National Aeronautics and Space Administration would like. The Voyager program, once seen as a multibillion-dollar project, has run into budget problems caused by the Vietnam war, and it's likely that NASA will extend its Mariner program as an inexpensive substitute. Already planned are a Mariner flight to Venus this summer and two Mariner flights to Mars in 1969; other shots may be attempted in 1971, and perhaps 1973 and 1975.



Instrument unit for Saturn rocket is being lowered into simulation chamber at Douglas Aircraft Co. for testing.

Other Government agencies have programs in the works too, such as the Interior Department Geological Survey's $20-million Earth Resources Observation Satellite and the Commerce Department Environmental Science Services Administration's Tiros-M weather satellite. In addition, the Communications Satellite Corp. will buy six Intelsat 3 satellites from TRW Inc. They will be deployed in 1968 in the global communications system.

NASA's supporting research and technology budget is expected to stay near its current level of about $30 million. This supports research in guidance, control communications, tracking and data acquisition, data handling and processing, instrumentation and electronic components.

IC's find a home in space

Integrated circuits will be one of the headline stories of 1967 in space technology. Integrated circuits made their first major appearance in the encoder of the interplanetary monitor platform in 1966 and are used throughout the Apollo spacecraft—in the guidance computer, in the television camera and in the equipment in the Lunar Module. This is just the beginning. An informal survey by NASA indicates that IC's will account for 70% of spacecraft electronics by 1970.

Another area of activity is space astronomy. A telescope is planned for one of the early Apollo applications flights about 1969, but first electronic techniques must be developed to operate large telescopes in space. In addition to optical astronomy, NASA is interested in developing laser radar systems with high definition for global surveys of crops and various natural resources.

Parallel efforts are continuing to improve tube efficiencies and increase the power levels of solid state devices. The power is needed for transmitters for direct broadcast satellites and interplanetary spacecraft. One possible solution under study at NASA's Electronics Research Center is an array of small solid-state power transistors.

To prepare for spacecraft landings in deep space probes, the Jet Propulsion Laboratory is working on approach guidance procedures. Although Mariner 4 achieved an accuracy to within 120 miles when it passed Mars in 1965, a landing would require an accuracy improvement of an order of magnitude. The problem is defining the planetary horizon to find the planet's center when the planet is only partially illuminated, like a half moon. The JPL approach involves a passive detector with an image dissector tube that scans the edge of the planet; the planet's center is calculated from the curvature of the edge.

Industrial electronics

Electronic controls gather momentum

Computer-based process controls and machine-tool controls will strengthen their hold this year on the number one and two spots in the industrial electronics market. By comparison, the amount of money spent for equipment in the glamor programs —air and water pollution control, high-speed railroads and highway automation—will be small.

Electronics magazine's survey estimates 1966's total market for industrial operations electronic equipment at $934.8 million, and forecasts a 13% rise from that level in 1967. The electronics share of the 1967 market for machine-tool controls is expected to surge to $242.3 million from last year's $217.3 million, with numerically controlled gear accounting for 30% of this year's total machine-tool sales, against 22% in 1966.

Process Computers

Capital investment in process-control computer systems should climb to about $235.8 million this year from the $202.2 million of 1966. Prime customers are still the petrochemical industry and public utilities, but metals, textiles, food, paper and cement processors are signing up in increasing numbers. Last year, for example, the Leeds & Northrup Co. installed a direct digital control system at the Ideal Cement Co.'s plant in Tijeras, N. M.

By 1969 or 1970, the new customers for this equipment will have sharply boosted computer sales, according to Thomas W. Waldron, industry development manager for the International Business Machines Corp.'s control systems marketing group. He notes that companies are refitting old plants with computer systems as well as installing them in new plants.

Direct digital control of processes is making amazing progress, says T.C. Williams, of Purdue University's Laboratory for Applied Industrial Control. More than 200 DDC systems are installed or planned, he says. "Almost every company selling process controls has already adopted a DDC computer or is choosing one," he adds.

Most of the current DDC systems are backed up by conventional analog systems, since customers are still hesitant about relying entirely on a digital process. But as operating experience with DDC grows, analog backups are expected to shrink.

Big machine-tool makers are apparently trying to develop their own numerical control systems, rather than buy them from electronics firms; the electronics package can account for as much as 40% of the price of a $300,000 machining center.

Some firms have long had their own electronics facilities, and keep up with the state of the art. For instance, The Cincinnati Milling Machine Co. is building a contour positioning control with integrated circuits. Why did the company choose to develop a contour positioner instead of a less complex point-to-point positioner? One reason, says H.V. Edwards, manager of the firm's Cimtrol division, was that engineers could learn more about applying IC's.

Railroads are so pleased with the way computers and controls have expedited their paperwork and their car-routing and train-assembly operations that they are preparing more comprehensive systems.

Sometime this summer, the Association of American Railroads hopes to select a standard car-identification system from among three being tested [Electronics, Nov. 28, p. 40]. Its goal is to tag the rail industry's entire fleet of 1.8 million cars.

Rapid Transit System

The problem of urban mass transportation is worsening, and planners hope to find answers in the Bay Area Rapid Transit District program in northern California, a vast rapid-transit commuter-train project partly financed by the Federal Government [Electronics, July 26, 1965, pp. 71-86].

A contract for BARTD's automatic control system should be awarded early this year. The total automatic-control outlay for this program is expected to range between $20 million and $30 million.

Two other potentially rich markets for electronic gear are air and water pollution control and highway traffic control. New York City will set up a $500,000 air pollution monitoring network this year, a project that may help other cities select their pollution sensors and reporting gear. New York City, San Jose, Calif., and Wichita Falls, Texas are using digital controls to help regulate traffic flow.

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g_m (μmhos, min/max)	350/1000	600/1500	350/1000	600/1500	350/1500	600/1500
I_{GSS} (na, max)	2	2	1	1	1	1
C_{rss} (pf, max)	1.5	1.5	1.5	1.5	1.5	1.5

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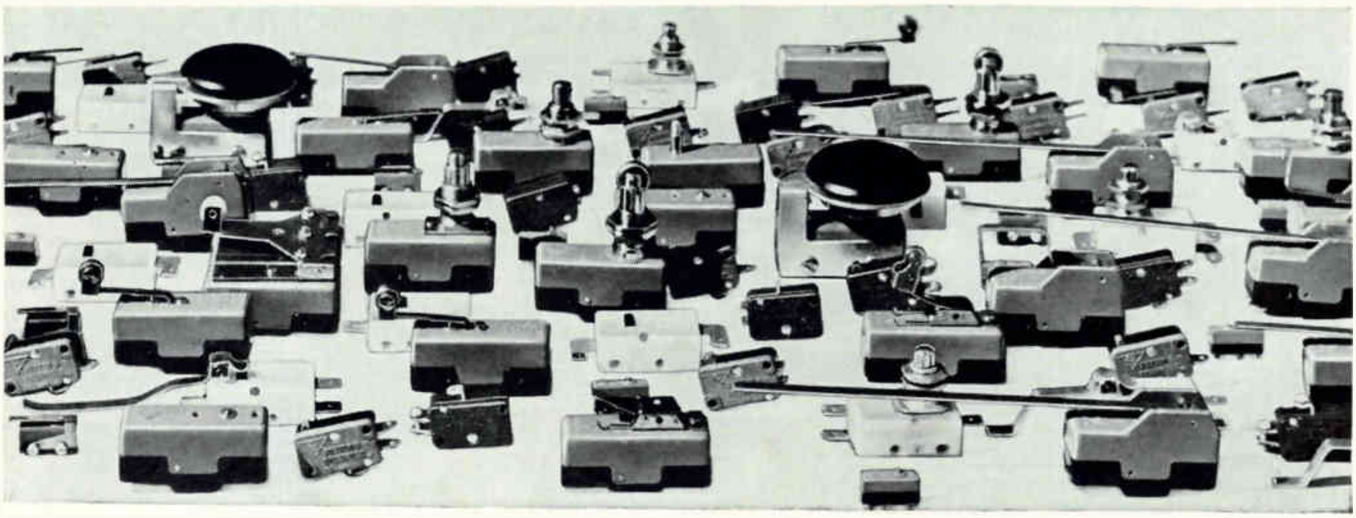

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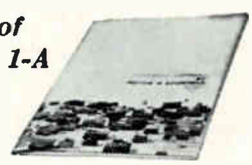

The hope of doing each other some good prompts these advertisements

Advice to holographers:

1. KODAK "Spectroscopic" Plates, Type 649-F (comparable to flour for a baker, nets for a fisherman), can now reach you within roughly two weeks of placing the order with your supplier who, if you do not already know him, can be introduced to you by Eastman Kodak Company, Special Applications, Rochester, N.Y. 14650. If you require a size other than 4" x 5" (either .040" glass or ¼" microflat glass), please continue to anticipate needs by 30 to 60 days.

2. Instructions for processing this product in a manner to yield relief images consisting only of variations in the height of the gelatin can be found on p. 1689 of the October, 1966 issue of *Applied Optics.* Density variations are converted to height variations with excellent linearity, leaving little other than the gelatin itself to absorb light and apparently little that affects its refractive index. A density of unity is translated to a relief height of about one-half micron. Do not assume that the linearity is maintained to the utmost limits of spatial frequency, whatever they may be. If you find this technique works well for phase holograms, the people at the address in the preceding paragraph would like to know.

What's an opticist, Pop?

Many employers are seeking persons qualified in optics and optical engineering. But for fear of sacrilege, they'd pray heaven to send them. In relation to demand, applied optics and optical engineering seem among the most severely undermanned of professions. Bright kids in school don't seem to find out about this (or to believe it if told) until after committing themselves to other disciplines. As a result, many of today's optical designers and engineers have to admit to themselves in black moments that they really aren't.

To spot a genuine pro in the field, try asking him if he knows a man named Rudolf Kingslake. Most reassuring would be a reply to the effect that not only does he know Dr. Kingslake but has taken courses under him and made good grades.

Kingslake came to the University of Rochester in 1929 from Imperial College of Science and Technology in London. In 1937 he also joined us and has been our full-time head of optical design since 1939. In the past two years he and his staff have been far busier than ever before, though we are not at liberty to disclose on what. Nevertheless, by skillfully using what little time his industrial and teaching undertakings leave him, he has managed during these same two years to bring out the first three volumes* of a five-volume comprehensive treatise entitled "Applied Optics and Optical Engineering" (Academic Press, New York and London).

Under his editorship, 29 of the projected 50 chapters are now in print, a few written by him and the rest by people from our own and 17 other organizations. Where this crew found the ambition and the devotion to scholarly obligation remains a mystery explicable only in terms of the resilience of the human spirit. Probably it is too much to hope that their effort could retread any significant numbers of physicists, electrical engineers, or mechanical engineers into opticists.

We could use a few more opticists ourselves. Indeed we could. They'd be in stimulating company. The address of our Director of Technical Personnel is simply Eastman Kodak Company, Rochester, N.Y. 14650.

---

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basic geometrical optics
diffraction
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combination of lens and film
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Volume III:
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optical manufacturing
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mirror and prism systems
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How one thing leads to another

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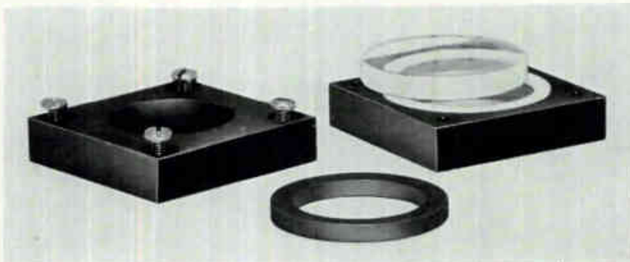
KODAK *Laser Glass correspondence is handled by Apparatus and Optical Division, Eastman Kodak Company, Rochester, N.Y. 14650.*

Photography is notable among technologies for its spinoffs. The dye chemists who devise photographic sensitizing dyes don't get to color the world their favorite colors, but they are very clever. When told that a dye with absorption mechanism saturable and all concentrated near 1.06μ would Q-switch neodymium glass and enhance its popularity, they produced one. Lasermen rejoiced. Mode-locking was achieved. Power could rise from zero to several gigawatts within a distance of 30 microns and a time around 10^{-13} sec.

EASTMAN *9740 Q-Switch Solution correspondence is handled by Distillation Products Industries, Rochester, N.Y. 14603 (Division of Eastman Kodak Company).*



But many lasermen found their Q-switch solution short-lived and were surprised to learn that the epoxy cement in their jerry-built cells was killing it. Few spectrophotometer cells are fit for resonant optical cavities. Help was needed. We have consequently designed a cell that uses simply the pressure of two glass windows against a precision tetrafluoroethylene gasket to keep it leakproof. Selection of the glass for the windows has been guided by a lot of work on damage resistance that the laser glass development has required. It is a borosilicate crown free from striae and bubbles and good to a quarter-wavelength of visible light over the 35mm aperture. Outer surfaces are MgF_2-coated to minimize reflection loss at 1.06μ. Forgetting in the interests of good sense the original motivation to promote neodymium, we also offer a coating tuned to pass the 0.69μ radiation of neodymium's rival, ruby. The wedge angle in the windows is not permitted to exceed 0.012°, or 0.006° on the gasket, and the thickness of the gasket fixes an optical path of 1.651 mm $\pm$ 25μ.

EASTMAN *Liquid Q-Switch Cells are available at $150 from the same Distillation Products Industries that supplies their contents. Specify No. 6088 for neodymium, No. 6097 for ruby.*

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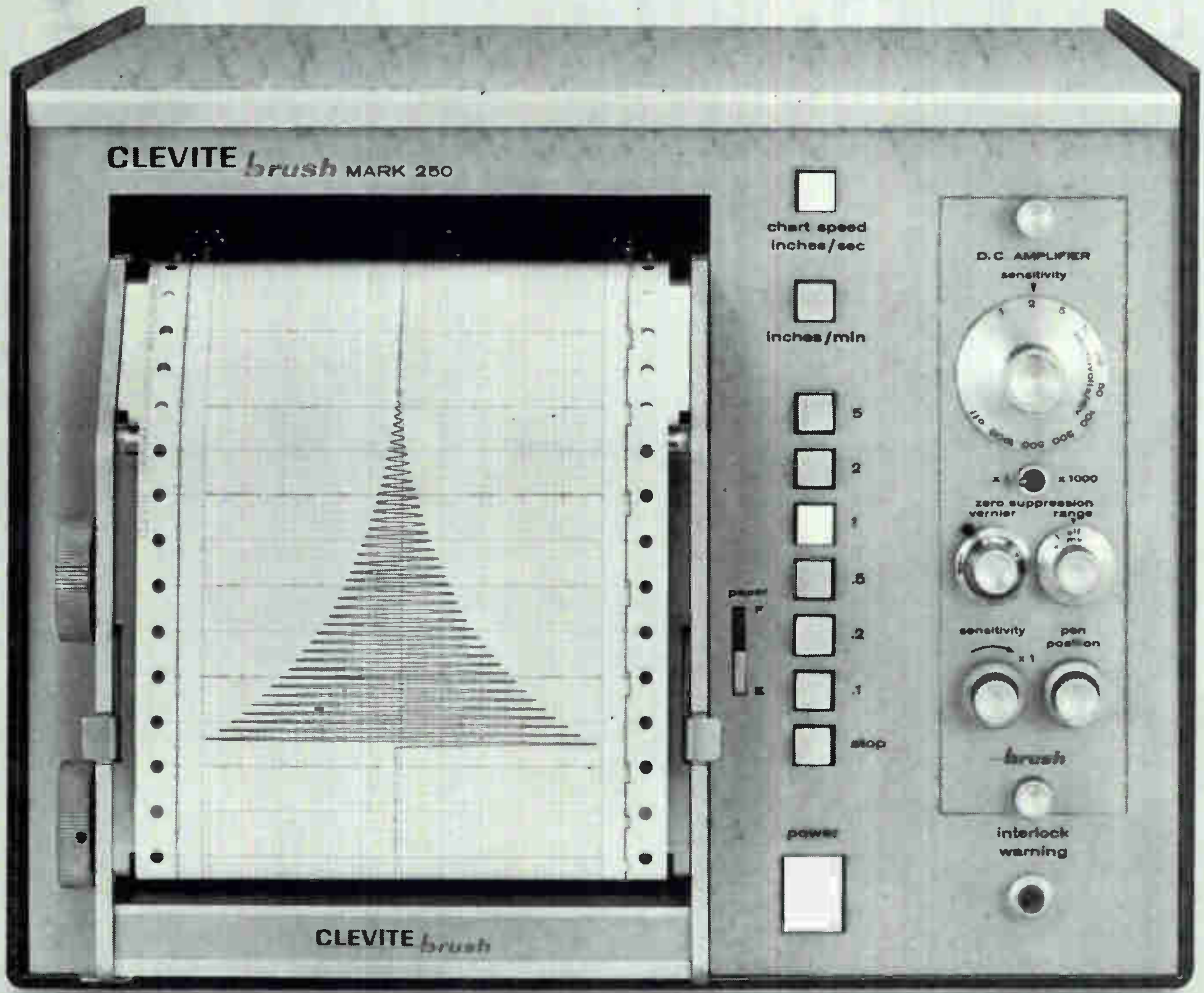

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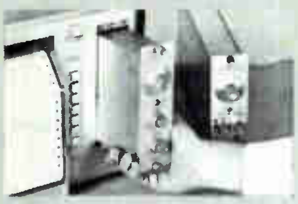

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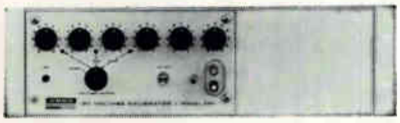

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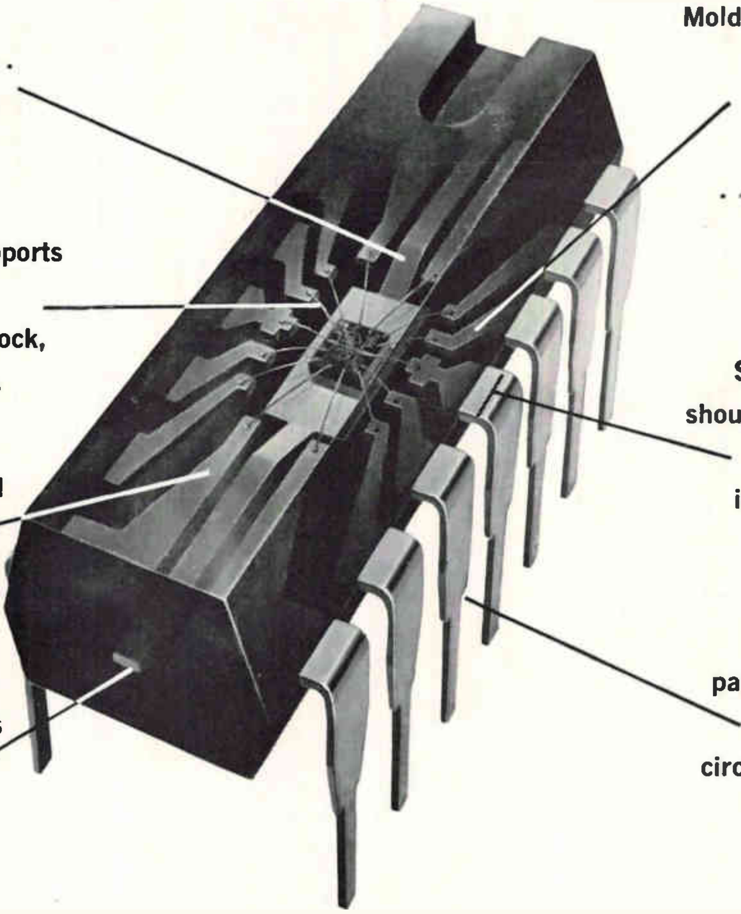

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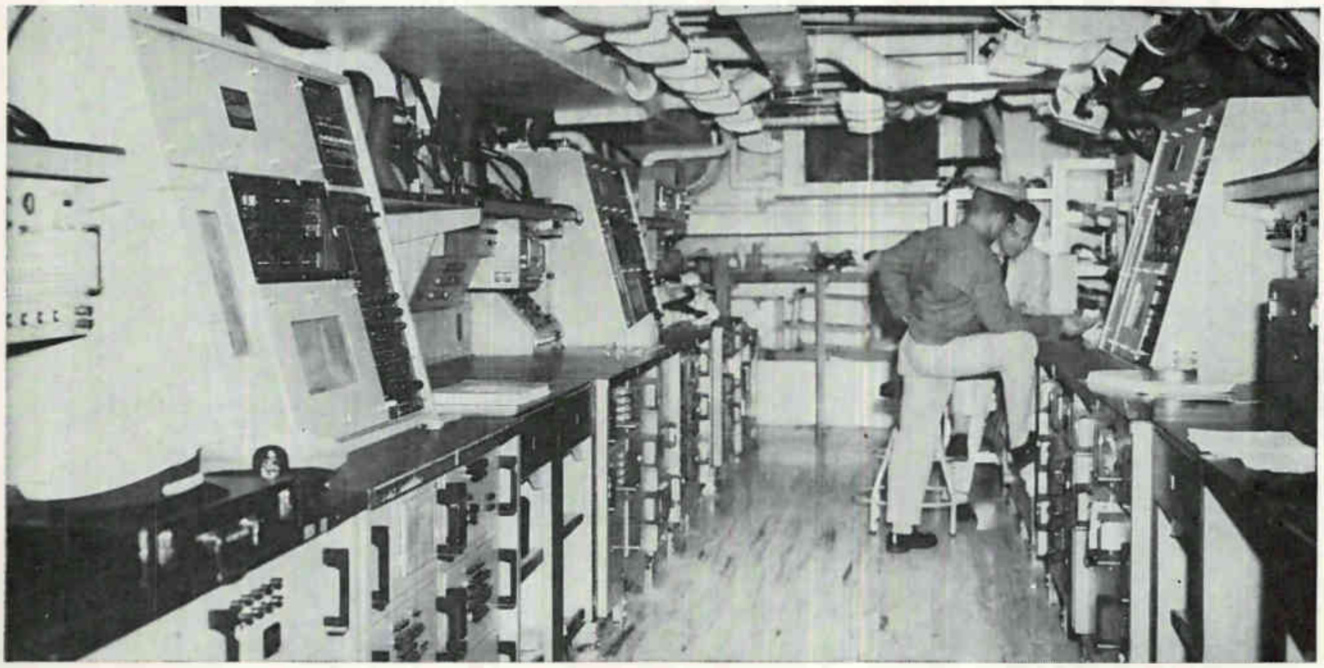


On the carrier, Constellation, semiautomatic checkout equipment provides operational support for E2A and A-6 aircraft.

Instrumentation

Support gear rides a roller coaster

Demand for electronic support equipment is soaring
but will plummet as prime systems use more IC's

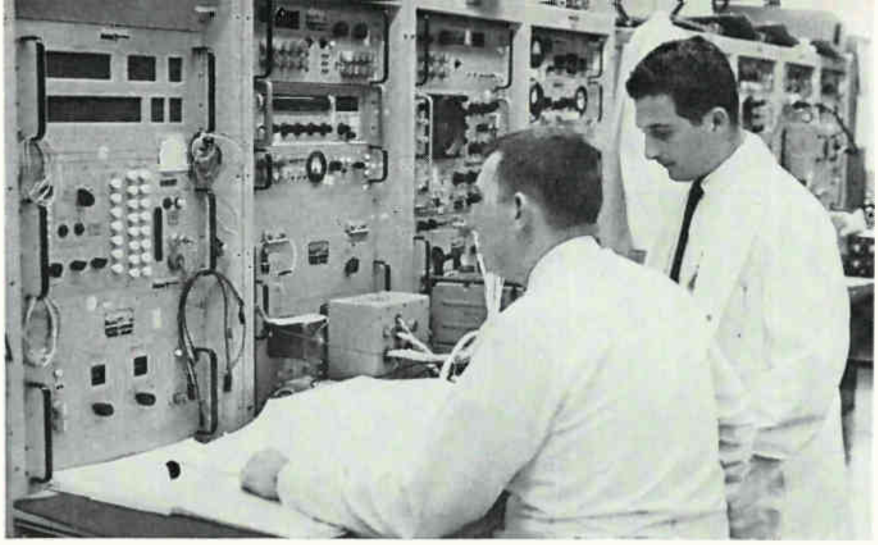
By John F. Mason
Military electronics editor

It's a cliche among support equipment engineers that systems men will one day design them out of business. The prospect is unlikely any time soon, however. Demand is booming for checkout and maintenance gear to back up and support the complex systems now being delivered to military and space agencies. Much of this apparatus incorporates some integrated circuitry. Eventually, the widespread use of IC's, in everything from gigantic radar installations to satellite telemetry, may indeed force whole sectors of the support field into retirement.

Commenting on the prospective changes Edward Dalva, director of Grumman Aircraft Engineering Corp.'s Product Support department, says, "Built-in test capabilities and the predicted reliability of integrated circuits will eliminate the need for electronic line support equipment—the portable test gear used on flight decks and flight lines. The amount of shop support can also be expected to decrease dramatically." Shop support gear is used in the big rooms below deck on carriers and near flight lines where defective systems are brought for repair.

Dalva believes, however, that demand will increase for test and repair equipment at the military depot level since this will be the only place where such work will be attempted. The more complicated systems will also intensify the demand for support equipment in development and production stages because of the need for tighter quality control. Dalva does not believe, however, that these three gains will offset the eventual decline of line and shop support equipment.

Long-term trends in the reliability of systems underlie the ferment in the support equipment field. When electronics gear was built primarily with vacuum tubes, there were chronic maintenance problems. The introduction of transistors and other solid state devices im-



Semiautomatic checkout equipment at Grumman tests all the analog components in the F-111B avionics systems.

proved the over-all dependability, but reductions in size tempted designers to add new capabilities. The net effect was greater complexity, greater potential for failure and, hence, a greater need for support.

The availability of IC's is changing the picture again. Future military and space systems will do more jobs better than any of their predecessors and they eventually will be free of the maintenance woes that plague hybrid and solid state assemblies. But the transition will be a slow and piecemeal process. During the interim, there must be shop and line support for systems still using tubes and transistors. And until IC-equipped gear proves entirely reliable, it must be backstopped by support equipment that may not have to be used very often. Thus everyone in the systems business will be forced to provide customers the support apparatus to maintain and operate equipment.

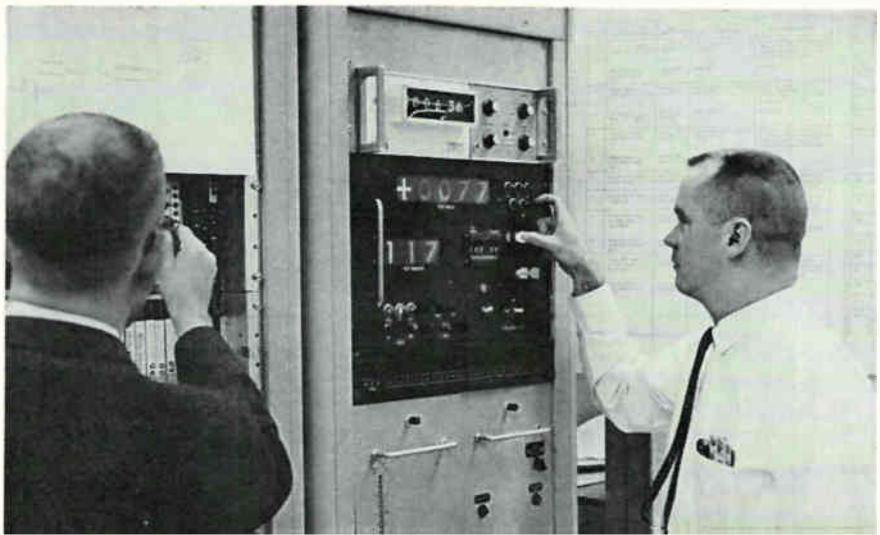
Grumman became deeply involved in support equipment when it was building the A-6 Intruder attack aircraft and the E2A Hawkeye early warning/command and control plane for the Navy. The Hawkeye carries more than five tons of electronics gear, about 80% of which is solid state.

Now Grumman's electronics products support business has grown from compact to Cadillac status in seven years. The operation, which employed only 200 to 300 people, has blossomed into a 2,000-man empire that accounted for 25% of last year's billion dollar volume.

Mixed blessing. Even now, the greater use of IC's is not an unalloyed blessing for support equipment manufacturers. To make their test and checkout apparatus effective at a reasonable cost, the companies are investigating new technical concepts in all five areas of the support field: development, production, line, shop and depot.

Grumman is building all five kinds of support equipment for the systems it is producing. These include apparatus with a few IC's,

Computer-adapter (right) feeds simulated signals from a general-purpose computer through a test station (left) to avionics systems.



such as the avionics for the Navy's F-111B and systems for delivery in the 1970's that will be entirely given over to IC's. This creates a whole new set of problems according to George Emilio, manager of the advanced systems section in Grumman's Product Support department.

"The complexities created by even partial IC application make it clear that new test concepts are needed," he says. "For one, the number of functions per test point will increase astronomically and such current test methods as point-by-point checks will be inadequate."

I. Inside jobs

As a possible solution to the difficulties posed by IC's, Grumman and other manufacturers are investigating built-in tests. Victor Green, program marketing manager of the Data Systems division of the Autonetics division of North American Aviation Inc., says, "We believe on-board self-checking will increase markedly over the next few years, particularly fault isolation techniques to permit module substitution at the operational level. Boards that fail will be forwarded elsewhere for detailed testing" [Electronics, Oct. 17, 1966, p. 103].

A spokesman for the support department of Hughes Aircraft Co.'s Aerospace Group agrees: "It's surprising how many built-in checks can be designed into a single IC module. It's apparent that there will be sizable shifting from external test gear to internal self-test."

But, he cautions, "Built-in IC's can create problems while solving them. As built-in test equipment becomes more sophisticated and extensive, weight and reliability difficulties develop. If the test equipment fails, it is as bad as if the system itself failed."

A representative of the Nortronics division of Northrup Corp. suggests there may be absolute limits as well. According to an extensive survey made by the company, cost and reliability reduce the number of circuits that can be assigned self-test routines to 15%.

Computer testing. A number of companies use digital computers to program and control testing as well as to display data. And, to a lesser extent, computers have been assigned the job of analyzing test

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Another increasingly favored approach is a functional test set designed to check particular circuit families, rather than an entire system. A digital test set, for example, could test the digital portions of the inertial guidance, radar and communications systems in an aircraft.

In the more distant future is the use of failure prediction techniques to detect significant degradation of components soon enough to prevent a failure. Hands-off testing is also a possibility. This is a way of diagnosing an entire situation from small symptoms as easily as a doctor can spot measles from blemishes. Autonetics, for one, has been working on noncontact testing of IC modules using infrared techniques. The company has a breadboard model which is very close to production.

II. Where the action is

Grumman is also developing test methods that go beyond manual and tape-controlled point-to-point voltage checks as well as ways of replacing voltage measurements altogether.

One approach uses a computer programed with a mathematical model of the system to be tested. Identical test signals are fed into the real system and the computer.

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One approach uses a computer programed with a mathematical model of the system to be tested. Identical test signals are fed into the real system and the computer.

When the two outputs differ, a malfunctioning component has been detected. To isolate the fault, elements in the model are deliberately degraded until the output matches that of the real system, thus pinpointing the trouble.

Grumman engineers have also detected malfunctions in one type of digital circuit by putting a signal into the circuit and analyzing the output. No internal test points are required. Grumman plans to apply the approach to complex airborne systems. Also, an advanced mathematical technique, called the Markov Chain, has enabled engineers to analyze an airborne unit that exhibited random signal degradation and to predict future performance characteristics. The results were sufficiently accurate to convince staff members this method will prove a practical tool.

The use of transfer function techniques to isolate malfunctioning parts within the module is also under study. Previously, this method was applied only to a whole module.

Changing times. The changing character of support requirements and hardware will have a profound impact upon the logistics, training, field service, spare parts and publications side of the business.

Training military and space agency personnel to operate systems is already a big business that will grow tremendously as more complicated equipment is introduced. At the moment, the development of instruction courses and the building or buying of training devices accounts for most of this part of the market. But new techniques, including programed learning, will be necessary to qualify personnel to operate advanced systems.

The LTV Electrosystems division of Ling-Temco-Vought Inc. says IC's will cut down on the number of company field representatives but they will have to be much better trained.

The number of service personnel to help customers maintain IC-equipped systems in the field will depend on how much maintenance the systems will need plus how successful the Defense Department is in training its own military and civilian employees to do the work. Sales of spare parts will go down if IC's are as dependable as hoped.

Railroads on the automation track

They have finally realized electronic controls can help them untrack the freight cars sitting profitlessly in classification yards

Ever so tentatively, American railroads are approaching the electronics industry for more help in straightening out the costly tangle in their freight classification yards. The long-term reward for success could be $1 billion.

It's not yet "clear the track" for computerization or even automation. But a number of projects, some near completion, others under way and more on the drawing boards, suggests that railroading, which has toyed with automatic classification for more than 10 years, may at last be receptive to the advantages of technology.

The scorecard: work has just started on a fully automated classification yard for the Union Pacific Railroad in North Platte, Neb. The job, being run by the Union Switch & Signal division (US&S) of the Westinghouse Air Brake Co., marks the debut of the International Business Machines Corp. in the railroad field. An IBM 1800 process-control computer is at the heart of the system which will be in the hardware stage this summer.

A similar terminal yard for the Norfolk & Western Railway near Cleveland will be on-line by summer. US&S is also coordinating this project which features a Computer Communications Corp. (CCC) 116 digit data processor.

Another US&S system with a CCC 116 computer is almost on-line at the Southern Pacific Co.'s Eugene, Ore. yard.

A big future. Further down the track is the contract for the New York Central System's giant Perlman yard in Albany, N.Y. When completed, this model 90-track facility will be the largest and most highly automated classification yard in the United States.

Isolated though they may be, such developments are a great leap forward in the light of the railroads' glaring deficiencies. There are 1,200 major classification yards scattered around the U.S. These are railroading's critical nerve centers, where incoming trains are broken down and reassembled as new trains bound for other parts of the country. To date, only 118 yards are equipped with some automatic control equipment, but merely 37 of these systems incorporate computers and 34 of them are relatively inflexible analog units.

The advantages of electronics have been available to railroads since 1949 when semiautomatic switching of rolling stock in a classification yard was proved feasible at the Illinois Central Railroad Co.'s Markham, Ill. facility. In 1952, the first analog computer to control car switching was introduced at the Elgin, Joliet & Eastern Railroad's Gary, Ind. yard. Later that year, potentiometer control of car speed on make-up tracks proved practicable. Subsequently radar speed control worked out and in 1965 the General Electric Co. put the first digital process-control computer on-line at the Alton & Southern Railroad's Gateway yard in East St. Louis, Ill.

Slow progress. Even now, for every day the average loaded

Of the 1,200 major classification yards in the nation only 118 have automatic controls. This one, which boasts an installation with an analog computer, is in the St. Louis-San Francisco Railway Co.'s Tulsa, Okla. facility.

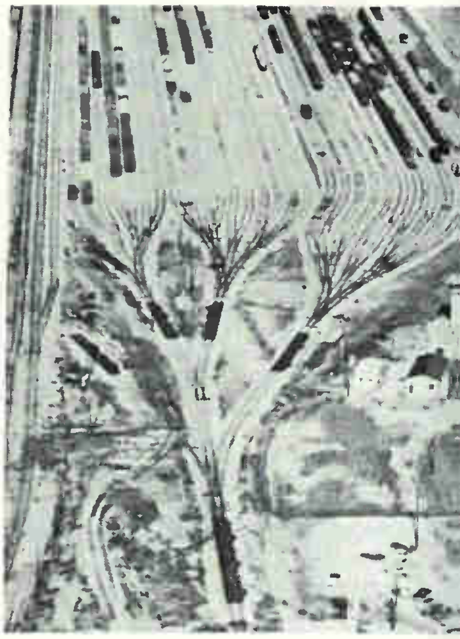
freight car is in a train, producing revenue ton-miles, it travels empty for another 20 hours, sits in customers' sidings for three days, and languishes in classification yards and interchanges for 15 days. The railroads' backwardness on using more control equipment is partially attributable to the strong position of unions within the industry. The roads claim the average computerized classification yard can be operated efficiently with 30 to 40 fewer men than are required in a conventional facility. As a result of labor's intransigence and the threat of strikes, railroaders are reluctant to rework existing installations. As a result most automated yards are built from scratch.

The industry's reluctance to stir up its work force is apparent from its budget. Last year only 13% of the $56 million invested in signal and communications equipment—any apparatus having to do with electricity, in the railroader's lexicon—was allocated for automation of classification yards. The balance was spent for central traffic control on the 200,000 miles of track around the country, rapid transit and spare parts.

Largely because of the slim pickings and the reputed resistance of railroads to progress, signal and communications suppliers are a select group. Just two companies—US&S and the General Railway Signal Co (GRS)—have long divided an estimated 85% of the available market. Other electronics concerns that have occasionally sidetracked into this sector of railroading include the American Brake Shoe Co., GE and Radiation Laboratories.

The very chumminess of the field is reportedly an additional drag on progress in control systems. Due to the low margins—5% or less—on process-control business, both GRS and US&S are reluctant to work on automated yards unless they get orders for such collateral hardware as track switches and electromechanical wheel-speed retarders.

Waste of time. Nonetheless, the loss of the use of a valuable freight car for an average of 256 days a year is increasingly viewed as far too high a price to pay. It's not surprising that much of the internal push for more widespread application of electronic controls to classification yards comes from account-



Tulsa layout shows the bottlenecks built into classification yards.

ants, rather than engineers. Accountants, concerned with securing a maximum return on all assets, are usually well-grounded in the capabilities of computers from having used such units for billing, bookkeeping and related operations. Their technical colleagues, in the railroad field at least, tend to be preoccupied with problems of power rather than control.

The conception and development of the Central's Perlman yard, which will follow closely at least three other projects, could establish a faster pace for additional control installations throughout the industry. GE's direct digital control system, after some startup woes is working out well. The pioneer analog computers cannot produce the data needed to break down and make up trains fast enough, although they do facilitate track-to-track switching. Thus the chances are that the computerized classification yard systems of the future will borrow the best features of both. Digital computers programed to provide information only when something goes wrong can satisfy the railroads' need to be put more completely in the picture. These units could be connected to analog loops that actually control the switching and make-up processes. Such a configuration would be flexible and able to avoid the problem of swamping the roads with voluminous amounts of digital data that they would be at a loss to use.

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Breakdown Voltage, Collector to Emitter, BV_{CEO} (SUS)	*$I_C=100mA$, $I_B=0$	30 A-60 B-100 C-150 D-200 E-250		30 A-60 B-100 C-150 D-200 E-250		Volts Volts Volts Volts Volts Volts
Collector Cutoff Current, I_{CEX}	V_{CE}=rated voltage $V_{BE}=1.5V$, $T_C=150°C$		20		20	mA
Emitter Cutoff Current I_{EBO}	$V_{EB}=25V$, $I_C=0$, $T_C=150°C$		20		20	mA
D.C. Forward Current Gain, h_{FE}	*$I_C=2$ Amps, $V_{CE}=4V$ *$I_C=5$ Amps, $V_{CE}=4V$	10		10		
Saturation Resistance, r_{CE} (sat)	*$I_C=2$ Amps, $I_B=300mA$	0.3 Typical	0.75			Ohms
	*$I_C=5$ Amps, $I_B=750mA$			0.2 Typical	0.5	Ohms
Base to Emitter Voltage, V_{BE}	*$I_C=2$ Amps $V_{CE}=4V$	1.5 Typical	2.5			Volts
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Tactical phased-array radar gets closer to the field

The military's increasing interest in the multifunctional capability of phased arrays is sparking a boom in tactical units

By Thomas Maguire
Electronics Boston Bureau

Electronics firms are zeroing in on the sizable new military market shaping up for tactical phased-array radars. This rugged and relatively small gear, now close to the systems test stage, will, when operational, have airborne, shipboard, and land-based applications.

While conventional electromechanical radar antennas must move about in search of targets, phased-array antennas are fixed. They have thousands of elements, the phases of which can be controlled electronically. The beam radiated by the elements can be focused like that of a conventional radar, or broken up to follow a number of targets within a 180° sector. With this beam-steering capacity, phased arrays can do double and even triple duty. They are especially practicable in such applications as tactical air defense systems for ground troops, where a large volume of data must be handled and high angular accuracies are required.

A number of companies are working on tactical phased arrays for the Armed Forces, with the Raytheon Co. alone working on four contracts. To get ahead of the pack, Raytheon has spent $2 million since early 1964 on the development of ferrite arrays. Its FAD project—for ferrite array demonstrator—dates back to 1961 Army studies that established requirements for gear handling simultaneous targets. The company is about to learn just how sound its investment has been.

I. First fruits

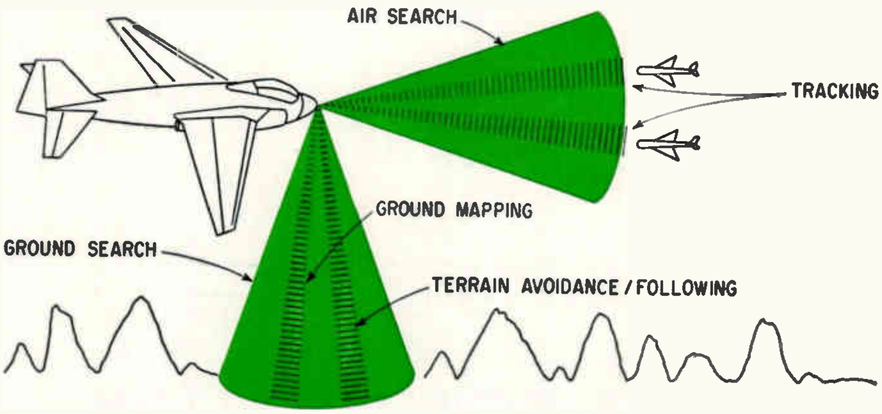
Two months from now, Raytheon will deliver an X-band phased-array antenna to the Naval Ordnance Test Station at China Lake, Calif. The Navy will use this system as a test bed in evaluating various approaches to small, lightweight, relatively inexpensive multitracking radar for weapons control aboard small warships.

Raytheon also has a $2 million contract from the Research and Technology division at Wright-Patterson Air Force Base, Dayton, Ohio, for a phased-array antenna operating in the Ku band. This system, similar in concept to the one being delivered to the Navy, will be used to determine the feasibility of airborne phased arrays. Multifunction capability is the principal requirement of such a unit, as a single antenna must be able to detect and track many targets simultaneously on a sampled basis. In addition, the airborne phased array would be used to warn of mountains and perform ground-mapping and reconnaissance operations.

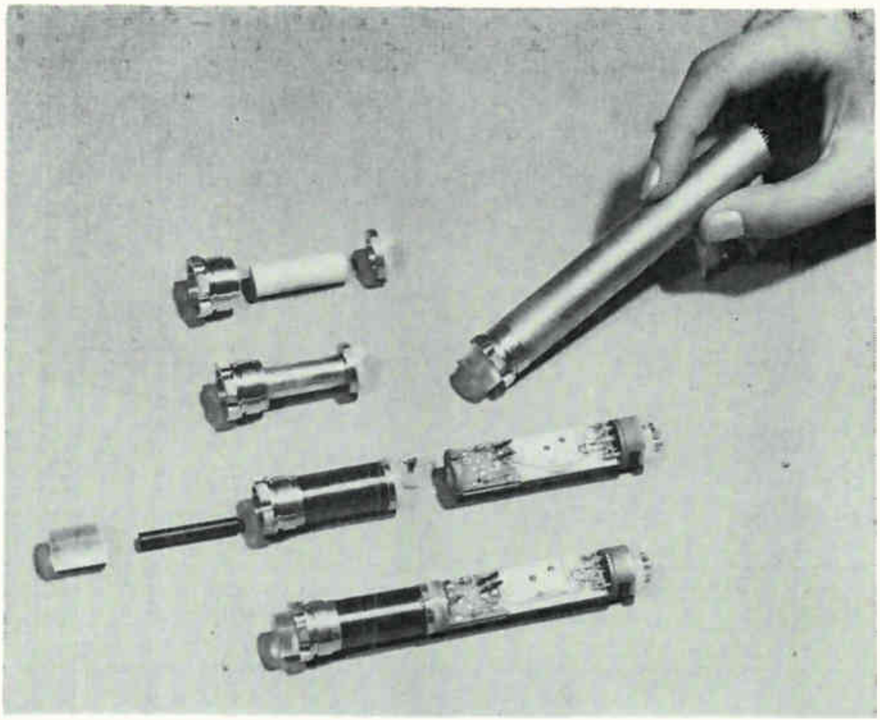
The Rantec Corp., a subsidiary of the Emerson Electric Manufacturing Co., is also working on an airborne system similar to Raytheon's for helicopter applications.

Missile radars. Technical proposals are due next week (Jan. 15) from Raytheon, the Radio Corp. of America and the Hughes Aircraft Co. on the ground-based tactical radars for the D version of the Army's proposed SAM-D surface-to-air missile. This weapon, slated to replace both the Nike-Hercules and Hawk missiles, will be designed to defend both troops in the field and fixed facilities from attack by aircraft or short-range ballistic missiles. Selection of one or more prime contractors is expected by midyear.

Whoever nails down the SAM-D order may get some extra business. The Navy, at the behest of the Pentagon, is trying to find areas of commonality between its own Advanced Surface Missile System and the SAM-D. The development and production costs of both programs



Phased arrays must be able to track and detect many targets and perform ground-mapping and reconnaissance operations in airborne applications.



The phasing element in Raytheon's array has driver circuitry and a ferrite phase shifter, which is enclosed in a coil, and a quartz window.

would be reduced if some interchangeability of major components could be achieved.

Along with Hughes, the Westinghouse Electric Co. and ITT Gilfillan, a subsidiary of the International Telephone and Telegraph Co., Raytheon is working on a definition study of a new ground-controlled approach radar, the TPN-19. This equipment will be developed for the tactical air command and control system managed by the Air Force Electronic Systems division, Hanscom Field, Mass. [Electronics, Nov. 28, 1966, p. 25].

II. Out of phase

Raytheon's technical approach to the new tactical radars centers on optically, or space-, fed arrays. This is a technique in which the transmitter is not coupled to the elements by waveguide or cable; instead, transmitter energy is beamed onto the array. In each element the energy goes through a quartz window to a ferrite rod, where the signal is given a computer-determined phase delay and returned through the window to form a part of the radar beam.

Raytheon's choice of technology differs sharply from the corporate-feed techniques used in the phased arrays for such giant installations as the FPS-85 space-track radar at Eglin Air Force Base in Florida. In corporate-feed systems, each element is a transceiver. In transmitting, beam-forming signals are fed through a phase-shifting transmission-line network and focused on the element by an electronic lens behind the array. The signal is then radiated out by the element. The process is reversed in receiving.

The Navy way. The Navy phased-array system with a Raytheon antenna will operate in the X band and have a peak power of 100 kilowatts. Circular polarization techniques will reject rain clutter. The array will have 4,638 elements arranged in a triangular grid, and each element will have a microminiature driver, a ferrite phase shifter and a quartz radiating window. The elements will be individually plugged into the wirewrap panel and each will be individually controlled by a beam-steering computer.

"In such a system, failures will occur in a random manner across the array," says A. Michael Briana, manager of Advanced Phase Array Programs at Raytheon's Missile Systems division. According to Briana, the built-in redundancy means that up to 10% of the elements can fail before performance is seriously degraded.

The Navy array has an on-axis, four-horn monopulse feed, and is controlled by a special-purpose, beam-steering computer plus row and column circuitry. The beam-steering unit requires only three inputs—two angle commands and a command proportional to the frequency—from a general-purpose or fire-control computer. On a two-axis pedestal, the array can search over 360° by combining electronic and mechanical scanning; it can also be positioned to completely scan any quadrant electronically.

The weight of the prototype Navy array, including mount and power supplies, is about 2,200 pounds. The elements each weigh 3½ ounces and cost $70; the price of the whole array is $325,000.

A corporate program. Westinghouse, which is also busy on several tactical phased-array projects, has opted for the corporate-feed system in its work on the TPN-19. The company plans to connect high-power transmitters to a corporate-feed network where the energy will be stepped down and supplied to individual latching ferrite phase-shifter elements. These units are expected to provide stability and permit the switching of relatively short pulses. Complex receivers with digital integrated circuitry will furnish high performance in the face of clutter and bad weather.

Westinghouse is not, however, overlooking low-cost, circularly polarized radiators with solid state transceivers. As a possible adjunct, the company is evaluating the use of a frequency-controlled local oscillator to achieve phase control for steering antenna beams.

Down the road. Tactical phased arrays operating at frequencies from the S band through the Ku band, with antenna diameters of 2½ to 8 feet and with 1,000 to 5,000 elements, will soon be available, according to Raytheon's Briana. Weights will range from 250 to 2,500 pounds, depending on the elements used and the frequency required, and costs will range from $50,000 to $250,000 on a volume basis.

Briana points out, however, that weight and cost are only two considerations. "With tactical phased arrays, we are trying to satisfy two new requirements," he says. "These are the capacity to handle multiple targets and perform multiple functions."

The next big space program

Space contractors, convinced that the earth resources survey program will mean big business, are swamping the Government with proposals

Despite its present troubles, a down-to-earth satellite to survey the world's water, food and mineral resources is likely to be the United States' next major space venture. Although there has been no request for proposals, the project known as EROS for Earth Resources Observation Satellite has attracted the interest of a flock of companies. The two government agencies nurturing EROS—the Interior Department's Geological Survey and the National Aeronautics and Space Administration—have already talked informally with 15 space contractors who are convinced the program will get a go-ahead in 1967 and be important for years to come.

The EROS must, however, elbow aside other projects for a share of the limited amount of available funds. It is also plagued by friction between the government agencies involved, technology that is at present inadequate for the mission requirements and the lack of a clearly defined system.

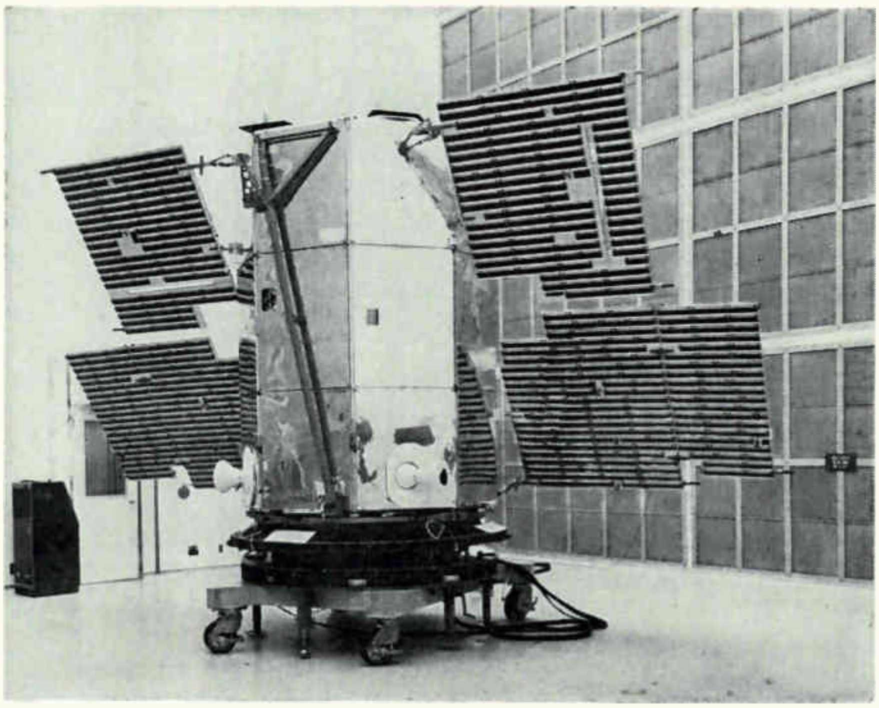
The logic of applying space technology to mundane problems is persuasive since the earth's exploding population is reportedly close to exhausting available resources. A number of independent studies agree that this trend may lead to worldwide famine by as early as 1985 unless something can be done almost immediately to improve resources utilization. The problem is equally severe with regard to the supply of potable water and is beginning to become pressing for minerals.

Unsolicited. With the need for additional resources clearly established, the Government only had to hint that it was considering a space system before it was swamped with proposals. The General Electric Co. submitted an unsolicited fixed-price proposal, and although no one is saying how much money the company asked for, it has to be less than $20 million since that's the amount budgeted for EROS by Interior. At least two other firms are rumored to be preparing fixed-price proposals for submission in the coming weeks. This increased competition may now keep costs down despite the growing weight and complexity of the spacecraft [Electronics, Dec. 26, 1966, p. 50].

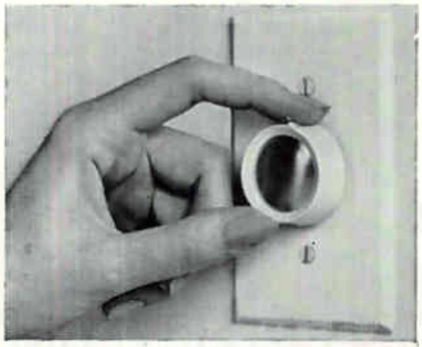
The Radio Corp. of America is also trying to move into the EROS project. RCA and GE have perennially had competing satellites—the Tiros and Nimbus weather satellites, respectively. When EROS was first announced last fall, RCA appeared to have an edge since the size and required capabilities closely resemble those of its Tiros [Electronics, Oct. 3, 1966, p. 52]. Now GE is gaining ground as the Geological Survey recognizes the need for more observation and data processing capability.

But RCA has already beefed up its basic 300-pound Tiros into a more advanced 625-pound weather satellite called Tiros-M that has some of Nimbus's extra features [Electronics, Sept. 5, 1966, p. 135]. The GE entry, called EPIC for earth pointing instrument carrier, is a 500-pound spacecraft similar to Nimbus that would carry "several hundred pounds" of instruments mounted on the base. Either satellite could use the Delta launch vehicle that the Geological Survey has selected for the project.

Also-runs. Many other companies are proposing modified versions of their existing spacecraft. Among these are the Boeing Co., Grumman Aircraft Engineering Corp., TRW Systems Group of TRW Inc. and Ball Brothers Research Corp. The International Business Machines Corp., which has never built a satellite but did a basic study for NASA on resources measurement from space, is also interested in building EROS. The Philco-Ford Corp., the



Orbiting Astronomical Observatory built by Grumman is one of many spacecraft being proposed for the EROS program.



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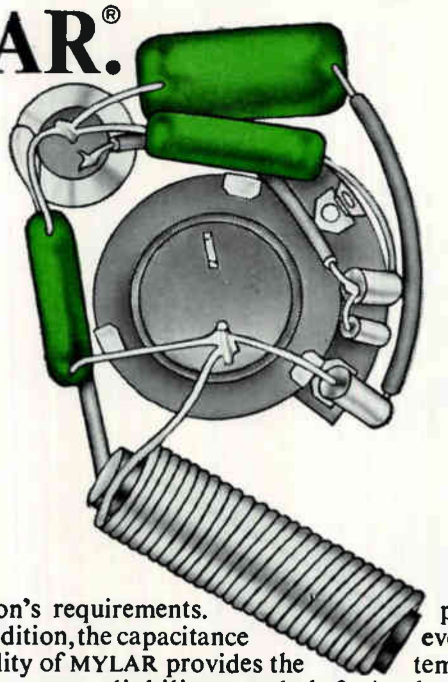

"Only capacitors of MYLAR* give us the size and reliability we must have, and at low cost," says Joseph M. Licata, Chief Engineer. Lutron Electronics Co., Inc.

Lutron's broad line of dimmers is miniaturized to fit single gang boxes for quick, easy installation. Because MYLAR has extremely high dielectric strength in thin gauges, capacitors made from this polyester film can be manufactured small enough to meet Lutron's requirements.

In addition, the capacitance stability of MYLAR provides the long-term reliability needed for trouble-free brightness control of all types of incandescent and fluorescent lighting.

Voltage requirements for Lutron's dimmers are 200 to 600 volts, and in many instances these units operate around the clock. Lutron's own tests and experience indicate capacitors of MYLAR perform well in these conditions, even under extremes of humidity and temperature. Lutron has also found that in many cases, capacitors of MYLAR cost less than paper.

If capacitor size, reliability and price are important to you, check into MYLAR by writing: Du Pont Co., Room 4671A, Wilmington, Delaware 19898. (In Canada write: Du Pont of Canada, Ltd., P.O. Box 660, Montreal, Quebec.)

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Raytheon Co. and at least six other firms have expressed interest in some phase of the project.

When the Interior Department launched the EROS project, officials urged that an operational satellite be flown by 1969. William Fischer, project manager at the Geological Survey, still stresses this urgency. "If the food and population lines cross in 1985, we won't be able to get them uncrossed," he says.

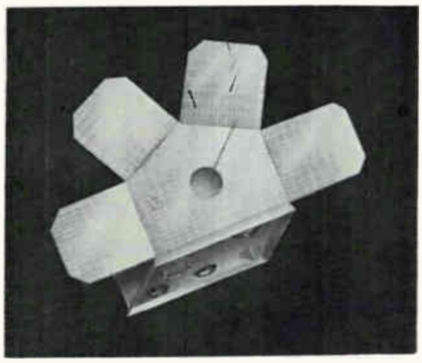
To meet what it considers pressing needs, the Geological Survey is asking for a satellite with three capabilities: high resolution in two spectral bands, near-global coverage and at least one year of useful lifetime in orbit. The two bands are around 750 millimicrons in the solar infrared spectrum that would permit observations of the distribution of water and 550 millimicrons in the blue-green spectrum that would penetrate the atmosphere and oceans to permit studies of the earth's terrain.

The purpose is to make a thorough survey of water in the soil and in plants as well as free water and to identify geological formations with mineral potential. "We're talking minerals not geology and water rather than hydrology," says Fischer. He compares EROS to helicopter traffic reports. Both provide information as it is needed.

But before EROS flies, major improvements will have to be made in space hardware, most of them in electronics. The problem of tape recorder reliability seems insoluble. The only way around this difficulty is to put more recorders on board the satellite. Resolution is an even greater problem. The Geological Survey wants resolution to 100 feet for each 100-mile-square picture. If a television system were used, a camera capable of taking pictures with as many as 5,000 lines would be required. In commercial broadcasting, 525-line pictures are standard. Some candidates are RCA's return-beam vidicon system and the Westinghouse Electric Corp.'s image dissectors. Another possibility is the clustering of 800-line Nimbus tv cameras so that each would cover a portion of a comparable area.

Fischer estimates that EROS needs a communications bandwidth of 20 to 30 megahertz.

The band has to be wide enough to return both photos and ground-



Beefed-up version of Tiros from RCA is also a contender for EROS project

based environmental data collected by EROS as it passes over specially built small transmitters located in areas selected for study. The most attractive frequency available is around 1,740 Mhz, which has been temporarily assigned to NASA. Another possibility is the 1,695 to 1,705 Mhz band used by the Environmental Science Services Administration's weather satellites.

Close tolerance. To solve the problem of stabilization, the Geological Survey favors the gravity-gradient method in which a long boom on the spacecraft extended away from the earth orients the spacecraft so that its sensors always point down. The requirement is for the spacecraft to maintain its earth orientation to within three degrees.

By placing the satellites in an orbit synchronized with the angle between sun and earth at all times, there would be no problem with shadows. With removal of this variable, the pictures could be run through an automatic analysis system that would instantly spot changes in vegetation or moisture. Aerial surveys performed by camera-carrying aircraft have always had the problem of changing light levels that make it difficult to compare photos taken at different times.

The value of space as a unique vantage point has already been confirmed by the spectacular color photos taken by the Gemini astronauts. Now the Geological Survey wants to use a space system to conduct a more accurate and cheaper aerial survey of the United States. The use of existing aircraft techniques would require 1.5 million photos, cost $12 million and take about three years. A satellite could do the same job for $750,000 with 400 photos in less than three weeks, Fischer estimates. The benefits to the economy of having up-to-date maps of the United States are estimated at $135 million a year. In American aid programs for underdeveloped countries, instant map substitutes gathered by satellites would cut three to five years off the time needed to survey the country in preparation for instituting agricultural and other reforms.

The space agency has an earth resources study program of its own, but it is barely visible among the high-priority, high-cost manned projects like Gemini and Apollo. NASA tends to think big and accordingly the studies have concentrated on large satellites in the Orbiting Astronomical Observatory class and manned earth orbital Apollo flights. A smaller satellite along the lines of Tiros and Nimbus, called Sorero for Small Orbiting Earth Resources Observatory, was studied for a while and then dropped last summer. The idea was revived when the Geological Survey put itself in the picture.

The space agency's position is that technology hasn't progressed far enough to jump into an operational system. A small study team at NASA that has been testing instruments in aircraft wants to continue this study program for several more years before making the transition to a space-borne system. One clue to the agency's hesitation is that the Space Act of 1958 which established NASA made it only a research and development organization rather than an operating agency. If EROS were to be an operational spacecraft, NASA would lose the project to the Interior Department. It has already turned over responsibility for communications satellites to the Communications Satellite Corp. and the Defense Department, and weather to the Environmental Science Services Administration.

The Interior Department is eager to get on with the job right now and plans to allocate funds from its current budget to make a firm start on EROS. The exact amount depends on how much the Budget Bureau will allow for the project in the next fiscal year, but Geological Survey officials plan to spread the $20 million cost over three fiscal years. They also hope for some money from the Agriculture and State Departments.

The devil's advocate

That's one of the many roles played by our Corporate Director of Reliability. He's responsible for the reliability of all IRC products. He double-checks basic designs. Keeps an eagle eye on production. Never goes easy on inspection and testing.

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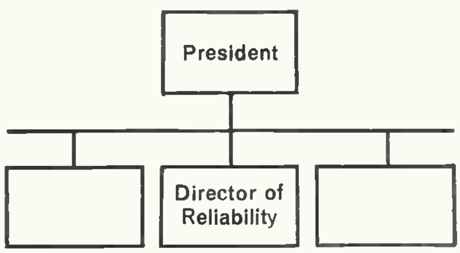
This IRC attitude toward total reliability has practical advantages for you. Now you can choose from several optimum economical levels of reliability in resistors, potentiometers and semiconductors. And IRC is the first to *publish* prices for standard metal films at three reliability levels.

At IRC, reliability is a management responsibility . . . not just a specification gesture. For top management attention, address your questions on reliability to our Director of Reliability.

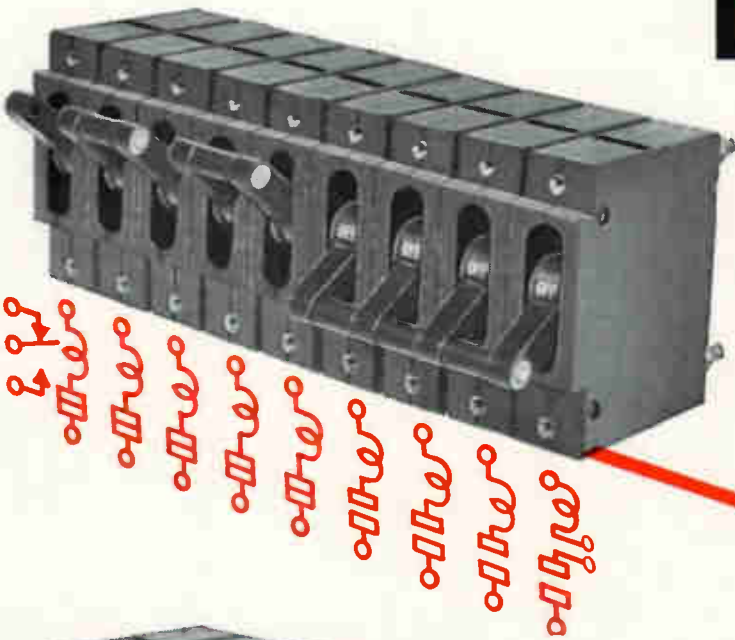


IRC, Inc., Philadelphia, Pa. 19108

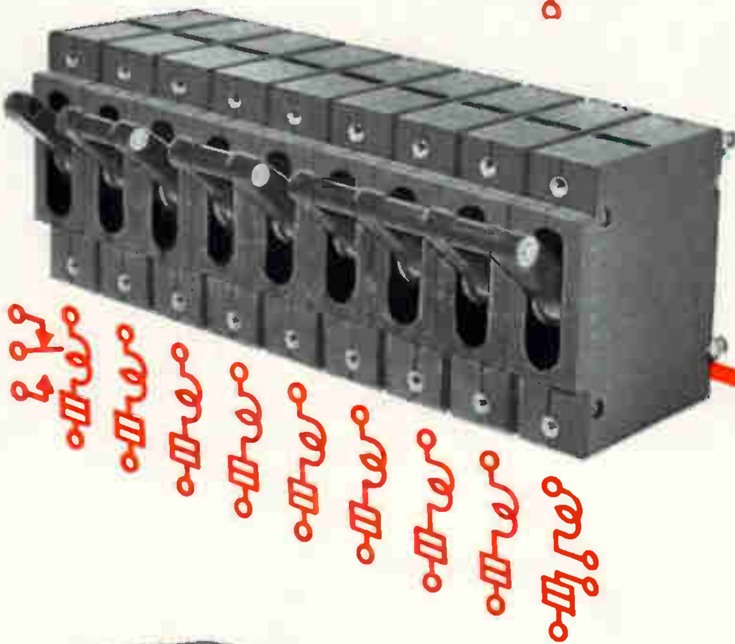
IRC

NINE-IN-LINE

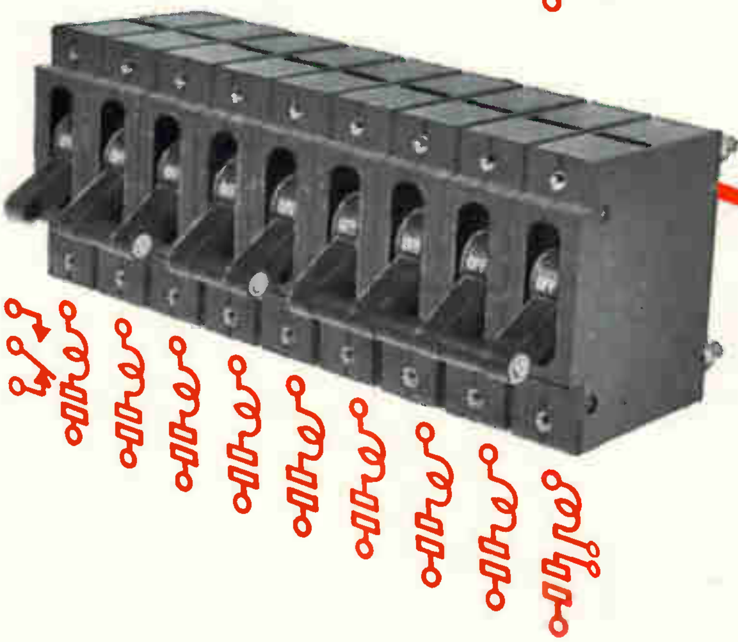
CIRCUIT PROTECTION and CIRCUIT CONTROL by AIRPAX ELECTRONICS



Step 1 is ON
Step 2 is ON
Step 3 is ON
Step 4 is waiting.



All steps are on and all functions are protected.



One circuit overloads.
All protectors trip open.
All safe.

AIRPAX ELECTRONICS
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CAMBRIDGE DIVISION, CAMBRIDGE, MD.
(301) 228-4600

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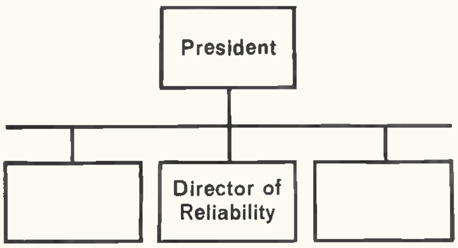

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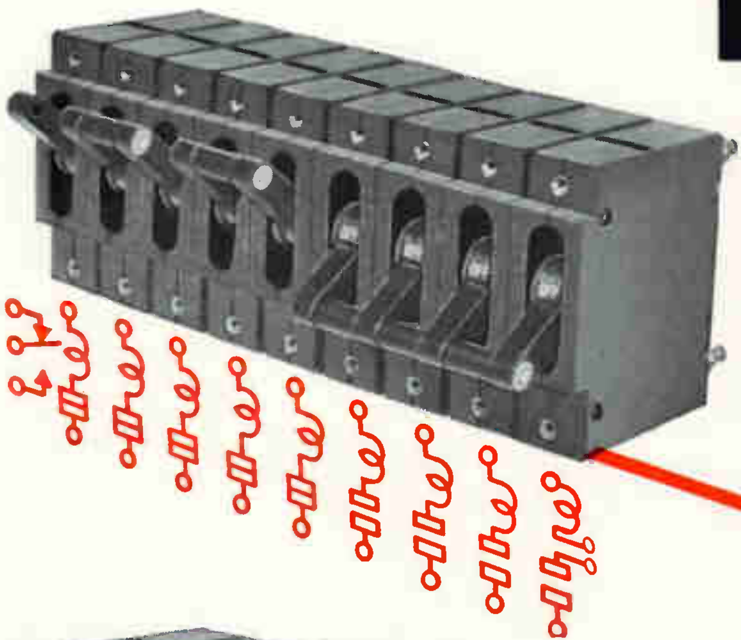
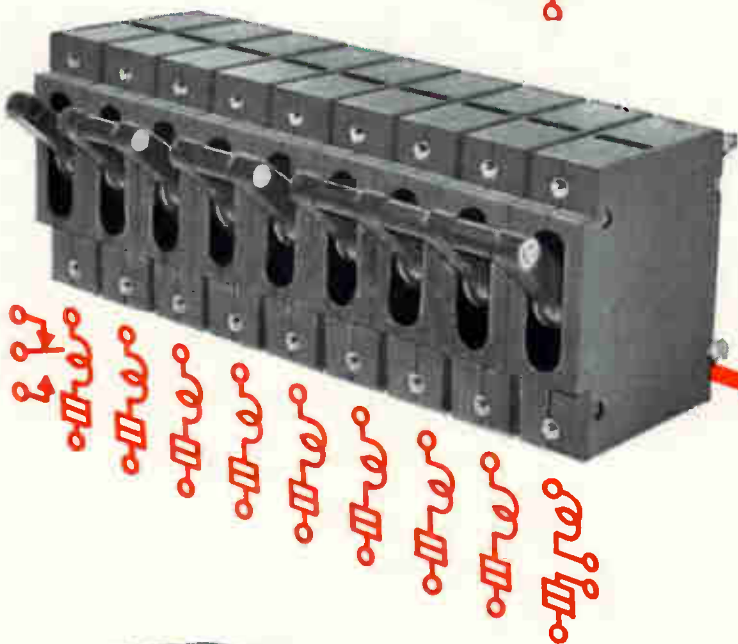
NINE-IN-LINE

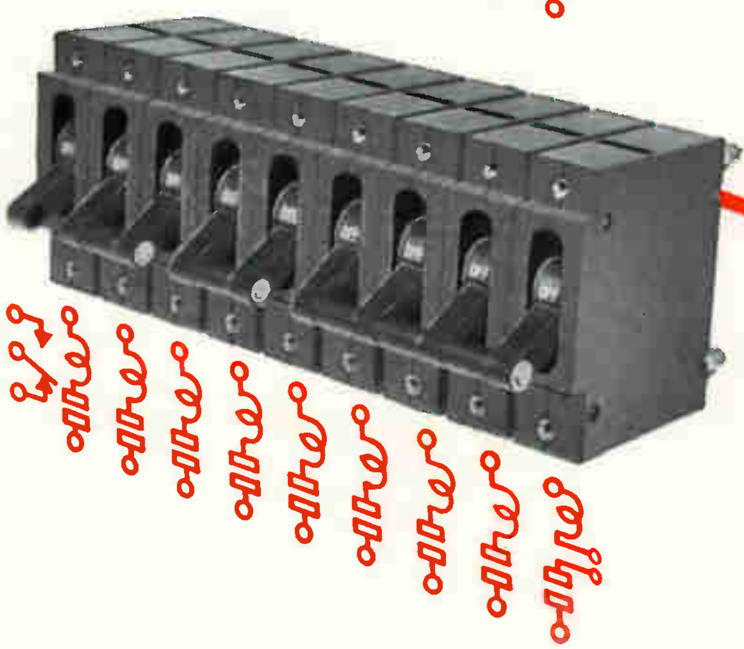
CIRCUIT PROTECTION and CIRCUIT CONTROL by AIRPAX ELECTRONICS



Step 1 is ON
Step 2 is ON
Step 3 is ON
Step 4 is waiting.



All steps are on and all functions are protected.



One circuit overloads.
All protectors trip open.
All safe.

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Add 20 Mhz to logic speeds

J-K flip-flop that toggles at 70 Mhz is part of a line of complex integrated circuits based on current mode logic

Countering the push to saturating integrated logic circuits, Motorola Inc.'s Semiconductor division is putting a new series of nonsaturating (current mode) IC's on the market. Called MECL II, the new line comprises complex multifunction circuits.

Three of the first circuits are a monolithic full adder that replaces three half-adders, a full subtracter and a J-K flip-flop with a minimum toggle frequency of 70 megahertz, about 20 Mhz above standard competitive IC's, according to the company.

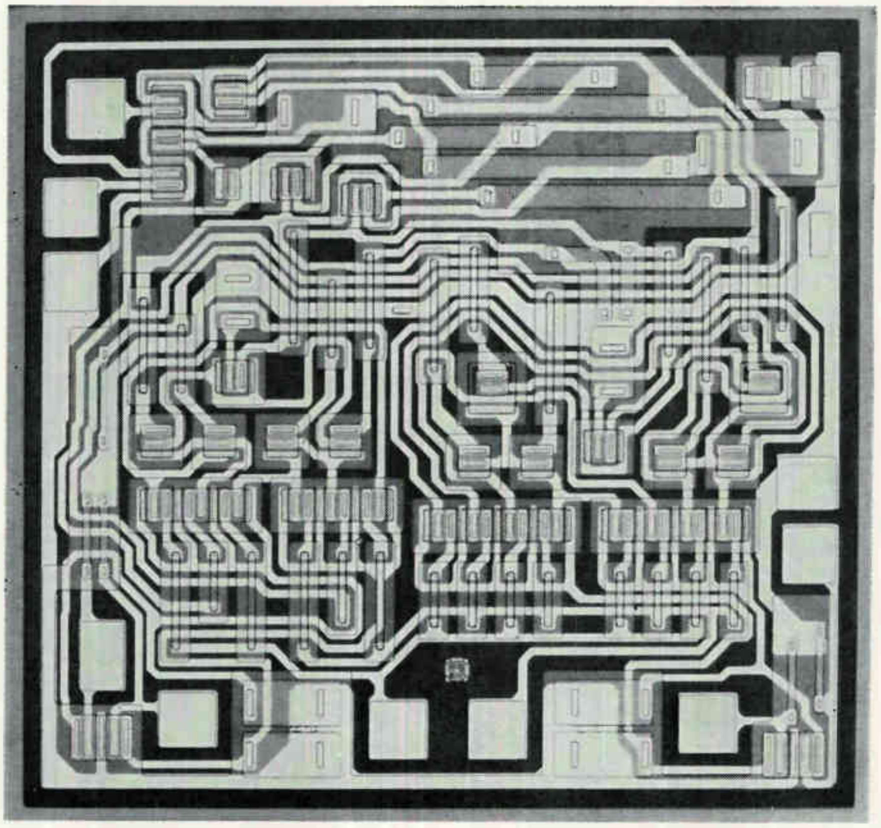
The chief advantage of nonsaturating logic over saturating logic is speed—an advantage gained by avoiding operating the transistors in their saturated regions with the attendant charge storage that has to be "swept out" prior to transistor turnoff.

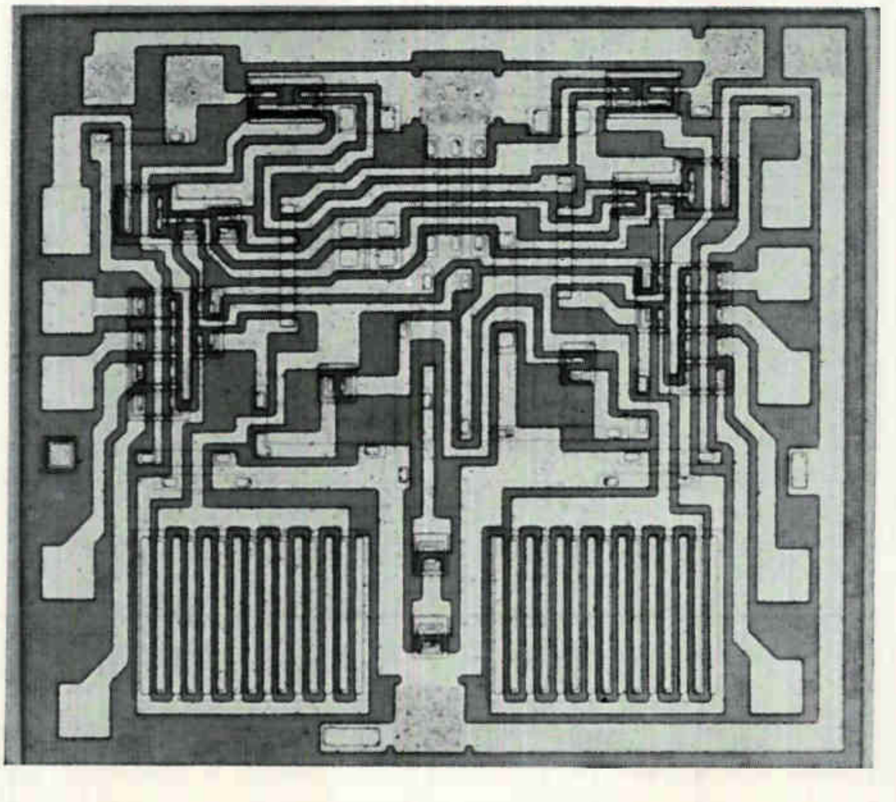
The MECL II circuits, notes Motorola, will permit a reduction of 30% to 50% in the number of packages compared with older, saturating families. In a few cases the reduction may be almost 70%.

The adder (right, above) accepts 2 binary digits and a carry. Operations are performed almost simultaneously so add time and rise time both are close to the 5-nanosecond propagation delay time. It, like its cousin the full-subtracter, costs $5.50 in lots of 1,000 to 4,999.

The J-K flip-flop (right, below) has exhibited a typical toggle frequency of about 90 Mhz but the company won't guarantee operation above 70 Mhz. Fan out in current mode logic circuits is normally good and MECL II is no exception; the circuit can drive up to 15 loads without sacrificing operating speed. In quantity, it costs $3.50.

The circuits, like the rest of the MECL II family, will be available in 14-lead dual in-line plastic packages and ceramic flatpacks. The





New Products

ceramic flatpacks will cost slightly more but will work from —15°C to 125°C, where the plastic's operating temperature range is O°C to 75°C. "These are," said a Motorola spokesman, "undoubtedly the fastest logic IC's available today in plastic."

All of the MECL II family are designed to be compatible with the earlier MECL I series. When using members of the two families together, though, there can sometimes be timing problems since the earlier group has a propagation delay time of 8 nsec.

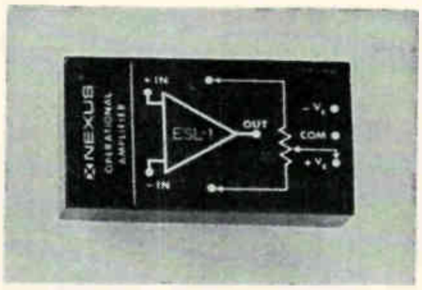
Other MECL II circuits available are 6 gates, with varying output configurations, dual 4-input gates and quad 2-input gates. Other circuits in the series will be available by the end of January.

Specifications

MECL II series	
Propagation delay	5 nsec, typical
Fan out	15 a-c loads, max
Power supply voltage	—5.2 v
Logic swing	800 mv
Noise immunity	About 350 mv
Delivery	Off the shelf
MC1013 J-K flip flop	
Output voltage at 25°C	
Q logical 1 (V_{oh})	—0.800 v, min; —0.680 v, max.
Q logical 0 (V_{ol})	—1.800 v, min; —1.465 v, max.
Switching speed	9 nsec
MC1019 adder, MC1021 subtracter	
Output voltage at 25°C	
high state	—0.75 v, nominal
low state	—1.55 v, nominal

Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. 85001
Circle [348] on reader service card.

Versatile operational amplifier



A new design in operational amplifiers could replace as many as 75% of the op amps now on the market, according to Nexus Research Laboratory, Inc., the manufacturer. The new amplifiers operate from a wide variety of either regulated or unregulated power supplies, and are practically immune to input power variations. They are fully protected against short circuits, overloads and overdrive.

Two grades of the all-silicon semiconductor, discrete component units are being offered. The top-line USL-1 has encapsulated, military-spec-qualified components. The lower-priced ESL-1 is built to less rigorous standards, but still offers specifications much superior to conventional operational amplifiers. Where the application allows use of an unregulated power supply, up to 90% can be cut from power supply cost. An additional saving can be gained with the USL-1, because its typical offset voltage of 0.1μv makes an external trim potentiometer unnecessary in most cases.

Other advantages stated for the design are an initial warm-up drift of only 50μv, and highly stable optimized characteristics over the rated supply voltage range. Significant improvements are claimed over currently available amplifiers, especially in offset voltage and current with respect to time and temperature during warm-up. The very high common-mode rejection of 125 db affords unusually good accuracy for use in follower, subtracter, noninverting and other amplifier designs. Versatility of the new amplifiers will allow cuts in inventories and reduce stocking problems.

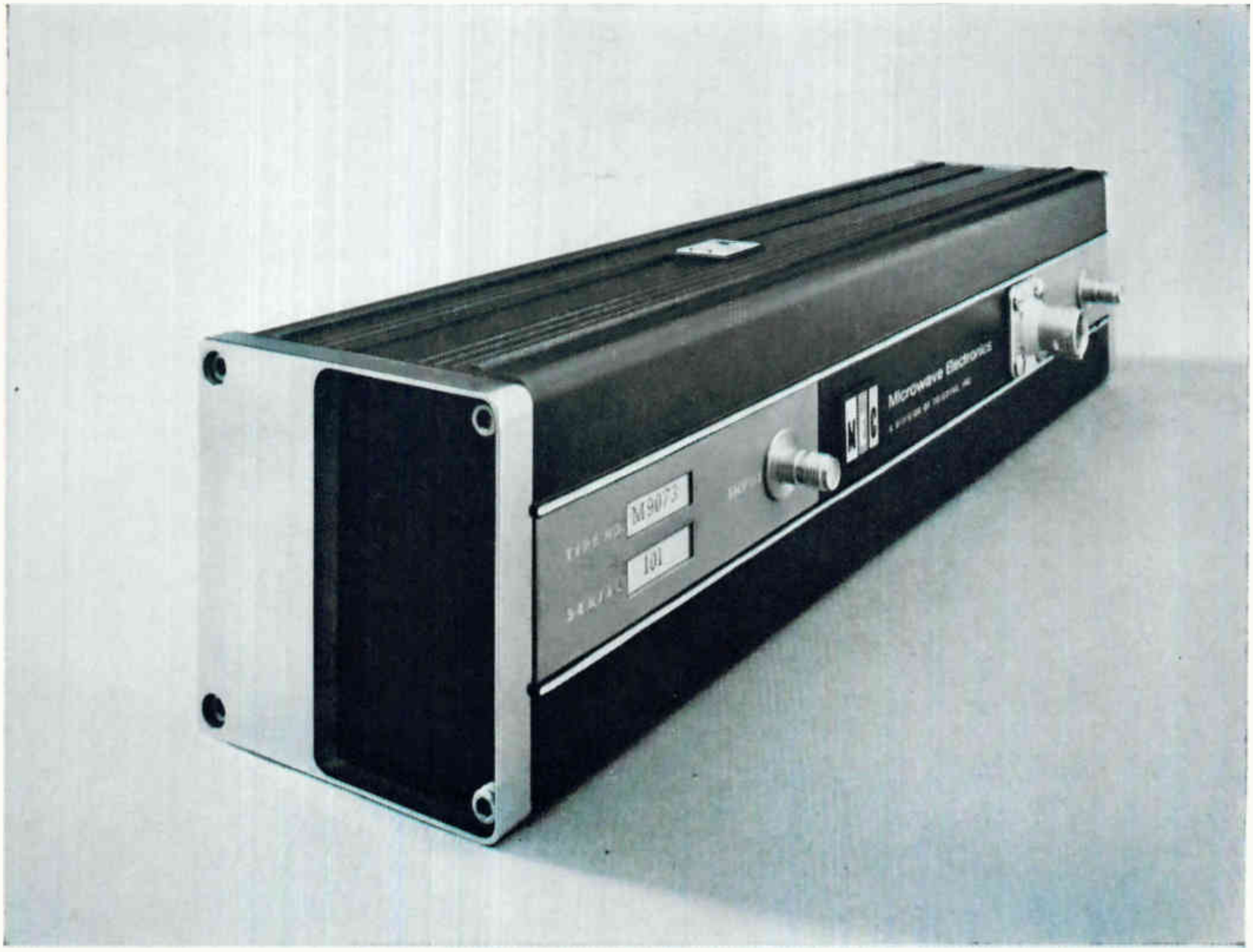
Specifications

Supply voltage (USL-1)	±8v to ±26v
Supply voltage (ESL-1)	±8v to ±16v
Output and common mode voltage	±20v @ ±25v supply (USL-1) ±10v @ ±15v supply ±3v @ ±8v supply
Output current	±5ma within supply range
Power supply rejection	3μv/volt
Input impedance	0.3 megohm
Gain into 10K load (USL-1)	200,000
Gain into 10K load (ESL-1)	100,000
Slewing rate, full ouput (USL-1)	1.1v/sec
Slewing rate, full output (ESL-1)	1.2v/μsec
Case size	L. 2.02x1.14x0.62 in.
Price (USL-1)	$75 (1-9)
Price (ESL-1)	$35 (1-9)

Nexus Research Laboratory, Inc., 480 Neponset St., Canton, Mass. 02021 [349]

New products in this issue

It's later than you think!



Here's the second generation TWT amplifier.

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

Let's be specific:

- ☐ MEC's rugged package weighs *less* than 4 pounds.
- ☐ It's only 11³/₈ inches long and is 2³/₈ inches square.
- ☐ It operates on *either* ac or dc.
- ☐ And, it meets MIL-E-5400 Class II requirements.

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

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

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

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

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

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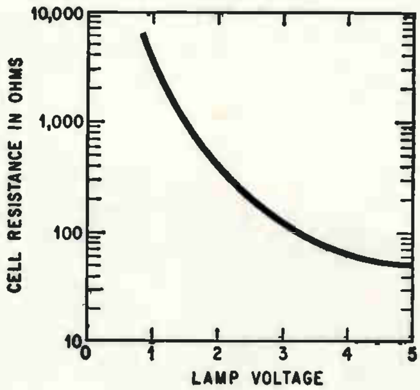
Microwave Electronics 3165 Porter Drive, Palo Alto, California a division of Teledyne, Inc.

Frictionless 'pot' cuts noise



Specifications

Operating temperature range	—40° to 65°C
Photoconductor power capability	100 mw, max
Photoconductor voltage	60 v, d-c or peak a-c, max
Cell resistance	50 ohms (5v on lamp) 150 kilohms, min (0v on lamp)
Lead length	1.375 inch, min, 1.625 inch max
Response time	100 msec, typical
Price	About $2.50 each for 500 or more
Delivery	1 to 2 weeks

General Electric Co., Tube Department, Owensboro, Ky. [350]

A photoconductive cell-lamp combination with greatly reduced resistance is the latest model in the General Electric Co.'s Tube department's family of "contactless potentiometers."

The model, PL5B2, contains a cadmium sulfide photoconductive cell that is controlled by varying the voltage of a miniature 5-volt lamp. Since the photoconductive cell has no moving parts, there is no mechanical noise when it is used to vary the resistance of a circuit.

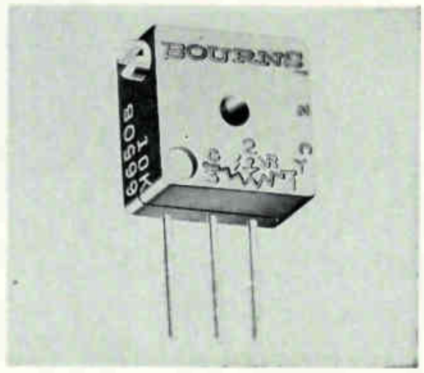
The new model is much more sensitive to changes in voltage than an earlier unit, type PL5B1. The cell resistance at 1 volt is 3,400 ohms compared to the prior model's 40,000 ohms at 1 volt. At 4 volts, the B2 model has a cell resistance of 64 ohms; the B1, 260 ohms. All the figures refer to initial resistances. The units degrade with time, with the biggest change occurring in the first 150 to 200 hours. Thus, life expectancy depends on the specific application.

The primary application is in low-level audio switching and potentiometry. The photoconductive cell is electrically isolated from the lamp, so the amount of hum from long lamp-control leads is negligible.

Other application areas are in volume expansion and compression and in automatic gain control circuits.

The unit is hermetically sealed in a metal package 0.65 inch in diameter and 0.35 inch high.

Adjustment pot measures ⅜ sq. in.



A microminiature adjustment potentiometer provides infinite resolution, has a standard resistance range of 2,000 ohms to 1 megohm and an operating temperature range of —65° to +170°C. The unit measures only ⅜ in. square and weighs approximately 0.1 oz.

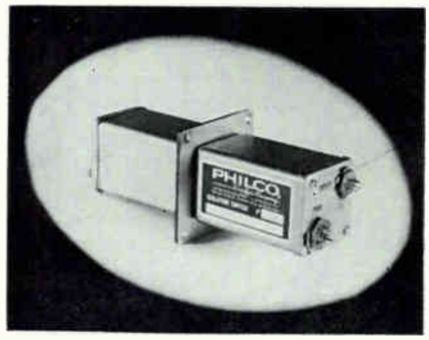
Resistance tolerance is ±10% standard; insulation resistance at 500 v d-c is 1,000 megohms minimum. Power ratings range from 1 w or 500 v maximum at 70°C ambient to 0 watt at 175°C ambient. Vibration, shock and load life per MIL-R-22097C are 30 g, 100 g and 1,000 hours respectively.

Model 3282 has positive wiper-stops at both ends of travel, and the wiper assembly idles at both ends of travel to prevent damage from forced adjustment. The model comes in five configurations.

Price is $5.20 each in 250 to 499-

piece quantities. Delivery is stock to 3 weeks.
Bourns, Inc., Trimpot division, 1200 Columbia Avenue, Riverside, Calif., 92507. [351]

Switch isolates extraneous signals



A switch that regenerates its timing signal is designed for applications that require extremely high levels of isolation to extraneous signals. Output-input isolation is in excess of 100 db (d-c to 1,000 Mhz). The same degree of input-output isolation is achieved within the signal passband with a signal-to-interfering-noise-margin of 20 db.

High isolation of the P651A switch is achieved with the L4450 photon-coupled isolator (PCI), a gallium arsenide infrared emitter coupled by a short shielded light path to a silicon photodetector. The L4450 PCI, housed in a stainless steel assembly for bulkhead mounting, is designed for rfi applications.

The P651A consists of an input circuit module that switches the incoming data-timing signals when a predetermined threshold is exceeded to appropriate levels for operating the L4450 PCI, and an output module that amplifies the detected PCI output and switches the output signal loop battery in a manner similar to a conventional solid state relay. The input and output interface characteristics are in accordance with MIL-STD-188B.

The unit has a bandwidth of 10 kilohertz with less than 1% distortion. However, there are no technical limitations for this type de-

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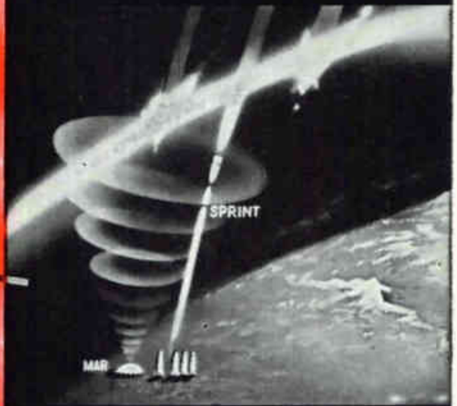
PORTABLE RADIO COMMAND PACK



MULTI-FUNCTION ARRAY RADAR

TRANSPORTABLE SAT COM TERMINAL

VISIBLE

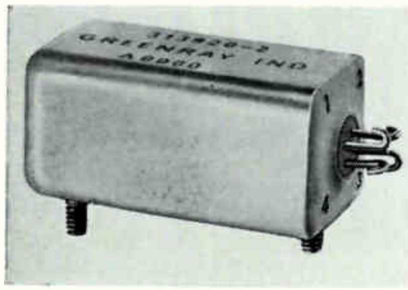
HIGH-POWER SINGLE-FREQUENCY LASER BEAM

vice for data rates through the h-f range.

The P651A switch is priced at \$330 in quantities of 1 to 9 with production quantities less than \$200. The L4450 photon-coupled isolator is priced at \$80 each in quantities of 1 to 9, and \$50 each in quantities of 100.

Philco-Corp., Microelectronics division, 2920 San Ysidro Way, Santa Clara, Calif. [352]

Crystal oscillator puts out 2.5 to 30 Mhz



Satellite and portable test equipment are two applications for a new crystal oscillator. The solid state device measures ¾ x ¾ x 1½ in. long, is hermetically sealed, meets military specs and is designed for a vibration of 20 g at 2 khz and shock of 100 g with an 11 msec pulse.

Fixed frequency output of model 105500-4 is 2.5 to 30 megahertz. Frequency tolerance over the —25° to +85°C temperature range is ±0.005%. Waveform is sinusoidal with 10% maximum harmonic distortion. Output is 0.5 v rms into a 1,000-ohm load; input, +15 v d-c, ±2% regulation.

Price is \$194 each in quantities of 1 to 3 units.

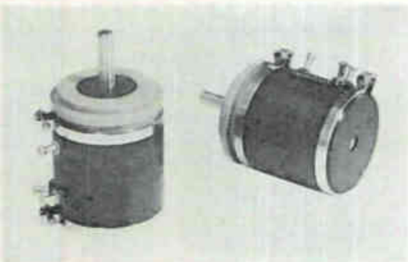
Greenray Industries, Inc., East Simpson Road, Mechanicsburg, Pa. [353]

Transformers change 3-wire data to 4-wire

Converting 3-wire information to 4-wire information is achieved with a new transformer that has an overall angular accuracy of ±30 seconds. The transformer is suited for synchro-to-resolver and resolver-to-synchro conversion equipment. It meets the requirements of MIL-T-27B. Input to the 3-wire transformer is 90 v rms at an impedance of 200,000 ohms minimum. The 4-wire output is 4.25 ±2% and impedance is less than 10 ohms with input shorted.

Size of the unit, type 9514, is $\frac{15}{16}$x15/16x¾ in.
Magnetics Inc., 6 Richter Court, East Northport, N.Y., 11731. [354]

Plastic housing cuts multiturn pot weight



Light weight and high mechanical strength are the characteristics of a new series of size 9 precision potentiometers that are multiturned and housed in plastic. According to the manufacturer, the short-length 3-, 5-, 10-and 20-turn devices cut more than 25% from the weight of comparable units with metal housings.

The housing is a precision, transfer-molded, glass-reinforced phenolic designed to meet MIL-M-14F. All the new units meet or exceed MIL-R-12934D for rotational and load life, high and low temperature operation, temperature cycling, high frequency vibration, shock, explosion, sand and dust, salt spray, power dissipation, temperature resistance characteristic and altitude.

The units designed for precision control and compact airborne instrumentation applications, are manufactured in standard resistance ranges from 1,000 to 30,000 ohms for 3-turns, 1,000 to 50,000 ohms for 5-turns, 1,000 to 100,000 ohms for 10-turns, and 1,000 to 200,000 ohms for 20-turns. They can be provided respectively with up to 12, 20, 30 or 40 accurately positioned taps.

Single gang, 3-turns units weigh 0.5 oz per cup and measure 0.682 in. in length to the servomounting register face; 5-turns weigh 0.6 oz and are 0.773 in. long; 10-turns are 1 in. long and weigh 0.7 oz; and 20-turns are 1.454 in. long and weigh 1 oz. Up to four caps can be ganged, each adding respectively 0.457, 0.548, 0.775 and 1.229 in. Stainless steel clamp bands permit precise phasing between cups.

Resolution for high resistance 10- and 20-turns ranges to better than 0.01%, with special linearities to better than 0.03%.

All units have precious metal wipers and contacts for low noise and high electrical integrity, encapsulated resistance elements, and the option of precision shaft ball bearings that reduce starting torque to well below 0.25 oz in. Technology Instrument Corp. of California, 850 Lawrence Drive, Newbury Park, Calif. [355]

Ceramic capacitor rated to 1 microfarad

Higher capacitance in a smaller package is provided by a radial-lead ceramic capacitor. The C12 Hi-D capacitances range from 0.18 μf to 1μf. The capacitor case measures 0.300 x 0.300 x 0.100 in. up to 0.47 μf, and 0.300 x 0.300 x 0.150 in. up to 1 μf.

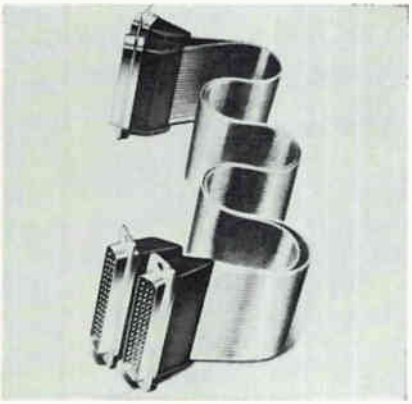
D-c working voltages are 50 v at 125° C for values from 0.18 to 0.27 μf and 25 v at 125° C for values from 0.33 to 1 μf. Operating temperature range is —55° to 125° C. Capacitance tolerance is ±10% standard, with 5% and 20% also available.

The use of a precision molded epoxy case provides both uniformity and excellent insulation. An epoxy end seal insures maximum bonding and moistureproofing for optimum performance. The C12 Hi-D meets all applicable requirements of MIL-C-11015.

The capacitors lend themselves to either soldering or welding through the use of 0.025-in. diameter nickel for lead material, per MIL-STD-1276 N-1.

U.S. Capacitor Corp., 2151 No. Lincoln St., Burbank, Calif., 91504. [356]

Compact, reliable flat-cable assemblies



The Flex-Weld flat-cable assembly consists of multiple ribbons of flat copper conductors uniformly spaced and laminated between Mylar or Teflon insulation, straight or corrugated. The flat cable can be terminated to itself or welded to any connector with a reliable all-welded technique. Since welding is performed through the insulation, stripping of the cable is eliminated. Flexible potting around the welded junctions prevent stress concentration where a change in cross section occurs in the termination area. The result is a durable termination that matches the flex-life of the flat cable.

Tests show Flex-Weld assemblies have higher reliability and longer flex-life than conventional round-wire cable, says the manufacturer. The company also claims that Flex-Weld assemblies offer up to a 50% combined size and weight reduction over comparable round-wire cable assemblies. The larger surface area of the flat conductors provides high heat dissipation.

Available with miniature, subminiature, and microminiature connector sizes, the flat cable product line can be adapted to present systems without special modification. Any shell configuration is offered including round, rectangular, or strip. Rfi shielding is optional.

Flex-Weld assemblies can be applied to gyro cables, digital data transmission lines, circuit-board jumpers, and in related applications where compactness and high reliability are necessary.

ITT Cannon Electric, a division of International Telephone and Telegraph Corp., 3208 Humboldt St., Los Angeles, Calif., 90031. [357]

Glass-encapsulated precision crystals

Higher Q, greater reliability and better frequency stability are offered by a series of miniature glass-sealed crystals than are obtained from crystal units in soldered containers.

The 76AX series units, measuring $\frac{1}{2}$ x $\frac{3}{8}$ x $\frac{5}{32}$ in., have aging rates of less than 1 part in 10^8 per day after initial stabilization, and are available in frequency ranges of 7.5 to 200 Mhz. They meet tolerances of 0.0025% over a temperature range of —55° to +105° C.

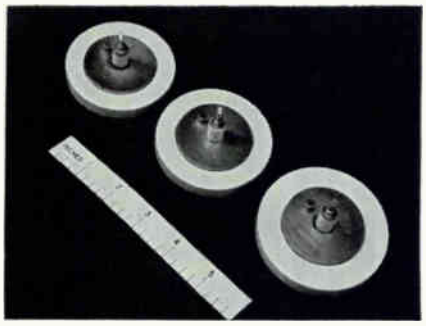
The new series is the equivalent of the HC-26/U leads and the HC-29/U pins.

Bulova Watch Co., Inc., 61-20 Woodside Ave., Woodside, N.Y., 11377 [358]

Trigger spark gaps handle high currents

A family of trigger spark gaps can be used as crowbars and to switch photoflash tubes. The gaps are ceramic-to-metal units capable of handling peak currents as high as 20 kiloamps.

The three spark gaps—TG-125, TG-126 and TG-127—have static breakdown ratings between the main electrodes of 15,000, 20,000 and 25,000 v d-c respectively. Minimum trigger voltage for the TG-125 is 6.3 to 3.5 kv d-c. For the TG-



126 it is 8.0 to 4.5 kv d-c, and for the TG-127 it is 9.7 to 5.2 kv d-c. The TG-125 and TG-126 are both rated for 300 joules, and the TG-127 is rated for 400 joules. All three have a delay time rating of 0.1 μsec.

These gaps are hermetically sealed and, the company says, exhibit excellent temperature characteristics. Height of the gap itself is 0.54 in. and over-all dimension from terminal to terminal is 1.56 in. Diameter of the TG-125 and TG-126 is 2.67 in. The TG-127 is 2.79 in. in diameter. The gaps are normally supplied with solder type terminals, although any conventional type of terminal can be provided.

Signalite Inc., 1933 Heck Ave., Neptune, N.J. [359]

Compactron triodes for color tv receivers

Two compactron beam triodes—the 6HS5 and 6EF4—have been developed for the high-voltage power supply of color tv receivers.

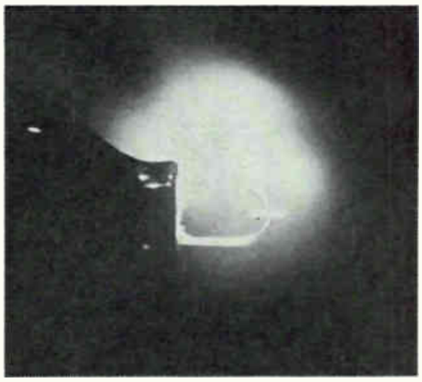
The 6HS5, a pulse-type regulator, was designed as a variable pulse shunt at the damping diode tap on the horizontal output transformer. It has a peak plate voltage rating of 5,500 v, a peak plate current rating of 325 ma and a plate dissipation rating of 30 w. Its amplification factor is 300 and transconductance is 65,000 μmhos at a plate current of 300 ma.

The 6EF4 is a low-current, high-voltage tube for use as a shunt regulator, shunting across the high-voltage d-c at the picture tube anode. It has a maximum d-c plate voltage rating of 27,000 v, a maximum d-c plate current rating of 1.6 ma and a maximum plate-dissipation rating of 40 w.

General Electric Co., Tube Department, Owensboro, Ky. [360]

New Semiconductors

Open-air diode emits light



The electroluminescent diode that sent the Norton Co. stock jumping [Electronics, Dec. 26, 1966, p. 35] is a rectangular parallelepiped of silicon carbide that is light-green in color, emits yellow light and comes in two sizes. A big advantage, the company reports, is that the diode need not be encapsulated, since silicon carbide is an inert refractory semiconductor material and can therefore operate in air.

One size, 0.030 x 0.030 x 0.15 inch, is aimed at adding sound to 8-millimeter movies; the other, 0.060 x 0.030 x 0.020 inch, is for 16-mm movies. Of the two diodes, the latter would probably be the better suited for such applications as recording data on film and in computer encoders.

For sound movies, the diode operates by converting the amplified current from a microphone into light which then "writes" the sound on ordinary film as the movie is taken. For computer encoders, the light from the diode would have to go to a detector, say, a solar cell, and then be routed through logic circuits that would convert the analog information into binary logic.

The diode's major advantage, the company says, should be reliability. While keeping details of their process secret, pending a patent application, the company reports the crystals are grown at 2,500° centigrade and the junctions are formed at 1,500°C. These figures indicate a long operating life at room temperature can be expected. Lifetime tests at military specifications haven't been completed, so exact figures aren't available; but one diode operated for more than 1,000 hours with a current of 60 milliamps, with no sign of degradation.

Leads can be attached to the top and bottom of the prism, but usually the company just attaches metal contact strips across the top and bottom of the crystal. All four open sides emit light. Some light is invariably lost, however, in any application requiring a single beam of light, where three of the four emitting sides must be covered.

The company is also studying the diodes as rectifiers in equipment subject to high ambient temperatures. The exact operating temperature range has not been decided yet, but Norton reports that one diode operated at 500°C for 72 hours and the final figures should be at least 300°C. The diode being made for movie cameras operates only to about 200°C.

Norton is not yet in mass production of the diodes. Developmental models are currently available for $100 each. Eventual prices, in quantity, should be in the $5 to $10 range, the company estimates.

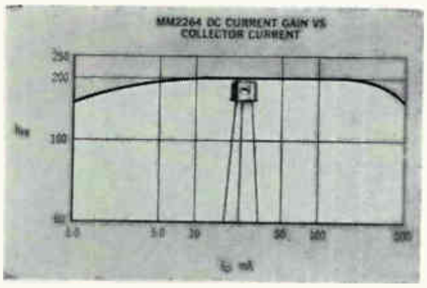
Specifications

Forward current	
typical	30 ma
maximum	About 100 ma
Total output light power	0.33 to 3.3 μw at 30 ma
Peak inverse voltage	10 to 20 v at 10 μa
Efficacy range	10^{-6} to 10^{-5} photons per electron
Capacitance at 0 bias	1,000 pf
Threshold voltage	2.5 v
Breakdown voltage	30v, d-c at −1 ma
Peak emission	5,400 to 6,200 At 30 ma
Series resistance	500 ohms, max

Norton Corporate Research Division, 70 Memorial Drive, Cambridge, Mass. 02142 [361]

Audio transistor handles over 1 watt

Flat beta, good thermal capabilities and a typical gain of 120 at a collector current of 150 ma, make the MM2264 transistor well suited for audio output stages in radios, tv



sets and as driver transistors in high power, high-fidelity entertainment circuits.

The wideband audio transistor offers high gain, low distortion, and more than 1 watt of audio power handling capability. The npn silicon device has flat beta characteristic over a collector current range of 1.0 ma to 500 ma, insuring linear operation in large signal audio amplifiers.

Thermal resistance between the junction and case, θ_{JC}, is less than 15°C/watt, a reduction of more than 50% for the TO-5 package. This low θ_{JC} is made possible by a solid steel header in the case and provides a power dissipation of more than 11 watts at a case temperature of 25°C. By comparison, a standard TO-5 packaged device would be rated at about 5 watts.

Specifications include a maximum collector-emitter voltage of 25 v d-c; maximum continuous collector current, 1.5 amps d-c; minimum d-c current gain (I_C = 150 ma d-c, V_{CE} = 1 v d-c), 70; current gain-bandwidth product, 50 Mhz.

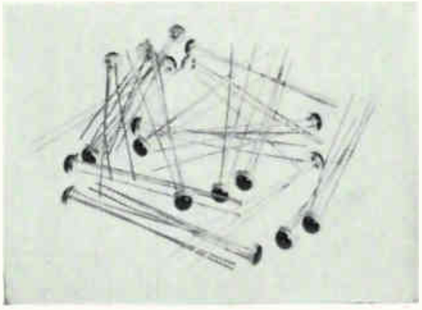
Price is $1.05 each in lots of 100 to 999.

Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix, Ariz., 85001. [362]

Silicon transistors for high-voltage use

By using a method of surface protection that yields low leakage currents under extended usage, the manufacturer is able to produce high-voltage, small-signal npn silicon transistors in quantity. The units meet all applicable paragraphs of MIL-S-19500.

Electrical parameters include a breakdown voltage (BV_{CBO}) ranging from 200 to 1,000 v, nominal current gain of 50 at 20 ma and a

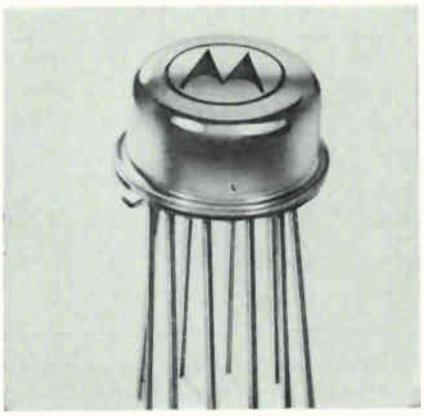


gain-bandwidth product of 20 Mhz.

The transistors, available in plastic-capped TO-46 packages, are intended as high-voltage switches for electroluminescent readout, as drivers for cathode-ray tubes, high-voltage amplifiers and as replacements for low-current silicon controlled rectifiers.

Prices start at $3.50 each in lots of 100. Delivery is from stock.
Micro Semiconductor Corp., 11250 Playa Court, Culver City, Calif., 90230. [363]

Versatile IC's priced for consumer products



Even less expensive than some transistors, the MC1550G integrated circuit r-f/i-f amplifier has a wide-variety of applications including narrow-band and wide band tuned amplifiers, oscillators, amplitude modulators and video amplifiers.

Automatic-gain-control voltage has little effect on the input impedance of the circuit and this prevents detuning of the input circuitry. In addition, when the device amplifies complex pulse waveforms (as in radar and television), the agc may be grounded for maximum gain.

Other features include low internal feedback (y_{12} <0.001 mmho) to insure easy alignment and high stability, high power gain (30 db at 60 Mhz) and low noise figure (5 db at 60 Mhz). They combine to bring high quality performance in the consumer product price range.

Price of the IC is $2.85 each in quantities of 100 and up; delivery is from stock.

Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz., 85001. **[364]**

High-power rectifiers use matched diodes

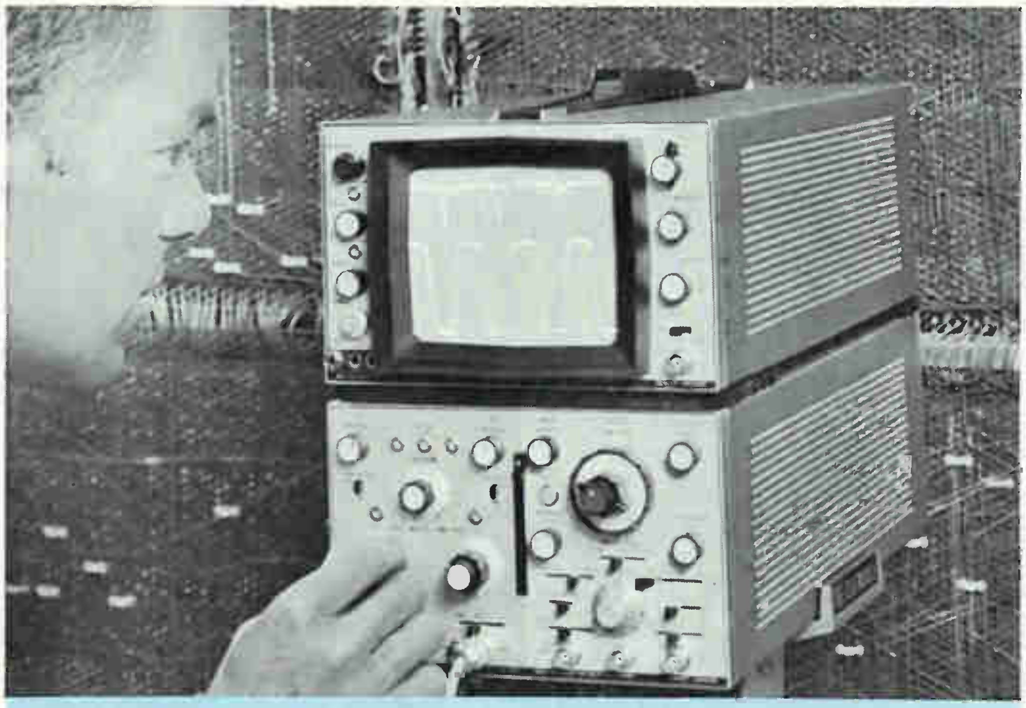
A series of rectifiers has been designed for use in battery chargers, welders, power supplies, electroplating equipment or any other requirement for high-current rectification. Rated at up to 500 amps at from 50 to 1,200 v, the unit combines two matched, time-proven diodes mounted on a compact high-mass heat sink measuring only 3 in. square.

The matched high-power diodes eliminate the need for further testing and matching by the customer. The built-in heat sink ensures temperature stability, effective cooling and ease of mounting and handling.

Cost savings are realized through low device cost per ampere rating; savings in selection, test and assembly time; and savings in handling, mounting and inventory costs, according to the manufacturer.

Prices of the 500UDF units range from $30 to $168 each in lots of 25 to 99.

International Rectifier Corp., 233 Kansas St., El Segundo, Calif., 90245. **[365]**



NEW hp 180A OSCILLOSCOPE

You can *see more, do more* with this 30-pound oscilloscope that goes anywhere—field, laboratory, or production line. Designed from the user's viewpoint in, this new dual-trace 50 MHz scope is packed with new ideas and innovations to give you big picture CRT, plug-in versatility, step-ahead all-solid-state performance, minimum weight and rugged design. These features add up to *more total performance, more usability than any other scope on the market!*

The hp 180A mainframe is the first with power supplies specifically designed for solid-state circuitry—gives you full performance benefits from solid-state devices in all present and future plug-ins. With hp's all-new big-picture 8 x 10 cm CRT, you have an extra-large display area —get bigger displays, make accurate measurements easier!

Vertical amplifiers drive the CRT vertical deflection plates directly, allowing even greater bandwidth capabilities in future plug-ins. Vertical amplifiers have low drift FET input stages for accurate DC measurements . . . plus quick 15-second warm-up. Time base plug-ins offer new easy to use delayed sweep for examining complex waveforms in detail. Tunnel diode triggering circuits lock in waveforms to 90 MHz. Exclusive hp mixed sweep feature combines display of first portion of trace at normal sweep speeds, and simultaneously expands trailing portion of trace at faster delayed sweep speed to allow magnified examination.

See the back of the actual size color photo at the right for abbreviated specifications and price. For full specifications and a demonstration of how you can *see more, do more* with this new, versatile, go-anywhere scope, call your nearest hp field representative. Or, write to Hewlett-Packard, Palo Alto, California, 94304. Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

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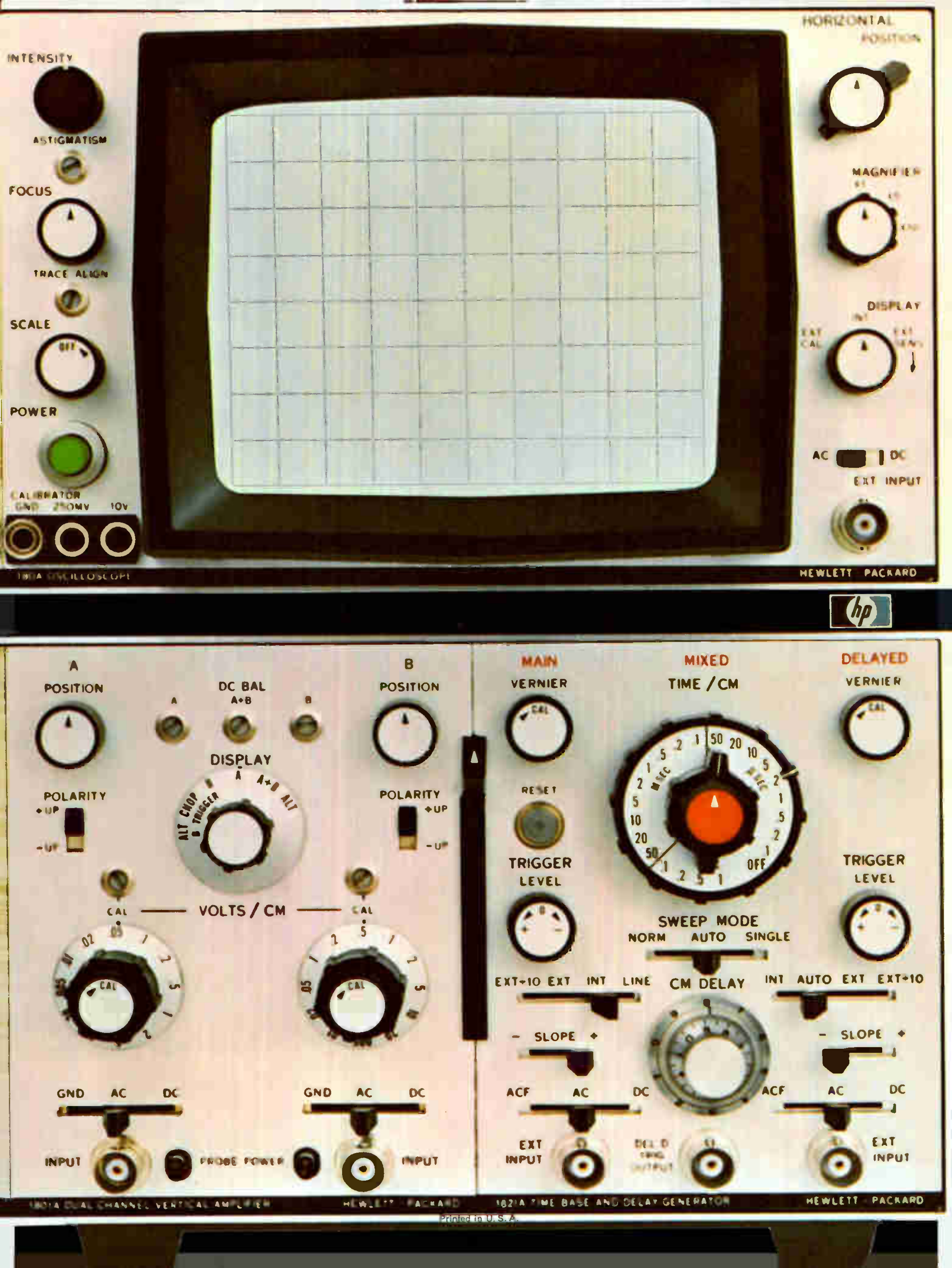
An extra measure of performance

SEE MORE! DO MORE!

Tear out actual photo of 180A Oscilloscope. Set it on your bench. See what the big picture display will mean to your work.



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hp 180A Oscilloscope

is shown here ACTUAL SIZE:

COMPARE DISPLAY!

See how the new 180A Big Picture Display can make it easier for you to get accurate measurements. Punch out this actual size CRT area on the perforations. Place the punched-out portion over the screen of your existing high-frequency scope. You will find the hp 180A Oscilloscope has 30% to 100% larger viewing area for easier-to-see, easier-to-read traces!

COMPARE SPECIFICATIONS! (Condensed)

180A Oscilloscope

Horizontal Amplifier:

External Input: DC coupled, dc to 5 MHz; AC coupled, 5 Hz to 5 MHz. Input RC, 1 megohm shunted by approximately 30 pf.

Sweep Magnifier: X1, X5, X10; magnified sweep accuracy ±5%.

Calibrator: 1 kHz square wave, 250 mv and 10 v p-p, ±1%.

Cathode-ray Tube: 8 x 10 cm parallax-free internal graticule marked in centimeter squares. Post-accelerator tube, 12 kv accelerating potential; aluminized P31 phosphor.

Beam Finder: Pressing Beam Finder control brings trace on CRT screen.

Intensity Modulation: Approx. +2 volts, dc to 15 MHz, will blank trace.

Active Components: All solid state, except CRT.

Environment: 180A scope with plug-ins operates within specs over the following ranges. Temperature: −28°C to +65°C. Humidity: To 95% relative humidity to 40°C. Altitude: To 15,000 ft. Vibration: Vibrated in three planes for 15 min. each with 0.010" excursion from 10 to 55 Hz.

Power: 115 or 230 volts, ±10%, 50-1000 Hz, 95 watts, convection cooled.

Dimensions: Cabinet, overall dimensions with feet and handle: 8" x 11" x 22½" deep. Rack mount: 5¼" x 19" x 19½" deep behind front panel.

Weight: With plug-ins, net 30 pounds.

Outputs: Main and delayed gates, main and delayed sweeps.

Accessories Furnished: Two 10:1 voltage divider probes, mesh contrast filter.

Price: Without plug-ins, Model 180A, $825.00; Model 180AR (rack), $900.00.

1801A Dual Channel Vertical Amplifier

Modes of Operation: Chan. A alone; Chan. B alone; Chan. A and B displayed on alternate sweeps; Chan. A and B displayed by switching at 400 kHz rate, with blanking during switching; Chan. A plus Chan. B (algebraic addition).

Deflection Factor (Sensitivity): 0.005 v/cm to 20 v/cm; attenuator accuracy, ±3%.

Bandwidth and Rise Time: DC coupled, dc to 50 MHz; AC coupled, 2Hz to 50MHz; rise time, <7 nsec.

Input RC: 1 megohm shunted by approx. 25 pf.

Polarity Presentation: + or − Up.

Triggering: Provides sufficient signal to the time base to trigger from dc to 50 MHz.

Price: Model 1801A, $650.00.

1820A Time Base

Sweep Range: 24 ranges, 0.05 μsec/cm to 2 sec/cm in a 1,2,5 sequence; accuracy, ±3%; to 5 nsec/cm with X10 magnifier. Also single sweep.

Triggering:

Internal: See vertical amplifier.

External: dc to 50 MHz from signals 0.5 v p-p, 90 MHz with 1 v p-p.

Automatic: Bright base line displayed in absence of input signal. Triggers from 40 Hz to >50 MHz.

Trigger point and slope: Controls allow selection of level and pos or neg. slope; trigger level on external signal adjustable ±5 v, ±50 v in ÷ 10 position.

Coupling: AC, DC, ACF.

Variable Holdoff: Permits variation of time between sweeps to allow triggering on asymmetrical pulse trains.

Price: Model 1820A, $475.00.

1821A Time Base and Delay Generator

Main Sweep: 22 ranges, 0.1μsec/cm to 1 sec/cm in 1,2,5 sequence; accuracy, ±3%; to 10 nsec/cm with X10 magnifier. Also single sweep.

Triggering:

Internal: See vertical amplifier. External: dc to 50 MHz from signals 0.5 v p-p, 90 MHz with 1 v p-p.

Automatic: Bright base line displayed in absence of an input signal. Triggers from 40 Hz to >50 MHz.

Trigger point and slope: Controls allow selection of level and pos. and neg. slope; trigger level on external signal adjustable ±5 v, ±50 v in ÷ 10 position. Coupling: AC, DC, ACF.

Trace Intensification: Used for setting up delayed or mixed sweep. Increases in brightness that part of main sweep to be expanded full screen in delayed sweep or made magnified part of display in mixed sweep.

Delayed Sweep: Delayed time base sweeps after time delay set by main sweep and delay controls. 18 ranges, 0.1μsec/cm to 50 msec/cm in 1,2,5 sequence; accuracy, ±3%.

Triggering: Applied to intensified Main, Delayed, and Mixed Sweep modes. Automatic: Delayed sweep starts at end of delayed period. Internal, External, Slope, Level, and Coupling: same as Main Sweep.

Delay Time: (before start of delayed sweep): Continuously variable from 0.1 μsec to 10 sec; accuracy, ±1%; linearity, ±0.2%; time jitter. <0 005% of maximum delay of each range.

Trigger Output: (at end of delay time): approx. 1.5 v pulse.

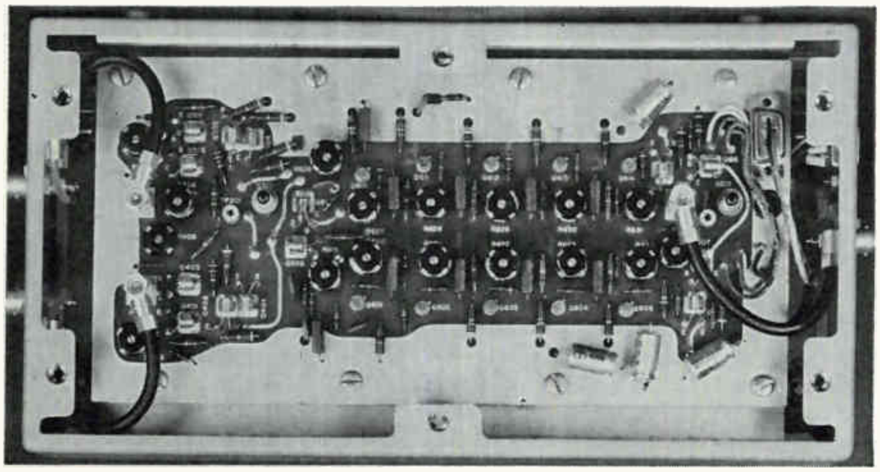
Mixed Sweep: Dual sweep display in which main sweep drives first portion of display and delayed sweep completes display at speeds up to 1000 times faster.

Price: Model 1821A, $800.00.

HEWLETT hp PACKARD

An extra measure of quality

Multiplying voltages in less than a usec



Borrowing from two standard methods of signal multiplication—the time-division method and the instantaneous method—Bendix Corp.'s Radio division has built an analog voltage multiplier that benefits from both. The instrument has the higher accuracy—±1% of full scale—of the first method and the higher frequency capabilities—up to 3.5 megahertz—of the latter. It has a multiplication time of only 0.12 microsecond.

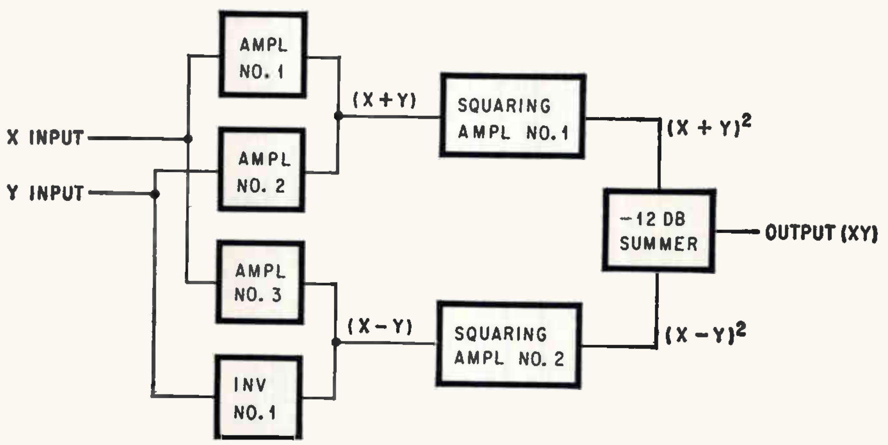
A high frequency passband is possible, Bendix says, because its solid-state amplifier circuits perform the quarter-square computation,

$$\tfrac{1}{4}[(x+y)^2 - (x-y)^2]$$

to obtain the product of the two input voltages.

The four-quadrant device can accept input voltages ranging from —2 to +2 volts. The input signals are first applied to adder-amplifier circuits. Two amplifier circuits produce the x + y term by adding their current signal outputs in a common resistor; an amplifier and inverter combine their current outputs in a resistor to form the x — y term. These four amplifiers are linear, voltage-fed direct-coupled units with closely matched gain and linearity characteristics. The sum and difference signals are then fed to squaring circuits—direct coupled translator circuits which produce square law outputs from linear inputs. The outputs of the two squaring circuits are then coupled to a 12-decibel loss adder which produces the difference of the squared terms and simultaneously divides by four to form the xy product signal.

Originally developed to handle cross-correlated video data for ra-



←Circle 204 on reader service card

Circle 205 on reader service card

dar, the multiplier is currently being used by Bendix in pattern recognition, where the main problem is handling large quantities of data quickly and high accuracy is not needed. The company also sees application in control systems.

The accuracy of the measured output voltages will be best when the inputs, either positive or negative, are close to the ends of the voltage range because of the ±1% of full-scale accuracy, or ±0.02 volt. To obtain the full accuracy, the power supplies must be regulated to better than 0.05%.

The unit is operated simply by connecting power supply voltages to it and plugging in the x and y input signals and the xy output load to the appropriate jacks. There are no operating controls. However, each day the d-c voltages should be checked and, if necessary, calibrated.

Developmental models of the signal multiplier cost $3,500; delivery time is two months.

Specifications

Accuracy	±1% of full scale, or ±0.02v
Input voltage	0 to ±2v d-c
Input power	±8 or ±20v d-c; 0.05% regulation
Operating temperature range	0° to 60°C
Size	2¾ x 6¼ x 12 in.

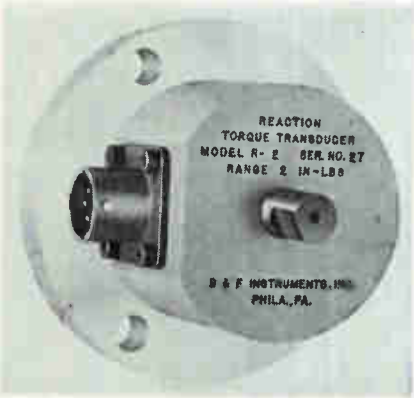
The Bendix Corp., Radio Division, Towson, Md. [371]

Transducers measure reaction torque

The speed of rotation of a machine no longer limits the performance of a torque measuring transducer. A new fixed-shaft transducer attaches directly to the housing of the machine under test.

By using semiconductor gauges as the sensing elements, the model R reaction torque transducers produce an output of 250 mv d-c at rated torque for an input of 6v. A choice of six torque ratings is offered: 2, 5, 10, 20, 30 or 60 in.-lbs. Linearity of output signal is ±0.25%.

The transducer measures reaction torques exerted by the housing of an operating rotary device. The

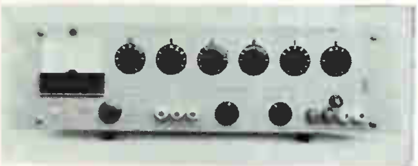


transducer shaft does not rotate—it is fixed to the transducer base. To measure reaction torque, the transducer is bolted to a rigid structural member and the transducer shaft is coupled to the housing of the rotary device.

The reaction transducers employ no bearings, slip rings or brushes and thus eliminate problems of wear inherent in rotating-shaft torque transducers.

B&F Instruments, Inc., 3644 N. Lawrence St., Philadelphia, Pa., 19140. [372]

Accurate, ultrastable power reference source



An ultraprecision, solid state power reference source is stable to within 0.001% over a 100-hour period. Outputs from 0 to 60 v, at currents up to 2 amps, are selectable on direct-reading digital dials. Line and load regulation is 0.0001%.

Absolute accuracy of the model TC-260R is within 0.01% of setting and the resolution capability is 20 μv. Temperature stability over an ambient temperature range of 15° to 35°C is within 5 ppm/°C. Output impedance at d-c is less than 10 microhms, and combined a-c components in the output (hum, noise, ripple, transients, etc.) are less than 50 μv rms at any output level.

Standard features include provisions for remote programing and sensing, as well as automatic cur-

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rent limiting and complete short-circuit protection.

The accuracy, stability and regulation of the model TC-260R are obtained through the use of an accurate, stabilized and temperature-controlled internal reference, and a high-gain chopper-stabilized feedback amplifier. The chopper amplifier has an open loop gain of 5x10^6, falling off no faster than 6 db/octave to unity gain. This insures low output impedance while retaining fast transient response—25 μsec recovery time—without ringing.

Price is $1,250; delivery, approximately 30 days.

Princeton Applied Research Corp., P.O. Box 565, Princeton, N.J., 08540. **[373]**

Frequency synthesizer covers 470 to 1,000 Mhz

A solid state frequency synthesizer directly covers the range of 470 to 1,000 Mhz and eliminates the problem encountered with low frequency synthesizers. The l-f synthesizers require multiplication of the output frequency, with corresponding increase in noise and unwanted spurious levels.

The output frequency is derived from two components. The frequency of the crystal-controlled standard can be locked in 10-Mhz steps. The other is furnished by an interpolation oscillator which is tunable within these steps. Resolution is 5 khz (0.5 hz with ND30M synthesizer used as a vernier).

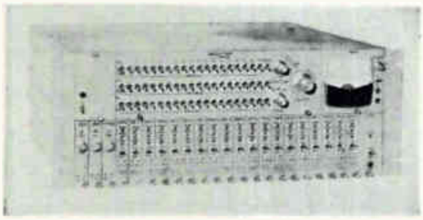
The built-in frequency standard is accurate in 2 parts in 10^9. It can also be operated from an external 12-v battery.

Output voltage of type XUC synthesizer into 50 ohms is continuously adjustable or adjustable in steps and between 250μv and 1.5 v. The suppression of nonharmonic spurious frequencies is more than 80 db; spurious frequency deviation is less than 0.5 hz. Frequency fluctuations due to external influences (within the tolerable limits of supply voltage, supply frequency and ambient temperature) are less than 2x10^{-9}. The mean daily frequency drift after constant use is less than 1x10^{-9}.

Type XUC is equipped for mounting in 19-in. racks and, with the exception of five uhf disk-seal triodes, uses transistors. Delivery is from stock at $7,705.

Rohde & Schwarz, P.O. Box 148, Passaic, N.J., 07055. [374]

Instrument generates f-m multiplex signals



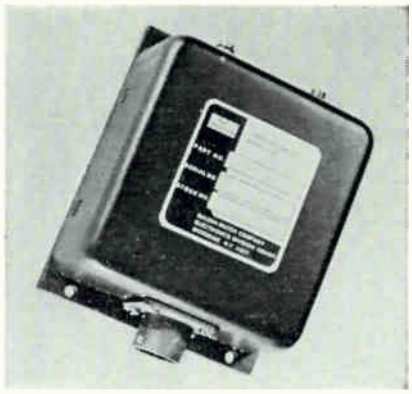
An f-m multiplexer has been developed for data acquisition or for use as a versatile test instrument in a telemetry ground station. Model 48 contains nineteen S-24 voltage-controlled oscillators and an S-41 voice annotator which provide the means for generating three independent composite f-m multiplex signals. The unit features an S-48 switch panel enabling each vco output to be independently switched into any one of the three S-29 amplifiers contained in the unit. An S-42 voltmeter is provided for monitoring all vco input and output signals.

Subcarrier frequencies between 300 hz and 1.2 Mhz, with peak deviations of 1% to 16%, can be provided through the use of plug-in channel selectors. The vco's have a linearity of better than $\pm 0.05\%$ of bandwidth and stability of $\pm 0.05\%$ of center frequency.

Model 48 f-m multiplexer fulfills the functions of an auxiliary signal mixer, data-insertion converter, signal simulator or f-m calibrator.

Sonex, Inc., 20 E. Herman St., Philadelphia, Pa., 19144. [375]

Line drive amplifier offers adjustable gain



Model 274 line drive amplifier offers a continuously adjustable gain from 1 to 1,000, a frequency response within ±1.0 db from 3 hz to 15 khz, and an input impedance greater than 500 megohms.

The unit requires a +28 v ±15%, 40 ma maximum power supply. Output is 5 v rms minimum driving through 1,500 ft of cable terminating in a 10,000 ohm load. Linearity is within 1% from best straight line, and noise is less than 25 μv equivalent input with 0.001 shunting input. Distortion is less than 1% and gain stability is within ±0.2 db. Operating temperature range is —55° to +125°C.

Price in small quantities is $175 per unit, with delivery in 8 to 10 weeks.

Bulova Watch Co., Inc., 61-20 Woodside Ave., Woodside, N.Y., 11377. [381]

H-v bench supplies in half-rack package

High-voltage d-c power supplies feature all-silicon circuitry in a convenient, half-rack package. They are more compact than equivalent-rated competitive supplies by a factor of three to five, according to the manufacturer.

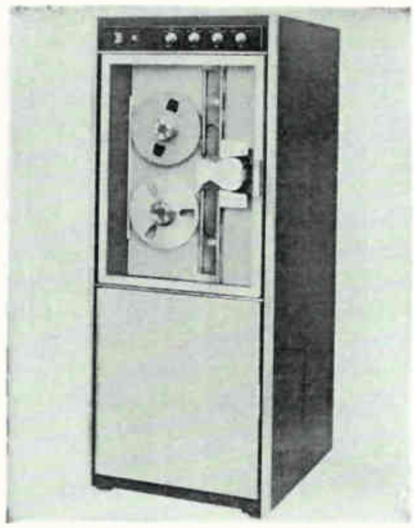
Model 6515A, only 3½ in. high, has an output of 0 to 1,600 v d-c, 0 to 5 ma; and the 6516A, 5¼ in. high, has an output of 0 to 3,000 v d-c, 0 to 6 ma. Load regulation is 0.01% or 16 mv and line regulation is the same.

The supplies have low ripple and noise, and are short circuit-proof. A 10-turn vernier permits full adjustment with 100 mv resolution over each voltage span—no blind spots.

The units are suited for high-voltage experiments and circuit development. They are also said to be ideal for use as general-purpose d-c high-voltage sources, and for photomultiplier applications.

Hewlett-Packard, Harrison division, 100 Locust Ave., Berkeley Heights, N.J., 07922. [382]

Medium-performance digital transport



Designed for applications requiring moderate data transfer rates, the model MT-36 magnetic tape transport is suited for use with small and medium scale computers, in mass storage and sequential access applications for which high-priced, high-performance transports cannot be justified. The unit offers unrestricted tape speeds to

50 in. per sec at densities to 800 bits per in. It is qualified to meet Federal Standard 222 and MIL-16910A.

The complete system consists of the tape transport assembly, manual control unit, and a model MA-310 read/write electronic package. It is completely compatible with IBM systems, such as the 729 and 2400 series. Other conventional tape formats on either ½- or 1-in. tape are also available.

The unit has smooth start-stop profiles and no program restrictions over a command frequency rate up to 200 per sec.

Potter Instrument Co., Inc., 151 Sunnyside Blvd., Plainview, L.I., N.Y., 11803. [383]

Differential amplifier with multiple outputs

Four simultaneous outputs from a single input signal are provided by the model 7202 differential amplifier. The multiple outputs are of sufficient power to drive computers, tape recorders, and galvanometers. Galvanometer output provides a ±10 v into a 100-ohm load; each of the other three outputs are capable of providing a ±10 v into 1,000-ohm loads. Gain accuracy over the entire gain range is ± 1%.

A 10,000-ohm input impedance rating, individual direct-reading gain controls for each output, high common-mode rejection, and maximum input-to-output isolation features are claimed to make the model 7202's per-channel cost the most economical presently available.

Additional features include re-

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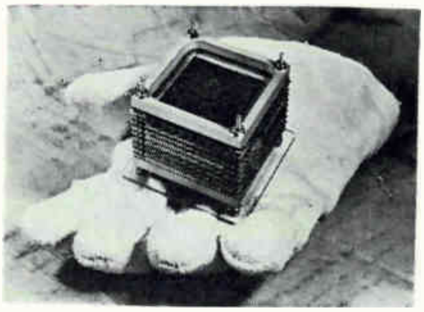
cessed adjustment screws to offset each output signal positively or negatively, and a turns-counting dial on the front panel to regulate signal gain from 0 to 2.5. Input connectors may be reversed to provide inverting or noninverting gain polarity.

Dynamics Instrumentation Co., 583 Monterey Pass Road, Monterey Park, Calif., 91754. **[384]**

Core memory stack has high reliability



A rugged, militarized core memory stack bypasses inherent reliability problems of current memory stacks, according to the manufacturer. It provides greater system tolerances, higher resistance to shock, and built-in temperature dissipation. It stores the same amount of information in only two-thirds of the space compared with an ordinary memory stack.

Called Semstak (severe environmental memory system) it is designed for airborne and space applications where high reliability, low weight and small volume are prime considerations. The unit's construction has no bus wire connections found in many other printed-circuit-board stacks. Such connections are said to be a common source of stack failures. Planes are interconnected with half the number of solder joints usually required, using a proprietary design with etched finger contacts. In addition, the design increases solder joint reliability with a compression technique.

A built-in heat sink prevents temperature gradients within the stack from varying the output voltage, which could cause information to be lost or misinterpreted. Temperature dissipation keeps all cores within 10°C of each other regardless of power or temperature changes.

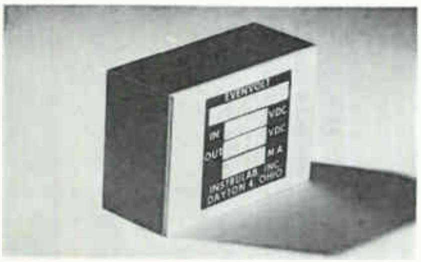
The unit can withstand vibrations that impose 30g's at 2,000 hertz. It meets applicable temperature, shock and vibration requirements of MIL-E-5400 and operates over a temperature range of —55°C to +125°C.

A typical Semstak containing 4,096 words of 24 bits each, and built with 30 mil cores, measures only 3 x 3 x 2 in. and weighs only 18 ounces. The planes are stacked only ½ in. apart, instead of the conventional ⅛ in.

The stack is available with capacities up to 16,384 words of any bit length.

Electronic Memories, 12621 Chadron Ave., Hawthorne, Calif. [385]

Reference source boasts high stability



A voltage reference source designated model 771-PK-50 is a result of seven years of design and development in zener circuitry techniques, according to the manufacturer.

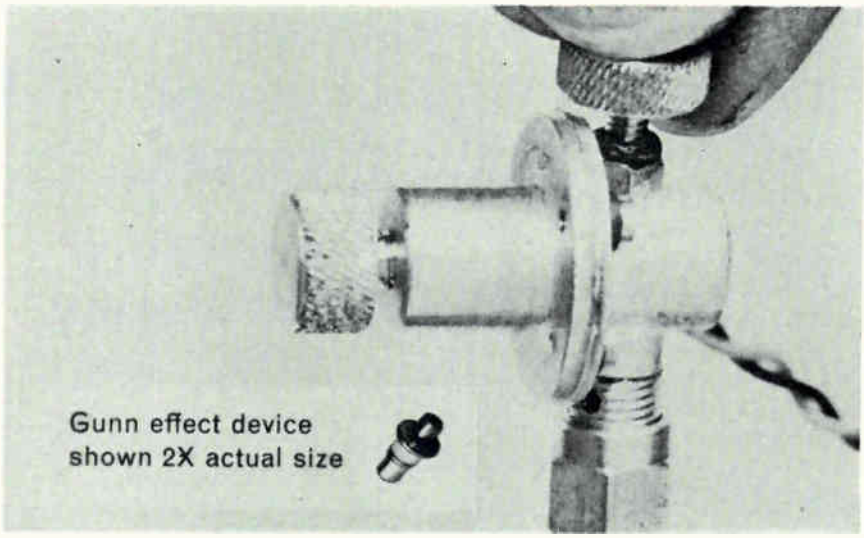
The device has an input voltage of 30 v d-c ±1% at 30 ma maximum; output voltage, 12.6 v d-c ±5%; output current, 100 μa; temperature coefficient, 0.00015%/°C referred to 35° over a range of 20° to 50°C; output regulation, 10μv maximum output change per 1% input change; short-term stability, 0.0005% per 24 hours; long-term stability, 0.0018% per 6 months; and noise, 25μv peak to peak maximum, d-c to 50 khz.

Prices range from $75 to $150 each, depending on the customer requirements.

InstruLab, Inc., 1205 Lamar St., Dayton, Ohio, 45404. [386]

New Microwave

Oscillator Gunns up to 12 Ghz



Gunn effect device shown 2X actual size

Britain may turn out to be the winner in the race to produce a commercially feasible Gunn-effect oscillator, "brain drain" notwithstanding. An American firm was the first to offer such a device [Electronics, Aug. 8, 1966, p. 221] but took it off the market when no oscillator functioned for more than 24 hours.

Reliability data for the new Gunn device is not available, but the manufacturer says that operating life "is expected to be at least 1,000 hours at its continuous rating of 5 milliwatts output."

The oscillator is the product of Mullard, Ltd., a British subsidiary of Philips Gloeilampenfabrieken NV, and is being marketed in this country by Mullard, Inc. It is designed to operate at frequencies from 7 to 12 gigahertz and requires only a 6-volt supply.

The British Royal Radar Establishment cooperated with Mullard in developing the device. One of the researchers at the radar lab has used the oscillator in a tiny low-power radar transmitter. Other possible applications include the mixer stages of microwave communication links, bench-top microwave systems for teaching demonstrations and medical radar pills for gastrointestinal diagnoses.

Gunn-effect oscillation results when an electric field exists between the two faces of a thin slice of gallium arsenide. When the slices are thinned by a grinding and lapping, maximum operating frequency is about 4 Ghz.

However, Mullard uses epitaxial deposition that allows a very thin layer of high-resistivity GaAs to be formed on a thicker slice of the low-resistivity material. The device's active element is the high-resistivity layer, with the Gunn effect occurring throughout the layer. The company claims that the epitaxial technique not only increases the device's operating frequency, but also offers higher power dissipation and greater control of resistance in a given resistivity layer.

Others, including the Bell Telephone Laboratories, Inc., are also using epitaxial deposition to make experimental oscillators. Mullard reports its process is similar to that used by Bell Labs.

The ceramic-encapsulated device, 5 millimeters long and 3 mm in diameter, is operated by coupling it into a simple microwave cavity. It will oscillate both with fixed-frequency cavities and with those that are tuned over the entire frequency range.

Specifications

Operating frequency	7 to 12 Ghz
Operating voltage	6 v
Continuous power output	5 mw
Peak power output	20 to 30 mw
D-c current	150 ma, typ.

Only developmental models are available right now. In sample quantities, the price is about $175, with a four- to six-week delivery time.

Mullard, Inc., 100 Finn Court, Farmingdale, N.Y. [391]

Pulse source generates high peak power

A microwave signal source designated PG5K features plug-in r-f heads and a solid state power supplier. It can generate up to 5 kw over any band in the 150 Mhz to 2,350 Mhz region, with lesser powers up to 6,100 Mhz.

The PG5K uses the grid pulsing techniques to save space and weight. It will fit into a standard 19-in. rack and is 8¾ in. high.

Units are in initial production and will soon be available from stock.

Applied Microwave Laboratory, Inc., Andover St., Andover, Mass., 01810. [392]

Continuously variable coaxial attenuator

A continuously variable attenuator that has a power capacity of 5 w c-w measures ½ cu in. and weighs only about an ounce. Frequency range is 5.2 to 10.9 Ghz and attenuation range, 0 to 10 db minimum.

The unit, a model 6604-10, is supplied with miniature APM type connectors that mate with a 1.41 in. diameter coaxial line connector such as OSM and BRM.

Maximum vswr is 1.50; maximum insertion loss, 0.5 db.

Price is approximately $300, and small quantity delivery is eight weeks or sooner after receipt of order.

Antenna & Radome Research Associates, Inc., 27 Bond St., Westbury, N.Y. [393]

New Production Equipment

Putting IC's to the test

A $28,000 tester for integrated circuits operates so speedily and simply that, says the manufacturer, in a production line it is more economical than a pair of $10,000 manual testers.

Texas Instruments Incorporated explains that with the machine an unskilled operator can make an IC test in only 8 milliseconds. The machine can also be programed for test times of 20 msec, 100 msec and indefinite (hold).

Turnaround time, or the time needed to change from one setup to another, is almost eliminated since test programs are run from a punched Mylar or paper tape. In addition, TI says, several test stations can operate from a single tester through multiplexing.

The model 668 test system can perform d-c and diagnostic tests for almost any type of IC or logic module. It can be used to probe slices and can fully test complex arrays instead of merely giving representative readings.

The programing input is a 1,000-character-per-second optical reader. A variable word-length program allows unlimited data to be entered serially. Each function is coded with a letter address for lead identification that is then followed by three to seven digits of numerical data.

A switch on the control chassis identifies the program and can also be used to manually program one instruction at a time for special testing. Any device lead can be programed to any d-c stimulus, ground, load resistor, detector, internal or external buss line or diode for clamping—under either momentary or static conditions.

There are three pass and nine fail categories. When devices are being classified, the most severe tests are run first. As soon as a chip or device passes all the tests in one class, a "home on pass" step can return the program to the beginning and commence testing the next unit. For example, class B tests are skipped on devices that have proved to be class A in quality.

It is also possible to program

in "home on fail"—if a device fails, for instance, test number eight, the remaining tests aren't performed. For debugging tapes, checking developmental models or checking the test itself, a "stop on fail" step allows close scrutiny at the point of failure.

The basic system consists of a chassis for the tape reader and power supplies, another for program-decoding logic circuitry and a stimuli and matrix chassis.

Specifications

System leads	10 d-c, expandable to 16
Voltage ranges	0 to ±3.99 v in 1 mv steps; 0 to ±39.99 v in 10 mv steps, both 390 ma max
Operating temperature range	15° to 35°C
Humidity	Less than 75%
Size	22x30x36 inches
Weight	400 lbs.
Table area	4.5 sq ft.
Power	100-125 v, 50 or 60 hz, 700 va

Texas Instruments Incorporated, Apparatus Division, Box 66027, Houston, Texas 77066 [401]

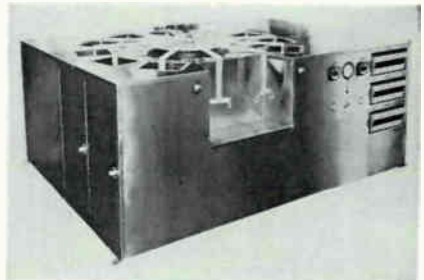
Encapsulation molder for components makers

A portable press, designated model EP-200, is suited for both prototype and production molding encapsulating of electronic components such as resistors, transistors, transformers, coil, semiconductors, integrated circuits and various electronic modules.

The EP-200 operates on shop line press and 100 v a-c and features controls for pressures, timing, and temperature control. Shorter lead times and inexpensive prototype tooling are among the many advantages this press offers, according to the manufacturer.

The unit occupies a bench area of 10 x 14 in. and is 28 in. high. Rolenn Manufacturing Co., 3151 Kansas Ave., Riverside, Calif. [402]

Ultrasonic cleaners are program-controlled



Rotary cleaning and processing systems feature program control and offer the option of either pneumatic or hydraulic operation. The equipment can incorporate ultrasonics at 25 khz or 40 khz to provide fast, thorough cleaning of semiconductors, optical components and many other precision or critical parts.

The basic material handler has a maximum of five moving parts which insures a minimum of maintenance downtime.

Program controls provide differential insertion and withdrawal speeds to and from the cleaning tanks; short-stroke vertical agitation or dwell during the immersion phase and a secondary dwell above the liquid for drying or vapor cleaning.

The systems are designed with 6, 8, 10, 12 and 14 stations. Tank openings range in size from 6x6 in. to 24x24 in., capable of handling work loads up to tons per hour.

Rotary cleaning systems are available with remote service racks for white room installations where all pumps, filters and auxiliary equipment are mounted in the service area outside the white room. This makes routine maintenance easier and minimizes the possibility of introducing contamination into the critical area. Integrated systems in laminar flow enclosures meeting Federal Standard 209 are

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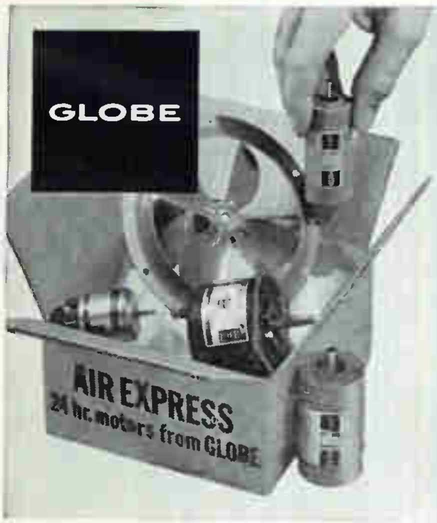

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	230A107-4	1 6"	4.3"	19.0	60	115 a.c.	1	60
CMC°	144A110-2	1.2"	2.7"	.7	3,600	115 a.c.	1	60
	144A110-4	1.2"	2.7"	.7	1,800	115 a.c.	1	60
UC**	186A101-5	2.3"	2.4"	3.0	1,500	115 a.c.	1	60
	186A111-5	2.3"	2.4"	2.5	1,800	115 a.c.	1	60
UCL	186A112-1	2.3"	3.4"	6.5	3,600	115 a.c.	1	60
CMM	235A106-1	1.3"	2"	.5	17,500	24 d.c.	—	—
CLL	313A102-1	1.3"	2$\frac{3}{32}$"	1.0	11,300	24 d.c.	—	—
SS-91	Screamer	0.9"	1.4"	.1	40,000	12 d.c.	—	—

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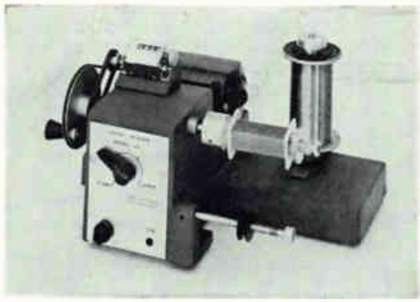
also available.

Prices range from $8,000 to $35,000 depending on the number of stations, size of tanks and the amount of auxiliary equipment.
Branson Equipment Co., 51 Terminal Ave., Clark, N.J. [403]

Portable coil winder sets up rapidly



A low-cost portable coil winder features smooth-action, electronic-control motor drive, digital turns counter and extended capability for winding fine wire. The precision mechanical structure is a unit aluminum casting.

Model 4A hand-fed winder is engineered for laboratory and prototype winding of wire and filament on round or square bobbins and tubular forms. It winds electronic coils for ferrite pot cores, C-cores, rods, or laminated core stacks.

Set-up time is under 2 minutes for typical jobs. All accessories are supplied with the machine. Bobbins and wire supply spools are held between machined conical centers accommodating a wide range of dimensions.

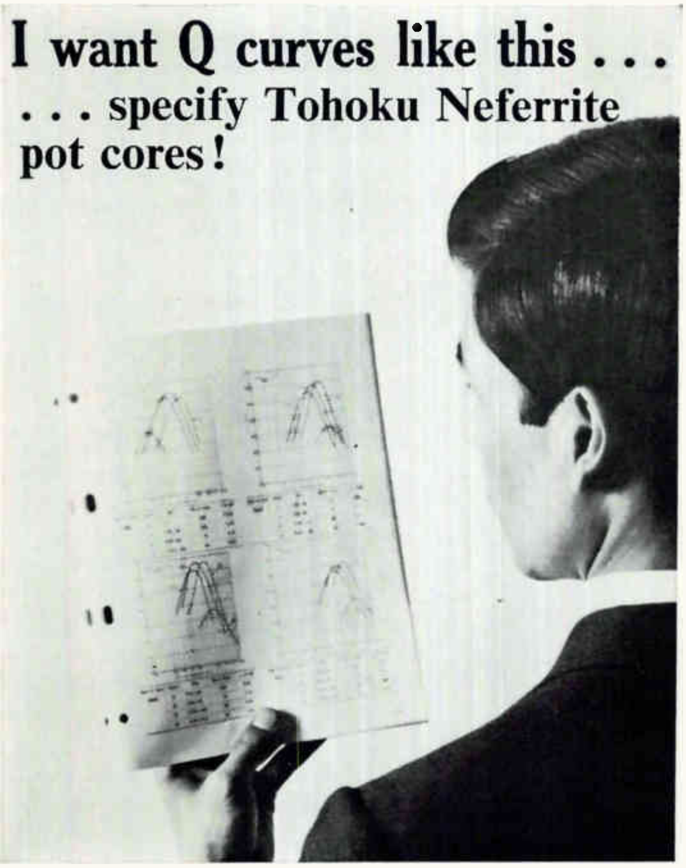
The unit accommodates bobbins and forms $\frac{3}{16}$ in. to 1⅛ in. inside diameter, up to 3 in. long. It winds wire from No. 20 to No. 48 Awg, and down to 0.001 in. on smaller forms. Speed range is 35 to 850 rpm, continuously variable. Turns counter is of the 4-digit, reset-type.

Dimensions are 8x12x7 in. high. Frame is cast aluminum. Weight is 8 lbs. Power required is nominally 120 v, 50/60 hz, 1 amp maximum.

Price is $138; availability, from stock.
Innes Instruments, 881 W. 18th St., Costa Mesa, Calif., 92627. [404]

I want Q curves like this . . .

. . . specify Tohoku Neferrite pot cores!



Designed in association with Japan's famous Nippon Electric Company, and featuring new NEFERRITE Mn-Zn ferromagnetic ferrite, Tohoku pot cores make possible drastic reductions in the size and weight of quality coils. NEFERRITE's own high quality standard is evidenced by the Temperature Factor of Initial Permeability ($\Delta\mu/\mu^2/0°C$) which is $(0.8 \pm 0.5) \times 10^{-6}$ from 0° to 40° C—and a loss factor ($\tan \partial/\mu$) of 2×10^{-6} at 100 Kcs. These and other improved characteristics offer important design advantages—giving Tohoku pot cored coils exceptionally high Q value with low distortion over a wide frequency range.

For further information, specifications, comprehensive characteristics data and sample core, write for our free booklet, "Neferrite & Ferribrox".

Fundamental Characteristics of NEFERRITE

Item		Grade 1	Grade 2
$\mu 0$		2000	2000
B_{10} (Gauss)		4200	4200
Br (Gauss)		1000	1000
Hc (Oersted)		0.3	0.3
$\frac{\tan \delta}{\mu 0}$	10 Kc	0.7×10^{-6}	0.7×10^{-6}
	100 Kc	2×10^{-6}	2×10^{-6}
	500 Kc	15×10^{-6}	15×10^{-6}
h_{10} (cm/A)	10 Kc	15	15
	100 Kc	20	20
T. F	0~40°C	$\pm 0.5 \times 10^{-6}$	$(0.8 \pm 0.5) \times 10^{-6}$
T. C (°C)		180	180
D. F		3×10^{-6}	3×10^{-6}
ρ (Ω·cm)		700	700

U.S. Pat. No. 3106534

Tohoku Metal Industries, Ltd.

7-4, GINZA-HIGASHI, CHUO-KU, TOKYO, JAPAN
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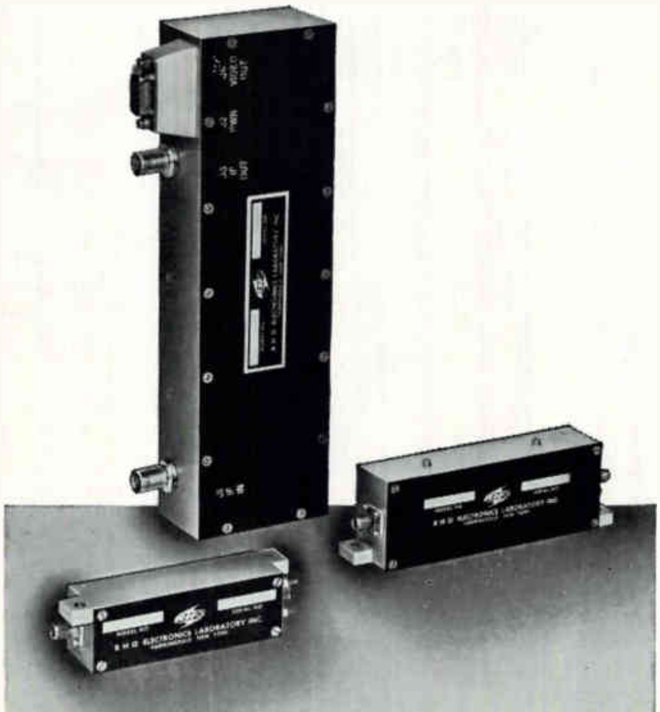

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Electrical and mechanical properties of components at high temperatures are protected by a clear epoxy impregnant. The material may be subjected to continuous use at 450°F and short exposure to 550°F.

It is primarily intended for coils, transformers, chokes, solenoids and assemblies. The dielectric constant is 3.3 and the dissipation factor, 0.006 at 1 khz. Volume resistivity is 7.6×10^{14} ohm-cm.

The material, Eccoseal W-67, is mixed just before it is used. The viscosity of the blend is about 500 centipoise at room temperature, giving excellent penetration into tight windings.

Units to be impregnated are dried and then immersed in the epoxy. A vacuum removes air from the windings and after a short draining period, the unit is cured at 250°F, and then at 350°F. Useful pot life at room temperature is several days to a month. The impregnant, available from stock, costs about $2.75 per lb.

Emerson & Cuming, Inc., Dielectric Materials division, Canton, Mass., 02021. [406]

Photoresist has varied applications

A positive-working photoresist has wide application in the printed-circuit, semiconductor and thin-film fields. It can be applied by roller-coating, dip-coating, spray and whirl or spin-coating. In addition, the company says, it is the only positive resist that can be applied in relatively thick coatings of over 0.0002 in. and still routinely achieve resolution of over 5,000 lines per inch. Also, the ability to apply thick coatings makes the over-all process more reliable and pinhole-free.

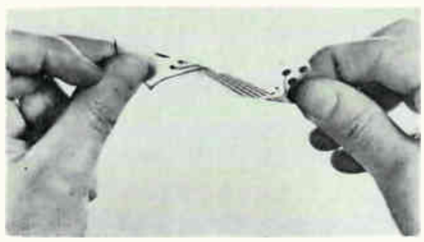
Images develop clean, having no residues on the substrate that could interfere with subsequent steps in the process. No post-baking is necessary. Adhesion to most substrates including highly phosphorus-doped silicon dioxide, is excellent.

The photoresist, AZ-111, uses a non-solvent developer that does not soften the image. This, coupled with its versatility, makes the resist practical in automated roll-to-roll processing, such as flexible printed circuits.

The resist can be easily removed by common solvents and alkaline soak cleaners, or by exposure and developing of the remaining resist.

Shipley Co., Newton, Mass [407]

Thermoset laminate provides flexibility



Flexiglas 6100 is a flexible epoxy-glass copper-clad laminate for contoured printed circuitry and flexible flat cabling. It is a true thermosetting plastic with premium electrical qualities but without the usual disadvantages of a thermoset polymeric system.

A 0.003-in. thickness of this Flexiglas base laminate may be wrapped around a 0.020-in. mandrel without danger of a fracture

or permanent deformation. In the past, only thermoplastics such as Mylar could provide this kind of flexibility. Thermoplastics, however, lack the high-temperature tolerance that is required in many applications. During soldering or welding operations, the flexible laminate will withstand temperatures as high as 500°F for 20 seconds without ill effects. It can be resoldered repeatedly without degradation.

The combination of flexibility, dimensional stability, bondability and extreme-temperature tolerance is particularly applicable in high-density packaging, contoured circuits and flat cables for high-temperature environments. The excellent electrical characteristics of the laminate are attributed to its very high resin content. Yet, since it is a glass-reinforced thermostat, thickness can be closely controlled.

New England Laminates Co., Inc., 481 Canal St., Stamford, Conn. [408]

Quartz braiding yarns for high temperatures

Braiding yarns known as Astroquartz feature a new Teflon-based lubricant permitting great handling ease for applications in the high temperature insulation field. The new binder will broaden the range of uses for these yarns in the electronics and electrical industries for temperatures ranging from 1,200°F to 2,000°F.

Made from fine, high purity continuous filaments of fused quartz, the yarns have already found extensive use as braided insulation in thermocouple wire, coaxial cables, space separators, hook-up wire and heating elements. The new binder allows for superior flexibility. Astroquartz yarn has more than five times the yield of silica yarn, higher tensile strength and abrasion resistance, according to the manufacturer.

The new binder has high temperature resistance and completely vaporizes above 800°F, leaving no carbon residue.

J.P. Stevens & Co., Inc., 1460 Broadway, New York, N.Y. [409].

New Books

Radio waves from afar

Radio Astronomy
John D. Kraus
McGraw-Hill Book Co., 481 pp., $13.75

An author who attempts a comprehensive treatment of radio astronomy faces a seemingly insurmountable problem. Advances come so rapidly in this field that any book stressing the spectacular developments is likely to be outdated by the time it reaches its readers.

John Kraus, a professor at Ohio State University, has, therefore, wisely stressed the more permanent topics in his textbook. Roughly three-quarters of the text concentrates on the fundamentals and techniques which a serious student must grasp. The remainder of his text summarizes the various sources of extraterrestrial radio emission. This section is probably as up to date as is possible, and Kraus emphasizes the need for frequent references to pertinent journals.

A knowledge of vector analysis and of elementary electromagnetic and circuit theory is required of the reader. A summary of general astronomy, containing the essentials, is followed by the fundamental topics of radio astronomy, including the specification of radiation and noise, black-body radiation laws and radiation transfer. Short chapters are devoted to the description and measurement of wave polarization and wave propagation, mainly propagation through a plasma that is in a magnetic field and the Faraday rotation of linearly polarized waves. General properties of antennas, application of the spatial-frequency concept to pattern smoothing, the principles of various interferometer systems and of the lunar occultation method are all given. In addition to the general outlines, a number of actual antenna systems are described and illustrated.

The chapter on receivers was contributed by Martti E. Tiuri, a professor at the Institute of Technology in Finland. It includes the general principles of commonly used systems, the specification of the noisiness of a device and fairly detailed description of sever types of low-noise, negative-resi tance amplifiers.

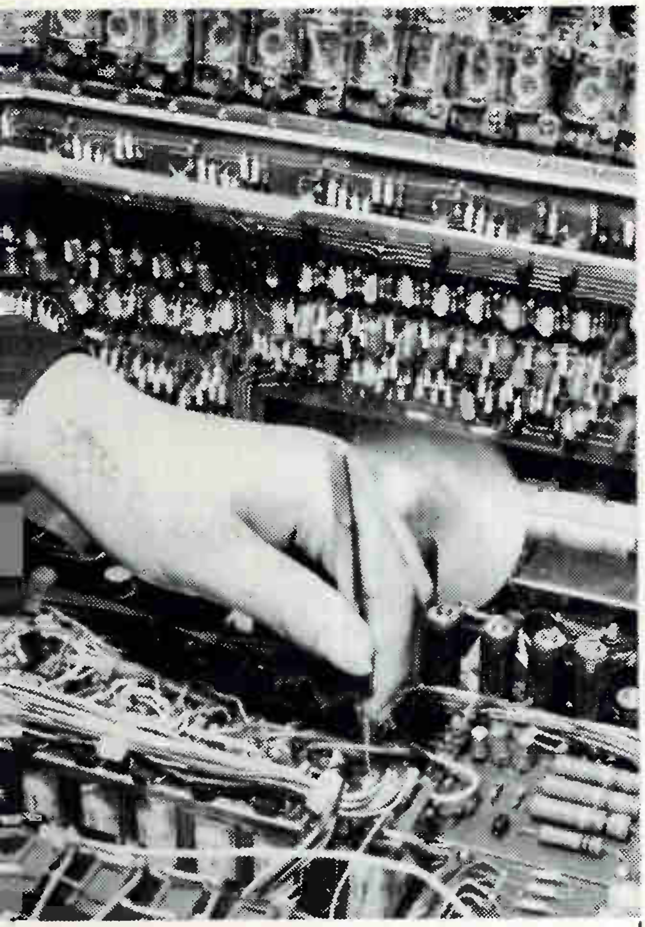
Several appendixes contain us ful reference material, including number of recent lists of rad sources. Each chapter is accom panied by problems, mainly nume ical exercises with answers, and list of references, often qui long though somewhat arbitrar Throughout the book, liberal use instructive illustrations and tabl shows the hand of an experience teacher.

The author's clear, accurate sty is marred by few errors, most which will not trouble the ale reader. But even he may be co fused by errors and misleadin points in the section on radiati transfer, beginning on page 9 First, the right-hand signs are r versed in the equation of transf which is used to calculate t change in a source's brightness d to the received radiation havi passed through a cloud that bo emits and absorbs radiation. Al the theory is developed in terms the mass absorption coefficie (m^2kg^{-1}); this is customary in op cal theory but it is not used b radio.

Later in the book, in giving t actual absorption coefficient for thermal plasma, the same symbol used for the more convention linear coefficient: m^{-1}. Finally, is incorrectly indicated that in un optical depth a wave's amplitu is attenuated by a factor of 1/ this factor actually holds for wave's intensity, the square of amplitude.

There is also a misleading ite in Tiuri's otherwise excellent d cussion of receivers. The read could calculate that an interfero eter used in the phase-switch mode reduces sensitivity by a fact of four compared to the total-pow mode—unless he notices that Ti switches standards in the midd of the table on page 258. Even careful reading of the text leav the actual degree of sensitivity l ambiguous.

Within the confines Kraus has



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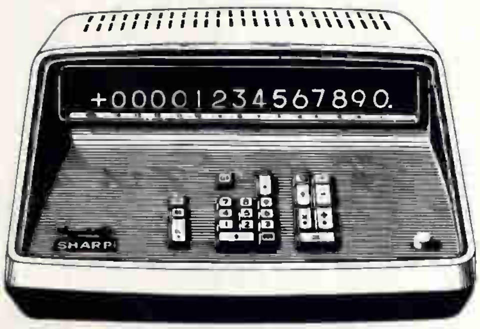

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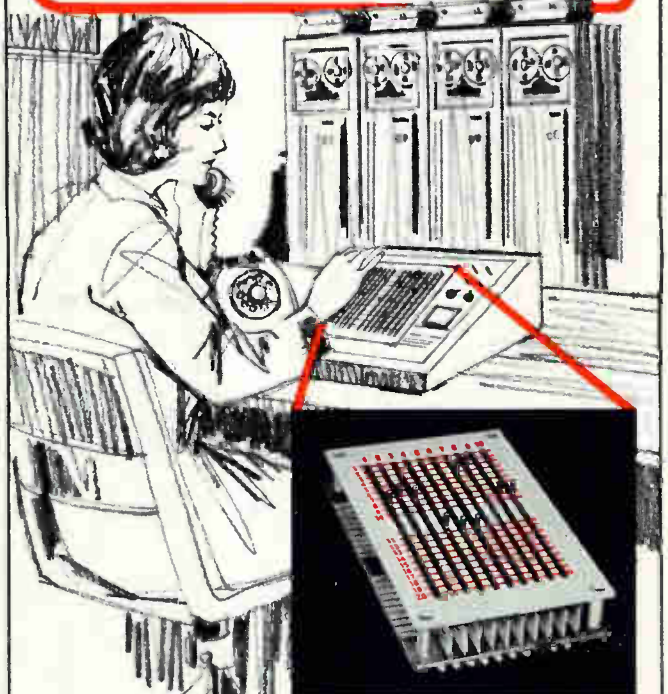

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New Books

for himself, his book may be criticized for lack of balance and omissions. For example, there is a lengthy discussion, with many formulas, on general laws of blackbody radiation, most of which are of marginal importance in radio astronomy. Yet relatively cursory treatment is given to the two mechanisms of greatest importance: free-free emission [free electrons which remain free after interaction with an ion are responsible for thermal radio emission from an ionized gas] and synchrotron emission [the acceleration of high-energy electrons in magnetic fields which is believed responsible for most nonthermal radio sources]. No formula is given for the radiation rate of a synchrotron electron, resulting perforce in a limited treatment of such topics as energy content and the lifetime of radio sources.

Barely a page is devoted to the principles of the Mills cross interferometer and the aperture-synthesis technique combined. No mention is made of the cross' sidelobe problems and the consequent desirability of tapering the illumination, even though the theory of the binomial array used for suppressing sidelobes has previously been developed with no indication of its potential applications. Nor is there much discussion about the relative merits of various antenna systems for particular applications. One might have hoped for an indication of the pros and cons of, say, the two-antenna interferometer with fixed baseline, the cross and the aperture-synthesis techniques for source-survey work.

Inevitably, however, different writers choose to emphasize different aspects of the subject, and Kraus, on the whole, has done a good job.

The book is probably the best available text for an introductory graduate-level course. It is likely to have a long and useful life in the classroom.

One hopes, however, that subsequent editions will retain the many merits of this first one while remedying its few flaws.

D. Walsh
The University of Michigan
Ann Arbor

Technical Abstracts

Digital displays

The plasma display panel—a digitally addressable display with inherent memory
D.L. Bitzer and H.G. Slottow, University of Illinois

Although plasma displays are still experimental and very small, it appears they may overcome most disadvantages of cathode-ray tube displays for computer input and output. The new displays respond directly to digital signals, can be interrogated by the computer, will display data for relatively long periods without continual regeneration and should have better resolution than crt displays if the displays are large.

In contrast, crt displays require digital-analog conversion circuitry, have no memory except phosphorescence, are bulky, need high driving voltages and signal transmission at video bandwidths. Information may be written into a crt display with a light pen, but even this appears feasible with plasma displays. It should be possible to display up to 1 million points a second on a plasma display, about five times the maximum rate for commercially available crt displays, and to provide as many as 10,000 points per square inch of display.

The experimental plasma displays consist of small matrixes of gas cells formed by three adjacent sheets of glass. On the outer sheets are orthogonal grids of transparent conductors, stripes of vapor-deposited gold. The inner sheet is a matrix of small holes, located between the intersecting conductors. The holes are filled with gas.

A plasma discharge causes the cells to glow when an alternating voltage is applied to the conductors. The glow is quenched when the applied voltage drops below the firing level. This cycle takes 50 to 75 nanoseconds.

After quenching, a charge remains on the cell walls. This charge constitutes a memory function and makes the cells bistable at intermediate voltages. If a sustaining voltage is applied to the display, the charged cells will glow without further input from the computer. If the computer applies a balancing potential to the glowing cells, the display is erased.

To interrogate a display, the computer can apply the sustaining voltage to the cells sequentially and detect light output through photocells at the rear of the display. If primed cells are subjected to a beam of light, the release of photoelectrons from the cell walls will turn on the cells. However, it may be necessary to optically shield the cells to prevent one cell from triggering others until the entire display is lit.

Presented at the Fall Joint Computer Conference, San Francisco, Nov. 7-10.

Logic massager

Automated logic design techniques applicable to integrated circuit technology
R. Waxman, M.T. McMahon, B.J. Crawford and A.B. DeAndrade
International Business Machines Corp., Hopewell Junction, N.Y.

Computer-aided design offers a happy medium between the old and the still-too-new styles of arranging integrated circuits into logic systems.

The old way, the use of similar logic units to keep the number of types of circuits low, results in low circuit density and is an inefficient way to apply monolithic IC technology. The new way, highly dense packaging of one-of-a-kind functional blocks (large-scale integration, or LSI), tends to increase the numbers of part types, presenting inventory and engineering change problems. If the LSI blocks are made from a large matrix of simple cells, the designer also runs into limits on the matrix interconnections.

LSI arrays composed of complex, but versatile cells, appears to be the solution. Interconnection of the cells with "personality" wiring can be done as almost the last step in the production process. If the intercell wiring is on the outside layer of the IC chip, the "impersonalized" arrays can be stocked, awaiting custom wiring or engineering changes.

The problem of deciding which

Technical Abstracts

logical functions the complex cells should generate can be attacked by applying the theory of equivalence classes. That is, each cell can perform more than one function by rearrangement of the inputs to each cell or its outputs. If either the true or the complement of a given function is available at the input or output of the cell, each cell can have four functions. If the set of input variables can also be permuted, many additional functions would be available, without changing the cell's internal circuitry.

A computer-aided design program, called the equivalence class descriptor program, has been devised to implement this concept. With its aid, a logic system can be partitioned into several hundred sections, the section functions identified by descriptors, and the equivalent functions produced as common elements. The program is written in Fortran. It is presently restricted to functions of six variables, or less. The limit is imposed by the use of a truth table; a table of six variables is the largest that can be handled in the memory of the computer used, an IBM 1620.

With the aid of instructions flashed onto a cathode-ray-tube display by the computer, the logic designer partitions sections, called clusters, from the over-all logic design. For example, a cluster may be a related group of AND, OR and inverter circuits. Each cluster is analyzed to obtain its function descriptor.

As the designer works, he determines the quantity of each equivalence class needed to replace the original logic. As portions of the logic system are partitioned out of the original diagram, the remainder is shown on the display screen for further partitioning until the redesign of the logic system has been completed. The designer can at any time review the entire system with the partitioned sections inserted into the unpartitioned remainder.

Presented at the Fall Joint Computer Conference, San Francisco, Nov. 7-10.

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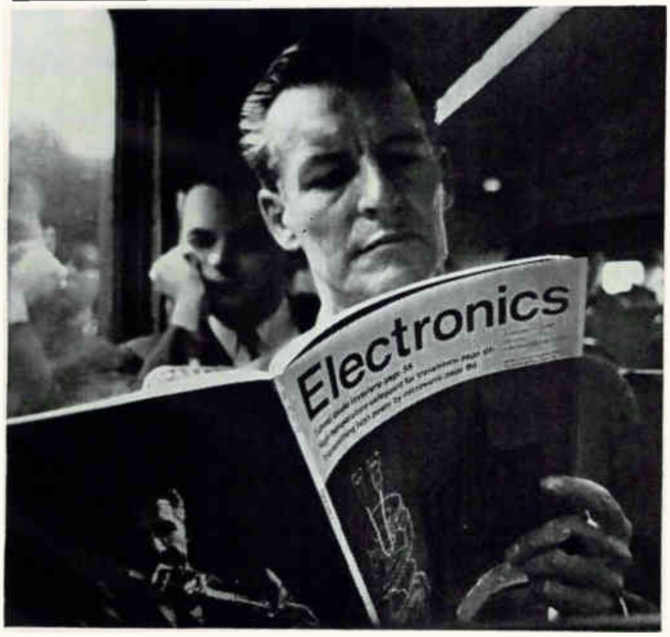

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New Literature

Instrument motors. Amphenol Controls division, Amphenol Corp., 120 South Main St., Janesville, Wisc., 53545. An eight-page catalog illustrates and describes models 1020, 1060 and 1080 instrument motors.
Circle 420 on reader service card.

Nonlinear functions. Bourns, Inc., 1200 Columbia Ave., Riverside, Calif., 92507, has released a four-page nonlinear function catalog sheet, featuring a wide selection of single and multiturn, precision potentiometers in servo and bushing-mount styles. [421]

Silicon stack assemblies. International Rectifier Corp., 233 Kansas St., El Segundo, Calif., 90245. Catalog D-66 lists a complete line of silicon stack assemblies, providing 80 pages of description, ratings, and specifications. [422]

General-purpose relays. Guardian Electric Manufacturing Co., 1550 West Carroll Ave., Chicago, Ill., 60607, has issued an 18-page bulletin providing complete information on its line of 23 general-purpose relays. [423]

Wire and cable. Harbour Industries, Inc., P.O. Box 188, Shelburne, Vt., has available an illustrated brochure covering its facilities for the manufacture of high temperature wires, cables and specialty components. [424]

Relay test system. Sparton Southwest, Inc., P.O. Box 1784, Albuquerque, N.M. Product data sheet number 21 contains detailed specifications and operating performance of the RTS-100 system for rapid, accurate and reliable testing of relays. [425]

Coaxial switches. Microwave Associates, Inc., Burlington, Mass. Technical bulletins 2034 and 2036 describe a series of compact and lightweight electromechanical coaxial switches. [426]

Solid state oscillators. Krohn-Hite Corp., 580 Massachusetts Ave., Cambridge, Mass., 02139, offers a technical bulletin on the series 4000 solid state standard oscillators that feature ultralow distortion and stable amplitude. [427]

Subminiature connectors. ITT Cannon Electric, 3208 Humboldt St., Los Angeles, Calif., 90031, has published a catalog on the DRA line of subminiature connectors used in aircraft, missiles and ground support equipment. [428]

Solid state amplifier. Studio Electronics Corp., 11922 Valerio St., North Hollywood, Calif., offers bulletin SE-08 containing a two-page technical description of the model 1108 solid state amplifier. [429]

Film thickness measurement. Monsanto Co., 800 North Lindbergh Blvd., St. Louis, Mo., 63166. An evaluation procedure manual describes a new method of determining epitaxial silicon film thickness by spherical angle lapping. [430]

Dual-output supply. Deltron, Inc., Wissahickon Ave., North Wales, Pa., 19454. Bulletin 406A deals with a compact, low cost, dual-output, tracking power supply designed for use with almost all types of operational amplifiers and integrated circuits. [431]

Reed relays. Essex Wire Corp., Controls division, 131 Godfrey St., Logansport, Ind. Bulletin 2020 covers a complete family of standard, open-construction reed relays. [432]

Potentiometer production. SP Elettronica SpA, Via Carlo Pisacane 10/4, Pero (Milan), Italy. A four-color brochure illustrates the company's facilities for the manufacture of Spectrol precision and trimming potentiometers. [433]

Time-delay relays. Heinemann Electric Co., 252 Magnetic Drive, Trenton, N.J., 08602. Twelve-page bulletin 5006 describes the company's line of Silic-O-Netic time-delay relays. [434]

Noise generator. Signalite Inc., 1933 Heck Ave., Neptune, N.J., has issued a two-page illustrated data sheet on the type TN-1 miniature X-band noise generator. [435]

Snap-reed switch. Cherry Electrical Products Corp., P.O. Box 439, Highland Park, Ill., 60036, offers a brochure on the E66 series, which weds the mechanical utility of the snap-action switch to the electrical reliability of the reed switch in a single, compact and convenient package. [436]

Feed-through terminals. Taurus Corp., Academy Hill, Lambertville, N.J., 08530, has released a catalog on the SFU series subminiature feed-through terminals designed for snap-fit installation into predrilled or prepunched chamfered holes in electronic chassis. [437]

Carbon film resistors. Pyrofilm Resistor Co., Inc., 3 Saddle Road, Cedar Knolls, N.J. A four-page folder describes a line of hermetically glass-sealed, deposited carbon film resistors. [438]

Electronic measuring instruments. Ballantine Laboratories Inc., P.O. Box 97, Boonton, N.J., 07005. The 1967 catalog contains photos and specifications for a variety of measuring instruments, including voltmeters and ammeters, a-c/d-c volt ohmmeters, amplifiers, calibrators, capacitance meters, a-c/d-c linear converters, laboratory voltage standards, and accessories. [439]

New Literature

Current-to-current converter. Fischer & Porter Co., 108 Jacksonville Rd., Warminster, Pa., 18974. Specification 50EK1000 describes a converter for transforming current signals, in selected ranges up to 50 ma, to a proportional 4 to 20 ma current signal. **[440]**

Tunable electronic filters. Spectrum Instruments, Inc., P.O. Box 474, Tuckahoe, N.Y., 10707, offers a technical data sheet on its line of type LH-42D spectrum analog electronic filters, which are active network devices usable singly or in pairs to accomplish a wide variety of frequency selective functions. **[441]**

Magnetic shielding foil. Magnetic Shield division, Perfection Mica Co., 1322 No. Elston Ave., Chicago, Ill., 60622. Four-page data manual 185 gives technical data on a new rust-inhibited Blue Netic magnetic shielding foil plus a multitude of applications for other magnetic foil shielding. **[442]**

Folded-array memory. Indiana General Corp., Crows Mill Road, Keasbey, N.J. A miniaturized, folded-array memory, the Microstack, is described in an eight-page booklet. **[443]**

Potentiometers. Helipot division of Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif., 92634, has available a 72-page catalog covering precision potentiometers, trimmers, dials and servo system components. **[444]**

Angular accelerometers. Gulton Industries, Inc., 212 Durham Ave., Metuchen, N.J., 08840. An illustrated bulletin describes compact, inexpensive, angular accelerometers for accurate measurement and control of roll, pitch and yaw in aircraft, missile, shipborne and industrial applications. **[445]**

Thermoelectric module. EG&G, Inc., Products division, 160 Brookline Ave., Boston, Mass., 02215, has published a four-page data sheet on the model H9-65 thermoelectric module, a device having an unloaded temperature differential of 65°C at 9 amps. **[466]**

Terminal junctions. The Deutsch Co., Electronic Components division, Municipal Airport, Banning, Calif., has released a four-page, two-color brochure describing terminal junctions, a new class of point-to-point interconnection and housing devices. **[447]**

Limiting amplifier. Studio Electronics Corp., Universal Audio division, 11922 Valerio St., North Hollywood, Calif., has issued a technical data sheet, bulletin SE-15, to describe the Universal Audio 176 limiting amplifier. **[448]**

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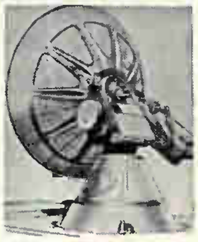

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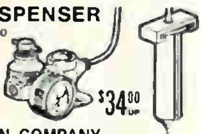

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Newsletter from Abroad

January 9, 1967

Color-set makers in Japan face antitrust action

Japanese set makers have their problems even though they're poised to push color television receiver output past the 1-million mark—double the 1966 figure—during the year ahead.

Late this month, hearings will begin in an antitrust action the government has launched against six major producers.

The government's fair trade commission contends that the leading producers violated Japan's antitrust laws by setting a minimum retail price of $500 for 19-inch color sets at monthly meetings of company vice-presidents at the Palace Hotel in Tokyo. The commission has raided the companies three times to gather evidence.

The companies—Matsushita Electric Industrial Co., Hitachi Ltd., Tokyo Shibaura Electric Co., Mitsubishi Electric Corp., Sanyo Electric Co. and Hayakawa Electric Co.—admit their executives hold regular meetings. But at the hearings, they'll maintain there's been no price fixing. They claim their prices—the popular 19-inch sets are bunched around $550 retail—are realistic.

What's more, the six producers say their meetings are justified and will continue. Their argument: exchanges of information among domestic producers is important since they'll eventually be up against strong outside competition because of the government's policy to ease restrictions on foreign investment in the country.

Production models of tiny U.K. radar year or so away

The matchbox size low-power radar developed at Britain's Royal Radar Establishment should be on the market in a year or so, predicts RRE's Cyril Hilsum. Hilsum led the research team that worked on the gallium arsenide Gunn-effect oscillator used as the radar's microwave source.

The GaAs oscillator, encapsulated in a 3 by 5 millimeter package, was developed jointly with Mullard Ltd., a subsidiary of the Dutch company Philips Gloeilampenfabrieken NV. Mullard now is getting yields of 70% on the oscillators but production versions of the radar won't be forthcoming until further development is done on the resonance cavity.

In addition to Mullard, the Plessey Co. and Standard Telephones and Cables Ltd, a subsidiary of the International Telephone and Telegraph Corp., have the "mini" radars under development.

ICT long on orders but short on cash

Success has put Britain's leading computer maker, International Computers & Tabulators Ltd., in a bind for cash and the company is looking for help from the government.

ICT came up with a best-seller with its 1900 series, introduced two years ago. Since, the company has delivered some 250 systems and has orders in hand for an additional 400. But most of the machines are rented; so ICT needs tide-over financing, at a time when money is tight, to keep up its fast expansion.

With the Labor government determined to maintain an independent computer industry, ICT can almost certainly count on some sort of aid. The company currently has talks under way with the government's export-credit agency for financing overseas deliveries and with the Ministry of Technology for domestic deliveries. But ICT's plight brings up again the perennial and perturbing question of how many computer companies the British economy can support.

Newsletter from Abroad

East German goal: national computer network by 1970

A countrywide complex of computer centers will be set up in East Germany by 1970 if the plans of Guenther Kleiber, newly appointed state secretary for data processing, pan out.

Kleiber's scheme calls for more than 100 computer installations—linked together—at major industrial firms, research institutes and government agencies. At present, there are some 25 computer centers in the country, almost all of them equipped with Bull Gamma-10 machines. But the existing centers operate individually as service bureaus.

The East Germans most likely will turn to Russia for the hardware and build their complex around Ural, Minsk and BESM computers. There's a slight chance, though, that U.S. third-generation machines would be integrated into the complex should the North Atlantic Treaty Organization ease its embargo on exports of advanced data-processing equipment to Communist-bloc countries.

Bull-GE withdraws pair of computers

The General Electric Co.'s worldwide troubles with software delivery for its 600-series computers have doomed a pair of models developed by GE's French subsidiary, Bull-General Electric. To slim down the GE computer line, Bull-GE last week dropped its Gamma 140 and Gamma 145 models, two small machines introduced last year.

With two less models to sell and service, GE expects to fare better with its larger machines in the French market. GE had to recall one 600 machine installed at the state-owned public utility Electricite de France and lost a sale—because of program difficulties—for a second machine tentatively ordered by the French weather bureau.

French fail in bid to win Austrians over to Secam

Executives at West Germany's Telefunken AG now are fairly confident that Austria will end up on the list of countries that have adopted the company's PAL (for phase-line-alternation) color-television system.

The French made a year-end bid to win Austria for their competing Secam (for sequential and memory) system but their demonstration didn't make much of an impression on Austrian broadcasting officials. Meanwhile, PAL has acquired a powerful supporter: Austria's Federal Chamber of Commerce, which represents the country's business community. The Chamber of Commerce is convinced PAL would work best in the mountainous country and would simplify exchange of color programs with neighboring West Germany and Switzerland. They both already have opted for PAL.

Nippon Electric wins USAF contract for microwave net

The United States Air Force has picked the Nippon Electric Co. as prime contractor for $13.7-million microwave communications system in the Kanto Plains area of Japan. The system will link 24 U.S. military stations and connect into the regular Japanese communications network.

Despite the Pentagon's "Buy American" policy, Nippon won out over ITT Federal Electric Corp. Nippon is the only company now producing the 300-channel equipment that was specified for the job. Nonetheless, the system, which will cover Tokyo and four surrounding provinces, will have considerable U.S. hardware. Nippon has awarded a $6-million contract to the Lenkurt Electric Co., a subsidiary of the General Telephone & Electronics Corp., for the multiplex equipment.

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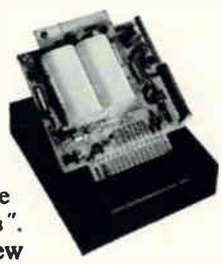

The advanced new electronic module offers a multiplicity of advantages over the electromechanical devices now in general use, yet it costs no more. It's faster, more reliable, and many times smaller.

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TI semiconductors help brokers read market quotatious easier

Texas Instruments semiconductors will soon be in brokers' offices all over the country as part of a new stock quotation display made by Trans-Lux Corporation.

The new "Trans-Jet" display is a brokerage-size, self-contained unit that can be mounted on a wall or hung in the middle of the room for viewing from both sides. It takes incoming signals directly from the stock exchange communications network and converts them to a moving display via a new electronic-electromechanical-pneumatic system.

The new system incorporates Texas Instruments low-cost industrial integrated circuits, Silect™ plastic-encapsulated silicon bipolar and unijunction transistors, germanium transistors, silicon diodes, SCR's and semiconductor light sensors.

In the conventional display an electromechanical tape-feeding system and film projector require a separate console. The new "Trans-Jet" built-in electronic control is only 12" x 10" x 6". And maintenance has been reduced from bi-weekly to semi-annually.

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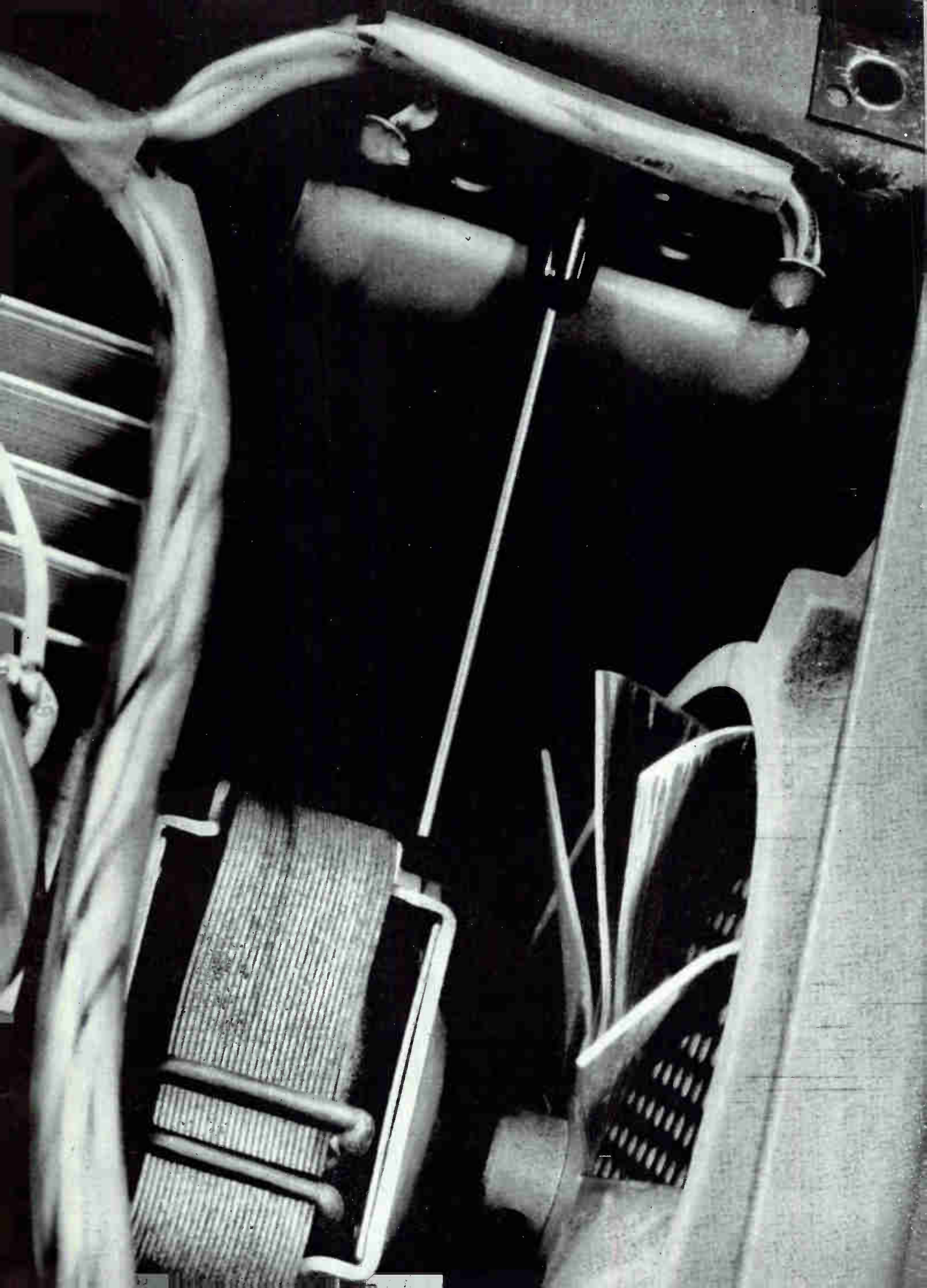


Electronics Abroad

Volume 40
Number 1

Japan

All aboard

For most electronickers involved in the Lilliputian world of integrated circuits, large-scale integration means just one thing—hundreds of tiny silicon chips mounted on a common substrate and interconnected. But for circuit designers at the Hayakawa Electric Co., large-scale integration has a second meaning—hybrid circuits large in size, rather than complexity, for radios and television sets.

Hayakawa now has on the market a six-transistor radio with all 16 of the set's resistors integrated on the component side of the set's printed-circuit board. This first use of the circuits will be followed by even larger boards for frequency-modulation radios and tv sets.

The big advantage of the integrated resistors is that they eliminate a substantial number of solder joints, a major cause of rejects in transistorized consumer equipment. What's more, the integrated resistors cost less than discrete resistors, even in the pilot production Hayakawa so far has used to fabricate the boards.

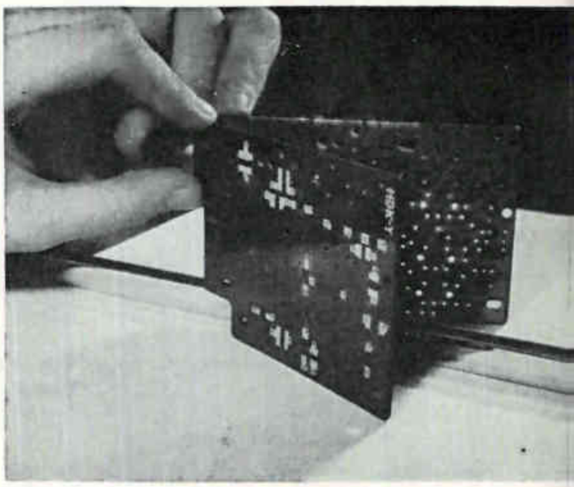
Making passes. For the integrated resistors, Hayakawa uses a combination of carbon black and binders similar to the "inks" found in volume controls and multivalue printed resistors. But the company says it has a patent on the silver paste that connects the resistors to the copper terminals on the printed-circuit boards and a design patent on the idea of putting resistors directly on the board.

The resistors are laid down after the copper printed wiring has been etched on the reverse side of the board. First, a thin layer of phenolic varnish is applied to areas where the resistors will go. The varnish is baked, then the resistors screened on and baked. For a radio with resistors ranging in value between 100 and 100,000 ohms, three or four different inks with different resistivities are needed; each ink is screened on and baked in turn.

Once the resistors are in place, the silver-paste terminal areas are screened on and baked. In the process, the paste is forced into holes that connect the resistor terminals to the copper terminals on the reverse side of the board. Finishing operations include a protective phenolic varnish over the resistors and a phenolic-base solder resist over silver-filled terminals on the wiring side of the board.

Good values. The integrated resistors vary in length from about 2 millimeters to 12 mm. However, Hayakawa is trying out even smaller sizes—lengths as short as 0.5 mm. With careful screening, the process gives a resistor tolerance of ±20%, good enough for transistor radios. For higher tolerances the values can be adjusted by shortening the resistor's active length with additional silver paint at the terminals or by abrading the resistor after baking. Stability under load is about 1% or 2%, about the same as the discrete composition resistors normally used in radios. The resistors fabricated so far are conservatively rated at 1/32 watt and can range up to 1/8 watt.

Although Hayakawa is in pilot-plant production with integrated-resistor boards for one of its transistor-radio models, the company still is tinkering with the technique. It is trying different resistor shapes and sizes and has work under way aimed at integrating capacitors onto the printed-circuit boards along with resistors.



On-board. All 16 resistors for Hayakawa six-transistor radio are integrated onto printed-circuit board on side opposite copper.

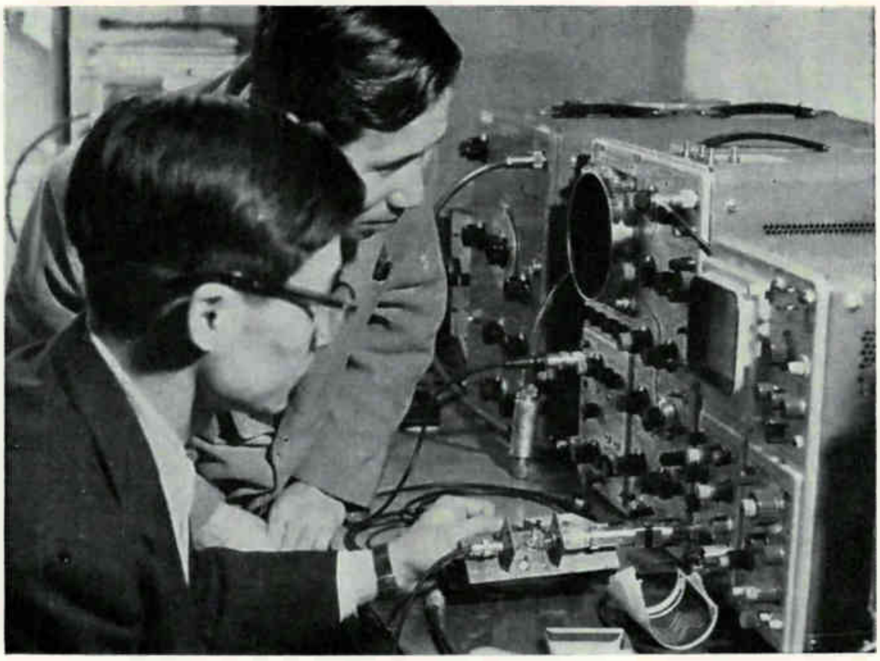
Fast on the punch

Circuit designers who need high-speed pulses may soon have a new device to work with—a punch-through avalanche transistor.

The transistor, faster than the conventional avalanche devices often used to generate high-speed pulses, has been developed by the Electrical Communication Laboratory of the state-owned Nippon Telegraph and Telephone Public Corp. in cooperation with Fujitsu Ltd.

NTT sees the punch-through avalanche transistor (PAT) as a possibility for a high-speed pulse code modulation system it is considering. But the transistor also seems a good bet for a variety of other applications like sampling oscilloscopes, pulse generators, voltage comparators and analog-digital converters. Fujitsu currently is looking at the potential market and may put PAT into production even if NTT decides not to use it.

Short. Punch-through, sometimes called electrical reach-through, occurs in a transistor when the space charge region of the collector extends through the base layer to the emitter. Under this condition, a nondestructive short circuit develops between collector and emitter; for that reason, the effective base width narrows and the response time is not limited by car-



Researchers at the Electrical Communication Laboratory of the state-run Japanese telephone system check characteristics of punch-through avalanche transistor for high-speed pulse generation.

rier transit time in the base as it is in conventional avalanche transistors.

The PAT operates very close to the punch-through condition and thus has a fast response time. However, some avalanche multiplication of minority carriers is necessary in the base region to get a higher-than-one current amplification for regenerative switching. The key to the combination of near-punch-through operation with some carrier multiplication is an avalanche breakdown voltage only slightly higher than the punch-through voltage.

To hold the voltage spread, and at the same time get adequate yields in production, Fujitsu and NTT jointly developed a proprietary electrode structure and fabrication methods for the silicon npn PAT. Makato Wantanabe, the communication laboratory engineer in charge of device design, says the PAT compares favorably with two-terminal devices like snap-off diodes, tunnel diodes and hot-carrier diodes as a source of high-speed pulses but has an additional advantage—it can be tailored for various applications.

Ready for market. Fujitsu already has set tentative characteristics for the first production PAT. It will operate either in triggered or recurrent mode and generate (at half-width) 1-nanosecond pulses. The interval between pulses is less than 5 ns and the typical trigger delay 0.5 ns. Pulse output is 1 volt into a 50-ohm line. A second version now in development will be even faster with an interval between pulses of less than 2 ns.

The PAT will work in many different circuits. It can be triggered, for example, by pulse inputs to the collector, base or emitter. About the only circuit precaution needed is to keep the total bias voltage across the emitter and collector slightly lower than the turn-on voltage; otherwise the PAT will generate pulses on its own without trigger pulses. The turn-on voltage differs slightly from device to device but remains stable over a wide temperature range so this is not a serious drawback.

Murmur monitor

Japanese doctors soon will be able to turn over to their aides the chore of screening people by the hundreds for heart defects.

Tokyo Shibaura Electric Co. (Toshiba) plans to have ready for the Japan International Trade Fair in April the commercial version of a special-purpose analog computer that automatically spots suspicious heart sounds. Using the equipment, a nurse or a technician can run a heartbeat test in less than a minute and refer to a doctor any patient with an abnormal-sounding heart.

Toshiba isn't the first to develop an electronic heartbeat analyzer. The Humetricas division of the Thiokol Chemical Corp. produces a portable unit, for school heart-test programs, that can detect heart defects in three minutes [Electronics, Dec. 13, 1965, p. 38]. Toshiba's analyzer, though, is faster and more sophisticated. It shows what phase of the heart cycle is abnormal, not merely that something sounds wrong.

Two mikes. Inputs for the heartbeat analyzer come from two microphones. One is placed against the patient's chest to pick up the heartbeats; the other is placed against his throat to pick up his carotid pulse. A cathode-ray-tube monitor shows when the microphones have been properly placed.

The carotid pulse input identifies the start of a cycle, during which a normal heart produces two distinct sounds called first sound and second sound. The rise in the carotid pulse corresponds to the first sound and the notch in the pulse to the second sound.

The analyzer processes signals from the chest microphone in analog logic circuits, which compare the signals to normal heart-sound patterns. Because the start of the comparison is timed by the input from the throat microphone, the input from the chest microphone is delayed for 80 milliseconds to offset the time it takes for the carotid pulse to travel from the heart to the neck. The delay is obtained by passing the chest microphone signal through a continuous-loop tape recorder with the recording and playback heads spaced for an 80-msec delay.

Three beats. Toshiba's analyzer makes a checkup during just three heartbeats. In tests at the medical school at the University of Tokyo, technicians using the equipment fared as well at spotting abnormal heart sounds as general practitioners using stethescopes. The analyzer even bested the average practitioner at picking up second sounds split into two parts, a symtom very hard to detect with a stethescope.

A lighted-panel display on the analyzer shows what suspicious sounds have been detected by the comparison in the analog logic circuits. The readouts include amplitude of the heartbeat if it's 20 decibels or more outside the norm, murmurs between first sound and second sound or between second sound and first sound, over-fast or too-slow heartbeat, split second sound and irregular beats.

There is also a chart recorder that can be switched on when a record of the heart-sound waveform is desired.

Great Britain

In the picture

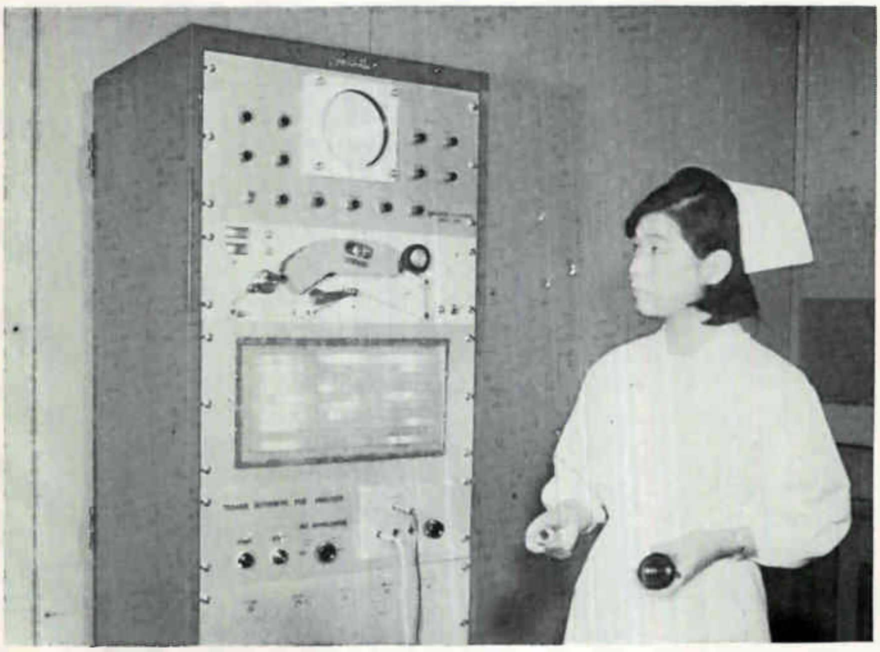
Aircraft traffic control radar specialists long ago found a way to cull ground clutter—fixed echoes from high terrain or buildings—from radar displays. The technique, called moving target indication, feeds to the display only echoes from objects that have moved in toward the radar antenna or away from it during successive sweeps.

But standard MTI can't spot an aircraft that is moving on a tangential course at right angles to the radar beam. As long as the radar is located at an airport, the tangential fade doesn't create much of a problem since the planes are flying toward or away from the radar. But with more and more remote radars going into air traffic control, the fade is becoming a serious defect. At a 60-nautical-mile distance, for example, an aircraft flying at 400 knots on a tangential course will disappear from the display for about 1.5 minutes.

Selective. Now the Solartron Electronic Group Ltd., in collaboration with Britain's Ministry of Aviation, has come up with equipment that does away with tangential fade. Essentially, the Solartron system switches in the moving target indication for sectors of the radar sweep where there's ground clutter and MTI is necessary. In all other sectors, the display shows raw radar echoes and, since there's no MTI cancellation, aircraft flying tangential courses show up.

Key to Solartron's scheme is a video plate of the sort used to make video radar maps. The plate is opaque over most of its surface but has clear areas that match the permanent clutter pattern. The plate is used in one channel of a dual video map display and scanned by a flying spot. When the spot hits a clear area, a photomultiplier on the back of the plate develops an output that drives a transistor switching circuit. The transistor switch is biased to feed raw radar input to the display except when there's an output signal from the photomultiplier.

On trial. The selective MTI system is currently being evaluated by the Ministry of Aviation at London's air traffic control center and by Canada's Department of Transport as well. As an addition to existing Solartron video map equipment, the system will cost about $2,000; it can also be adapted to other manufacturers' displays.



Nurse using Toshiba's analog analyzer can detect abnormal heart sounds as accurately as can the average general practitioner using a stethescope. Analyzer checkup takes less than one minute.

White paper on color

The Labor government last month killed any chance that Britain might go on a double-standard for her early years of color telecasting.

Despite a clamor by independent broadcasters for color on both 405-line and 625-line standards, the government in a year-end White Paper on the future of broadcasting in Britain confirmed its previous position—color tv on 625 lines in the ultrahigh-frequency band using the West German PAL (for phase-alternation-line) system. What's more, Labor made it clear that it would eventually phase out black-and-white tv broadcasting on the original British 405-line standard in order to have a uniform system throughout the country.

There was additional black news for independent broadcasters in the White Paper. In Britain there are four uhf channels available, three of them already earmarked. The commercial tv companies have long coveted the fourth channel and three years ago had a half-promise they'd get it eventually. Now the government says the precarious state of the economy makes a fourth tv channel a luxury Britain can't afford and that no allocation of the channel will be forthcoming for at least three years.

Color broadcasts, though, will start as previously planned late this year. This early start, the government feels, will help British set makers in European export markets as well as give a lift to lagging set sales at home. The 625-line PAL system has been chosen in practically all West-European countries except France.

Transmitter manufacturers stand to pick up some new business from a policy set forth in the White Paper. Plans for radio include local very-high-frequency stations run jointly by the government-owned British Broadcasting Corp. and private interests. At present there is regional radio in Britain but no really local stations.

Export exchange

By deliberately thinking small in electronic telephone exchanges, Great Britain may have hit on a way to cut a big swath in world markets for telephone gear.

Last month Britain's General Post Office, which runs the country's telephone network, put into service its first production model electronic exchange. Britain thus trailed the United States by nearly two years in getting a full-fledged electronic exchange into service. But Britain is off the mark fast in exports. Already Ericsson Telephones Ltd., the Plessey Group company that supplied the exchange, has orders for the production-line electronic exchange from telephone systems in Jamaica and New Zealand.

Big switch. The exchange, developed by Plessey in cooperation with four other major British manufacturers of telephone switching gear, has a capacity of 2,000 lines and is called the TXE-2. Although Britain has a 50,000-line exchange under development, the much smaller TXE-2 exchange will be a bread-and-butter item for communications equipment producers during the next few years. Nearly two-thirds of the exchanges in Britain have less than 2,000 lines and the Post Office plans to convert 50 exchanges to electronic switching during the next 18 months and then step up the conversion rate to 80 exchanges yearly.

The British believe that world demand for electronic exchanges will be overwhelmingly for small units. The few export sales to date bear them out; of a half-dozen exchanges, only one has large capacity, the 30,000-line system that Sweden's L.M. Ericsson Telephone Co. will deliver to the Netherlands [Electronics, Dec. 12, 1966, p. 258]. Under the arrangement set up by the Post Office to develop the TXE-2, all five major British telephone equipment makers can produce the Plessey design using their own production techniques.

Reed sections. The TXE-2 equipment consists basically of blocks of switching matrixes that connect callers, plus electronic controls. Reed relays are used for the matrix switching functions. The control electronics is built up of silicon semiconductors, tin oxide resistors, and reed relays. The circuits are fast enough to allow a single set of call control equipment to handle all the calls through the exchange in sequence.

The switching matrixes are grouped in five-by-five blocks. Each of the 25 reed relays in a block has four reeds actuated by a single coil. Two of the reeds carry the speech path, one carries a metering line and the other the actuating coil current. This arrangement is less sophisticated than the one used in the Bell System's No. 1 ESS exchange [Electronics, Oct. 19, 1964, p. 72]. However, the TXE-2 can handle all the extra facilities associated with electronic exchanges — pushbutton dialing, direct dialing to an extension, transfer of calls to another line by a subscriber and abbreviated dialing.

Denmark

A new voice

So far, the best electronic aid available to people rendered speechless by the loss of their larynx has been a clearly visible throat transducer. But now Danavox International has come through with a cleverly disguised speech aid for men—a white-noise generator built into a pipe.

Held as if its user were a pipe-smoker who chomps on an unlit pipe, a loudspeaker in the speech aid injects into the throat a mixture of the main sound frequencies found in the human voice. The user then articulates the words he wants to say and in so doing speaks. The action resembles to a large extent natural speaking, where the larynx generates the spectrum of voice sounds and the articulation apparatus shapes them.

The pipe's sound output is a mixture of frequencies from 60 to 2,500 hertz. The basic frequencies are produced in a pair of transistorized multivibrators and then fed to an amplifier-mixer stage. Output at the mouthpiece loudspeaker is 136 decibels on a reference level of 0.0002 microbar, equivalent to a speech intensity of 65 db.

A potentiometer in the mixer stage adjusts the frequency mix to the best value for individual users. An on-off switch on the pipe bowl enables the user to inject one burst of sound for each syllable. A constant tone would make speech indistinct.

West Germany

Stretching the fax

The Kiel-based firm of Dr.-Ing. Rudolf Hell is small even by European standards. But Hell has no qualms about tackling the American market.

Last summer, Hell's computer-controlled typesetting equipment was put on the United States market through the sales and service network of the Radio Corp. of America. Now Hell has appeared on the U.S. scene again with a desktop facsimile transmission system called Zetfax.

In so doing, Hell has entered the arena with some U.S. giants like the Westrex division of Litton In-

dustries Inc. and the Zerox Corp. But Hell figures its typewriter-sized Zetfax can match in performance and price the small facsimile systems of its American competitors. In Europe, Hell has already sold the equipment to banks, hospitals, libraries, hotels and industrial plants.

Quick check. In many cases, the small facsimile units do jobs that heretofore had to be done by expensive closed circuit television systems. A bank, for example, uses Zetfax to speed check handling between branches and the main office. Checks presented at branches for payment are scanned by a branch-office transmitter at the teller's booth and sent to the central office receiver.

The central office, after verifying the signature and the balance, approves the check by actuating remotely a cancellation stamp at the transmitter. At the same time, a green "accept" lamp lights up at the transmitter. A red lamp lights up at the transmitter if the central office decides the check should not be paid. The facsimile of the check is used by the central office as a temporary voucher until the original check comes in.

Doctor's orders. Nurse gets diagnosis by facsimile transmission over telephone lines from specialist at hospital 100 miles away.

Self-starter. The basic Zetfax system consists of a transmitter and a receiver but up to 10 receivers can be hooked up in parallel to a single transmitter. In the transmitter, information written on ordinary paper is scanned optically by bouncing light off the paper and onto a photocell. The scanning resolution is 100 lines per inch.

The output of the photocell, which varies as the light hits dark and light areas on the paper, is amplified by a transistor amplifier and the signals sent over a 2-wire line to the receiver. Since the bandwidth for the facsimile transmisson is narrow—1500 ± 800 hertz—the units can also be linked by radio or by a normal telephone line.

An incoming signal to the receiver automatically turns on its writing mechanism. A paper tape travels past a metal scribing point, which presses the paper against an inked writing spindle to duplicate the original copy. At the end of each message, the transmitter sends a stop signal that shuts off the receiver's writing mechanism.

The transmitter exists in two versions. One uses a 110-yard-long roll of paper strip 1½" wide on which messages are scribbled for transmission to the receiver. The other is designed to handle individual sheets of paper up to 6½ x 8½ inches in size.

New frontiers

Travelers going by train from one country to another on Europe's electrified main lines must often put up with delays at border crossing points because engines have to be changed. That nuisance results from the four different power systems European countries have adopted for their electric railways. In Austria, West Germany, Switzerland, Sweden and Norway, for instance, electric trains are driven by a single-phase, 16⅔-hertz, 15-kilovolt power system. In the Soviet Union and most of France a single-phase, 50-hertz 25-kv supply is used. Belgium, Italy and some East European countries use 3-kv direct current, while the Netherlands and southwestern France have also adopted d-c but at 1.5 kv.

Silicon controlled rectifiers are basis of control circuits in German locomotive that can run on all four European rail power supplies.

This variety of power supplies has led to the construction of multisystem locomotives that can run anywhere on the Continent. However, because such locomotives require complex rectification and control gear, they are far from becoming standard railway equipment, and many travelers still encounter delays at border stations.

The key to relieving the situation is the silicon controlled rectifier, which is finding application in various European railroad control projects [Electronics, Sept. 6, 1965, p. 177].

Four ways. Engineers of the Allgemeine Elektricitaets-Gesellschaft and Fried. Krupp Machinenfabriken have built a multisystem locomotive engine employing regulation and control techniques based on scr's. At 84 tons and 4,300 horsepower, the engine has roughly the same weight and output as the single-system types currently in operation on Germany's electrified main lines. The new locomotive, called "Europa," can travel on any electrified standard-gauge line on the Continent regardless of the power supply system used. It's the first scr-controlled, four-system unit ever built, according to AEG.

The first of three such engines has been delivered to the German Federal Railway to be put into operation next spring on runs between Cologne and points in Belgium and the Netherlands.

Scr bridge. High-power, AEG-made scr's are the key control elements in the engine's electric traction system. Each scr can handle up to 170 amperes at a peak voltage of 900 volts. Connected in a bridge circuit configuration, they not only function as rectifiers but also as voltage control elements. The voltage is controlled steplessly without loss of power and no mechanical control switches are required. Used in inverter circuits, the scr's act as variable-frequency dc-ac converters.

The locomotive's basic electrical system is laid out for single-phase, 16⅔- and 50-hz operation and is made up of transformers and scr bridge rectifiers. The transformers step down the a-c voltage derived from overhead contact wires to a level suitable for drive-motor operation. The rectifiers deliver to the four drive motors a pulsating direct current that is steplessly adjusted by the scr's. Each motor has a one-hour rating of about 800 kilowatts at 1,050 volts and 1,150 revolutions per minute.

For operation on d-c supplies of either 1.5 or 3 kv, the inverter changes the power derived from the overhead contact wire into a-c voltage. The inverter consists of two scr bridge circuits connected in series for 3-kv engine operation and connected in parallel for 1.5-kv operation.

Czechoslovakia

Righting the balance

A do-it-yourself kick in Czechoslovakia bodes no good for Western electronics firms seeking business there. To cut down on their foreign exchange deficit the Czechs are turning out their own radars, television sets and semiconductors.

The exception is computers. Four

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orders have recently been snagged by Western firms. But for other areas of electronics, the production drive means less dependence on foreign equipment.

In the past two years, most of the country's semiconductor production has been concentrated in the CKD enterprise at Prague-Pankrac. Transistors, diodes and power thyristors are produced.

Similarly, television sets are manufactured in the factory-village of the Tesla-Orava enterprise in the Tatra mountains near the Polish border. Production amounts to over 200,000 sets annually, some 85% of the Czech output. The Czechs even manage to export some tv sets. During 1965, the Tesla enterprise alone sold some 20,000 sets abroad, and reportedly topped that figure in 1966.

Tesla still imports picture tubes and loudspeakers from Hungary and the West, but the firm makes its own printed circuits, and buys transistors from CKD and other plants in the state Electrical and Electronics Trust.

The drive also threatens foreign supplied radars. The first trial of a Czech-built radar will be held early next year, as the Czechs seek to supply the demands for equipment for ships navigating the Danube.

However, the Czechs continue to purchase computers from the West. They recently spent $630,000 for an Elliott-Automation Ltd. 4130 machine for the Prague National Research Institute for Computer Techniques and Automation, and $1.4 million for an English Electric computer for the State Pension Office. Two other computers, an IBM 1410 and a 1905 from International Computers and Tabulators Ltd., have also been purchased.

Around the world

France. The computer company set up six months ago to build an all-French third generation computer under the de Gaulle government's "Plan-Calcul" finally has a name: Compagnie Internationale pour l'Informatique, INFI for short. INFI was dubbed Société "S" for the six months it had no official name. The company joins the computer manufacturing subsidiaries of the Schneider industrial group and two major French electronics companies — Compagnie Générale d'Electricité and CSF-Compagnie Générale de Télégraphie Sans Fil [Electronics, June 27, 1966, p. 197].

Britain. Hawker Siddeley Dynamics Ltd., a leading missile maker, has developed a profitable sideline—building receiving stations to process pictures taken by weather satellites. The British Meteorological Office has bought five of the $28,000 stations. Singapore, Cyprus and the Maldive Islands also have stations. Plans call for a worldwide network of 50 stations to keep an eye on the weather.

Hungary. The electronic scoreboards for the 1968 Olympics in Mexico City will be built by Electro-Impex. The contract was awarded to the Hungarian company by the international Olympic committee, which will pay 85% of the cost, and by the Omega Watch Co. of Switzerland.

France. CSF-Compagnie Générale de Télégraphie Sans Fil has a contract to set up a school for electronics engineers at Dekouaneh, near Beirut in Lebanon, to help meet the nation's demand for consumer electronics. The center, with facilities for up to 200 students, will house a pilot television and radio production department. CSF will provide a technical assistance team, testing and instructional equipment and tv and radio components. Some components will eventually be made in Lebanon under CSF license.

India. The first commercial plant for development and manufacture of electronic process-control instrumentation has begun production in Jaipur, Rajasthan state. The $10.6-million facility, built with Soviet aid, is expected to turn out an estimated $15 million in electronic equipment annually by 1970 or 1971.

Britain. Production of semiconductor devices has outstripped thermionic tubes and related components for the past two years, according to the British tube and semiconductor manufacturers trade association.

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