Electronic Design

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THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

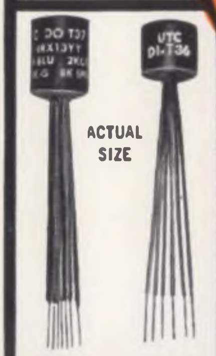
JAN. 4, 1966

Focus '66 peers from the far reaches of space to the depths of the sea, from semiconductors for household gadgets to Gunn-effect devices. Thirteen experts explore the major developments that design engineers can look for in six vital areas. What about IC arrays? Or computer-aided circuit design? (See pg 66).

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. *Units newly added to series
§Series connected; §§Parallel connected



UTC

PIONEERS IN MINIATURIZATION

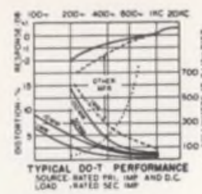
DO-T™ & DI-T™

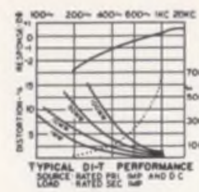
Transistor TRANSFORMERS and INDUCTORS

NOW! Hermetically Sealed to MIL-T-27B

***16 New Items Added to Stock Line**

IMMEDIATE DELIVERY FROM STOCK





- **High Power Rating** .... up to 10 times greater
- **Excellent Response** .... twice as good at low end
- **Low Distortion** .... reduced 80%
- **High Efficiency** .... up to 30% better . . . compare DCR
- **Moisture Proof** .... hermetically sealed to MIL-T-27B
- **Rugged** .... Grade 4, completely metal cased
- **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.)

Write for catalog of over 1,300 UTC HIGH RELIABILITY STOCK ITEMS IMMEDIATELY AVAILABLE from your local distributor.

UNITED TRANSFORMER CORP.

150 VARICK STREET, NEW YORK 13, N.Y.

PACIFIC MFG. DIVISION: 3630 EASTHAM DRIVE, CULVER CITY, CALIF.

EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N.Y. CABLE: "ARLAB"

A 10 Hz to 10 MHz AC Voltmeter with DC Output!

With 1 mV to 300 V Linear/Log Ranges!

for $285

THAT'S WHAT HAPPENS WHEN THE HEWLETT-PACKARD 400 SERIES GOES SOLID-STATE! Here's the world's first averaging ac voltmeter with a 0.5% of reading dc output . . . something you've never been able to get before. Offers a broad ac range, 10 Hz (cps) to 10 MHz (mc), 1 mV to 300 V, plus a log model, −72 to + 52 dBm.

Highest available input impedance, too, (10 MΩ) with shunt capacity at a low value (8pf) unequalled by other instruments.

WHAT'S EVEN BETTER: Price . . . only $285 for the 400E, only $295 for the 400EL log model!

If you have any of the following responsibilities, you should consider these points:

Design and production: 1 mV-300 V range, adjustable meter setting

Systems: 0.5% of reading dc out (1 V) for ac/dc conversion

Communications: 10 Hz-10 MHz, dB scales, external battery operation

Sciences: ac amplifier output (150 mV), long-term stability

Military: More rugged than the reliability-proven tube versions

University: budget price

The brief specs here tell the story. Compare them with any others . . . and then call your Hewlett-Packard field engineer (you probably won't even need a demonstration). Or write for complete specs to Hewlett-Packard, Palo Alto, Calif. 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

SPECIFICATIONS

Voltage range: 1 mV to 300 V full scale, 12 ranges

Frequency range: 10 Hz to 10 MHz

hp 400E/EL — Accuracy % of reading, 3 mV to 300 V ranges

Frequency	10 Hz	20 Hz	40 Hz	2 MHz	4 MHz	10 MHz
At full scale	±4	±2	±1	±2	±4	

Accuracy % of reading, 1 mV range

Frequency	10 Hz	20 Hz	40 Hz	500 kHz	1 MHz	4 MHz	6 MHz
At full scale	+4 −10	±2	±1	±2	±4	+4 −10	

hp 400E/EL — AC-to-DC Converter Output — Accuracy % of reading, 3 mV to 300 V ranges

Frequency	10 Hz	20 Hz	40 Hz	100 Hz	500 kHz	2 MHz	4 MHz	10 MHz
At full scale	±4	±2	±1	±0.5*	±1	±2	±4	

*For 15°C-40°C on 1 mV-1 V ranges only.

Input Impedance: 10 megohms shunted by 21 pf on the 1 mV-1 V ranges, 10 megohms shunted by 8 pf on the 3 V-300 V ranges

Amplifier ac output: 150 mV rms for full-scale meter indication; output impedance 50 ohms, 10 Hz to 10 MHz (105 mV on the 1 mV range)

AC-DC converter output: 1 V dc output for full-scale meter deflection; output is linear for both 400E and 400EL

External battery operation: terminals provided on rear panel

Price: 400E, $285 (replaces 400H-$325)
400 EL, $295 (replaces 400L-$325)

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

HEWLETT hp PACKARD

An extra measure of quality

862

◄ ON READER-SERVICE CARD CIRCLE 211

ON READER-SERVICE CARD CIRCLE 2

See it? We've got a new battlefield ally. Rutherford Electronics . . . the nation's number one name in pulse and time delay instrumentation . . . has joined our crusade as a division of CMC. What a way to finesse big, bad Beckman. (Poor guys, they don't even make a line of pulse generators or time delay generators.) And how about that for keeping our promise to compete with high-powered H-P right up and down their full line!

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So, Crusading Engineers, look sharp! Look twice! Now we double-dare you to "check the specs". Check the specs of CMC counters and digital printers . . . AND, check the specs of our Rutherford division's great line of pulse generators, time delay generators, and the new dynamic range simulator. We honestly believe that spec-for-spec, you won't be able to beat CMC/Rutherford instruments for the money anywhere.

Write us! You'll double your pleasure, and earn a glorious Crusading Engineer medal, too.

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COMPUTER MEASUREMENTS COMPANY IS A LEADING DESIGNER AND MANUFACTURER OF ELECTRONIC INSTRUMENTATION TO COUNT, MEASURE, AND CONTROL

ON READER-SERVICE CARD CIRCLE 3

Electronic Design

VOL. 14, NO. 1

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JAN. 4, 1966

NEWS

TECHNOLOGY

Be our guest to Paris!
See page 140 for details

PRODUCTS

Regular features

ELECTRONIC DESIGN is published bi-weekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y., 10022. T. Richard Gascoigne, Chairman of the Board; James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled-circulation postage paid at Chicago, Ill., and New York, N. Y. 58,062 copies this issue.

A Wave Analyzer That Gives You A Choice

A Choice of BANDWIDTHS: 3, 10, and 50 c/s

Bandwidth skirts are better than 80-dB down at ±25 c/s, ±80 c/s, and ±500 c/s for 3-, 10-, and 50-cycle bandwidths, respectively.

A Choice of READOUTS

Permanent chart record of analyzed spectrum plotted over an 80-dB dynamic range.

Meter readout for manual measurement of individual components present in a signal. Range is 30μV to 300 V, full scale, in 15 ranges. Accuracy is ± (3% of reading + 2% of full scale).

A Choice of 3 METER SPEEDS

Provides the correct response for measurements of either periodic signals or noise.

A Choice of TWO RECORDER OUTPUTS

A 100-kc filtered-and-amplified output for driving a GR Type 1521-A Recorder (80-dB dynamic range for inputs over 0.1 V), and a dc output for driving 1-mA recorders.

A Choice of 3 OPERATING MODES

NORMAL for spectrum analysis

AFC to hold analyzer in tune despite input signal drift

TRACKING GENERATOR provides an output signal which is always in tune with the analyzer for use as an input signal to devices under test.

. . . and, in Addition . . .

A Linear 20-c to 54-kc Range

Easy-to-read in-line readout is graduated in 10-cycle increments. ±0.5% calibration accuracy. Output is provided for measurement of frequency components with a counter, where extreme accuracy is desired.

Precise Frequency Setting

Incremental-frequency dial has twice the resolution of main dial — lets you fine-tune any component. Covers ±100-cycle range, independent of analyzer center frequency.

High Input Impedence

1-MΩ on all ranges, coupled with low-noise i-f circuits, makes for excellent sensitivity.

An Excellent Tunable Filter

For example, this instrument can be used to produce 3-, 10-, and 50-cycle bands of noise over a tunable range from 20 c/s to 54 kc/s when a random-noise generator is connected to the analyzer input.

Type 1900-A Wave Analyzer
$2350 (in U.S.A.)

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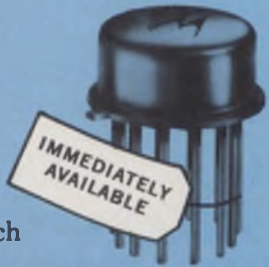
MILITARY RTL
MC900G SERIES

. . . for the most critical design jobs!



Designed for low-power military applications in which wide environmental extremes may be encountered in normal application, the series is specified for −55°C to +125°C operation.

INDUSTRIAL RTL
MC800G SERIES

. . . for broad applications of all types!

Specially intended for reliable operation in industrial logic applications, this series operates over a temperature range from 0 to +100°C. Priced for economical use in areas where wider temperature of operation is not required.

Both Offer These Key Performance Features . . .

- 12 nsec Propagation Delay
- Fan-out Capability Up to 5
- 15 mW/Node Dissipation
- For System Clock Rates to 8 mc

. . . and this wide range of circuit functions:

Buffer	MC900G/MC800G
Counter Adapter	MC901G/MC801G
Flip-Flop	MC902G/MC802G
3-Input Gate	MC903G/MC803G
Half-Adder	MC904G/MC804G
Half-Shift Register	MC905G/MC805G
Half-Shift Register (W/O Inv.)	MC906G/MC806G
4-Input Gate	MC907G/MC807G
Dual 2-Input Gate	MC914G/MC814G
Dual 3-Input Gate	MC915G/MC815G
J-K Flip-Flop	MC916G/MC816G
J-K Flip-Flop	MC926G/MC826G
Quad Inverter	MC927G/MC827G

...THERE'S A MOTOROLA RTL INTEGRATED CIRCUIT TO FIT YOUR EXACT PERFORMANCE AND COST REQUIREMENT!

(*. . . you can choose from* 4 *different RTL complements for your design.*)

LOW-COST COMMERCIAL RTL

MC700G SERIES

. . . combining RTL & mWRTL circuits for utmost versatility!

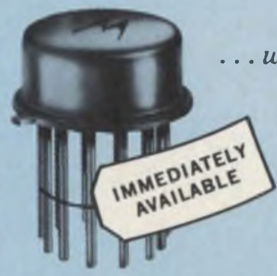
Designed and priced for a wide variety of commercial applications (as low as $2.55 for a 3-input gate circuit in quantities of 100 or more), this low-cost series offers a combination of mWRTL and RTL circuits including some 22 circuit functions from which to choose. They open the door to new economical integrated circuit applications in such areas as instrumentation, industrial controls, test equipment, and many commercial computer designs.

COMPARE THESE LOW, LOW PRICES!

		100-Up
Buffer	MC700G	$2.55
Counter Adapter	MC701G	3.80
Flip-Flop	MC702G	3.20
3-Input Gate	MC703G	2.55
Half-Adder	MC704G	2.65
Half-Shift Register	MC705G	4.35
Half-Shift Register (W/O Inv.)	MC706G	3.65
4-Input Gate	MC707G	2.65
Adder	MC708G	3.75
Buffer	MC709G	2.55
Dual 2-Input Gate	MC710G	2.65
4-Input Gate	MC711G	2.65
Half-Adder	MC712G	3.65
Type D Flip-Flop	MC713G	6.35
Dual 2-Input Gate	MC714G	2.65
Dual 3-Input Gate	MC715G	3.20
Dual 3-Input Gate	MC718G	3.20
J-K Flip-Flop	MC720G	6.35
Expander	MC721G	2.65
J-K Flip-Flop	MC723G	6.35
J-K Flip-Flop	MC726G	6.35
Quad Inverter	MC727G	4.60

LOW-POWER MILLIWATT RTL

MC908G SERIES



. . . where minimum operating power level is required!

- 2.5 mW/Node Power Dissipation
- 40 nsec Propagation Delay
- Full Military Temperature Range — −55°C to +125°C

The low-operating power requirements of this Motorola RTL circuit series (only 2.5 mW/node) makes this logic complement especially attractive to military and space users. To meet the requirements of this market, the series is designed for operation throughout the full military operating temperature range from −55°C to +125°C.

Adder	MC908G
Buffer	MC909G
Dual 2-Input Gate	MC910G
4-Input Gate	MC911G
Half Adder	MC912G
Type D Flip-Flop	MC913G
Dual 3-Input Gate	MC918G
J-K Flip-Flop	MC920G
Gate Expander	MC921G

See your local Motorola semiconductor distributor for the Motorola RTL integrated circuit type which fits your immediate need. For production quantity requirements, call your nearest Motorola district office — or write Motorola Semiconductor Products Inc., Box 955, Phoenix, Arizona 85001.

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Semiconductor Products Inc.

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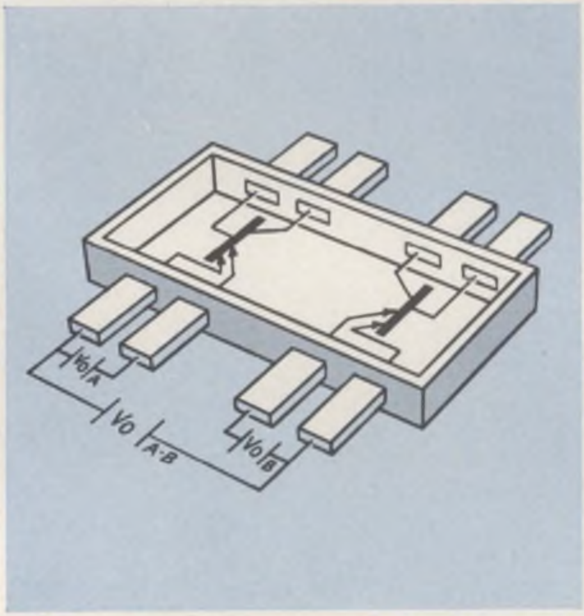

Sprague leads again with two dual-emitter chopper transistors in one flat-pack case, with tight V_{OFF} matching of both devices

CHECK THESE KEY PARAMETERS			
Type No.	V_{EEO}	V_{ECO}	$\|V_O\|$ A-B
3N112	30V	30V	20μV
3N113	50V	50V	20μV

Standard TO-18 case Duet* Transistors...the broadest line of dual-emitter choppers

Type No.	BV_{EEO}	V_O
3N90	30V	50μV
3N91	30V	100μV
3N92	30V	200μV
3N93	50V	50μV

Type No.	BV_{EEO}	V_O
3N94	50V	100μV
3N95	50V	200μV
3N108	50V	30μV
3N109	50V	150μV

Type No.	BV_{EEO}	V_O
3N110	30V	30μV
3N111	30V	150μV
3N114	12V	50μV
3N115	12V	100μV

Type No.	BV_{EEO}	V_O
3N116	12V	200μV
3N117	20V	50μV
3N118	20V	100μV
3N119	20V	200μV

*TRADEMARK

For complete information, write to Technical Literature Service, Sprague Electric Company, 347 Marshall Street, North Adams, Mass. 01248

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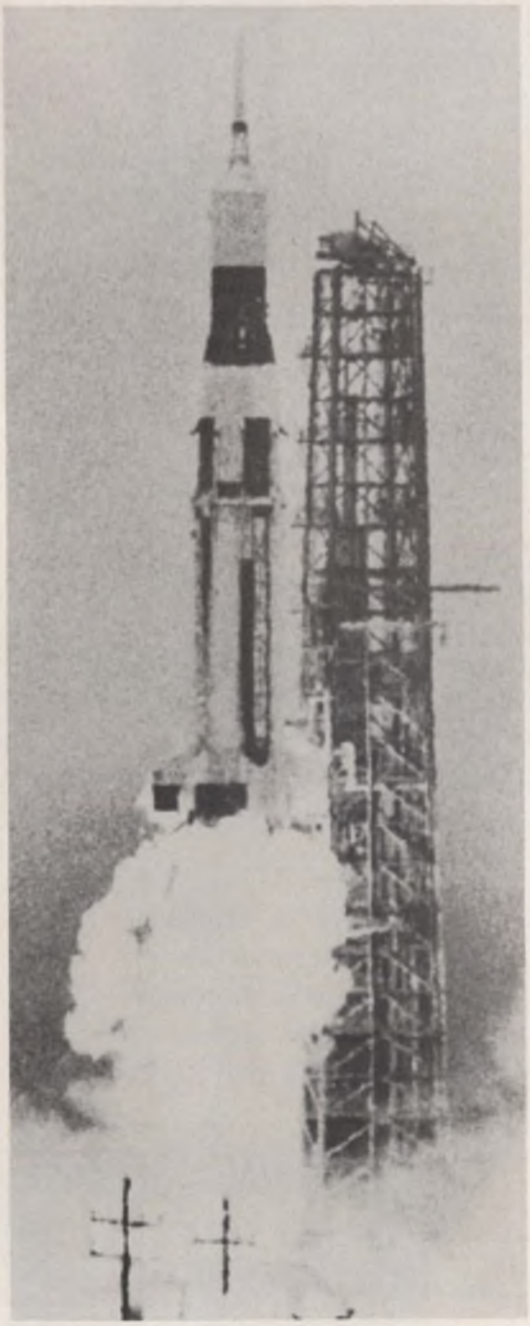
ON READER-SERVICE CARD CIRCLE 9

ED News



Wide World

1966: The year of the Apollo

Pop art invades electronics!

Tactical-warfare electronics boosts industry

The view from GT-6

News Report

New radar spelled rendezvous success

The recent success of the Gemini rendezvous mission, which will hopefully aid NASA in its bid for more money, was due in large part to a new radar concept.

NASA Officials, who have been worrying about their budget for the next few years (see E/D, Washington Report, December 20, p 20) are hoping that the rather spectacular success will give them a boost on Capitol Hill, where the agency's request for $5.6 billion for fiscal 1967 operations is expected to be chopped to $5.1 billion or less.

The rendezvous feat is being touted as putting the U.S. in the lead in the "race" in several areas and proving the feasibility of rendezvous. Gemini 8, now scheduled for late February or early March, will attempt actual contact, probably with an Agena vehicle.

The most interesting electronic feature in the Gemini 6/7 rendezvous and the one most responsible for the success of 6T-6 in locating and approaching the GT-7 was the cooperative radar system developed by Westinghouse specifically for rendezvous between vehicles.

A transponder aboard the target, GT-7, took weak signals from the emitter on GT-6 and, after a known time delay, sent them back at full power on another frequency. The heart of the system is the array of four spinning plane-spiral antennas, one transmitting and three receiving. The system's computers used two types of information in calculating the range and angle of the two crafts: 1) Time-lapse information from GT-6 through the transponder in GT-7 and back to GT-6 yielded the range. (2) Azimuth and elevation were determined by evaluating phase differences between the two antennas in each of the sets.

Close spacing of the antennas eliminated the difficulty of determining just which cycle of the plane-polarized wave is being nulled. If the target vehicle is not dead ahead, one or two of the antennas will see a phase difference compared with the third reference receiving antenna. This phase difference can be measured by changing the phase of the appropriate antenna and using a nulling technique. The azimuth and elevation of the target vehicle are thus determined. This system eliminates the need for scanning to locate a target because of its high-acceptance angle. It also served to conserve fuel for maneuvering.

Plan SLBM early-warning system

The nation's first early-warning system against sea-launched ballistic missiles (SLBM) to be built will rely heavily on the AN/FPS-26 height-finder radar. Known as the 416-N, the new system is intended to give NORAD and SAC a detection, identification and warning capability.

ELECTRONIC DESIGN has learned from the Air Force Systems Division that the radar segment of the 416-N SLBM will be a modified version of the FPS-26. A $10.5 million contract was recently awarded to Avco Corp.'s Electronics Div., Cincinnati, Ohio, for the radar segment. Avco developed and produced the FPS-26 for the Air Force, and it is now operational in the SAGE system. The FPS-26 has been officially cited by the Air Force as a significant improvement in the state-of-the-art of height-finder radars. The new sea-launched ballistic-missile system will not have over-the-horizon capabilities, according to the Air Force.

EMC standards to be issued

New standards for electromagnetic compatibility (EMC) to be used by all government and military agencies are being shaped by a committee of the Society of Automotive Engineers.

The first standard, covering jet aircraft engines, is expected to be issued shortly after the SAE committee meets on January 25-26 at General Dynamics/Convair's San Diego plant.

The work is being done through an SAE committee because the machinery for setting up new standards was better than in other societies, according to Walter McKerchar, McDonnell Aircraft Co., St. Louis, who is secretary of the AE-4 committee.

Later this year, the committee hopes to issue a standard interference control plan to be used by subcontractors in supplying equipment to a main contractor. It is hoped that the standard will replace the many varied military specs covering this area. Vendors will have to satisfy a prime contractor that they have the technical capability necessary to assure that delivered equipment will meet electromagnetic compatibility requirements, McKerchar told ELECTRONIC DESIGN.

The third standard to be issued will be on interference test methods. McKerchar said it is anticipated that this would replace present military specifications, such as the Air Force and Bureau of Weapons Mil-I-6181D. Shortly thereafter a standard is planned that would replace the present weapons system compatibility specification, Mil-E-6051C.

All military agencies concerned with EMC, including the EMC Analysis Center in Annapolis, are assisting the committee in preparing the new standards.

No more money for AOSO

Development of the Advanced Orbiting Solar Observatory (AOSO) will be halted immediately because of "budgetary considerations."

NASA officials emphasized, however, that the AOSO mission is considered an important one and expressed the intention that it would be reinstated in the future.

At the time of cancellation, a prototype craft was being developed. Through fiscal 1966, $39 million had been budgeted and only a portion of the $24.9 million appropriated for FY 1966 will be recoverable.

The project called for the development of a 1250-pound satellite capable of accurately pointing 250 pounds of instrumentation at the sun. The contract was let in November of 1963 to Republic Aviation of Farmingdale, N. Y. which recently merged with Fairchild-Hiller Corp.

Major subcontractors to Fairchild-Hiller in the project were Honeywell, for the stabilization and control system, and Texas Instruments, for communications and data handling.

Laser patent rights challenged

During the coming months the United States Court of Customs and Patent Appeals will decide who owns the patent rights on that monochromatic glint in the industry's eye: the laser.

Since the award of the first laser patent on March 22, 1960, the invention has been generally attributed to the recipients of that patent, Charles H. Townes and Arthur L. Schawlow.

Richard Gordon Gould, contestant in the suit, claims he had similar information, which he had entered in a notebook, notarized about 2-1/2 years before the award of the Townes-Schawlow patent. Townes' lawyers counter with a notebook containing comparable statements of the optical maser principal dated and witnessed by a Columbia graduate physics student two months before the notarization of the Gould notebook.

According to sources in the technical patent field, statements like those of Gould's wife and the notary public have limited value in the case if they didn't have enough technical competence to understand the material that they were witnessing.

In addition, the lawyers representing Townes and Schawlow are hinging their defense on the requirement in patent law that the recipient of a patent must exercise "reasonable diligence" in putting an abstract idea to use.

Sperry, IBM cross-license patents

A cross-licensing agreement between Sperry-Rand Corp. and IBM "resolves all outstanding patent differences" between the two companies, according to a Sperry statement.

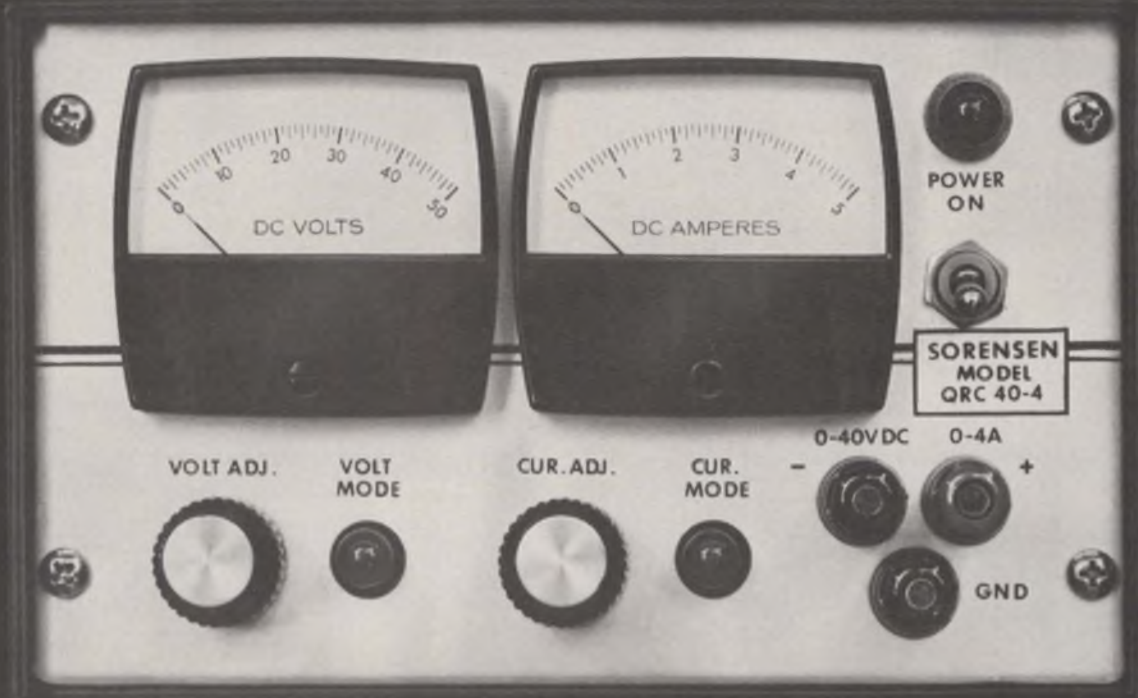
The non-exclusive agreement includes all patents of the two companies in the broad field of information handling. Reported "differences" between the two companies were related to negotiations on the cross-licensing and not to any basic patent arguments, a Sperry official stated. The company is now looking to agreements with other computer manufacturers on an individual basis, he added.

Industry officials are reportedly not too excited over the agreement, but some feel that the move could prove of great benefit to Sperry. If the agreement is extended to other manufacturers, Sperry may have at its command the technical know-how of the entire industry.

60% more engineers will be hired from 1966 graduating classes than last year, a Northwestern University survey has predicted. Average monthly salary offers should run to $662, but this figure may go up, as the survey predicts unusually competitive hiring this year. This figure is $20-$30 more than last year's average offer.

The recent ITT-ABC merger is meeting little industry opposition. The FCC, however, may look at ITT's foreign ownership, since broadcast licensees must be less than 20% foreign-owned.

Six 1200-channel satellites for ComSat, deliverable within 24 months of contract award, are under negotiation between TRW Systems Corp. and ComSat. TRW won out over RCA and Hughes Aircraft with its proposal.



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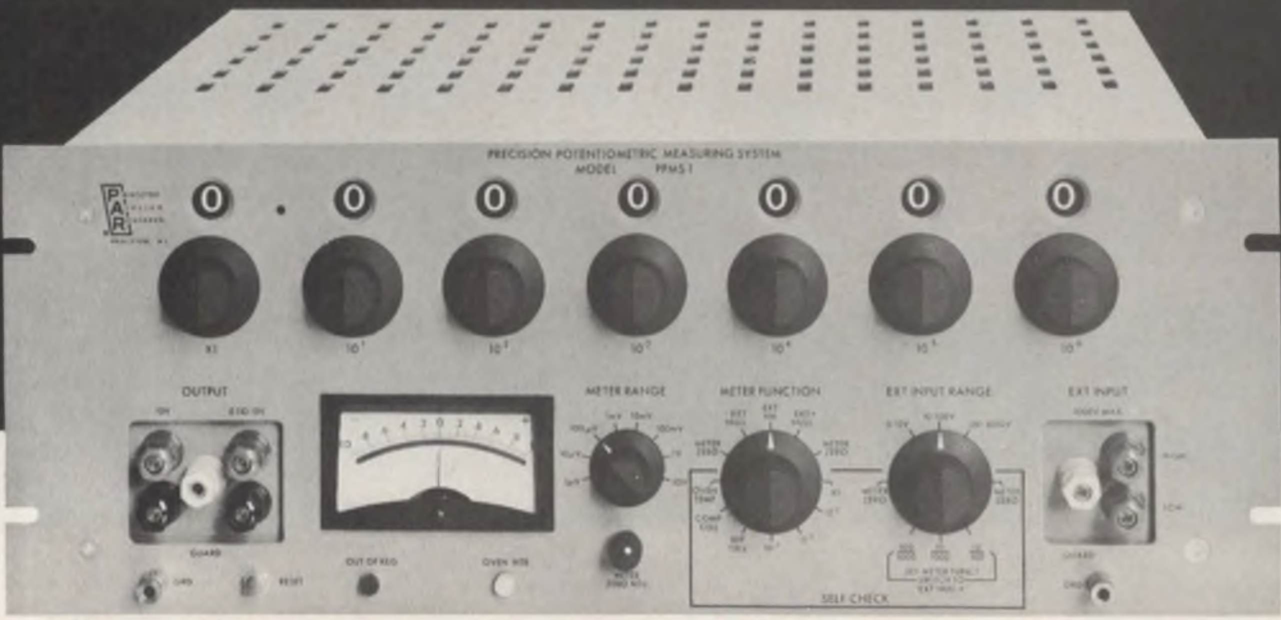
QRC20-8	0-20	0-8	± .005% or ± 1 mv	1 mv	0-8	± .05% or ± 4 ma	2 ma	3½	$410.00
QRC40-4	0-40	0-4	± .005% or ± 1 mv	1 mv	0-4	± .05% or ± 2 ma	1 ma	5¼†	315.00
QRC20-15	0-20	0-15	± .005% or ± 1 mv	1 mv	0-15	± .05% or ± 8 ma	4 ma	5¼	525.00
QRC40-8	0-40	0-8	± .005% or ± 1 mv	1 mv	0-8	± .05% or ± 4 ma	2 ma	3½	450.00
QRC20-30	0-20	0-30	± .005% or ± 1 mv	1 mv	0-30	± .05% or ± 16 ma	8 ma	7	700.00
QRC40-15	0-40	0-15	± .005% or ± 1 mv	1 mv	0-15	± .05% or ± 8 ma	4 ma	5¼	575.00
QRC40-30	0-40	0-30	± .005% or ± 1 mv	1 mv	0-30	± .05% or ± 16 ma	8 ma	7	775.00

†Half rack

1 PPM

Potentiometric Measuring System



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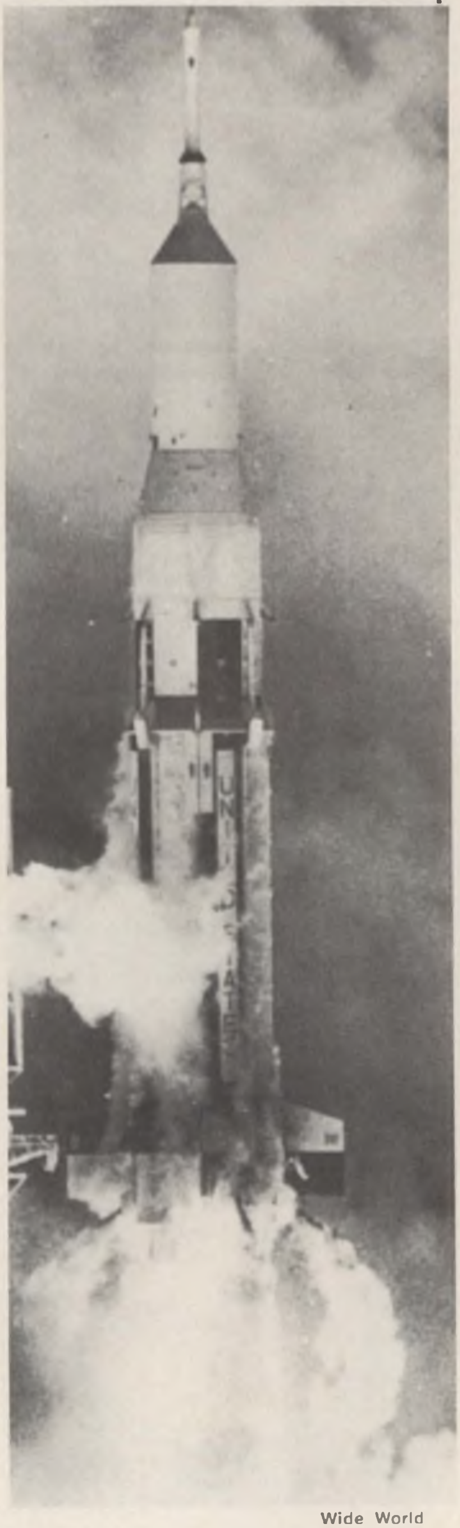
ON READER-SERVICE CARD CIRCLE 12

Focus '66: $18 billion for electronics

Vietnam, space still lead government expenditures; integrated devices expand into linear modules and consumer and industrial products; color TV booms.



Wide World

The Saturn-Apollo moon trip is scheduled for 1966, while tests of the vehicle continue at Cape Kennedy.

Richard Harnar
News Editor

The electronics market will continue upward in the second half of the Sixties, with hardly a ripple from significant realignments in spending by government, industry and consumers.

Another $1 billion was added to the total picture in 1965, bringing the factory sales figure to just over $17 billion. The Electronic Industries Association expects about the same increase in 1966, but indications are that this may be a somewhat conservative estimate.

The industry's growth rate, which has been slowing from 14% in 1960-61, is expected to have bottomed out in 1965 at about 5.5% and should start up again in 1966. The EIA looks for a 7.2% growth this year, led by increased Government spending, which also bottomed out in 1965 at a 1% growth rate, down from 17% in 1960. Increased requirements in Vietnam and elsewhere should play a large role in a 1966 growth of 5.3% for Government electronics spending. (See graph at the bottom of page 18.)

The current picure in this major area of the electronics market reflects some realignments from last year.

Defense electronics, which many expected to drop off this year, still leads all other areas in the market in total dollars spent. Tactical-warfare requirements have shifted the emphasis to short-range aircraft and radar, local communications gear and other tactical electronics equipment, including practical applications of some newer technologies, such as lasers. Defense Secretary Robert S. McNamara expects the military budget to stay between $45 and $55 billion for the next five years, with the electronics portion growing from less than $8 billion to $10 billion.

Space electronics remains a big market and a major hiring-place for engineers. NASA electronics expenditures are now around $1.6 billion, about a third of its entire budget. A new factor has been introduced with the final approval of the Air Force MOL project. There is speculation around Washington about the future of NASA vs MOL: Will the Air Force take over all space activities? (See ED, Washington Report, December 20, p 20.)

Industrial electronics, expected

Battlefield communications equipment used by Air Force Commandos has a major defense electronics role.

Biomedical electronics has accelerated with the monitoring systems developed for the Gemini astronauts.

NEWS

(continued from p 17)

by many observers to have taken over factory space and personnel left idle by the losses of big defense contracts in the last two years, saw a modest increase in 1965. EIA predicts a slight drop in 1966, but automation remains as one of the fastest growing businesses, paced by the data-processing equipment field.

Consumer electronics in 1965 fulfilled and even exceeded the expectations of a boom year for color TV. Expansion is evident in all companies having anything to do with color; small companies supplying components are especially healthy. Other consumer electronics areas are seeing the introduction of semiconductors, FETs and, in some areas, microelectronics on a conservative basis. Video tape recorders will undoubtedly become reasonably priced in 1966—at least to the point where they'll compete with better quality home sound-movie equipment. They may become the big consumer product for 1966.

The components field is currently being paced by circuit modules, which, until now, were almost exclusively of digital types. They should blossom fully into analog and linear circuits in 1966. The annual growth in sales of these devices will top that of semiconductors for the next few years, but will remain appreciably behind transistors and non-circuit-type integrated electronics in total sales. The latter are rapidly approaching the $1 billion sales mark.

Employment stabilizing

At this time last year, hundreds of engineers were out of jobs, victims of widespread layoffs at companies that had never had an engineering layoff before. Today, most of these engineers have been rehired in the biggest spurt of hiring seen in some years. But companies have generally been more selective, and many of the engineers that had been laid off found that their limited defense-industry-oriented or obsoleted skills were not much in demand any longer.

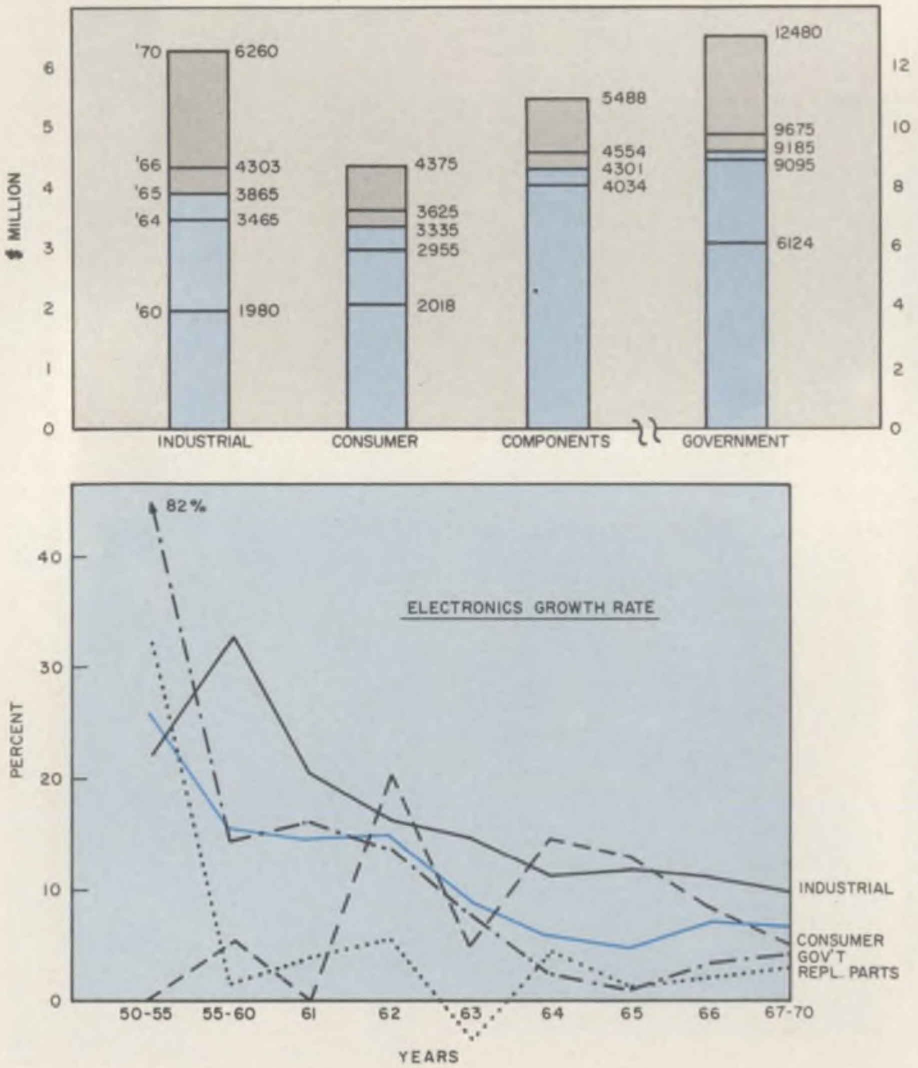
The Vietnam situation has brought about an apparent stabilization of employment in engineering. But opinion is divided on whether this picture will remain stable when and if the Vietnam problem is settled.

Spotlight on hot areas

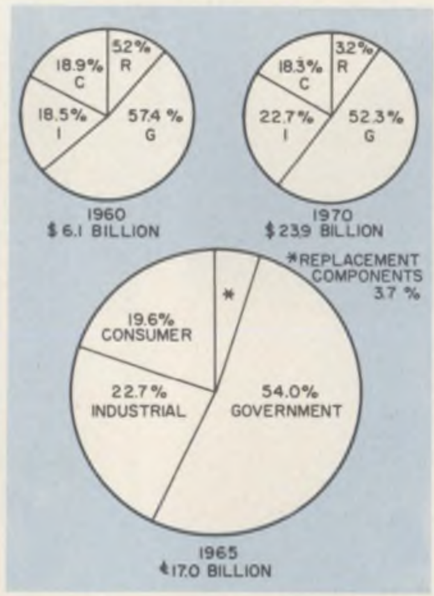
Starting on page 66 of this issue, some of the more promising growth specialties in the industry —integrated microwave circuits, oceanography, space electronics, integrated-circuit arrays and semiconductors in the industrial and consumer markets—are explored in depth. Here we will touch on these and other areas and discuss their current and future prospects.

Components

Linear circuit modules have not until recently lent themselves to the modular technique now common for digital circuits. The reason has been more a matter of



The annual electronics growth rate (bottom) shows a continuing drop through 1965, with some pickup this year. The bar graph at the top shows **comparative sales** of the four major electronics areas for various years.



The electronics pie. A comparison of the beginning, middle and end of the decade shows little change in slices.

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Coercive Force Oersteds	Residual Induction Gausses	Energy Product BH Max. x 10^6
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1730	7900	5.38
1850	8200	6.20
1780	7950	5.52

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(continued from p 18)

high cost than lack of technological know-how. Operational amplifiers are now available for under $30 and are by far the best sellers because of their wide applicability. These devices promise to play a major role in equipment design in the coming years. At any rate, the role of the circuit designer will be changed; he will need to be more aware of the possibilities of the modular approach to his design problems.

Microwave integrated circuits have been developed successfully, but the quantity needs sufficient to justify the cost of product development have not appeared. Digital ICs achieved product status rapidly because of the thousands of identical circuits required in computers. Some observers feel that phased arrays and needs in space programs may bring about several microwave integrated devices this year. (See p 34.)

Field-effect transistors, which became available under military specifications last summer, should burgeon in sales in 1966. Their introduction into consumer and industrial products to a significant extent will be a major factor in the increased sales. Their ability to handle higher signal levels will also contribute.

Data Processing

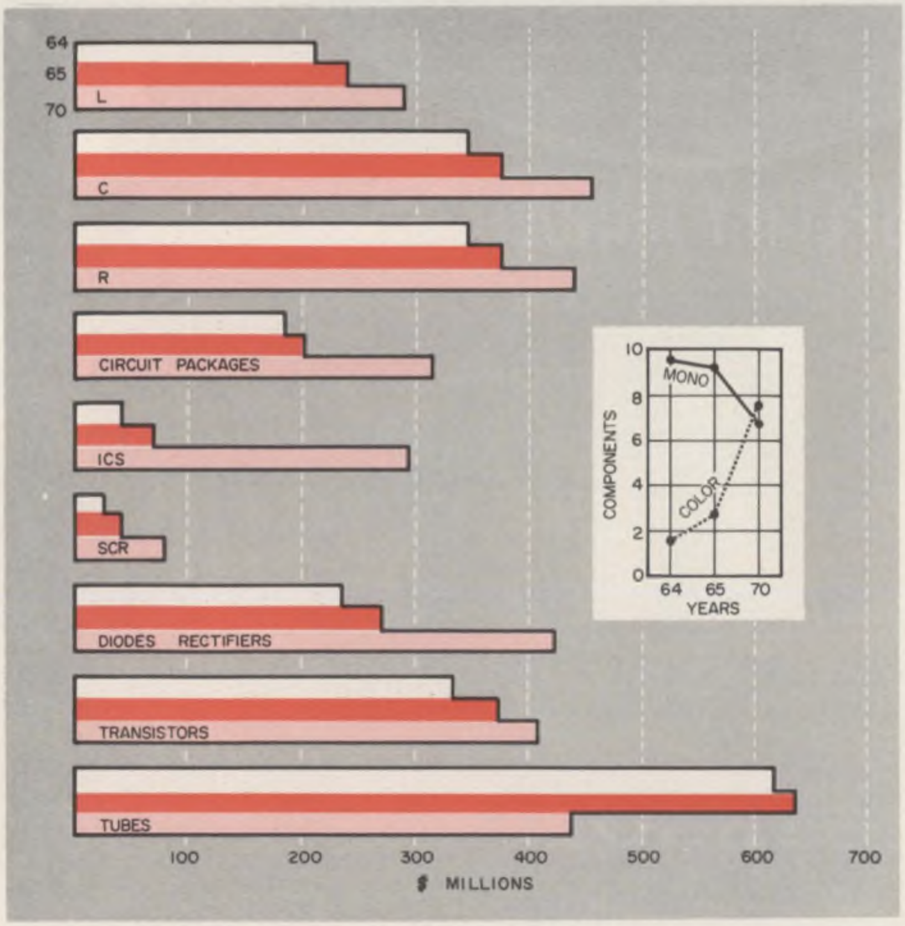
The computer as a public utility is becoming a distinct possibility, with the growing field of time-shared systems. At this point, operating time-sharing installations are limited, but all the major manufacturers are introducing expanded multi-processor and multi-input systems. One manufacturer even has a universal credit system available for communities that want to eliminate money!

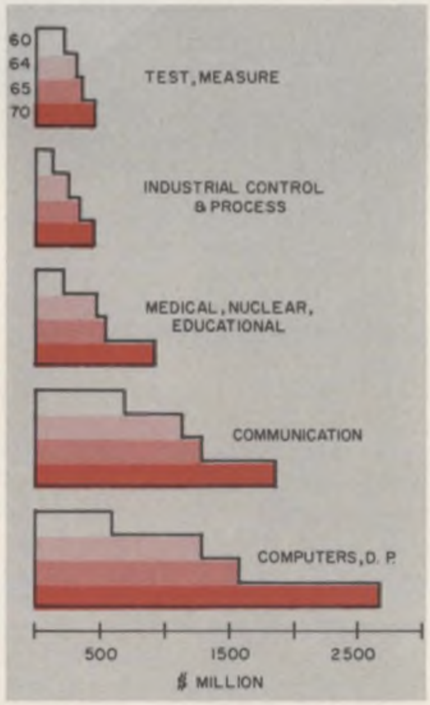
A major gap in **computer design** —memory speeds and sizes compatible with integrated-circuit techniques—is being filled. But there is unexpected competition between smaller, faster core units, thin-films and IC-array memories to fill that gap. (See E|D, December 20, p 6.) Most of the big computers are still using discrete components, but integrated circuits are finding their way in, especially in military-space units. For a picture of

Computer equipment shipments—U. S. ($million)

Year	General Purpose	Special Purpose	Peripherals	Software Bureaus, Consultants	Supplies Services	TOTAL
1955	75	80	14	15	155	339
1960	720	900	105	125	375	2225
1964	2200	1200	170	320	680	4570
1965 est	2300	1250	175	425	730	4880
1970	5000	2000	350	560	1200	9100
1975	9-10,000		1000	825	1350	12000

Note that in the 1970s, the distinction between general and special-purpose types is due to disappear. (Figures after 1965 are estimates.)





The components and industrial electronics portions of the market are broken down as shown, with EIA's five-year projection.

the current and future dollar market in computers, see the table on page 20.

Commercial electronics

Automation still continues to grow at a rapid pace, in spite of some well-publicized problems. One area which has been largely neglected is in simulation and control of electrical **power distribution systems.** Power engineers will probably be called on to give up their traditional independence of electronic technologies, following the "Big Blackout" of 1965. The Federal Power Commission's report bore out the opinions of many in the electronics industry that much of the chain reaction could have been prevented with electronics.

High-speed rail transit will be a major area of interest in 1966. The $90 million Federal program has already been started with a $900,000 award for souped-up versions of present designs that will hit speeds of up to 150 mph. MIT and others are working on more blue-sky proposals, such as a pneumatic-tube system to reach speeds of at least 300 mph. Electronics will play a major role in all of the new systems.

Hybrid areas

Biomedical electronics will undoubtedly receive a shot in the arm in July with the implementation of the Medicare program. Automated hospital operations and patient-monitoring equipment will be easier to pay for with indirect Government help. Other biomedical devices—artificial organs, implantable telemetry devices and the big market of hearing aids—will all benefit.

Increasing demands for hospital diagnostic testing, coupled with a shortage of qualified laboratory workers, is leading to further **automation of analytic instruments** (blood-cell analyzers, enzyme-reaction monitors, amino-acid analyzers, etc.) One large hospital laboratory that did 250,000 blood tests last year expects to do 500,000 this year by increased automation.

Analytic instruments used in the processing industries—especially petroleum and chemistry—are being redesigned to provide direct outputs for digital systems. Direct

(continued from p 21)

digital control is being considered for many processes, and adaptive computing techniques are being studied. (See E|D, October 25, p 12.) In one lab, a central computer not only keeps track of all tests performed but also computes bonus payments to laboratory workers based on their performance.

Nuclear electronics. Even before the long-time-building Stanford Linear Accelerator is completed (it's due for turn-on this spring), construction on the next biggest accelerator—a 2 GeV monster—is scheduled to get underway. The announcement of its location is expected very soon by the AEC. Challenging the technology of these units is an experimental superconducting accelerator in the million-electron-volt range, also at Stanford. Researchers have reportedly overcome the problem of supercooling such large devices.

Avionics and space electronics

Because of Vietnam, the Government electronics picture for 1966 is as cloudy as is the Federal budget in general. It became even less discernible following announcement of the FB-111 bomber force, for which $1.75 billion more must be found for the fiscal 1967 budget.

Although some of the electronics packages for the 454 **F-111s** now under order have been procured, it is not possible yet to give an indication of the hardware still to be procured or its dollar value. Nor is it possible to estimate the electronics requirements of the 200-plus FB-111 bombers recently added to the program.

While an important factor in the over-all fiscal picture, the Vietnam situation does not draw heavily on the electronic market. More sophisticated tactical communications gear appears to be the major area where the Defense Department is still looking.

On the other side of the DOD ledger is a series of programs that are or soon will be relying heavily on electronics. Among them are the MOL (manned orbiting laboratory), the F-111 family of aircraft, the C5A transport and anti-submarine warfare and other oceanographic projects.

The Manned Orbiting Laboratory will undoubtedly go heavily on electronics. However, what systems and components, to what extent and when are questions still to be determined pending the DOD's budget decision and further mission determination.

Electronics for the first 58 **C5A transports,** on the other hand, has been estimated to involve $150 million. Starting in the first quarter

The $100 million club

In fiscal-1965 defense contracts, 40 companies gleaned $100 million or more of the taxpayers' money. The top firms are on top because of big production jobs: Lockheed for C-141 and C-130 transports and P3-A patrol bombers (C5A not yet included); General Dynamics for the F-111s; McDonnell largely for the F-4 fighter-bombers (Gemini not included.)

The 100 major contractors hold 69% of the total dollar volume of prime military jobs worth over $10,000. Their holdings dropped 4.5% since last year, mainly because of the $1.6 billion cut in missile-aircraft contracts.

	$Million	'64 rank
Lockheed Aircraft	1715	1
General Dynamics	1178	5
McDonnell Aircraft	856	3
General Electric	824	6
North American Aviation	746	4
American Tel & Tel	588	7
Boeing Co.	583	2
Grumman Aircraft	353	11
Sperry Rand Corp.	318	12
Martin Marietta Corp	316	9
Ford Motor Co.	312	27
General Tire & Rubber	302	13
Raytheon Co.	293	21
Hughes Aircraft	278	15
Ling-Temco-Vought	264	22
Westinghouse Electric	261	23
Northrop Co.	256	31
General Motors	254	19
Bendix Corp.	235	17
Avco Corp.	234	16

Also: GT&E-223; RCA-214; ITT-207; Litton-190; IBM-186; Douglas-170; Collins-141; MIT-124; Gen Precision-101.

Electronics in the Balance of Trade—1964 ($ Thousands)

Country	Consumer Exports To	Consumer Imports From	Mil, Indust. Exports To	Mil, Indust. Imports From	Components Exports To	Components Imports From	TOTAL Exports To	TOTAL Imports From
West Germany	5,641	13,268	32,738	1,840	11,906	5,440	50,285	20,548
France	806	109	48,109	361	19,253	2,746	68,168	3,216
Italy	1,973	379	14,547	1,747	6,182	2,324	22,702	4,450
Netherlands	283	3,517	12,347	735	4,672	8,920	17,302	13,172
U.K.	3,118	18,212	77,905	6,964	11,025	6,908	92,048	32,084
Canada	10,174	5,211	74,946	25,496	23,427	6,222	108,547	36,929
Japan	2,068	165,730	57,467	8,411	4,303	39,356	63,838	213,497
Switzerland	665	723	14,606	487	5,050	706	20,321	1,916
Other	44,193	11,511	118,919	1,474	37,099	9,033	199,460	22,018
			125,354[1] 147,001[2]	— —	25,349[3]	—	297,704	—
TOTALS	68,921	218,660	723,939	47,515	148,266	81,655	941,126	347,830

1. Electronic Detec. & Navig. Eqpt.—not speciifed by country
2. Radio Comm. Eqpt.—not specified by country
3. Electron Tubes—not specified by country

SOURCE: Bureau of the Census &EIA Mktg. Services Dept.

(continued from p 23)

of this year, Lockheed will let subcontracts for multi-mode radar, doppler navigators, radar altimeters and miscellaneous communications and control packages.

One DOD project that could wind up on the Vietnam casualty list is **Nike-X.** Concern for the project goes all the way to the White House, and the President is reportedly in a dilemma whether to push the "go" or "no-go" button at this point.

Anti-submarine warfare electronics continue to command considerable attention. Of primary interest are electro-magnetic submarine detection systems and underwater lasers.

On the **military R&D** front, the "pause" still seems to be in effect while the services are catching up with the results of past R&D. Meanwhile, off-the-shelf items remain in style. Apparently, DOD considers new components and systems developed with company funding as "off-the-shelf" also.

Whether NASA will get its requested fiscal 1967 budget increase apears doubtful, partly because of Vietnam, but even more because of the lack of any specific post-Apollo programs. The Bureau of the Budget is reported to have recommended shaving NASA's request to $5.1 billion, $0.1 billion less than this year's budget.

Among the major projects on NASA's fiscal 1967 budget is the **Voyager,** set to land instruments on Mars by 1971. If approved, some $200 million will be fed into the program. This is in addition to the $48 million approved by Congress for study purposes and included in the current budget. Based on former standards, as. much as 75% of these funds could be absorbed by electronics.

Aside from the two major areas of defense and space, the Government will also be needing electronics hardware and services in a series of other fields. Most prominent among these is air-traffic control under the Federal Aviation Agency. It is expected that FAA's requirements will remain unchanged from the current level of about $100 million annually.

International electronics

The overseas market portion of the electronics picture this year continues to reflect that of United States industry in general: overbalanced on the side of dollar-drain.

Total electronics exports for 1965 represented about twice the dollar value of imports:

	'61	'64	'65	'70
		($ million)		
Imports	199	348	482	734
Exports	605	941	999	1200

The trend of the past few years is continuing: an average annual increase in imports of some 25%, compared with less than 20% annual increase in. exports.

By 1970, EIA estimates indicate that imports and exports should increase 52% and 21%, respectively.

The largest factor in the unfavorable import picture is still the tide of consumer electronics from Japan: some $165 million in 1964. In 1961, 55% of all U.S. electronics imports were of Japanese origin; by 1964, this figure had reached 65%.

Military and industrial equipment (which are included together in Government figures) have for several years represented the largest dollar value of U.S. exports. This should begin to level off this year, according to industry estimates.

Last year saw the largest increase in dollar value of electronics imports in several years, paced by components and consumer equipment.

Because many traditional overseas markets either have begun to develop their own domestic industry or have turned to more competitive sources, there has been a slowing down in the growth of exports. Nevertheless, the technological lead of the U.S. is expected to guarantee a good international market for many years. ■ ■

SCRs control ac induction motors to drive Army truck

Performance details are expected to be announced soon of a two-year development and test program on a novel electric-drive concept for U.S. Army vehicles.

The concept is novel in that it uses ac squirrel-cage induction motors with their inherent simplicity, ruggedness and low cost. Previous electric drive systems have employed dc motors, since no practical means was available for controlling the speed-torque characteristic of ac motors. Dc systems do not meet the electric-drive requirements of an Army vehicle because of control deficiencies. Such requirements include:

Operation of the prime mover at maximum fuel economy under all conditions, vehicle mobility over all types of terrain, the adjustment of vehicle traction forces in accordance with grades and axle loadings and the limitation of speed, acceleration, deceleration and jerk.

The development of highly efficient frequency converters using silicon controlled rectifiers has made the practical ac electric-drive system possible. The superior control of excitation frequency that the SCRs provide enable these converters to vary the slip frequency of an induction motor precisely in a closed-loop system. In this way, any appropriate output speed and torque of the motor may be selected by a low-power control circuit.

The system, which was developed by the Power Equipment Div. of Lear-Siegler Corp., has been installed in a standard six-wheel U.S. Army vehicle. The prime mover in the system is still the vehicle's gasoline engine. Electric power is generated by an alternator driven by the engine. The power is then applied to six induction motors, one for each wheel, through individual frequency converters.

Each converter controls the power applied to one of the wheel motors. In this way, the wheels are controlled independently by milliwatt-level control signals activated by the vehicle operator. ■ ■

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ON READER-SERVICE CARD CIRCLE 18

Washington Report

S. DAVID PURSGLOVE
WASHINGTON EDITOR

FB-111 avionics in doubt

The planned bomber version of the TFX, F-111, has the electronics industry's Washington reps working overtime to find out what the electronics will be. At this point, nobody at either the Pentagon or the White House has been able to do more than agree that (1) the strain involved in trying to make the FB-111 do strategic bomber duty seems to call for the development of new avionics and (2) new gear will *not* likely be developed, despite the apparent need.

The FB-111 is somewhat smaller and lacks the range and carrying capacity that the Air Force wants in a new bomber. Normally, a program of this sort would call for considerable redesign of equipment to reduce its weight and for miniaturization wherever possible. Much of such an effort would be applied to the electronics.

However, the first FB-111 is scheduled to be combat-ready by 1968. That short modification period indicates to many observers that this fighter version will be adapted with as much of its design and equipment intact as possible.

One Air Force officer, disgruntled that the Defense Department okayed a modification rather than a new, advanced manned strategic-aircraft (AMSA) program, made this reply to an ELECTRONIC DESIGN query: "Why should we develop long-range bomber command and navigation gear for an FB-111 when it's not going to be able to go any further than a fighter; we've already got the fighter electronics." The Defense Department, however, is expected to permit the Air Force to continue its low-budget studies on a totally new AMSA.

Is Nike-X behind propaganda switch?

Officials outside of the innermost White House-State-Defense circle are wondering what is behind the marked U.S. propaganda switch toward the Soviet Union. They point out that the era of Cold War thaw, during which we had a few nice things to say about Russia and even made Russia appear almost a U.S. ally against China and North Vietnam, has come to an end. Administration officials have become brusque in their public references, Democratic Congressmen publicly view the Soviets with pessimism, and newspapers known to launch White House trial balloons in return for favors have been all but damning Russia recently. Some of the questioning observers believe they have the answer: Nike-X.

Powerful government forces—not just the Army—want to produce and deploy an anti-ballistic missile (ABM) system. Even the White House recognizes that the impact on industry, the shot-in-the-arm to R&D and the possible beneficial economic fallout in depressed areas may outweigh the cash delay needed to institute the program.

But the U.S. is tacitly committed not to deploy an ABM system if the action might initiate another arms-race spiral by encouraging the Soviet Union to develop improved ICBMs and countermeasures. Dr. Jerome Wiesner's Disarmament Panel of the White House Conference on International Cooperation urged a three-year moratorium on ABM deployment and other arms advances that might "deflect" the Soviet Union from its course of improved relations with the West.

Almost since the Cold War was first recognized as such, U.S. administrations have admitted an obligation to avoid actions that might heat up the arms and counter-arms race—unless those actions could be publicly justified. So long as Americans believe that we are on a course toward agreement with Russia, the U.S. Government cannot deploy a major new weapon. However, one official pointed out, if relations seem to be deteriorating, the Government can exercise any of its several options without adverse consequences from the people.

He added, "These are the same noises I'd make if I thought I might want to put a fence between my house and my neighbor's. The community would then not think ill of me if I built it; but nobody would be upset if I decided not to." He pointed out that the guessing game on Nike-X, or some modification of that ABM system, will have to continue for several more weeks until the fiscal 1967 budget is made public. The game could continue even past the budget-announcement time if the wording is as vague as it has been at times in past years' budgets.

Electro-optical reader automatically sorts P.O. letters

The world's first practical automatic system for reading zip-codes on mail was put into service this month in Detroit.

The U.S. Post Office said that an electro-optical method of locating and reading zip-codes will handle up to 36,000 pieces of mail per hour.

The reader, developed and built by the Philco Corp., Philadelphia, focuses a scanning dot from the face of a CRT onto the zip-code digits to be read. Each digit is scanned about 15 times. Four photo-sensitive tubes sample reflected light from the envelope 20 times during this period and compare the measurements with patterns derived from thousands of sample digits in the machine's memory unit. It then directs a Borroughs sorter to slide the letter into one of 300 slots.

Before reading takes place, a search scan locates the zip-code at the bottom of the address and determines the height of the characters to be read. This allows acceptance of a wide variety of typed and printed characters. The machine will not read handwritten digits.

According to Lawrence O'Brien, Postmaster General, the new readers are about 15 times faster than a good hand sorter. Three of the $260,000 Philco-designed systems will be added in Detroit, and two more will start work in Buffalo, N. Y., by the end of the year. Observers see a potential $40 million market for this equipment. ■ ■

Electro-optical reader tackles zip-codes in Detroit post office. Scanning head (under worker's right hand) reads as fast as 15 men.

Roundup of 1966 Electronics Conferences

So you can plan your 1966 conference schedule, and so you can watch ELECTRONIC DESIGN for reports on the significant developments announced at meetings, we present a roundup of the year's major electronics conventions, symposiums and exhibitions.

Jan. 5-8
NSPE Winter Meeting, Bal Harbour, Fla.

Jan. 25-27
Symposium on Reliability, San Francisco.

Feb. 2-4
Aerospace & Electronic Systems Winter Convention, Los Angeles,

Feb. 3-8
International Exhibition of Electronic Components, Paris, France.

Feb. 9-11
Solid-State Circuits Conference, Philadelphia.

Mar. 21-25
IEEE International Convention, New York.

Apr. 12-15
Quantum Electronics International Conference, Phoenix, Ariz.

Apr. 20-22
Intermag, Stuttgart, Germany.

Apr. 26-27
National Relay Conference, Oklahoma State University, Stillwater, Okla.

Apr. 26-28
SJCC, Spring Joint Computer Conference, Boston.

May 4-6
Electronic Components Conference, Washington, D.C.

May 10-12
National Telemetry Conference, Boston.

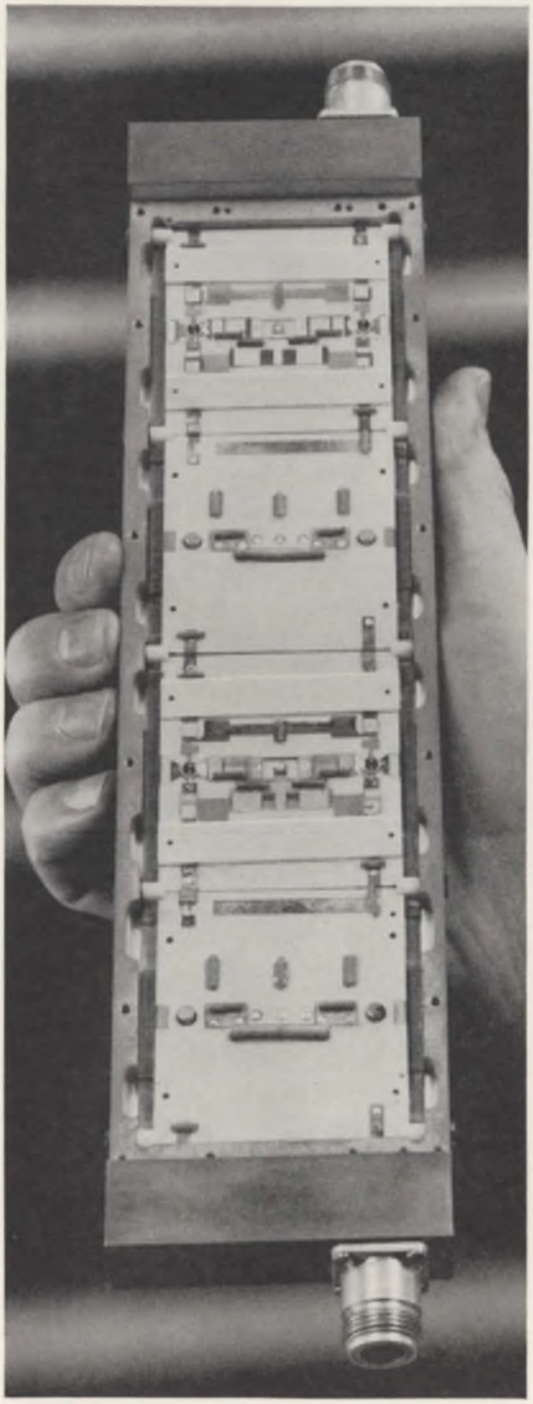
Report from

BELL LABORATORIES

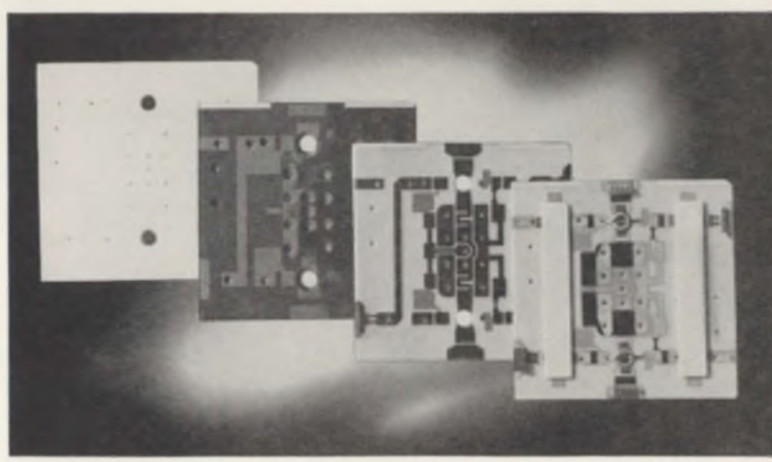
Integrated circuits at microwave frequencies

Engineers at Bell Telephone Laboratories have developed integrated circuits for use as amplifiers in the microwave range. Thin-film tantalum techniques are used to provide the precise, stable resistors, capacitors and transmission-line components required at microwave frequencies. Improved transistors provide up to 10 db of gain per stage and noise figures as low as 3 db.

A "balanced" design, using a power-splitting directional coupler, makes possible wideband, stable gain characteristics without the need for tuning adjustments. Up to the highest frequency for which these amplifiers are now usable—4 gigacycles—the electrical performance characteristics are equal or superior to those of low-noise traveling-wave tubes. In addition, they have the other advantages of solid-state circuitry, such as long life and reliability.



Laboratory model of a four-stage microwave amplifier which can provide up to 40-db gain and noise figures as low as 3 db in the 1- to 2-gigacycle frequency range. Similar amplifiers have been developed to operate at frequencies from 0.5 to 4 gigacycles with bandwidths of 1000 mc.



Thin-film techniques are used in the integrated microwave amplifier. Starting from bare ceramic substrates of about 2 x 2 inches (left), partially finished circuits are shown during the multi-step fabrication process. Circuit at right, complete with transistors, comprises one stage of amplifier. "Balanced" design with electrically similar transistors gives precise wideband amplification in the low-microwave-frequency range.

Bell Telephone Laboratories
Research and Development Unit of the Bell System

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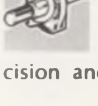
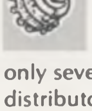


New Unidex universal index has velvet-feel consistent torque for full switch life. It provides closer limits of precision and uniformity, lasts for thousands more operations than other indexes. Many Oak rotary switches are now available with Unidex.



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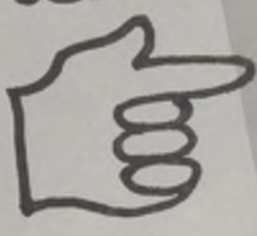

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ON READER-SERVICE CARD CIRCLE 141

May 16-18

NAECON, National Aerospace Electronics Conference, Dayton, Ohio.

May 16-18

Microwave Theory & Techniques International Symposium, Palo Alto, Calif.

June 15-17

International Communications Conference, Philadelphia.

June 20-25

IFAC, International Federation for Automatic Control, London, England.

July 11-15

Aerospace Systems Conference, Seattle, Wash.

Aug. 17-19

Automatic Control Joint Conference, Seattle, Wash.

Aug. 23-26

WESCON, Los Angeles.

Sept. 12-14

MILECON, Washington, D. C.

Sept. 18-22

National Power Conference, Denver.

Oct. 3-5

NEC, National Electronics Conference, Chicago.

Oct. 10-13

ISA International Conference, New York.

Oct. 20-22

Electron Devices Meeting, Washington, D.C.

Oct. 20-26

Electronica '66, Munich, Germany.

Nov. 2-4

NEREM, Northeast Electronics Research & Engineering Meeting, Boston.

Nov. 8-10

FJCC, Fall Joint Computer Conference, San Francisco.

Microwave ICs are on the horizon

Phased arrays and space systems are providing the cost justification necessary to spur development of integrated-circuit subsystems.

Maria Dekany, Technical Editor

Microwave companies are quietly learning the secrets of microelectronics and adapting them to microwave integrated circuits, an Electronic Design survey has found.

Even though the fabrication techniques are similar to those of low-frequency ICs, the special characteristics of microwave circuits is creating two major areas of research.

One is to duplicate waveguide and transmission-line effects in integrated structures and to create devices like ferrite phase-shifters, couplers and circulators.

The other area is to find active devices (signal sources and amplifiers) that are adaptable to and compatible with the devices above.

The huge amount of money invested by integrated-circuit manufacturers a few years ago in developing low-frequency ICs paved the way for microwave companies. Microwave ICs are inheriting fabrication processes, design approaches and even the problems from low-frequency circuits, said Carl Blake, leader of the phased-array group at MIT's Lincoln Lab.

The hybrid approach (passive, film-deposited elements bonded to active elements) appears to have an edge over the monolithic design today, noted Blake. Its advantages for microwaves are a closer control over dielectric losses and the opportunity to pre-test active components. Control over dielectric losses in the substrate is important, since these losses are of great concern in microwave systems, he continued. The size of hybrid systems, however, is usually large: A typical system dimension would be 0.5 by 0.5 inches.

Another advantage of the hybrid approach is that yttrium iron garnet may be used for integrated filters and tuned circuits, commented Dr. L. B. Valdes, manager, semiconductor devices, Watkins-Johnson, Palo Alto, Calif. Also, even in hybrid structures, silicon monolithic circuits may be used as sub-blocks mounted on the common substrate, added Valdes.

The preliminary investigation of substrate materials indicates silicon as the winner, according to Blake. The use of high-resistivity silicon permits the formation of integrated monolithic structures, since active devices, like the Schottky-barrier diode, can be formed on the substrate with multiple-layer diffusion.

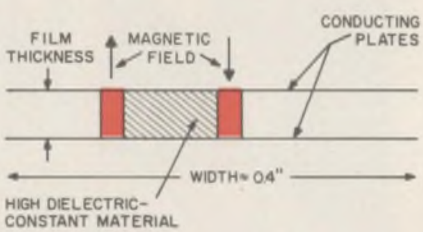
The most likely candidates for integration are balanced mixers and their IF amplifiers, diode switches, low-power signal sources and tunnel-diode amplifiers. These subsystems eventually lead up to the integration of complete front ends, Blake said.

A perennial problem inherited from low-frequency integrated circuits is the realization of an inductor in the microhenry range and above. In monolithic designs, the designer is forced to leave the circuit and use external inductors at frequencies up to X-band. In hybrid circuits, this problem becomes less serious at S-band.

Packaging causes problems

A major difference between low- and high-frequency integrated circuits is in the area of packaging.

Conventional flat-packs cannot be used for microwave circuits—an impedance-matching interface is required. The solution to this problem is approached from two directions, explained Blake. If a waveguide is used, the chip may be placed in the guide. Or miniaturized connectors can provide the matching transition from the chip to conventional circuits.



Thin (10-micron) ferrimagnetic films (color) and high dielectric-constant loading materials in this configuration are suitable for reproducing all ferrite devices made in rectangular waveguides.

Ferrite films duplicate components

The eventual realization of a truly integrated microwave system requires integrated phase-shifters, couplers, circulators and, of course, active devices.

Feasibility studies of ferrite and garnet films (10 micron thick) duplicating bulk microwave components show every sign of eventual success, said Bernard Hershenov, head of the ferrite group at Radio Corp. of America, Princeton, N. J.

However, there are still many problems to be solved before these devices become available, he cautioned. At high frequencies, lumped elements are replaced by distributed elements. This causes difficulties in getting a ferrite film that has good magnetic properties, low loss and controllable magnetization.

The ferrite film may be obtained in two ways, he pointed out. It can be evaporated or vapor-deposited onto a substrate, or a single-crystal film (yttrium iron garnet) can be grown on a substrate.

The structure of these equivalent thin-film microwave components includes two thin films loaded with a high-dielectric substrate and enclosed by two metal plates (see illustration). At RCA, methods for latching the material are under investigation, which would lead to the elimination of the magnets.

Since most energy is concentrated in the high-dielectric material (ϵ = 15-25), its loss tangent becomes a critical factor in decreasing the losses. Also, it is difficult to deposit the film on these substrates.

(text continued on pg 38)

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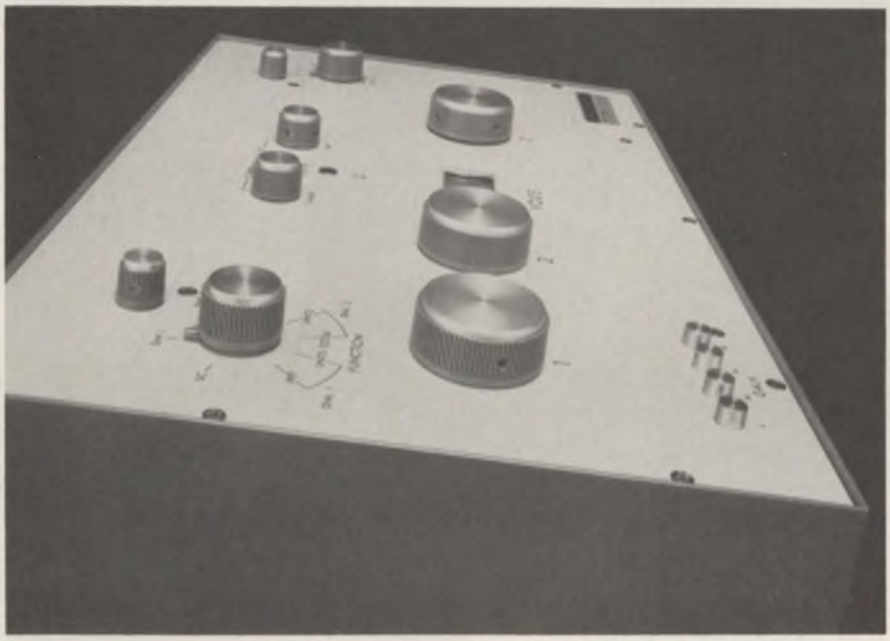

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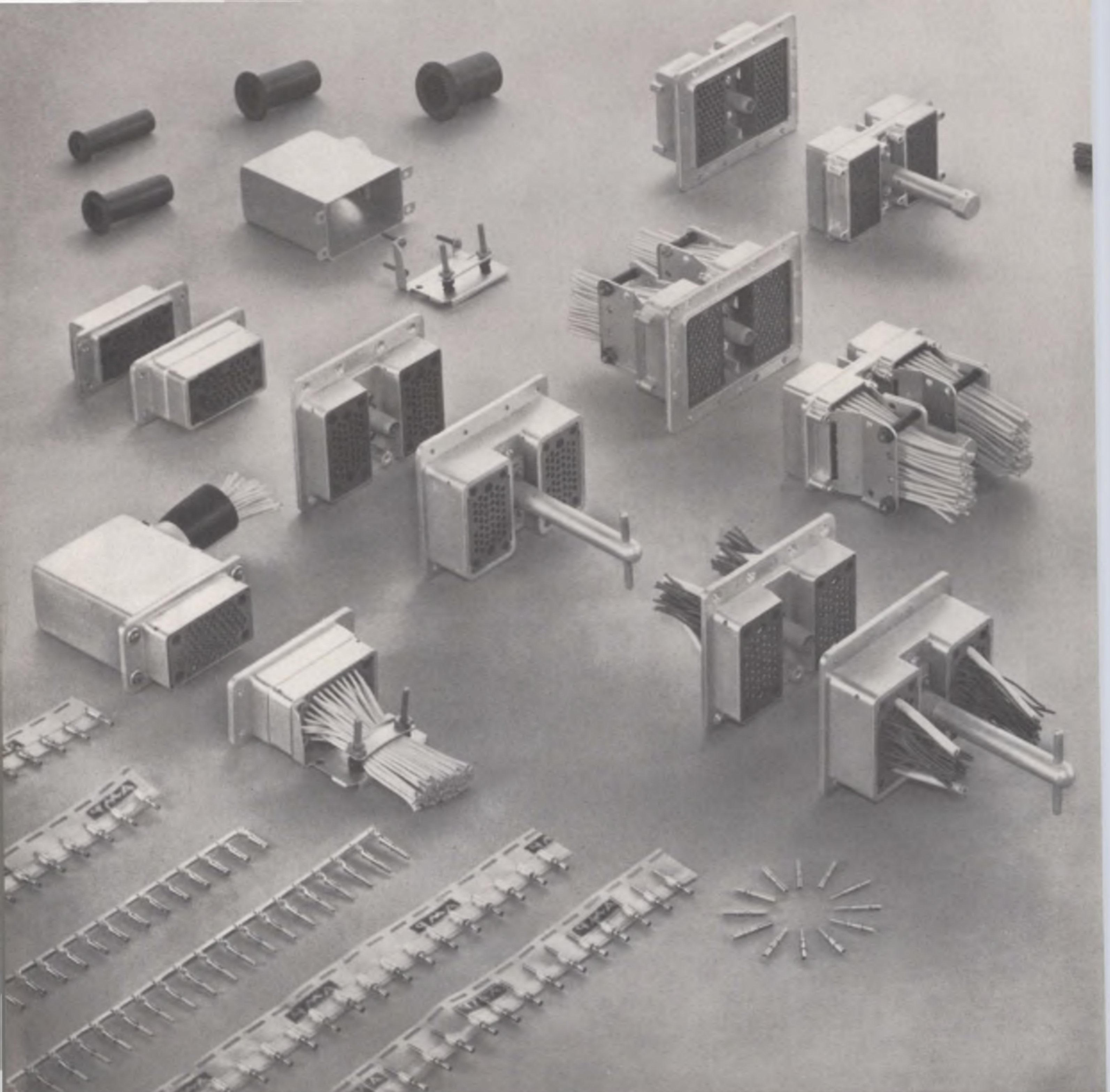

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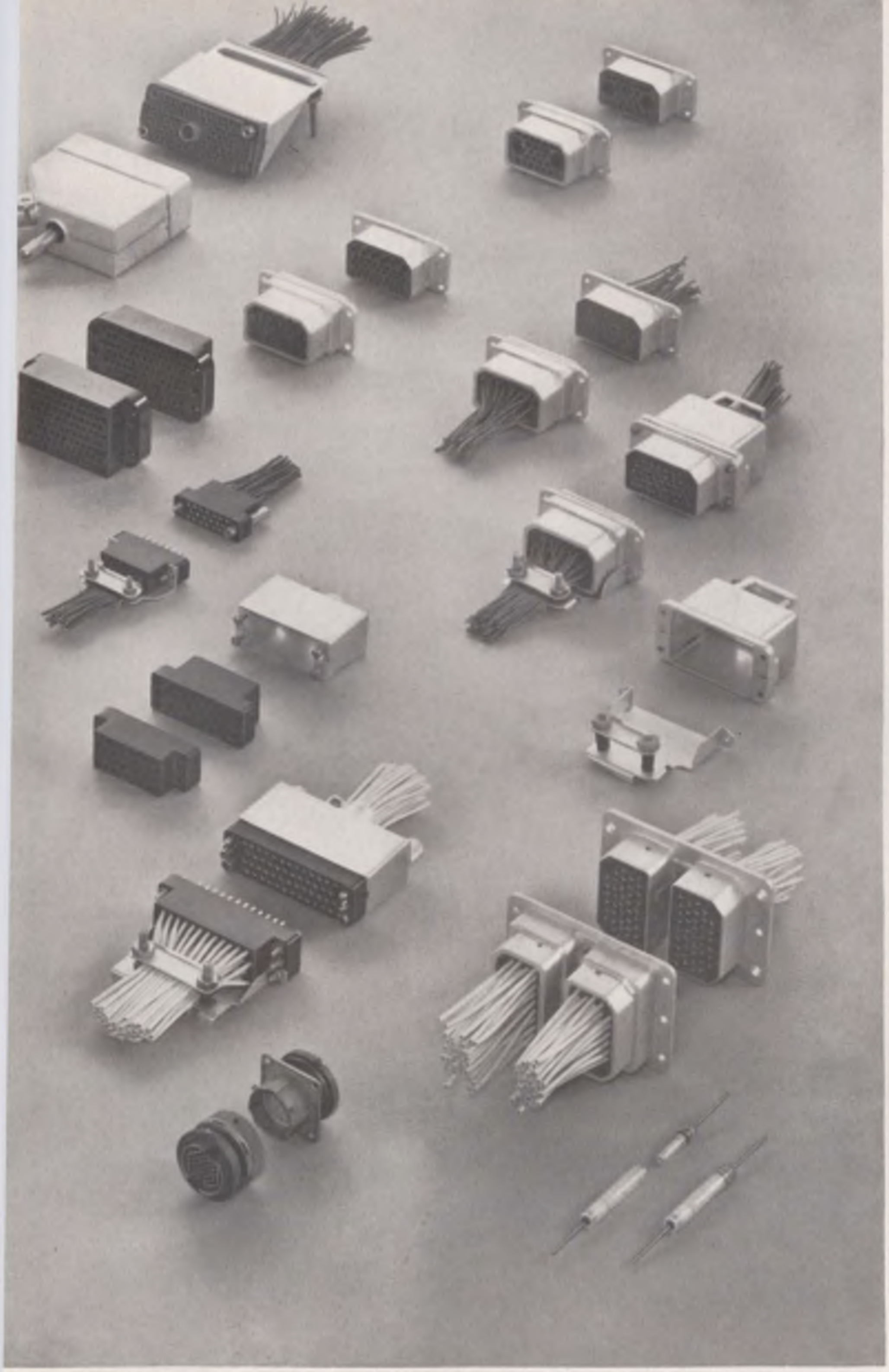
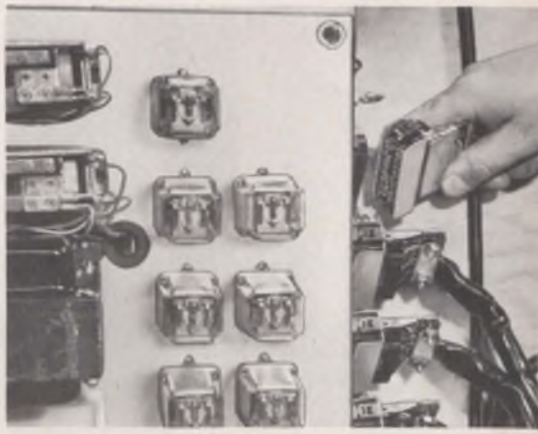
Because of this built-in connector capability, AMP can offer you custom quality connectors off the shelf. And, AMP supplies valuable engineering assistance as well. Write for specific information on pin and socket connectors today—we'll be glad to hear from you.

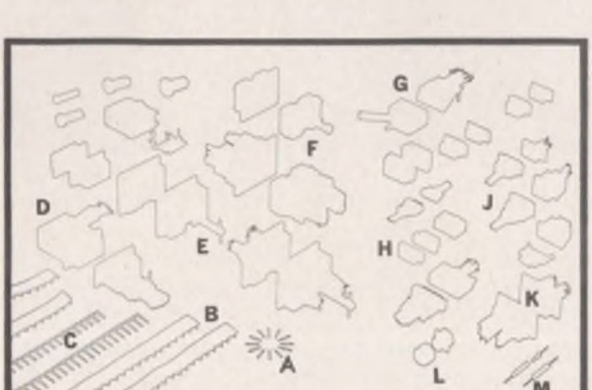


AMP's Series "DDE" pin and socket connectors are on twenty-four hour duty in the Nation's air defense surveillance systems.



The computer portion of this bowling machine is linked to its power source by AMP Series "M" connectors.

AMP connectors are important in stock market data systems; allow desk units to obtain instantly quotations on 4,000 securities.



A Single piece pin and socket contacts
B Tape-mounted pin and socket contacts
C Strip-mounted pin and socket contacts
D A-MP* Series "D" Connectors with accessories
E A-MP Series "DD" Connectors with accessories
F A-MP Series "DDE" Connectors with accessories
G A-MP 104 Position Center Fastener Connector
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K A-MP Series "WW" Connectors with accessories
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(Microwave ICS continued)

New approach to active devices

The work on active devices mostly centers on the examination of double-stream instability in solids, said Hershenov. This phenomenon is analogous to the operation of tubes with two electron beams. For example, a *p*-type material is diffused into an *n*-type. An applied voltage will cause a stream of holes and electrons to travel and hence provide a source of energy. Oscillators operating on the Gunn-effect principle and using epitaxial gallium arsenide also look promising, he added.

Another possibility for integrated structures is the so-called spin-wave interaction, continued Hershenov. Here a ferrite film and a semiconductor film having a large number of carriers are used. A spin wave propagating in the ferrite film will couple to an electron wave propagating in the semiconductor film. This coupling produces amplification, said Hershenov.

Where is the market?

It is well and good that microwave people can save a lot of money and still make integrated circuits. But where is the market? The low-frequency developments were spurred by the computer manufacturers, who needed hundreds of thousands of identical circuits. Where is there a microwave system requiring components even approaching the numbers used in computers?

Today there are two possibilities, according to Carl Blake: phased arrays, where thousands of components are needed, or space-borne systems, including weapons systems, where the emphasis is on low power consumption, light weight and small size.

Integrated microwave circuits may offer the solution to the biggest headache of phased arrays: cost. The high cost of initial design and upkeep (maintenance and reliability) prevents the use of phased arrays in many areas where their special properties offer distinct advantages. If successful, phased arrays can have a great potential as a replacement for many conventional radars in satellites, aircraft, ships, or for use in ground mapping and traffic control.

Other companies, including Motorola and Texas Instruments, are also active in this area. However, the companies declined to offer information on the type and direction of their research efforts. ■ ■

Superconductive atom smasher at SRI

A superconducting atom smasher, with a potential for being far more powerful and efficient than today's high-energy accelerators, was recently demonstrated at Stanford University's High Energy Physics Lab.

Successful operation of a four-inch, superconducting linear accelerator section climaxed more than four years of study and research sponsored by the U.S. Office of Naval Research.

The new accelerator is similar in design to Stanford's "linacs," the largest of which is a two-mile machine now under construction.

According to Stanford scientists, the new accelerator would outperform its Stanford predecessor and many other machines elsewhere for the following reasons:

- Its "duty cycle" would be 1000 times longer than those of present linear accelerators. High-energy electrons would pour out in a continuous stream instead of in short spurts as in conventional linacs.
- For a given length it could generate several times the energy of present linacs. High energy means increased ability to penetrate the nucleus and to cause particle reactions. These higher energy electrons also would have better "resolution" —quality sought-after by scientists trying to make comparisons of particle reactions.
- The superconducting technique could be applied to such high-energy devices as a proton linear accelerator, synchrotrons, particle separators and other apparatus.

The Stanford scientists fashioned a cylindrical copper cavity, four inches long and 3-1/2 inches in diameter, filled with disks about one inch apart. A one-inch hole through the center of each disk allows passage of electrons through the cavity.

Inside surfaces of the cavity are coated with lead, normally a poor conductor, but a superconductor at near-absolute-zero temperatures. At a temperature of 1.8 deg above absolute zero, the Stanford group has achieved a "Q" of 5 billion in one cavity. This is said to be 100 times higher than anyone had ever achieved before.

The superconducting cavity has accelerated electrons at a rate of 4 MeV per foot, or about the level obtained in present linacs. Theoretically, said the Stanford physicists, the lead-coated cavity should provide 10 MeV per foot.

They emphasized that the full potential of the new accelerator still have to be realized. They have proved that a superconducting linac is feasible and now they hope to build a pilot machine of a billion or so electron volts.

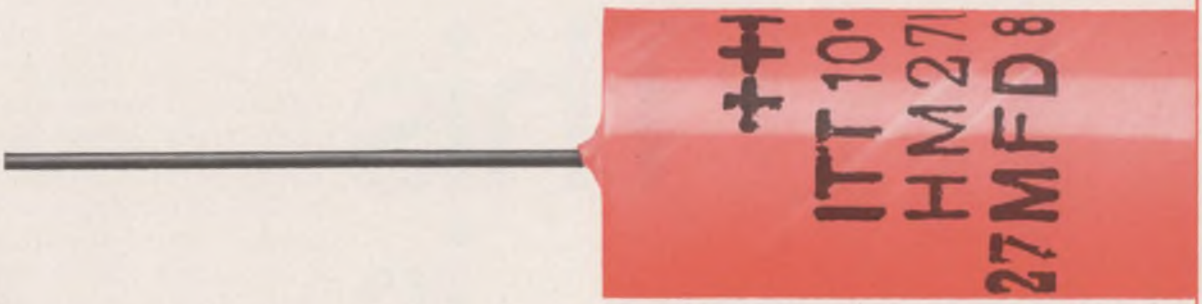
Ceramic laser tube

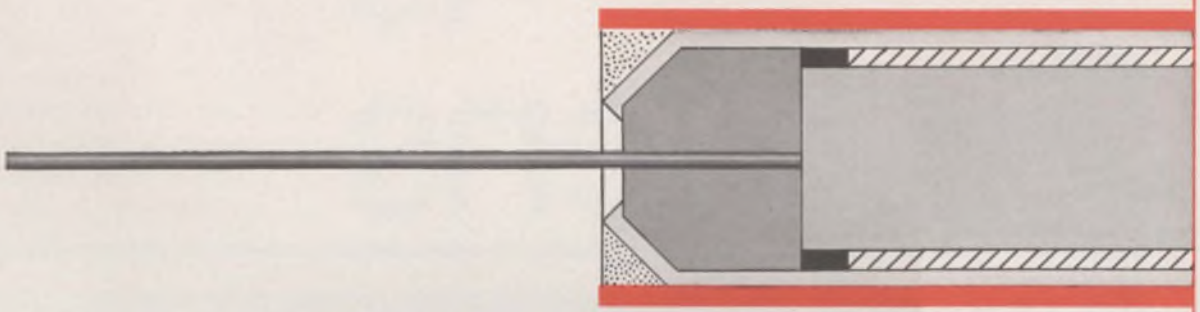
A cw ionized-argon gas laser now available contains a ceramic discharge tube which is said to have an operating life at least three times longer than the conventional quartz tubes.

Developed by Electro-Optical Systems, Inc.. a subsidiary of Xerox Corp., the Model 13 laser system incorporates a 3-mm discharge chamber with a guaranteed lifetime of 300 hours; it reportedly has shown no deterioration after 1000 hours of continuous testing at a beam current of 15 A.

According to Dr. H. R. Moore, EOI Operations manager, the Model 13's operative life is uniquely determined not by tube longevity but as a function of discharge cathode burnout. Quartz tubes have an approximate lifetime of only 100 hours since the glass itself tends to crack and vitrify from beam discharges well before cathode degradation.

Customized versions of the company's ceramic tube laser were built for use in Project Gemini as earth-based beacons for visual acquisition by astronauts.





Why ITT wet tantalum capacitors can't leak

Every ITT Red Cap® wet tantalum capacitor gets a "total stress" seal that, unlike the ordinary single-crimp seal, positively prevents electrolyte leakage. To accomplish this, ITT inserts a teflon end seal, then spins down the open end of the can until end seal, anode and insulating washer are under a predetermined compressive force.

Seal integrity is further insured by the addition of an epoxy end fill. Since the epoxy's expansion coefficient is less than that of the can, temperature cycling cannot relax the spun seal.

If you're tired of electrolyte leaks and the problems that go with them, here's an easy solution. Order the ones that can't leak — the Red Caps® — from your ITT Capacitor distributor or from ITT Semiconductors, 3301 Electronics Way, West Palm Beach, Florida.

ITT

SIEMENS

Siemens ferrite pot cores

Precision-engineered for adjustable, high-stability, high-Q coils

These pot cores meet the most critical requirements for filters used in multiplex and other carrier-frequency applications. They're unique in performance because of these built-in advantages—easy adjustment to precise inductance, high stability, high Q, low distortion, plus self-shielding that allows compact component density without regeneration or coupling.

Unique manufacturing controls Siemens pot cores offer uniform electrical characteristics month after month—complete dependability to close standards.

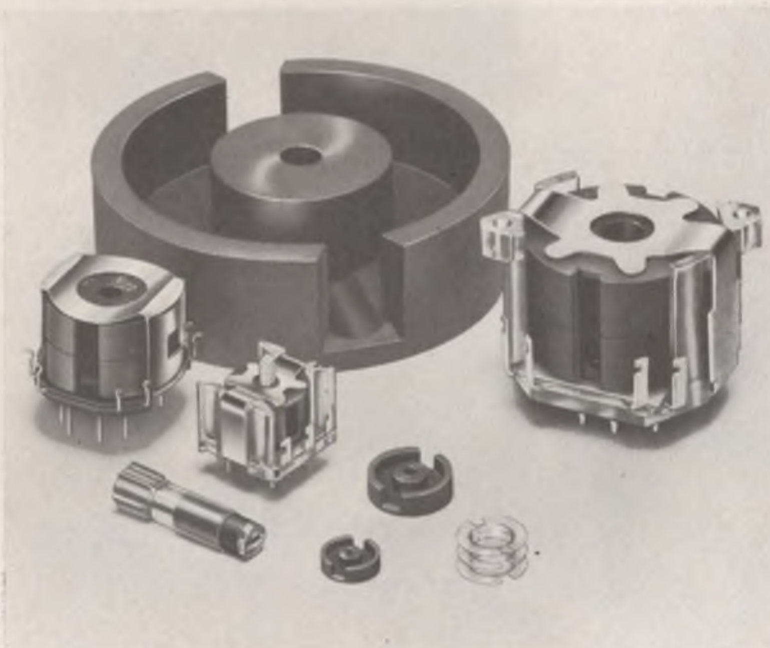
Wide range of materials 7 different types provide optimum properties for frequency ranges up to 40 mc/s for oscillating and filter coils—up to 400 mc/s for transformers.

Wide range of sizes Diameters range from 0.22" to 2.75" including all International Standard Sizes. Most of the listed pot core sizes, materials, and A_L values are stocked for immediate shipment from White Plains, N.Y.

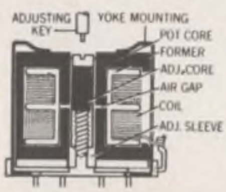
Stability Less than 0.2% change in permeability in 10 years at temperatures up to 70° for typically gapped cores used in filter coils.

Temperature coefficients are closely controlled.

High Q value with high stability is typical. For example, a 26 x 16 core of N22 or N28 material A_L 315 at 100 kc/s shows a Q value of approximately 950.



Complete line of "hardware" includes coil formers with one to four sections, mounting assemblies for chassis or printed circuits, adjustment devices and keys.



WRITE NOW for complete information on Siemens pot core application

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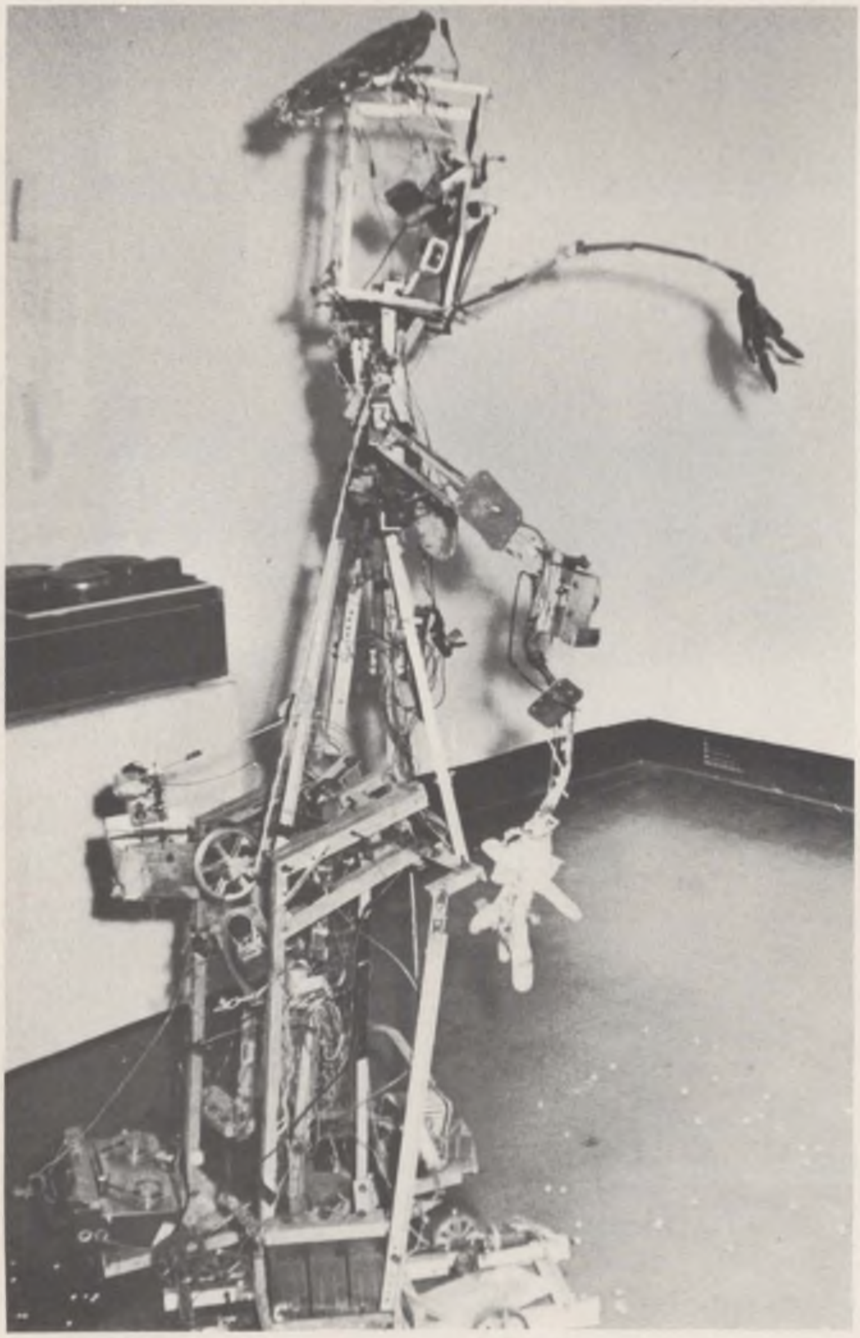
Components Division
230 Ferris Avenue, White Plains, N.Y.

In Canada: SIEMENS CANADA LIMITED
407 McGill Street, Montreal 1, P.Q.

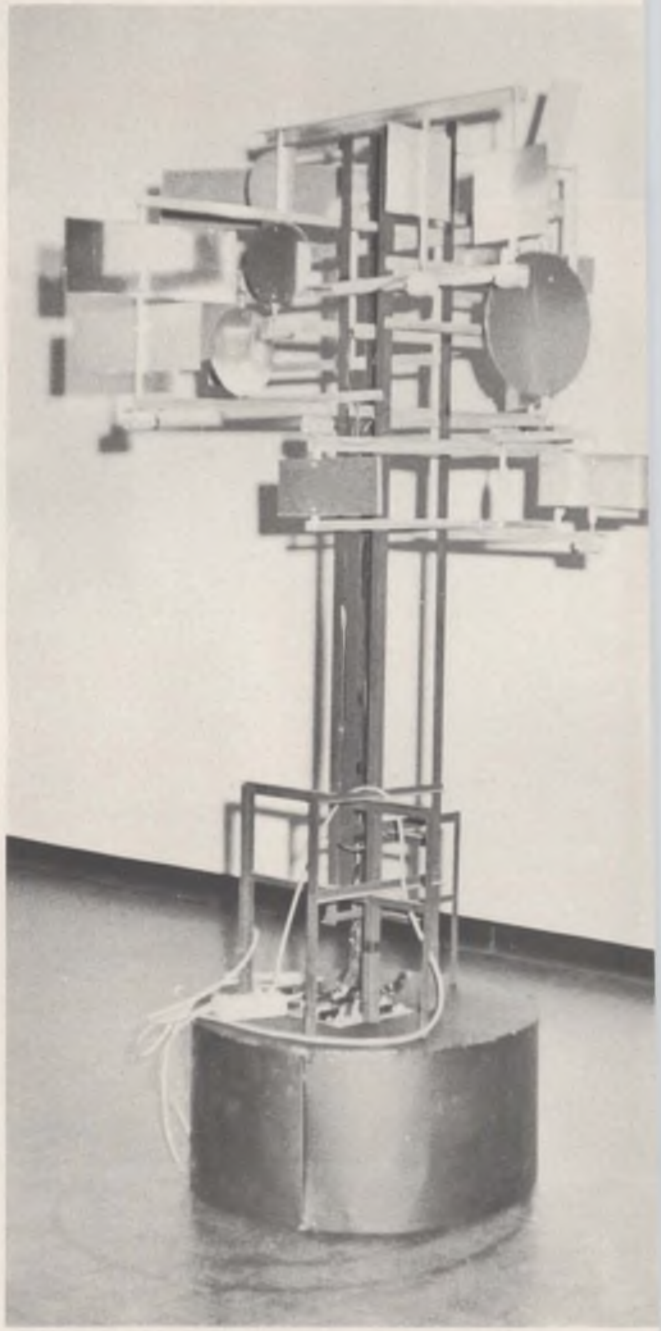
ON READER-SERVICE CARD CIRCLE 161

Electronic pop-op art pops on the scene

A new market for used components? Here is the electronics industry's first guide for the deployment of latent artistic talent.



Robot-K456, a radio-controlled belly dancer by Nam June Paik, can simulate most human functions.



Cysp 1, 1956, by Nicolas Schoffer, glides across the floor with a gyrating superstructure.

Roger Kenneth Field, News Editor

During the past month, exhibits of electronic art have blossomed in New York with a frequency that suggests an aesthetic explosion in electronics or, at the very least, an electronic explosion in aesthetics.

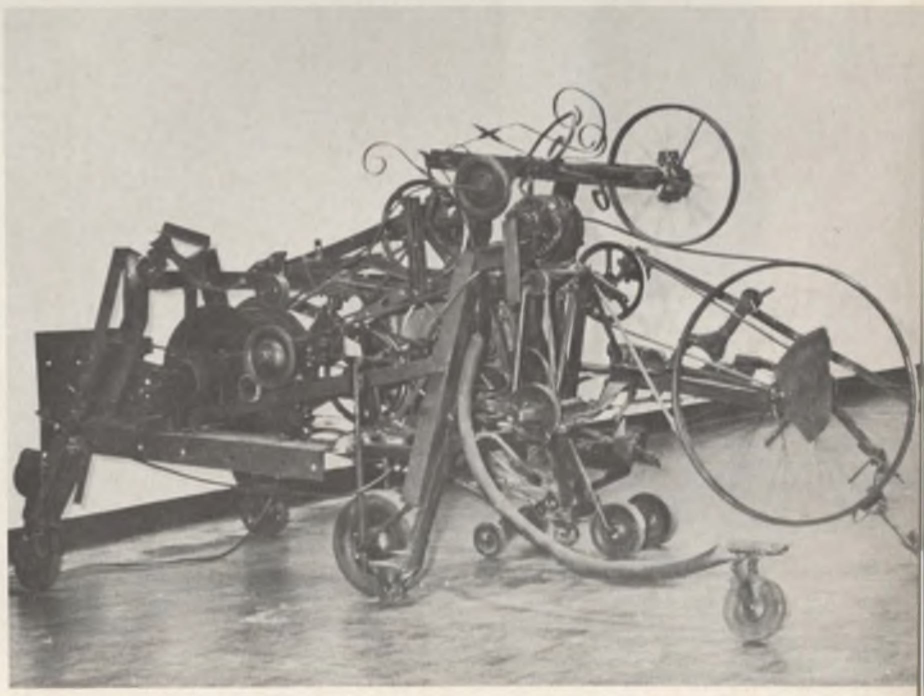
The word art is used advisedly. The creators of the works shown here do not represent these to be art in the classic sense. Not a single piece is fashioned of traditional material, nor with ordinary tools. In this new art, wire and junk iron replace marble and canvas; the welding torch and the screwdriver eliminate the chisel and the paintbrush.

All of the works move and most of them make funny noises. In theory, there is no reason why art objects shouldn't make noise, yet when the clatter of the other art completely drowns out the one you're trying to listen to, you quickly develop a respect for quiet museums. The creators of these

(Continued)

Nicolas Schoffer and one of his rotating creations. Some of Schoffer's works emit electronic music through speakers connected to internal tape recorders. He has also built a color organ that "plays" colors on a screen.

Radio Cocktail, 1961, by Tinguely uses superheterodyne circuit to advantage—?



Hannibal, 1963, by Tinguely moves to and from a wall to which it is anchored at its tail.

Whatever your PNP requirement we have the device to suit your need. Full current range from 1 microamp to 1 amp. High voltage, high gain, high speed, low noise. All featuring the stability and low leakage characteristics of Planar II epitaxial devices. In distributor stock. Write for complete data.

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Full line of high stability, low leakage, silicon Planar II epitaxial transistors.

AMPLIFIERS

General purpose, rf

Device number	LV_{CEO}	h_{FE} @ 10 mA	f_T (MIN.)	V_{CE} (SAT) (MAX.)	$r_b'C_c$ (MAX.)
2N4035	40V	150-300	450Mc	0.3V @ 50mA	40ps
2N4034	40V	70-200	400Mc	0.3V @ 50mA	40ps

High Voltage, linear, from low to high I_c

Device number	LV_{CEO}	h_{FE} @ 100mA	V_{CE} (SAT) (MAX.)
2N4032	60V	100-300	1V @ 1A
2N4030	60V	40-120	1V @ 1A
2N4033	80V	100-300	0.5V @ 500mA
2N4031	80V	40-120	0.5V @ 500mA

Also available in TO-18 package 2N4026 through 2N4029

High Voltage, ultra-low noise, low current

Device number	LV_{CEO}	h_{FE} @ 10μA	NOISE FIGURE (MAX.) @ I_C=20μA f=10cps	15.7Kc P.B.W.
2N3962	60V	100-300		3db
2N3963	80V	100-300		3db
2N3964	45V	250-500	8db	2db

SWITCHES

High current

Device number	LV_{CEO}	h_{FE} @ 150mA	h_{FE} @ 50mA	t_{on}	t_{off}
2N3502	45V	100-300	115-300	40 nsec.	100 nsec.
2N3503	60V	100-300	115-300	40 nsec.	100 nsec.
2N3504	45V	100-300	115-300	40 nsec.	100 nsec.
2N3505	60V	100-300	115-300	40 nsec.	100 nsec.

DUALS

Low level, low noise, differential amplifiers

Device number	LV_{CEO}	h_{FE}	h_{FE} (ratio)	V_{CE} (SAT) (MAX.)
2N4025	60V	250-500 @ 10μA; 5V	0.9 (MIN.) (matched)	0.40V @ I_C=50mA, I_B=5mA
2N4016	60V	80 (MIN.) @ 10μA; 5V	0.9 (MIN.) (matched)	0.25V @ I_C=50mA, I_B=2.5mA

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PLANAR: A PATENTED FAIRCHILD PROCESS

FAIRCHILD SEMICONDUCTOR

ON READER-SERVICE CARD CIRCLE 26

(Electronic art, continued)

contraptions may or may not be competent artists, (history must decide that), but they certainly have senses of humor.

Marshall McLuhan, Canadian philosopher, observes that modern art is always one technology behind life. This is amply illustrated by these electronic efforts in our nuclear age. But Oscar Wilde said, "Life imitates art" and, indeed, there are pop-art people who bend every effort to look like the chap in the bottom photo on this page.

A technically very primitive level was reached by a Swiss, Jean Tinguely. Famous for his "self-destructive" art (see p 11), he has experimented with dismembered radios to obtain a squawking noise by driving the station selector with a motor (see Radio Cocktail).

A more finished product was executed by Nicolas Schoffer, a Parisian visionary and city-planner, as well as artist. In his plan for a "cybernetic city," robots like his Cysp I (see photo) can be summoned by pocket transmitter to perform a little spectacle anywhere.

The most electronically sophisticated work was produced by a Korean, Nam June Paik. His "Robot-K456" (see photo) is directed by two 10-channel transmitters. Twenty radio-controlled mechanisms are powered by a battery on each foot. Robot-K456 can bow, walk, give a speech (recorded by the then Mayor-elect of New York, John Lindsay), lift each arm independently and wiggle its representational torso. It also defecates on the floor of the gallery by remote control.

Paik's robot looks mechanically unreliable and he admits that it needs constant attention. It has crashed to the floor twice when taking too deep a bow. He made it for next to nothing. When asked if it could be improved, he said, "In electronics you can do anything if you spend the time and money."

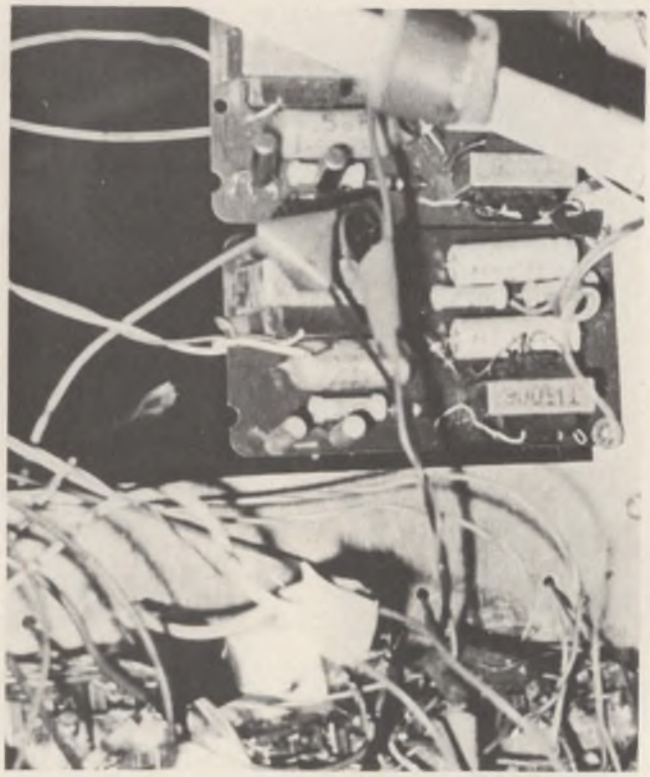
Paik has also been experimenting with TV set innards. He places a toroidal electromagnet in front of the screen face and achieves interesting patterns from the commercial transmissions (see below right).

A wire conductor is fixed to a donut shape with plastic tape. If the line current is left on more than a couple of minutes, the heat melts the tape. When Paik turns off the in-line switch to the coil, a giant spark, the result of the collapsing magnetic field, leaps from the contacts and illuminates the darkened room. Paik seems undisturbed by this.

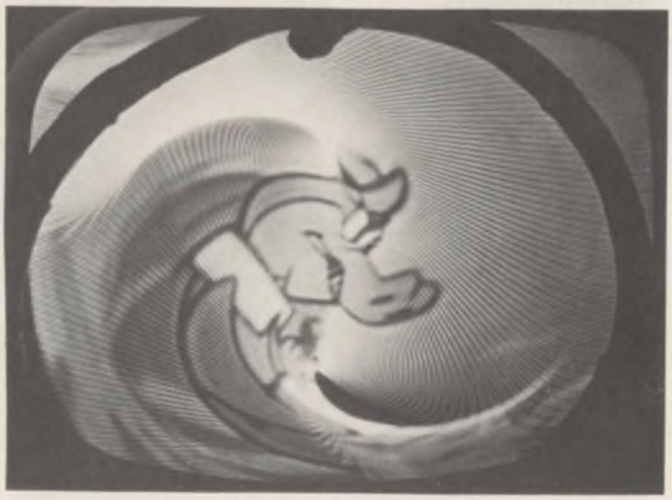
Design shortcomings are common to the other artists as well. Schoffer's Cysp I has a rear swivel wheel which jams because it has no caster. Tinguely's twisted wire bearings and wire gears would hardly meet military specifications.

Admittedly, these efforts merely represent a start. Whether the path will really ever be run or whether electronics artists will fade, as did the fist and shoulder pianists, is hard to predict.

Certainly these examples in no way approach the present "state-of-the art." Perhaps a flurry of artistic activity among electronics design engineers will contribute to the culture as well as the technology of future generations. ■ ■



Sophisticated components are used for pop art in Robot-K456. Note the printed-circuit board and small relays.



Toroidal electromagnet distorts TV for optical art. When line current ceases, giant spark lights the room.

Nothing new . . . nothing "state of the art" in low-cost digital voltmeters? Don't you believe it! Right now, all but one low-cost DVM is "old hat" because **only one**—EI's brand new Model 620—has AUTOJECT.

With AUTOJECT, noise is **automati**cally **rejected** by synchronizing the sample period with the noise component. The result? Noise integrates to zero—irrespective of its phase or frequency.

And that's not all. Even by the traditional yardsticks, the Model 620 is quite a package. Look at the year's best buy in low-cost DVM's . . . point by point . . .

AS OF NOVEMBER, 1965 IF YOU DON'T KNOW autoject, YOU NO LONGER KNOW DVM's

MODEL 620

	HP 3440A	NLS 5005	Cubic DV-271	Kintel 511	EI 620
Circuitry: All-solid-state?	Yes	No	No	No	Yes
Common-mode noise rejection (@ 60cps, no filters)	70db	106db	20db	100db	140db
Normal-mode noise rejection (superimposed noise)	30db	30db	40db	50db	60db
Accuracy (as % of reading)	±.05% ±1 digit	±.01% ±.01 FS	±.01% ±1 digit	±.01% ±1 digit	±.01% ±.01 FS
Encoding speed (readout to meter's full accuracy and max. noise rejection at any noise frequency) in milliseconds	450 (to .1%)	600 (avg)	500 (avg)	700 (to 2 sec.)	250 (fixed to full accuracy)
Over-range (5th digit to extend meter resolution)	5%	none	10%	none	20%
4-Wire ratio capability (ratio between 2 unknown voltages with no common lines)	no	no	no	no	yes

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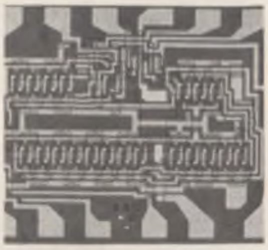
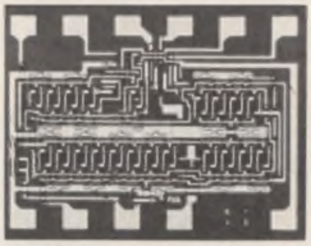
ON READER-SERVICE CARD CIRCLE 27

ARRAYS...

MEM4090
90-Bit Shift Register

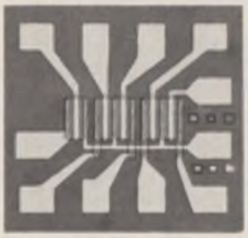


MEM521
Two-clock, 21-Bit Shift Register

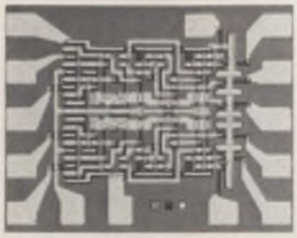


MEM501
Single-clock, 21-Bit Shift Register

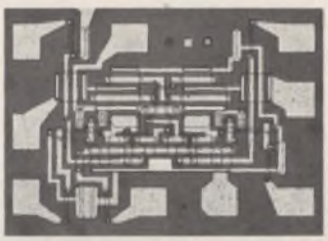
MEM1050
4-Bit Up-Down Counter



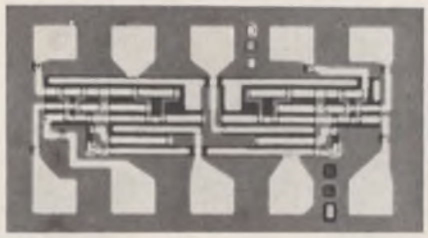
MEM2001
5-Channel Multiplexer



MEM1000
Dual Full Adder



MEM529
Binary



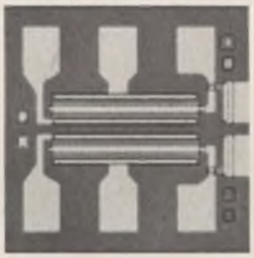
MEM522
Dual 3-Input NOR Gate

Plus...P-Channel, Enhancement Mode MOSFETS:

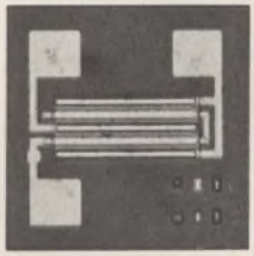
MEM517
4-Lead Power MOSFET. Protective Diode In Gate

MEM517A
3-Lead Power MOSFET. Protective Diode In Gate

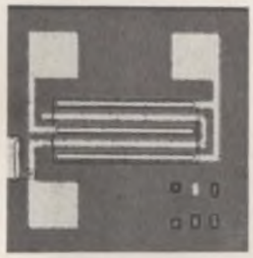
MEM590
Series Shunt Chopper. Zero offset voltage



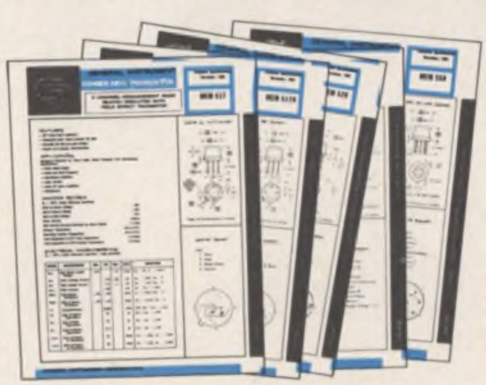
MEM550
Dual P-Channel Enhancement Mode MOSFET



MEM520
High Impedance MOSFET ($10^{15}\Omega$ Typ.)



MEM511
Low Power MOSFET



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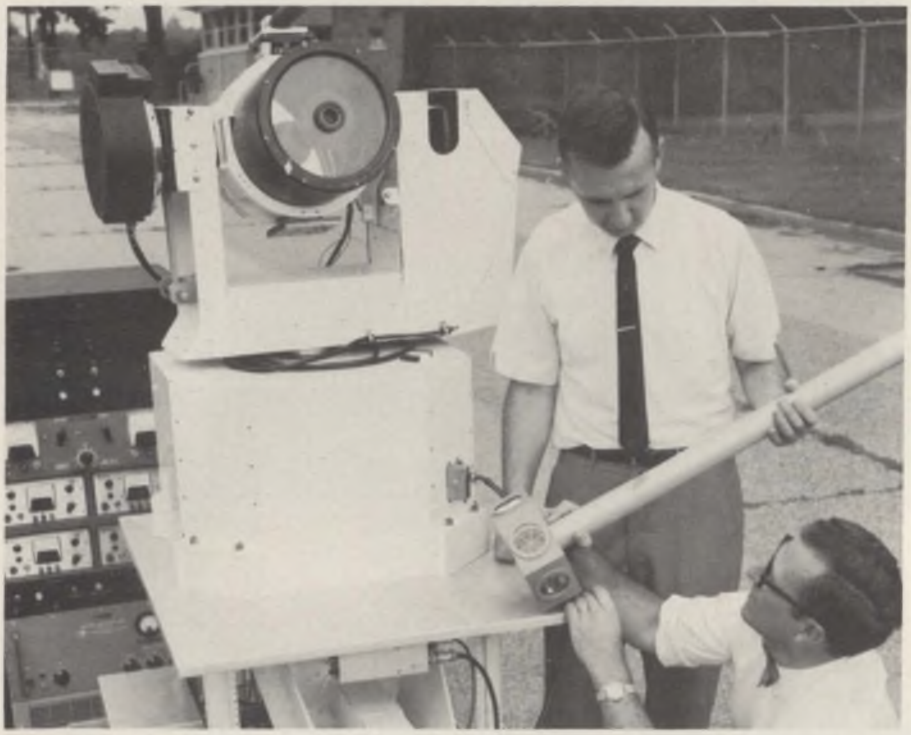
ON READER-SERVICE CARD CIRCLE 28

Infrared-aimed laser radar prototyped for Army



The SPOT-100-CLX IR-aimed laser radar designed for local-warfare tracking and ranging is checked out at Sperry Gyroscope Co.'s laboratory. The IR silicon detector is mounted at the top. The laser beam emits from the small U-shaped slot to the right of the tracker. The engineers are preparing a reflector target.

A laser radar aimed by an infrared detector-tracker may soon be used to search out cooperative aircraft, vehicles and personnel in local warfare situations.

The Combat Developments Command Experimentation Command (CDCEC) of the Army at Ft. Ord, Calif., will field-test a prototype unit early this year as an automatic position indicator of range, azimuth and elevation.

Called the SPOT-100-CLX (for Sperry Optical Tracker-Model 100-continuous-wave Laser, Experimental), the system combines in a single unit a passive IR silicon detector-tracker and a continuous-wave helium-neon red laser mechanically slaved together. The Sperry Gyroscope Div. of Sperry-Rand is currently testing a model at its Great Neck, N. Y., laboratory.

The system has demonstrated an azimuth and elevation accuracy of less than 10 arc-seconds and a range resolution of less than 1.5 feet at distances of a fifth of a mile to seven miles, according to a Sperry official. In clear, stable air, the range uncertainty at maximum range has been no more than a few inches, even when operating within two feet of large ground obstacles at both ends of the path, he added.

The range is measured 16 times per second. A subcarrier operating in the vhf band is used with the .6328-micron laser carrier to insure precise target designation, free of the ambiguities which often occur in more conventional vhf systems because of ground-return interference.

The near-IR spectrum from .85 to 1.15 microns was chosen as the operating frequency range of the angle-tracker for good atmospheric transmission, low solar or jet-plume interference, the availability of glass optics and silicon detectors and for high target-lamp spectral efficiency, the spokesman reported.

The major units of the truck-transportable system are an optical tracker, a ranging receiver and a computer. Gray-code angle-position data from the 16-bit accuracy elevation and azimuth shaft encoders are converted to binary form in the computer and read out in digital form. For initial positioning, the SPOT-100-CLX can accept one-to-one synchro data from a fire-control system, manual tracker or computer, it was explained. ■ ■

Flame amplifies sonic energy

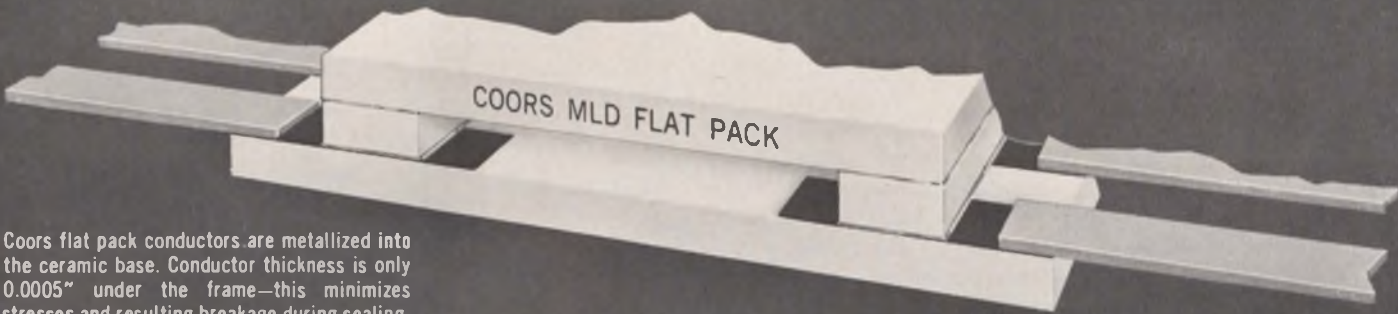
A flame can be used as an amplifier —with gains of 10 to 100—for the production of intense sound.

Experiments have been conducted at the Stanford Research Institute with a pyroacoustic loudspeaker that can amplify a human voice many times over what is possible with electrodynamic loudspeakers that have the same power.

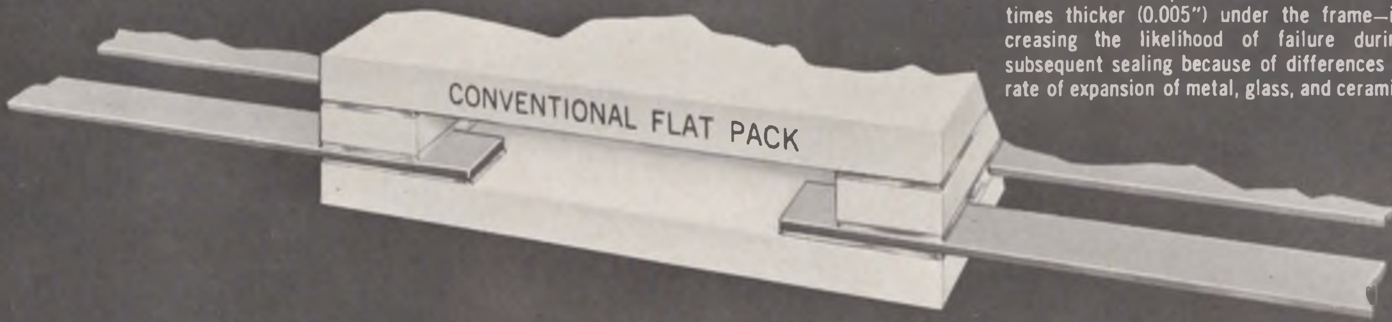
The physics division at SRI, in seeking ways to produce sound louder than is possible with conventional electronic or modulated air-stream loudspeakers, turned to the flames as a means of adding the necessary energy to sound output.

A small prototype was built under the direction of James Arnold of the SRI sonics department. A stream of combustible gas is modulated as it passes through an orifice formed by a metal block and the diaphragm of a conventional electromagnetic loudspeaker. The modulated gas stream expands through a throat and is ignited. The variation of the flame size caused by the variation in gas flow imparts varying mechanical energy to the gas molecules of the combustion products. As the large changes in molecule motion follow those of the loudspeaker diaphragm, the result is sound many times amplified. ■ ■

ON READER-SERVICE CARD CIRCLE 214 ➤



Coors flat pack conductors are metallized into the ceramic base. Conductor thickness is only 0.0005" under the frame—this minimizes stresses and resulting breakage during sealing.

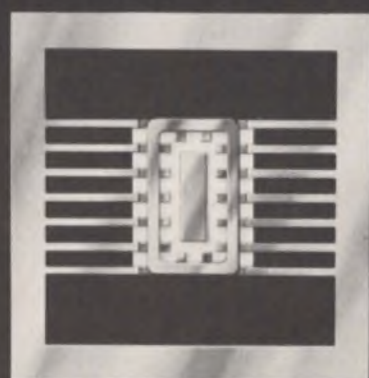


Conventional flat packs use conductors ten times thicker (0.005") under the frame—increasing the likelihood of failure during subsequent sealing because of differences in rate of expansion of metal, glass, and ceramic.

Take a closer look at flat pack reliability!

Coors Ceramic MLD* Flat Pack assemblies eliminate seal failures caused by differential expansion occurring between metal, glass and ceramic during sealing procedures and during operation. Coors flat pack leads are much thinner (0.0005" leads vs. 0.005" leads in conventional flat packs), so the forces induced by differential expansion are minimized. This means far fewer rejects from hermeticity failure—an expensive problem when both the flat pack and the assembled circuit components are lost. Coors Ceramic MLD Flat Packs (available in standard or special designs) provide high mechanical strength, excellent electrical properties and many times the thermal conductivity of electronic sealing glass. Write for Data Sheet 322-65 for complete information.

*Micro Lead Design



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Letters

Metric system or MKSA—readers give standing ovation to idea

Sir:

I have read with interest your editorial "Let's not put our best *foot* forward" which appeared on page 29 of the Nov. 22, 1965, issue of ELECTRONIC DESIGN.

I would like to commend your effort to make "progress" in communication among scientists and engineers throughout the world by pressing for a Senate study of a change from the "English" system to the "metric" system.

Progress can be considered to be a vector quantity expressed in terms of velocity and direction and measured with respect to a reference point. It is not your *velocity* that concerns me but your *direction*.

The metric system, according to Webster's Dictionary, is a decimal system of weights and measures based on the meter and kilogram.

I believe that your objective would be more rapidly achieved with less controversy if you acquainted your editorial staff and readers with the "International System of Units," the modern version of the metric system. These units have been officially designated "SI" units from the French "Systeme International."

The International System of Units is based on four, and only four, independent units—the meter for length, the kilogram for mass, the second for time, and the degree Kelvin for temperature. These we designate prototype units which are units of quantities which can be measured very accurately. Standards for them can be preserved or reproduced with fidelity. Furthermore, standards for other quantities of every conceivable kind can be constructed from these with adequate accuracy, in accordance with the defining physical equations. The International System of Units recognizes the ampere for electric current and the candela for light intensity as additional base units, but their definitions depend, in part, on the four prototypes.

The IEEE will shortly recommend the International System of Units to its authors. The American Society for Testing Materials has already adopted this policy.

Obviously, a change as drastic as the one you are pressing for cannot be made overnight. During the period of transition, it may be good practice to express data in SI units with the corresponding values in conventional US units in parentheses. In time, the non-SI units and values could be dropped.

Have you seen a copy of the relatively new *IEEE Standard Symbols for Units*, IEEE No. 260, Jan. 1965, which contains unit symbols for SI units and English units with some of the English units depreciated? [See note on page 63.]

Perhaps, it was your intent to press for the International System of Units in your editorial instead of the metric system.

Howard L. Cook
Sec'y IEEE Standards Coordinating Committee 11
ASA Sectional Subcommittee Y32.2
Task Group on International ElectroTechnical Commission Affairs
Cedar Grove, N. J.

Sir:

Your editorial of Nov. 22, 1965, ELECTRONIC DESIGN, page 29, contains a number of popular misconceptions about the metric system, DOD conversion and the legislative efforts to obtain funds for conversion study. I have been an advocate of the metric system for many years during which the controversy has been talked about, but very little has been done to actually use it.

First of all, let me say that the use of the term "metric system" is somewhat obsolete. A more complete and sophisticated dimension system has been introduced called Systeme International (SI), adopted by the International Committee on Weights and Measures at the 11th General Conference in Paris, France, 1960. The SI comprises six units as its fundamentals, and derives its system of standards from the MKSA (Meter-Kilogram-Second-Ampere), similar to MKS (Meter-Kilogram-Second) and CGS (Centimeter-Gram-Second) systems. The incorporation of the ampere as the fourth dimension within MKSA, realistically ties the electrical units to the more familiar mechanical units. The MKSA system was given the name *Giorgi System* by the International Electrotechnical Commission, after the Italian physicist who introduced it in 1936.

For those who wish to study SI further, the National Bureau of Standards has prepared many monographs on the subject; one, by F. B. Silsbee, was a remarkably concise review of the MKSA system. Also, *Physics Today*, published in July, 1962, page 19-30, a comprehensive survey on "Symbols, Units and Nomenclature in Physics," as adopted by the Commission for Symbols, Units and Nomenclature (SUN) of the International Union of Pure and Applied Physics (IUPAP) in 1960.

The DOD "conversion," at best, is only a dimensional conversion from the "designed in English" numbers to the equivalent in metric or SI. While it is a proper step, it does not embody the simplicity of working with whole numbers—i.e., the converted dimensions sometimes require decimal places for an otherwise simple dimension in English. This was by no means an agreement entered into without controversy, and for those readers who wish to pursue it further, the NATO Standardization Agreement, STANAG 4025, should be reviewed. Half a conversion, to me, causes more problems than it solves, because the "numbers game" becomes almost insurmountable. This is basically why I say we do not convert, *per se*, but rather adopt a new system of measurement. Hence, designing in metric, using geometric progressions (Renard Series), and so on, will really show the benefits of economy.

As to the cost of conversion, I have only one comment: What you do not know about, you tend to fear, and therefore fear-induced cost es-

(continued)

(Metric System continued)

timating tends to be unreasonably high. I do not believe enough people are familiar with SI and have a proclivity toward claiming astronomical costs.

The efforts of Congressman George P. Miller [D. Calif.], chairman, House Science and Astronautics Committee, to get the ball rolling have been less than comforting. Reading the House Records indicates extremely strong lobbying on the side lines. For those who do not believe this, they only have to wade through the hearings, for instance, H. R. 2626 (No. 4) Aug. 2 through 9, 1965, H. R. S. 1278 (Serial 64) Jan. 7, 1964, and H. R. 269 and H. R. 2049 (No. 14) June 29 and July 21, 1961, should provide an enjoyable session in observing science as a political football.

I am very pleased to see your personal support in this matter. However, you should endeavor to clean your house first, in a manner of speaking. Encourage our engineers to use the SI in their everyday work. NASA has recently gone on record that NASA publications shall use the metric system (Dr. A. J. Eggers, Jr., NASA, Deputy Associate Administrator for Advanced Research and Technology).

Lawrence J. Reeves
Philco Corp.
Palo Alto, Calif.

Sir:

I agree with your position favoring adoption of the metric system [E|D editorial, November 22, p 29]. In research activities, it is constantly necessary to switch back and forth between metric and English units, using up in the process a lot of energy that could be put to better use.

At present, there is prevalent an indigestible mixture of both types of units. Dieticians and semiconductor manufacturers use grams and calories, but furnace manufacturers use BTUs and pounds. Did you ever try to design a transistor heat dissipator with the help of a book on heat transfer that gave you the coefficients in BTU per square foot per hour? (How many watts in a BTU per hour?)

In tape recording, the international standard speeds are multiples and fractions of 15 inches per second (38.1 cm/sec), but abroad, gap lengths and other small dimensions are published in microns. Here they are in microinches (1 micron = 10^{-6} meter = 39.37 microinches)—unless they are very small indeed, when they are always given in Angstroms (1 Å = 10^{-10} meter = I forget what fraction of a microinch). Optical components such as lenses are always measured in millimeters, but shop drawings for the hardware in which they are mounted are dimensioned in inches.

Machinists necessarily use decimal subdivisions of an inch, and civil engineers decimals of a foot, but the two are not compatible; 1 mil = 0.0833 millifoot.

Ball bearings are standardized in metric sizes, but plain bushings in inches.

The main opposition to the adoption of the metric system comes, it appears, from the automobile manufacturing industry.

Widely quoted estimates of the cost of changeover run around $2 billion. The sources of the estimates are not usually given, nor is the basis on which they were made. We could certainly use, as a starter, a cost estimate made by a competent, unprejudiced group, *not* an association of any particular kind of manufacturers, nor any organization (such as the SAE) that is controlled by a particular industry. The national interest is concerned here. In a time of persistently unfavorable balance of payments, it behooves us to make all our products more efficiently and make them more acceptable abroad.

Lawrence Fleming
Bell & Howell Research Center
Pasadena, Calif.

Sir:

I appreciate any effort in support of a general adopting of the metric system of units, such as your editorial in the November 22 issue [p 29] suggests. However, your statement that the metric system involves dividing and multiplying by factors of ten confuses the matter.

The metric system of units is based on the meter, the gram, etc., as units of length, mass, and so forth, and makes use of the decimal system to define sub-units and super-units. The metric system and the decimal system are different and independent, and indeed the decimal system may well be used with English units. This is often done in subdividing the inch, as for example in 0.001 inch.

More disappointing and disturbing, however, is the fact that most of the proponents of the metric system seem to want somebody else to be the first in starting to use it. I urge you to adopt the metric system in your columns. If you do, your effort to have Congress reconsider its decision to postpone action on the matter will carry much more weight.

Conversion is not an easy matter, and will have to be made over a long period of time. I suggest a parallel notation of both metric and Engish units. For example, using data from [an Electronic Design article]:

W = 1.3 feet (40 cm)
L = 1.97 feet (60.0 cm)
H = 1.7 feet (52 cm)

Erik Wiik
Union Carbide Chemicals Co.
S. Charleston, W. Va.

Sir:

Your editorial on the metric system [E|D, November 22, p 29] was excellent, and I agree with you 1000%. I would like to offer one comment and one suggestion. Many people do not realize that Congress long ago adopted the metric system as the official system for the United States, and scientists (as opposed to engineers) and doctors use it almost exclusively. It is embarassing to me, as an engineer, to have to admit that my profession is so deep in this rut, while other professional people have seen the light and made the necessary adjustments long ago.

My suggestion is that we approach the real seat of economic power in the United States, the American housewife, through the ladies' magazines and similar media. When the American housewife realizes that she will get 10% more material in a meter than in a yard, and that she can multiply and divide recipes expressed in grams and liters more easily than those expressed in (pardon the expres-

(continued)

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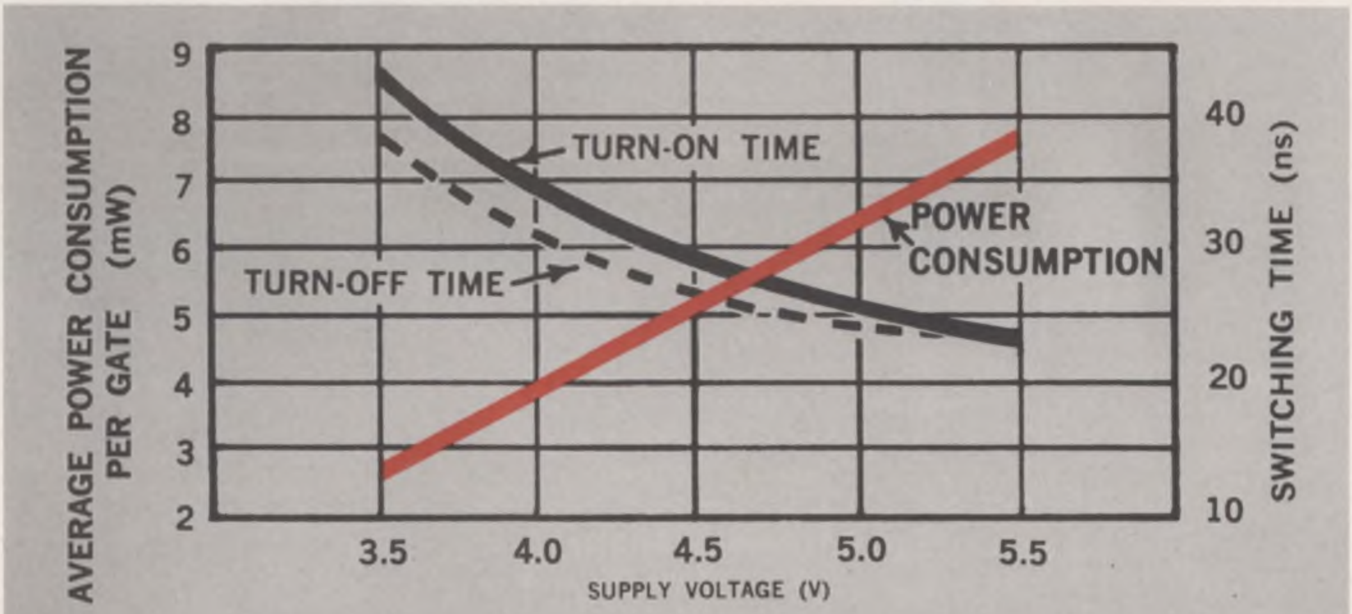

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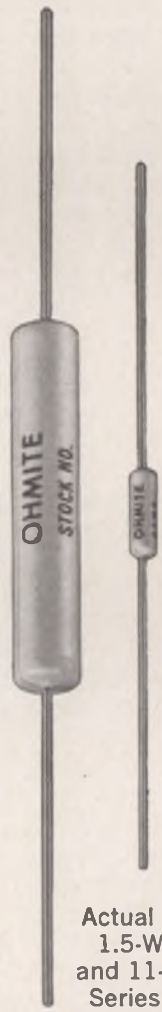

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ON READER-SERVICE CARD CIRCLE 32

(Metric System continued)

sion) pounds and quarts, industry will fall in line to a man, and we engineers, reluctant to the last, will have to design machines to produce 1 kilogram coffee cans.

Thank goodness our bankers do not make us use pounds, shillings, and pence!

Frank C. Smith, Jr.
Dannemiller-Smith, Inc.
Electronic Engineering Reps.
Houston, Tex.

Sir:

With reference to your editorial in the November 22, 1965, issue [p 29], I would like to offer our vocal support for Congressional effort in metric-unit standardization.

I can't understand why the logical beginning, a study, has been postponed by the House Rules Committee.

William H. Liederbach
Chairman
Indiana Section
American Ceramic Society
Carmel, Ind.

Sir:

Thank you for your excellent editorial in the November 22nd issue of your magazine.

While I have spent most of my career in this country, I received my education in industrial physics in Germany. Therefore, I have a lot of experience both with the inch and the metric systems. The amount of time one has to waste with conversions under the inch system is staggering indeed. I could never understand why a country which is so proud of its practical "Yankee Ingenuity," should put up with this continuous waste (and, incidentally, the increased chances for errors).

With even Great Britain changing to the metric system, I like to think that the USA must finally decide on this same move. There is a lot of talk about the high cost of change-over, but very little is being said about the savings. I firmly believe that the costs of the change are greatly exaggerated. After all, the dimensions of a part are not changed by measuring it in a different system.

Your statements about international trade are quite corret, however, I believe that the benefits of the metric system to the domestic economy would be even greater.

Your efforts to stir up action in the Congress deserve the fullest support of every citizen.

Max Bareiss
Mountain Lakes, N. J.

Sir:

Count me with you in favor of the switch to the metric system [E|D editorial, November 22, p 29]. It hardly makes sense to impede engineering thought and communications by forcing bilingual fluency in the English and metric systems, despite the fact that the English system is less systematic.

The bugaboo of the cost of conversion from the English to the metric system particularly in the area of packaging will always be raised despite the frequent changes already being made to new forms, such as the thirsty pint and the hungry pound. Such bugaboos can readily be dispelled by recognizing the offsetting gain from customer confusion, at least initially, before he discovers how easy the metric system really is.

We can expect from supporters of the *status quo* many temperamental outbursts (i.e., 90% temper and 10% mental). Much will be said and written against the change. To the stand-pat advocates I would like to leave this reminder: He who thinks by the inch and writes by the mile should be rewarded by the foot.

Walter Grzywacz
Electronics Engineer
U. S. Naval ADC
Johnsville, Pa.

Sir:

I welcome your initiative toward the abolishment of the medieval measuring system [E|D editorial, November 22, p 29], and I hope that Congress reconsiders this matter before it will enter history as "The American System."

I am optimistic in regard to the average engineer's attitude and dare to predict a vast majority for the metric system if the major engineering and scientific societies would ballot for this issue. Perhaps you could persuade their leaders to such a move.

To Congress conservatives, I would like to suggest as an alternative the reintroduction of the English money system to be consistent, since it's equally ridiculous.

Walter Fischer
Williamstown, Mass.

Sir:

In regards to your editorial in the November 22 magazine [p 29] on conversion to the metric system, I am with you all the way. This is a problem that will have to be faced. The longer it is delayed the more expensive it will be. Congress should reconsider its decision in postponing the feasibility study of the change over from the English system to the metric system.

DeLoyce Alcorn
Engineering Group
Supervisor
Jet Propulsion Laboratory
Pasadena, Calif.

Which is the hot one: silicon or germanium?

Sir:

In your news story, "Silicon and germanium battle at hi-fi show," October 25 [p 6], you state that the users of germanium transistors are condemning silicon transistors because of the heat they generate.

The heat generated in a silicon transistor is sensibly identical to the heat generated in a germanium, provided it is used in the same circuit; that is, it directly replaces the germanium transistor. The simple reason for this is that the heat generated in any transistor is proportional to the product of the collector-to-emitter voltage and the collector current. In hi-fi circuits, the heat-producing voltages and currents are, I hope, invariably the result of the transistors operating in the so-called linear portion of the first quadrant of their V_{ce} vs I_c characteristic. It is assumed that the transistors are never saturated, for this would invariably produce severe waveform distortion. It can readily be shown that the somewhat larger base-to-emitter voltage drop of silicon transistors can not significantly influence the heat generation of silicon transistors.

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ON READER-SERVICE CARD CIRCLE 33

(Silicon or germanium continued)

If anything, silicon transistors require smaller heat sinks than germanium because they are capable of operating at much higher junction temperatures. Silicon transistors can withstand far greater thermal overloads than can germanium transistors.

T. J. Maresca
Section Manager
Systems and Special Products
Electro-Mechanical Research, Inc.
Sarasota, Fla.

The right approach to FET circuit noise

Sir:

After studying the article on FET noise submitted by Dickson Electronics Corp. [E|D, Oct. 11, 1965, "Achieve Optimum Noise Performance in FET Circuits," p 40], we find two significant errors. The first error is in the derivation of Eq. 10; the second error is the assumption leading to Eq. 11.

In deriving Eq. 10, Mr. Rheinfelder makes the assumption that the open-circuit current noise (represented by R_I) and the short-circuit voltage noise (represented by R_N) have zero correlation—that is, he assumes that the two noise sources are random with respect to each other and that their total voltage contribution is the square root of the sum of the squares (rss). For unity correlation, the actual voltage contribution is the linear sum; when squared to obtain the power contribution to use in Eq. 10, the term:

$$2\sqrt{R_N/R_I}\ \ (1+R_S/R_I)$$

must be added. For any other correlation, the new term is modified by multiplying it by the correlation factor, γ. The correlation factor for FETs lies very close to one.

The assumption that the term $R_S R_I$ is negligible is only valid for a noise figure in the 3 dB and up range, since the first 1 (one) in Eq. 10 is really zero dB. When the noise figure gets low, an addition of 0.01, which would normally be ignored, becomes quite important. This is readily apparent when it is realized that 0.25 dB is 1.06.

As an example, let us assume that we have a field-effect transistor with R_N = 50k, R_I = 100 Meg and γ = 1. If R_S = 50k, then F = 2.046 = 3.11 dB; by the approximation, F = 2.0 = 3.0 dB. If R_S = 1 Meg, F = 1.106 = 0.44 dB; by the approximation F = 1.05 = 0.21 dB. The error, in decibels, caused by the approximation for the higher source impedance, is over 100%. This, of course, would result in many disputes between the supplier and the user, with the user being correct most of the time. These errors are present even if the value of R_N can be determined exactly.

Bob Mc Intyre
Applications Manager
Amelco Semiconductor
Mountain View, Calif.

The author's reply

Sir:

Generally a noisy four-pole network must be represented by four noise parameters which are independent of the other eight (real and imaginary) network parameters.* The four noise parameters can be taken, among other possibilities, as two voltage generators (such as one in series with base and emitter of a transistor) and their complex correlation; or a voltage and a current generator plus correlation; or, in latest engineering practice, as a noise resistance, noise conductance and their complex correlation. These four noise parameters are theoretically essential and sufficient to fully describe a noisy network. In practice, approximations are often preferred, particularly if sufficient accuracy is achieved. For example, it is found for tubes and FETs that a single noise parameter leads to very high accuracy at low frequencies. For tubes, four noise parameters should be used above 100 Mc. In transistors, two noise generators are always essential; however, at low frequencies zero correlation may be assumed.

A correlation of one, or full correlation, always means that a single noise parameter is a sufficient representation. This was the approach taken by the author and suggested by Mr. McIntyre. However, the resistance R_I in the author's calculation does not represent an open-circuit current noise generator as Mr. McIntyre believed, but rather the input resistance of the device itself. Since we also found a full correlation between any two arbitrary noise generators for FETs (in first approximation), a single noise generator may be used. Therefore, all device noise other than thermal noise in its associated impedance is lumped into the equivalent noise resistance R_N. This procedure is quite similar to the familiar form for tubes, but unlike bipolar transistors. Therefore, the author's equations are correct and no term should be added.

The second question relates to the statement that the term R_S/R_I, that is, the ratio of source (generator) resistance to input resistance of a FET, is usually negligible. This is based on the assumption that source resistances above 10 Meg are rarely used and normal FETs have input resistances of 1000 Meg or more. This approximation causes an error of usually much less than 2%, or 0.2 dB, in Eqs. 10 and 11, which is again less than the measurement accuracy of modern noise instrumentation of about 1 dB. Also, 0.2 dB is the same relative error in 20-dB or 1-dB noise figure readings. It is true, that there are occasional disputes between suppliers and users over values of 0.44- and 0.21-dB noise figures, as mentioned by Mr. McIntyre, but it is the author's opinion that these disputes are quite meaningless, in that they are tied to unrealistic specifications and measurement techniques. As a matter of fact, the paper's original title was "Noise Characterization of FETs," and the objective was to acquaint the user with methods of specifying FETs in a meaningful way.

For those readers who would like to see the full derivations for the equations, I would suggest requesting Engineering Report #1, "Noise Characterization of FETs," available from Dickson Electronics, Scottsdale, Ariz.

W. A. Rheinfelder
Applications Consultant
Dickson Eelectronics
Scottsdale, Ariz.

*A more thorough discussion is presented in the author's book "Design of Low-Noise Transistor Input Stages" (New York: Hayden Publishing Co., 1964).


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"A 'true democracy' will be based on electronic voting"

As a new year begins, it's time to sit back, put aside the stabilizing networks, the feedback loops and block diagrams for a minute and reflect on the future. What's coming in the next year or so isn't too tough to predict. You'll find some reliable forecasts in this issue. But what about 25 years from now? Or 100?

For this kind of way-out guessing we turned to the visionaries.

One of them is a French artist, Nicholas Schoffer, who did some of the electronic art shown on pages 42, 43, and 46.

Here's how he pictures the "true democracy" of the future.

A plastic-domed cybernetic city is buffeted by chill winds from the Canadian tundra. The icy blasts begin to cool the air within the dome. All over the city people reach into their pockets and press buttons. Their electronic "votes" are fed into a computer, which immediately signals the central air-conditioning-heating system to warm things up. Variations in heat and humidity levels continue until the "votes" for changes in one direction exactly counterbalance those in the opposite direction.

Similarly, lighting levels are increased as dark clouds scud across the sky, and the melodies filling the air within the city are adjusted to counter the annoying shrillness of the wind.

As a new visitor to the city is led through the streets, his host presses another button which summons a waltzing robot from a near by station. With whirling, reflecting discs illuminated by varying, multi-colored lights, the creature puts on a "spectacle."

This last touch stems from an idea that Schoffer has for the here-and-now—that is, mass-produced electronic art objects.

Another prognosticator is a Canadian professor, Marshall McLuhan, who feels that today's "electronic environment" is bringing radical changes to the human race. The world is growing into a huge tribe, tied together by a seamless web of electronics, says McLuhan, according to Tom Wolfe, the New York *Herald Tribune*'s avant-garde writer.

In the future, says McLuhan, people won't go to the office to work. They'll communicate with the rest of the corporation from their homes by means of closed-circuit TV and computers.

Whether these far-out thinkers are right or wrong, it is clear that electronics will make important contributions to the world of tomorrow. Over the next few years, every designer will play a part in building that world.

OK, that's enough for now. Back to those circuit diagrams . . .

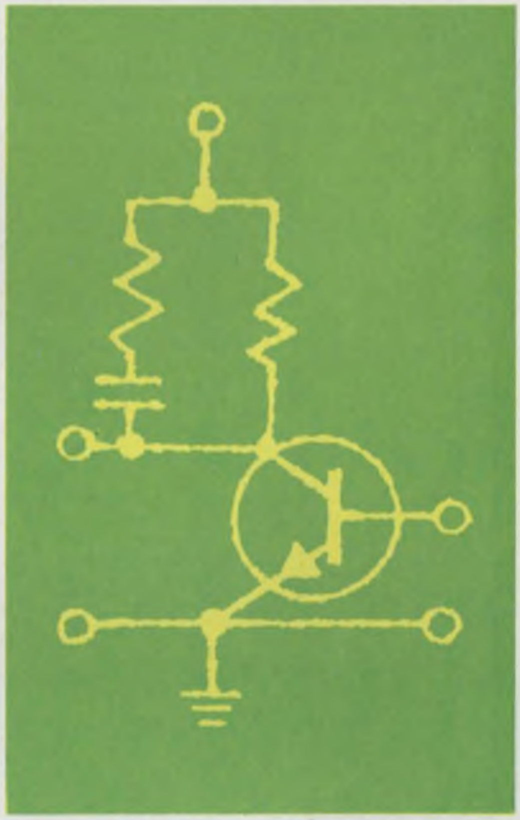
ROBERT HAAVIND

Note to readers:

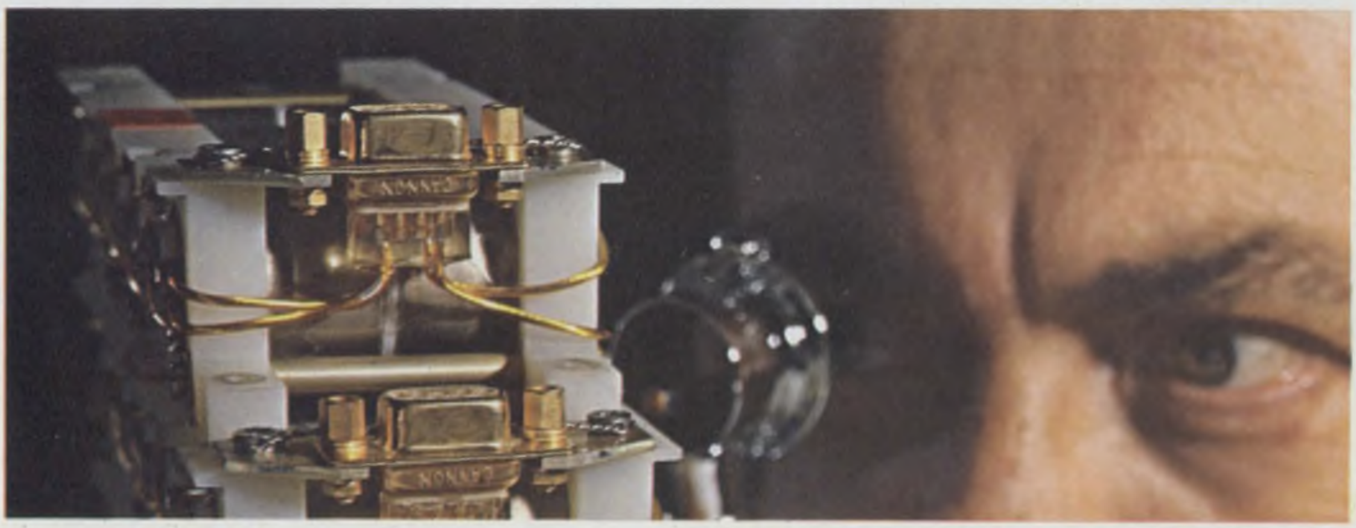
If you notice some Hzs, μAs, and mVs floating about the pages of this issue, it's because we've converted to the International Standards for abbreviations—that is, we've almost converted. We are using hertz for cps; but we stopped short of substituting siemens for mhos. Our reasoning is that we should cooperate in establishing worthwhile standards, but not at the expense of confusing our readers.

E|D Technology

FET amplifiers . . . 102



Mind your poles and zeros . . . 111

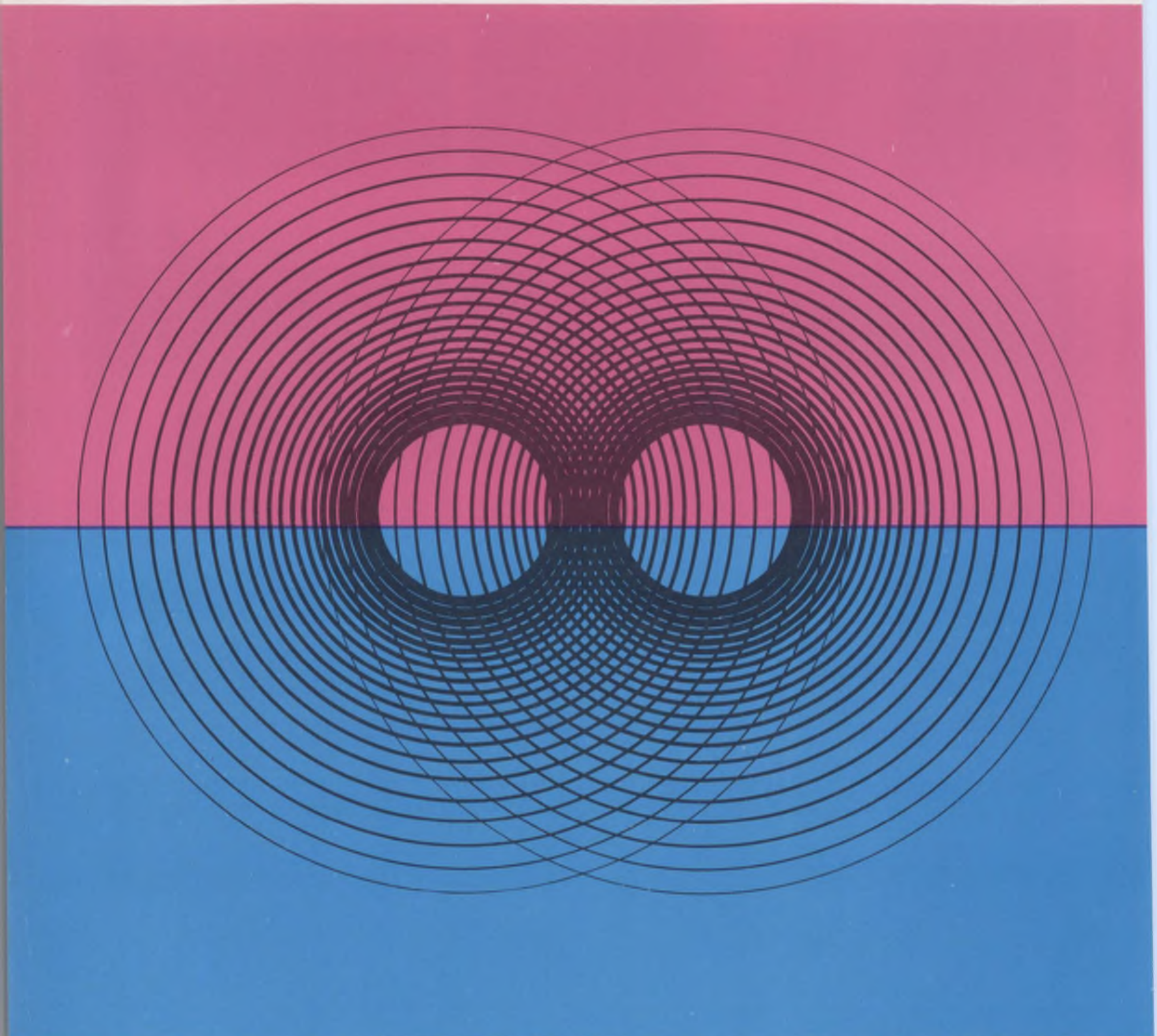


Focus on space electronics . . . 72

FOCUS '66

Well, back to the drawing board! Improved design is the watchword, say experts in the six fastest growing fields of electronics.

Coordinated by **Maria Dekany,** Technical Editor



Solid-state invades microwaves—integrated circuits are in sight now that new semiconductors and high-dielectric materials are perfected.

Generation, control and reception—the three basic functions of microwave semiconductors—are dramatically affected by recent advances in solid-state technology.

Microwave generation with the new semiconductor devices offers simplicity above all. Since the trend is toward integrated microwave circuits, this advantage is particularly significant.

As control devices, semiconductors find increasing use as power switches in the form of small passivated chips mounted directly in printed circuits.

The most immediate impact will be in reception: Better diodes will cut back the noise figure of superheterodyne receivers. Even though no new basic concepts are involved, some circuit redesign will be advisable to get the maximum benefits from the improved diodes.

In terms of research, the field of microwave generation is the most active. A wide research area has been opened up by the discovery that many types of diodes oscillate at microwave frequencies when pulsed sufficiently hard. Attention to the efficiency and thermal dissipation of these devices has resulted in significant cw power—as high as 20 mW at 13GHz.

The ultimate impact of these devices cannot be fully assessed at the present time. It is certainly premature to predict the demise of all other types of microwave sources. The continued use of low-noise klystrons and thermionic microwave triodes, at powers and frequencies attained by varactor multipliers, should serve as a lesson in this regard. While cost is sometimes a factor, the details of performance dictate the diverse choice of devices.

Oscillators: more study needed

The new oscillators receiving the most attention are derived from:

- Gunn effect in gallium arsenide.
- Other high-field oscillations in gallium arsenide.
- Avalanching gallium arsenide *pn* junctions.
- Avalanching silicon *pn* junctions.

Dr. Arthur Uhlir, Jr., Vice President,
Microwave Associates, Burlington, Mass.

Two distinct types of oscillations occur in gallium arsenide "resistors" (uniform conductivity n-type GaAs with nonrectifying contacts).

One of these may be called the Gunn-effect proper. It involves the buildup of a shock-wave disturbance in the electron velocity—a kind of relaxation oscillation at microwave frequencies.

The other type of oscillation is observed in materials with relatively low electron density and may be a true manifestation of the long-sought bulk negative resistance.

Most of the cw oscillations, which range in power up to 90 mW at L-band[1] and 25 mW at X-band,[2] seem to be of the second kind. Pulsed power (50 ns) over 200 watts peak has been obtained from the Gunn effect at frequencies below 1 GHz.

The Gunn effect is unprecedented in both vacuum and semiconductor electronics—there are no close analogies. For this reason, it has the best chance for really new and different results. It is also ahead of the other devices for power and efficiency (up to 13% has been reported).

A long-term and large-scale study of materials is needed to understand and develop fully the Gunn effect.

Avalanching gallium arsenide *pn* junctions are ahead of silicon for cw operation: 20 mW at 13 GHz and 4% efficiency has been reported by the U.S. Army Signal Corps.[3] One cannot but wonder if

Varactor quad under development. Its optimum dc return resistance has to be determined experimentally so that it can be integrated with varactors.

these GaAs junctions derive some benefit from bulk-effect negative resistance.

Pulsed operation has been studied more extensively with silicon junctions. For example, special silicon diodes* can generate up to 50 watts peak, 1 ns pulses in X-band.[4]

Better noise measurements are needed

At present, it is difficult to establish a true noise level for these oscillators. For instance, noise measurements with high-Q cavities are meaningless unless the Q is specified.

As far as the Gunn effect and bulk negative resistance are concerned, the supposed physical mechanisms do not imply a high inherent noise.

For the avalanche oscillators, the random initiation of breakdown events will definitely lead to a considerable noise, equivalent to an amplifier noise figure of 40 dB.[5] Until some means for overcoming this random nature is invented, the avalanche oscillator will be something less than a terror for competitors in the local-oscillator market. High-Q cavities can reduce the output noise, but their use conflicts with the small size and electronic-tuning features needed in local oscillators.

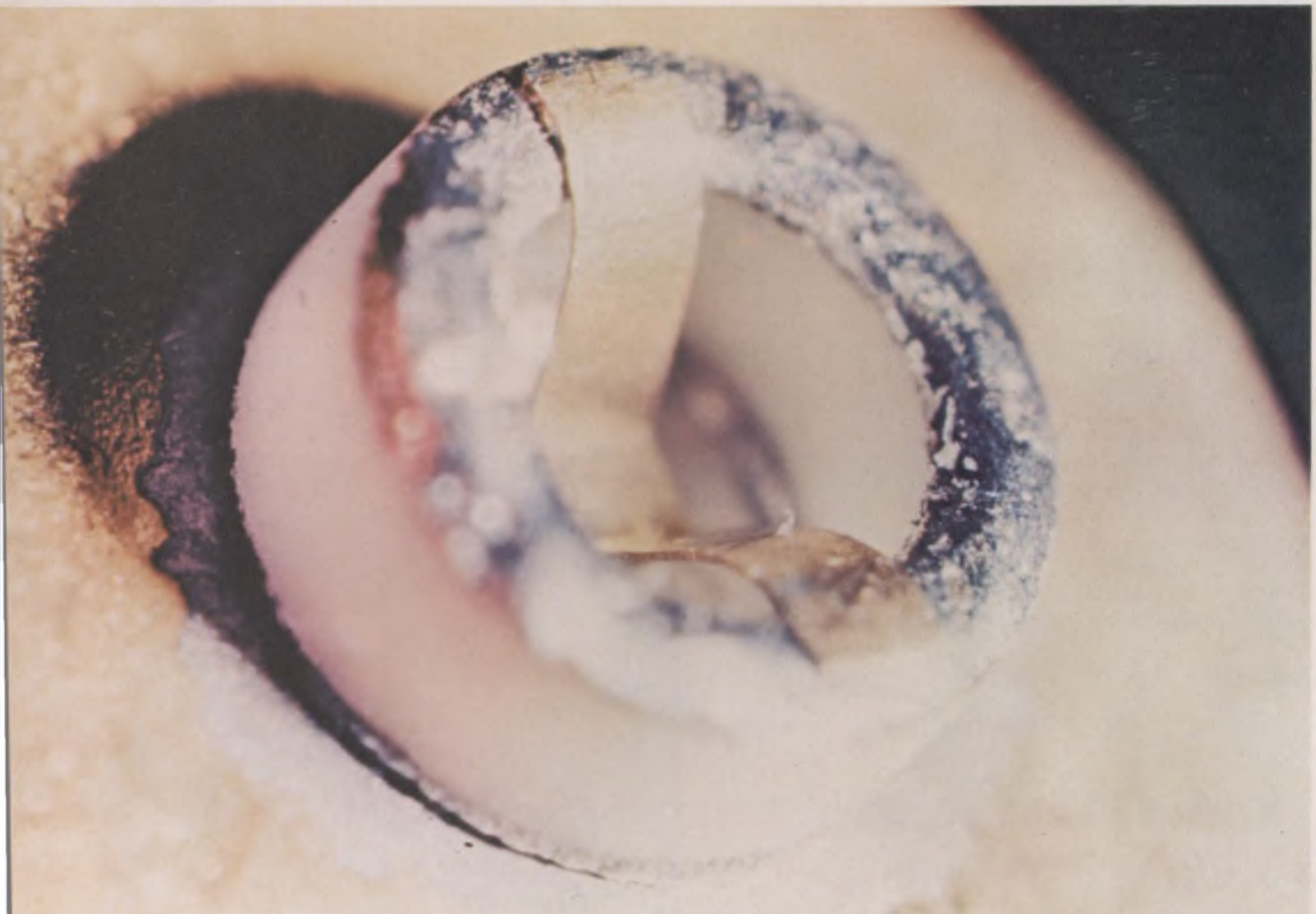
Compact high-Q-cavity resonators can be constructed with materials that have high dielectric constants, like rutile crystals. However, their practical applications have been limited in the past. Perhaps the noise problems of these new oscillators will stimulate their use. Tunability can be supplied by YIG resonators. The power and efficiency of avalanche oscillator diodes may be improved by tailoring the impurity distribution.[6]

We can expect to hear more laboratory results on negative-resistance amplifiers made as variations of the diode oscillators. Since a circulator is needed for good operation, transistors are still preferred at frequencies where available.

Transistors need new approach

Progress in microwave transistors may slow somewhat as recent advances are consolidated.

*This development and the illustrations accompanying this article represent work sponsored at Microwave Associates, Inc., by the Electronic Technology Division of the Air Force Avionics Laboratory under Contract Nos. AF33(657)-10001, AF33(657)-10925, and AF33(615)-2449.



Simple gallium arsenide oscillator consists of a thin slab of gallium arsenide mounted on a copper heat sink. The top contact is insulated by an alumina washer from the heat sink, which is the bottom contact. Its operation is a manifestation of the Gunn effect. (Courtesy of IBM, T. J. Watson Research Center, N. Y.

New fabrication techniques may be necessary to produce a further spurt in performance.

Recent improvements in transistors moved the fundamental frequency of transistor-varactor sources from the 100-MHz to the 500-MHz range.

For maximum efficiency and largest output power, relatively low-order multipliers are used in the multiplier chain, like doublers, triplers and quadruplers. Balanced and bridge circuits are making a comeback for high-power applications (E|D, September 27, p 37). The output power can be increased by connecting varactors in series.

Both the bridge and series connections of diodes encounter a serious problem at high powers unless each varactor is biased separately—and sometimes even that doesn't help. The difficulty is that a high-frequency voltage can induce a negative conductance in the apparent dc reverse characteristics. The problem is entirely analogous to the instability of series-connected tunnel diodes, except for the hundred or more times larger voltages involved. The best way of increasing the power capability may be in the plural connection of varactors. This solution lowers the RF voltage on each junction, providing a larger margin of safety.

The higher frequency power transistors also make possible another type of source that supplements, but does not replace, the multiplier chain. With several watts of power available at 500 MHz, it is possible to obtain local-oscillator power up through X-band (and higher for efficient mixers) by multiplying in one stage with a single varactor in a high-order multiplier. However, an extremely complicated circuit with idlers at many intermediate harmonic frequencies would be necessary to maximize the power output of such a system.

The single-stage multiplier is recommended when good efficiency is not needed. Then, quite simple circuits can be used. They consist primarily of a cavity at the output frequency that selects the desired harmonic and suppresses to some extent the neighboring harmonics. Low-impedance reactive termination of low-order harmonics, particularly the second, is a simple way to enhance the output power. Typical operation is an input power of 2 watts at 600 MHz and an output of 10 to 40 mW at 9600 MHz.

A significant amount of confusion has arisen from the insistence in some quarters that a varactor diode—used for this low-efficiency, high-order multiplication—is a distinct new device. In fact, the varactor design considerations for low- and high-order multipliers are essentially the same:

- The cutoff frequency based on series resistance must be much higher than the output frequency.
- The breakdown voltage must be high enough to accept the available input power.
- The charge should be an instantaneous function of voltage on a time scale corresponding to the output frequency.
- The forward conductance should be low enough so that little charge leaks off on a time scale corresponding to the input frequency.

High-Q cavity reduces noise of cw Gunn oscillators. However, the cavity is large and not tunable electronically.

One misleading factor was that the first formally complete theory of the multiplier's power and efficiency was based on the depletion-layer capacitance of abrupt-junction varactors. The theory was valuable in setting a pattern. Most practical multipliers did not, and do not, operate in close conformity to early theory.

Control: pin diodes best

The *pin* diode has long had remarkable electrical capabilities for switching high-power microwaves. Significant new developments going on at the present time are a consequence of the increasing need for these elements in microwave switches and, especially, in phase shifters for array antennas.

As a result, we can expect improved knowledge of the reliability with which the high-power capabilities can be sustained. Elements suitable for mounting in array antennas from uhf to X-band are available. For moderate power applications, these elements can be obtained in the form of small passivated chips which can be mounted directly in printed circuits.

While conventional stripline materials with organic dielectrics can be used with these chips, a future trend toward inorganic dielectrics, such as alumina and beryllia is plainly visible. Besides dimensional stability at elevated temperatures, these materials have higher dielectric constants that organic materials. Since the size of a given circuit is inversely proportional to the square root of the dielectric constant, inorganic dielectrics permit greater size reductions. The dielectric losses are generally negligible, while the conductive loss per effective wavelength varies inversely with linear dimensions.

The integration of microwave circuits can go considerably beyond the insertion of chips into ceramic stripline circuits. High-resistivity semiconductors with reproducible dielectric constants have dielectric losses that can sometimes be tolerated, particularly at X-band and high frequencies. When the dielectric losses of the semiconductor are too high, the advantages of batch fabrication can be sought through the deposition of high-quality dielectric on the semiconductor (or vice versa). Such a construction may be termed "bilithic" and should give the cost and reliability advantages to high frequency circuits usually associated with monolithic integrated circuits.

Surface pin suits monolithic integration

The *pin* switch area has provided the most plausible application of a concept that has been repeatedly considered for microwave semiconductors and then set aside: the idea of making an active junction perpendicular to the surface of a slice. This means that the junction area can be made arbitrarily small by using diffusion or epitaxy in an arbitrarily thin layer. In this way, low capacitance can be fabricated without a direct confrontation with small dimensions.

It seemed at one time that the most natural application of this concept would be in tunnel diodes, where the capacitance per unit area is extremely high. Interest diminished in this design when it was found difficult to obtain a low-enough series resistance in this way, even when relative to a reduced capacitance. The method was then tried for varactor diodes. The relatively high sheet resistance of the semiconductor region made extraordinary demands upon high-resolution metallizing when the cutoff frequencies of conventional designs had to be equaled.

For *pin* diodes, this concept seems to fill a need.[7] The significance of this development is that this surface diode can be integrated quite easily. One of its important aspects is the high-resolution metallizing used to obtain a low sheet resistance as close to the active area as possible. The general principle is that semiconductors, no matter how heavily doped, have inadequate conductivity for use as sheet conductors.

For receivers: Schottky-barrier diodes

The most significant development in microwave receivers is in the nature of a return to an earlier scene—to the superheterodyne mixer.

Where the point-contact mixers had dominated the field in the past, the new Schottky-barrier diodes are now gaining an excellent reputation. The remarkably improved noise figure of the point-contact types with epitaxial materials is the main reason it is still in competition below 5 GHz.

The continuously improving bandwidths of the coaxial crystals indicate a trend toward replacing cartridge types in X-band, especially in the 10.5 to 12 GHz region, where standard cartridge mixer diodes have severe resonance.

While the broadband glass-pin-bead coaxial diodes may represent the best point-contact design, we designed them with a conscious thought that they might also be the last.

The Schottky-barrier mixer is proving to be equal to, or better than the point-contact design in nearly all respects, except in its ability to duplicate the exact impedances of point-contact mixer crystals. This area will yield to further work. For new designs, Schottky-barrier diodes should definitely be considered. At the moment, based on the availability of reproducible devices, it is probably fair to say that the burden of explanation is on the designer who does *not* use Schottky-barrier diodes at frequencies up to 5 GHz.

Laboratory results show that it will not be long before the same can be said for higher frequencies. The only question is, what semiconductor material will be used at a given frequency. Silicon Schottky-barrier diodes are already close to the theoretical noise limits at S-band. Gallium arsenide will probably be used at K_u-band and higher frequencies. The dc bias thought to be essential for GaAs may be eliminated, according to recent process modifications.

With the prospect of substantial improvement in superheterodyne receivers, one may well ask what is to become of tunnel-diode amplifiers. Their use in microwave relay and radar may indeed be reduced. However, broadband detectors can make good use of microwave amplification, since IF amplifiers with several-gigahertz bandwidths may be immediately forthcoming.

The need for parametric amplifiers will similarly be reduced, although there is no present indication that the extremely low noise possible with parametric amplifiers can be approached by a passive device like a Schottky-barrier mixer. In fact, it is possible that the Schottky-barrier mixers as now tested may derive a small amount of amplification from variable capacitance.

The application of the parametric amplifier will continue to be limited by its expense and complexity, but not indefinitely. Microwave integrated-circuit techniques, applied to transistor-varactor power sources or diode oscillators, will eventually make inexpensive pumped sources available for integration with the parametric-amplifier circuit. When devices are thus developed that can be connected to dc and the RF ports of a receiving system, their use will expand and costs will go down as volume increases.

References:

1. T. B. Ramachandran, Microwave Associates, private communication, 1965.

2. C. Hilsum, P. N. Butcher, "Bulk Negative-Resistance Effects in Semiconductors," International Electron Devices Meeting, Washington, D. C., 1965.

3. V. J. Higgins, F. A. Brand, J. J. Baranowski, "Characteristics of Varactor Diodes Biased into Avalanche," International Electron Devices Meeting, Washington, D. C., 1965.

4. R. G. Agpar, M. D. Bear, H. Lane, General Dynamics Electronics, private communications, 1963.

5. Marion Hines, scheduled for publication in *IEEE Transactions on Electron Devices*, January, 1966.

6. W. T. Reed, "A Proposed High-Frequency Negative Resistance Diode," *BSTJ*, vol 37, Mar 1958, pp 401-466.

7. A. Ertel, "Microwave Evaluation of Surface-Oriented Switching Diodes," International Electron Devices Meeting, Washington, D. C., 1965. Reprints available from author at Texas Instruments, Dallas, Tex.

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Design Specifications. Operational Amplifier—A00-9. Photo chopper stabilized. DC gain: 4×10^7 (min). Gain bandwidth product: 1 mc (min). Output: 40mA @ ±100V with 2-5 k load, 10mA @ ±140V. Drift less than 1.0μV/°C. Long term drift: 2μV/100 hrs (max). No chopper drive required.

Operational Amplifier—A00-10. Photo chopper stabilized. DC gain: 5×10^7 (min). Gain bandwidth product: 1mc (min). Output: 5mA @ ±25V. Drift less than 0.5μV/°C from 0°C to +55°C. Long term drift: 1μV/100 hrs (max). No chopper drive required.

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First the moon, then Mars and along the way men and machines must depend on electronics. Four specialists speak on what to expect of 1966.

ComSats: bigger and better

Tom R. Jones, Early-Bird project engineer, Hughes Aircraft Corp., El Segundo, Calif.

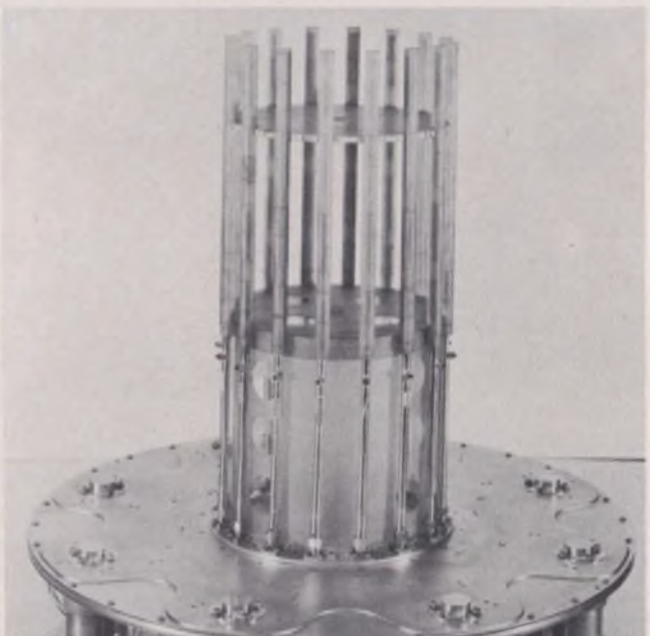
Larger synchronous satellites with longer lives are on the way. Syncom II, with a radiated power of 5 watts and a repeater bandwidth of 5 MHz, was a notable achievement when it was launched in 1963. Soon it will be little more than a museum curio. In 1966 there will be laboratory tests of satellites that have 100 times the bandwidth and 2000 times the power of Syncom II.

Single-conversion linear repeaters are now available that employ tunnel diodes capable of amplifying vhf signals directly without converting the signal to an IF. Bandwidth for these repeaters is over 500 MHz and total repeater noise ranges below 5 dB. In terms of capacity, these repeaters can carry 10,000 telephone conversations or 20 color television programs. Present Syncom II capability is limited to 50 conventional telephone lines and one black-and-white television picture.

Antenna designs are keeping pace

In order to keep pace with the repeater state-of-the-art, design emphasis has been placed on developing satellite antennas with wider bandwidths and higher gains. Of current interest are electrically and mechanically despun antennas, (antennas that compensate for the spin of the satellite). One version of an electronically despun

Gold-plated wiring harness connectors shown mounted on nickel-cadmium batteries carried in the Syncom communications satellite. Similar installation was used in the Early Bird satellite, and advanced version of Syncom.



A despun antenna for synchronous satellite transmitters. Units similar to this one, already in the hardware stage, will handle 2000 times the power of Syncom II and 100 times its bandwidth.

antenna, developed by Hughes Aircraft Corp., is a phased-array type that consists of 16 radiating elements. When four colinear dipoles are used for each element of this antenna, the total gain is over 18 dB.

A slightly different configuration of the phased-array antenna, also developed by Hughes, has the elements operating in conjunction with a biconical horn, which gives a gain of approximately 20 dB. Ferrite phase shifters are used to change the phase of the signal out of each element of the antenna and cause the composite signal to form into a narrow beam.

A currently proposed satellite (for television network relay use) employs a biconical-horn phased-array antenna having each of the 16 elements driven by individual traveling-wave tubes. With the use of 6.25-watt TWTs, the total effective radiated power of this configuration is 10 kW. This amount of radiated power allows TV-signal reception on relatively inexpensive receiving terminals—for example, with 30-foot dishes and cooled parametric amplifiers instead of the presently required 85-foot dishes and cooled maser amplifiers. Data and voice transmission could be received on antennas with diameters of only a few feet.

Launch vehicles ready

Due to improved launch vehicles, satellite weights have grown tenfold during the past three years. This growth in weight and size can be used effective radiated power for this configuration is power generated and to increase the station-keeping capacity of the satellite. Proposed satellites for 1966 would have solar power plants that are capable of producing over 500 watts and planned for as much as 10 years of station-keeping capability.

Integrated circuits are presently becoming more common in satellite systems. They have already found applications in digital logic circuits such as encoders and decoders. They also proved to be quite useful in the control electronics for despun antennas where they reduced the complexity, increased reliability and provided a weight and volume savings as well.

ICs a must for future probes

Herbert S. Kleiman, consultant, Arinc Research Corp., Annapolis, Md.

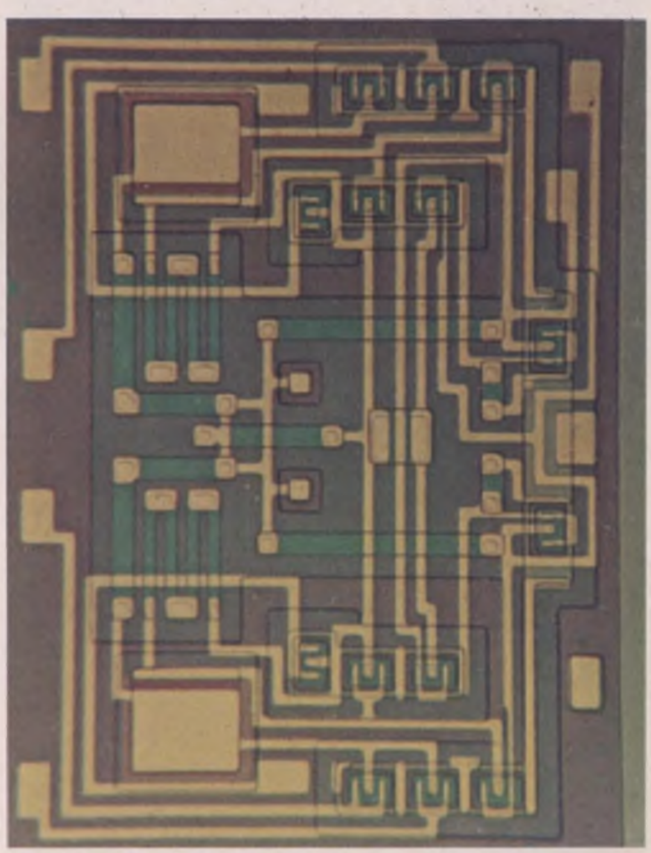
In 1966, NASA will increase its efforts to incorporate integrated circuits into spacecraft that are in the design or planning stages. IC usage will be limited for some time, but there are several factors demanding increased NASA attention to this new technology:

- NASA's reliability needs, already demanding, will become even greater for the extended probes and long-term space stations now on the drawing boards. This will result in the increased use of digital ICs and efforts to improve analog ICs.
- NASA's satisfactory, though limited, actual flight experience with integrated circuits will encourage the agency's faith in the technology's capabilities.
- NASA cannot ignore the developing price advantage of integrateds over discrete-component circuits. Cost is generally secondary to over-all performance for NASA contracts, but the recent cost reductions will exert a powerful influence wherever ICs are equal to discrete components in effectiveness.

By coincidence, the first integrated circuits were demonstrated in 1958, the year in which NASA was formed. In the first few years, ICs and NASA had very little else in common. Compared to the massive Department of Defense funding, NASA interest in IC technology has been slight. This situation is changing, however, as integrateds become more reliable and more flexible.

Mariner IV and the Interplanetary Monitoring Probe have both used small quantities of off-the-shelf digital ICs with good results. The Apollo guidance computer, perhaps the largest user of integrated circuits to date, has furnished the most reliable information for any IC program, NASA or otherwise.

The growing market volume, learning-curve improvements and an increase in the number of participating programs indicate that integrated-circuit technology has greatly matured. The cumulative military and aerospace experience seem to justify many of the early claims of en-



Typical of IC sophistication is the Motorola MC308. This high-speed JK flip-flop contains 16 transistors, two capacitors and many resistors.

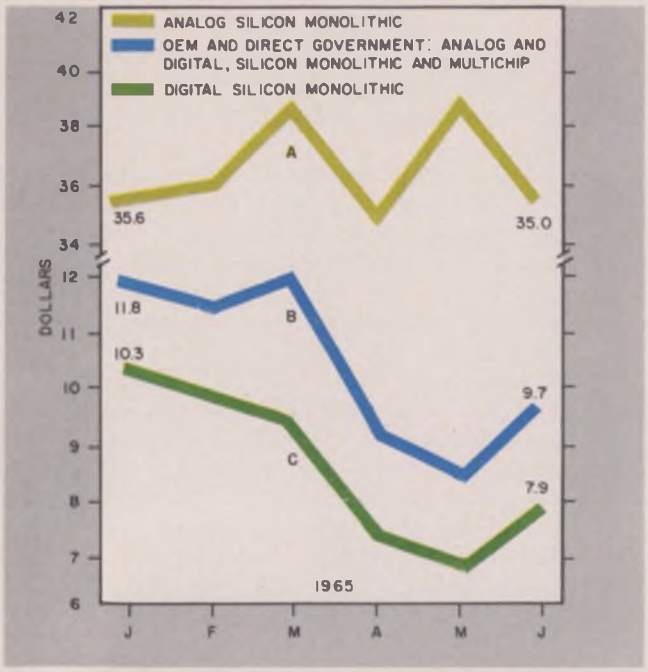


Fig. 1. EIA figures indicate a decreasing IC price trend. However, analog ICs (A) are still about four times as costly as digital (C).

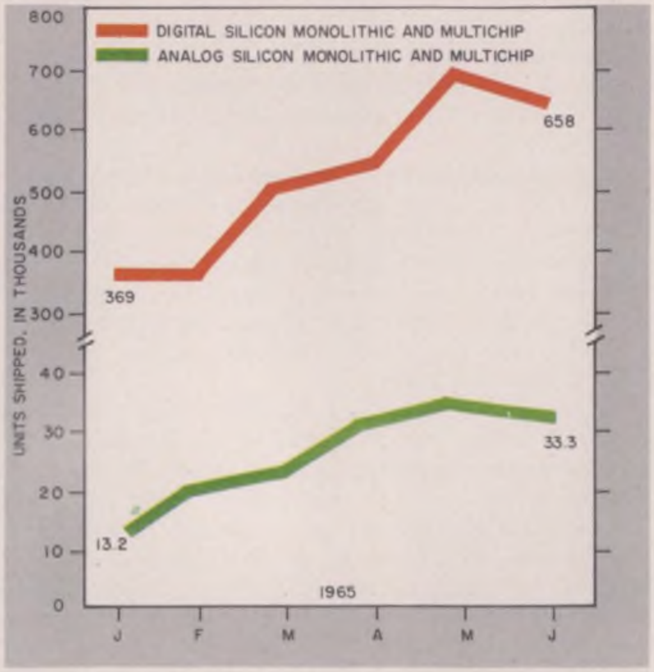


Fig. 2. Increasing sales volume is indicated for both digital (A) and analog (B) ICs. Despite the increase, analog sales lag by 200 percent.

thusiasts in the field. The high reliability, minimal weight and volume, combined with low power consumption, have made ICs indispensable to the success of several missions.

Still in the debit column are analog-device capability and availability. The devices are generally young compared with digital types and second-sourcing is rare.

Unit prices are down

As IC reliability and applicability have been rising in the past few years, their basic price has been falling.

As seen in Fig. 1, curve C, EIA statistics show a continuing decline in the average price of silicon monolithic integrated circuits. Curve B shows a similar decline in the average prices for combined analog-and-digital silicon monolithic and multichip components sold directly to the Government and to original equipment manufacturers. Though not directly verifiable from this graph, most of the IC components sold through this latter channel are destinted for Government programs either directly through systems contracts or through OEM equipment.

Curve A emphasizes again the lag in analog IC development. No useful trend is discernible, and, as noted, the average analog price is now about four times that of digital.

Belt-tightening expected

Although the NASA budget has increased tremendously over the past five years, thanks to a greater emphasis on the manned space-flight program, the space agency is necessarily cost-conscious and will therefore become more IC-conscious. Several factors imply that NASA will not only find increased appropriations hard to come by, but will have to justify its current budget level more vigorously.

These factors include the leveling of the NASA allocations at about $5.25 billion, the growing criticism and intensified review of the space budget as it grows, the emphasis placed on other Government projects and the effects of the concept of "cost effectiveness." (This amounts to a matter of determining, in advance, the value and utility gained for each Government expenditure.) The concept is being used extensively in the DOD and seems to be finding some measure of acceptance in other departments and agencies as well.

James E. Webb, NASA administrator, said in the spring of 1964 that NASA estimates that 40% of its booster costs, 70% of its major spacecraft dollars and 90% of its tracking and data-acquisition funds go into the electronics industry. In many instances, the offer of more service per dollar will literally force integrated circuits into space plans and a growing share of this multi-billion-dollar market.

Reliable power should be no problem

James E. Comer, Staff reliability and standards engineer, Gulton Industries, Inc., Hawthorne, Calif.

The need for greater reliability is still the single most important problem facing suppliers of power-conditioning (conversion and distribution) equipment for space and military vehicles. In the near future, important changes will be incorporated in the developmental routine to attain the reliability required by the planned deep probes and long-life satellites. The changes will be made in three major areas: reliability analysis, project scheduling and organization and component specification.

Reliability analysis

Too many charts and forms have been composed for stress analysis. The information required is many times duplicated on the same forms. The very mass of the data makes it almost impossible to determine if the stress figure is in agreement with the ratings.

Factors that do not contribute to the stress, such as leakage, gain and frequency, must be eliminated from stress charts, since they serve only to dilute the purpose of stress analysis. They are valuable data but their place is in limit-value analysis and they should be considered as such separately.

A major factor that is often overlooked in stress analysis is peak power. Studies of power-equipment failure mechanisms indicate that the majority of failures occurred as a result of high peak power. These failures are particularly prevalent in power-handling transistors under such conditions as turn-on, short-circuit or switching under heavy load. It is something of a rarity when power equipment fails due to a minor deviation or an out-of-tolerance condition.

In general, the idea that failures can simply be attributed to random factors is more often an excuse than an answer. Some factors that may be "random" at first glance may be the result of such unusual operating conditions as:

- Turn-on.
- Exceeding the base-emitter voltage limits during a critical operation.
- Exceeding the dv/dt limits of an SCR.
- High transient voltages.
- Exceeding the actual transistor peak-power level.
- Discharge of load-element stored energy.

While some failures simply cannot be explained, every possibility must be explored to reach the reliability levels required by extended service under the extreme conditions (radiation, temperature, shock acceleration, etc.) encountered in space.

Contract and organization

In the past, the practice has been to let the power-supply contract last after all the other requirements are established. Then someone discovers that none of the other equipment can be checked until the power supply is delivered. So the power section is inevitably the last to be called and the first to be scheduled for delivery. More recently, a trend toward early negotiations has begun to take shape and may eventually rectify this situation.

After the contract is let and the work begins, competition between reliability and design groups is both inevitable and advantageous. If handled properly, this competition can result in a better product. Then, the honors can be rightfully shared.

The key to the problem is early participation by the reliability group. This would eliminate much of the usual friction between reliability and design, while taking advantage of normal competition.

Component specification

For the present, the selection of semiconductors with proved low failure rates is limited to the older types. For some time it has happened that nearly every time a transistor-failure rate reaches the point where it is advantageous to use the device for reliability, the device becomes obsolete.

But the rate of growth in transistor development seems to have decreased recently, and general limits for frequency and power seem to be establishing themselves. Moreover, the experience gained in one device applies to the newer transistor. For instance, when a line of reliable mesa transistors converts to a planar epitaxial, a certain portion of the failure rate achieved by the mesa line will apply to its epitaxial counterpart. Processing accounts for a major portion, if not all, of the failure rate and this portion will apply to the newer device.

Integrated circuits

The impact of integrated circuits has yet to be felt in space power equipment. Compare the size of a 400-Hz transformer to an integrated-gate circuit and it can be seen that the size advantage is rather limited. The present trend is more toward packaging refinement, like flat-pack power devices with higher frequency capabilities, dual transistors in single packages, high-etch tantalum-foil capacitors and polycarbonate ac capacitors. Voltage regulator circuits are due for integrateds soon, but some convenient method must be developed to provide voltage selection.

Integrated circuits, when they do become useful in space vehicle power conditioning, will offer a greater challenge to the reliability engineer. If the reliability engineer is to expand into this area, he must be able to perform some additional tasks, such as limit-value and stress analyses on the integrated circuits now coming into service. This process is a good deal more complex than testing and evaluating discrete-component systems.

Instrumentation growing step by step

Frank J. Schutz, formerly research specialist with Jet Propulsion Laboratory of California Institute of Technology. Presently senior engineering specialist, Space General Corp., El Monte, Calif.

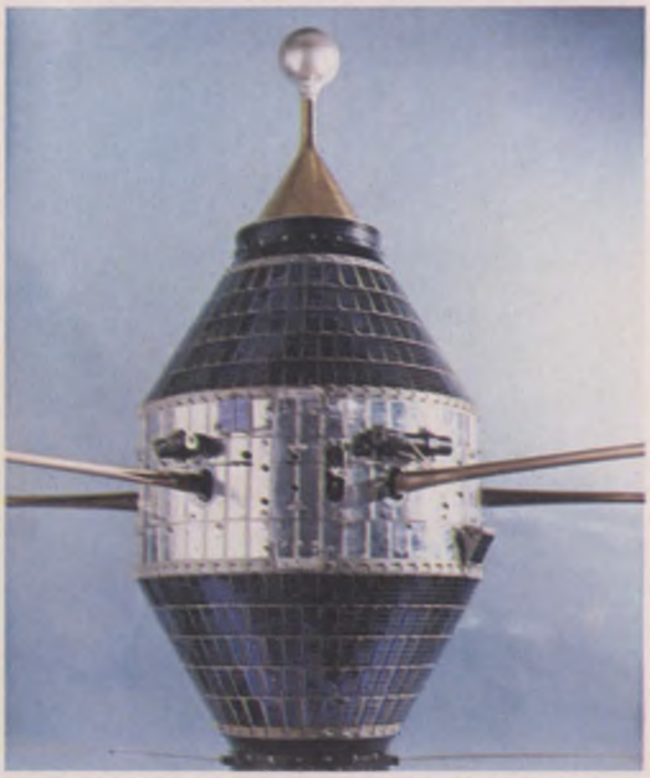
Space instrumentation for upcoming projects will demand complex and reliable devices for telemetry and for the investigation of biology outside the earth's atmosphere (exobiology). The specifications for this new instrumentation will depend on two factors:

- The objectives of the individual missions.
- The physical and electrical parameters of the spacecraft.

NASA plans to make a series of space probes, each with particular missions based on the results of previous missions.

Our imminent "invasion of Mars" is following this step-by-step form. The early Voyager missions will make preliminary measurements of Mars' atmospheric parameters, both chemical and physical, and this information will dictate the design of the future soft-landing spacecraft.

Now it's hardware and being checked out at the instrumentation site. IMP-C will measure magnetic fields, cosmic rays and solar wind.



350,000,000-mile mariner, the Mariner IV, operated like clockwork to give a close-up view of Mars. Its life in space lasted over seven months.

As our knowledge of Mars becomes greater, the electronics industry must evolve exotic exobiological instruments, among them, perhaps, a television microscope for direct visual examination of Martian surface samples. A two- or three-color television system for surface inspection is also a possibility.

As we progress in this series of missions, the spacecraft become more and more complex. As the demands on space instrumentations increase, reliability must keep pace. Some time in the distant future, it may be possible to have supplies of spare components or subsystems for manned spacecraft. During the next decade, however, this is not likely to occur. For the present, emphasis must be placed upon the design of inherently reliable instrument components and subsystems, backed up by redundant subsystems where absolutely necessary.

Telemetry a problem

However, before any of these specialized systems can be built, data-transmission rates will have to be boosted by inflatable or unfurlable antennas and higher power transmitters, like radio-thermonuclear generators (RTG). Data processing will also have to be stepped up with adaptive telemetry devices that compress the transmitted data and keep data redundancy at a minimum.

For the near future

Before we can launch a manned moon-shot, the moon's surface must be studied to enable scientists to select landing sites for lunar landing vehicles. The unmanned-lunar-project researchers are experimenting with a satellite and a landing vehicle for this purpose.

This Lunar Orbiter satellite will make detailed photographic studies of extended areas of the lunar surface and will measure the gravitational field of the moon. The soft-landing Surveyor is designed to measure volcanic activity, the roughness and composition of the moon's surface and the effects of the landing on the spacecraft. It will carry a survey stereo television system, touchdown-dynamics and surface-sampler/soil-mechanics experiments, a seismograph, a micrometeorite ejecta detector and an alpha-scattering experiment.

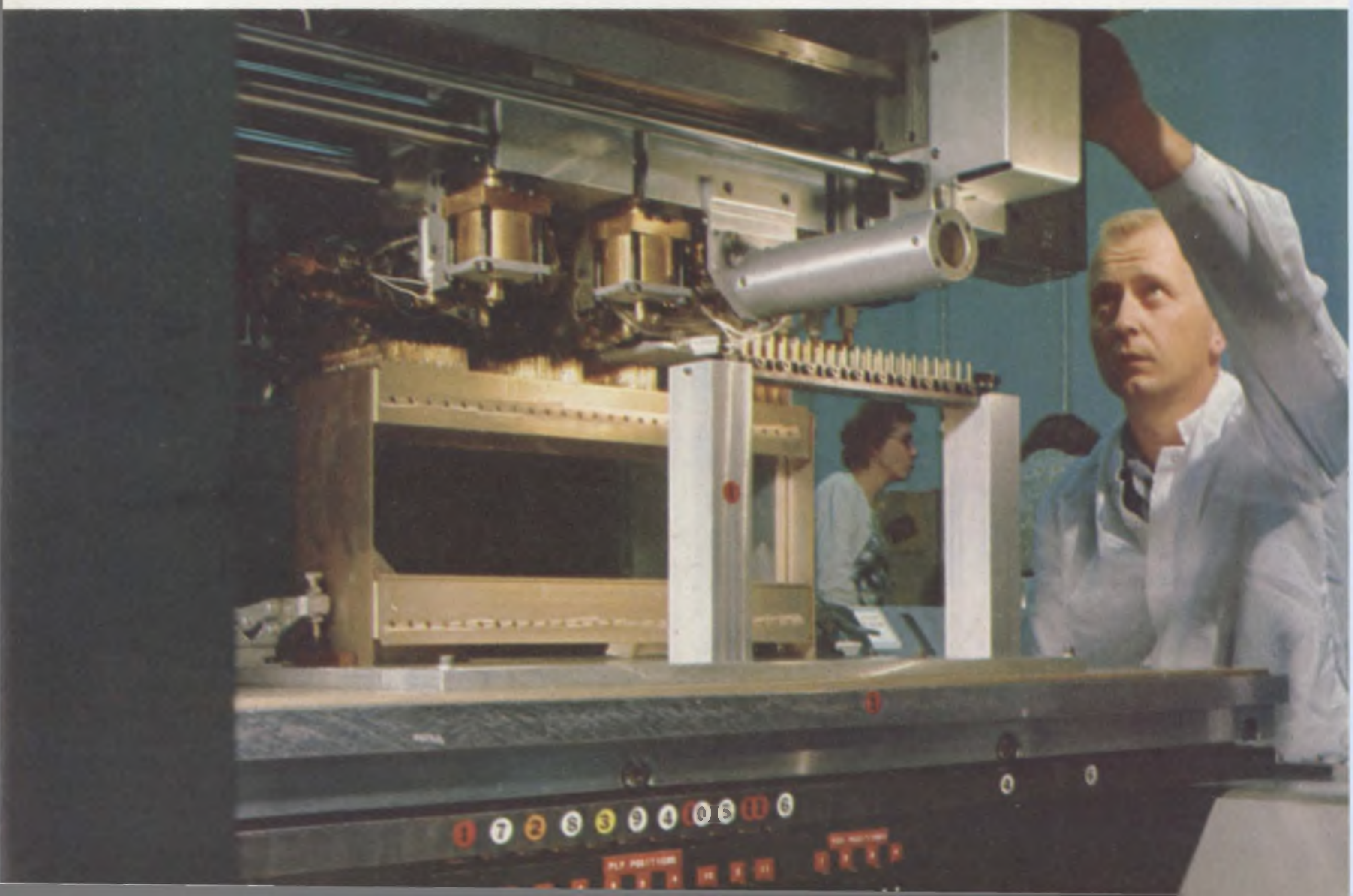
Developed by Jet Propulsion Laboratory at the California Institute of Technology, the Surveyor vehicle is contracted to Hughes Aircraft Corp. The Lunar Orbiter is being built by Boeing Aircraft Corp. under a contract from NASA's Langley facility.

Plans for the lunar-landing program range from the Apollo Earth Orbiter to the extended Apollo manned lunar surface missions. The instruments for these craft are basically the same as those used in laboratory tests. However, they still have to be miniaturized and made more rugged and reliable before they can be used in space.

Scheduled Missions

Project	Launch dates	Type of vehicle	Brief description
Lunar Orbiter I-V	1966-1967	Lunar satellite	The 12-month Lunar Orbiter will be used to obtain high resolution photographs of the lunar surface during a 30-day TV operating time. These will be used to select suitable sites for future manned landings and to gather data on the lunar gravitational field.
Nimbus II-IV	1967, 1969	Satellite	The Nimbus will consist of a series of significantly improved meteorological satellites having a 6-12 month operating lifetime.
ISIS II (International Satellites for Ionospheric Studies)	1968	Satellite	The International Satellites for Ionospheric Studies are part of a joint Canadian/United States program in ionospheric research.
OSO VII (Orbiting Solar Observatory)	1968	Satellite	The Orbiting Solar Observatory program will conduct experiments in solar physics, astronomy and geophysics from a stabilized platform above the Earth's atmosphere. Operating lifetime is 6 months.
Surveyor XI-XVII	1968-1969	Lunar lander	The Surveyor series of spacecraft is being developed to soft-land on the lunar surface. During their 14 day lifetime, these spacecraft will survey prospective areas for manned landings and provide detailed scientific information on the composition and seismic activity of the lunar surface.
AOSO I-IV (Advanced Orbiting Solar Observatory)	1969-1972	Satellite	Over a 12-month period, the Advanced Orbiting Solar Observatory will make continuous, detailed studies of solar phenomena to learn the mechanisms of their occurrence.
Manned Space Science Program	1969-1972	Satellite, lunar orbiter and lander	The Manned Space Science Program is directed toward scientific investigations that will use and expand upon the capabilities of man in space.
Voyager	1971	Martian satellite and lander	The Voyager's objectives will be to obtain fundamental scientific information concerning Mars and to seek additional data on the interplanetary medium between Earth and Mars. Lifetime will be 6 months. The voyage will include a one-month stay on the moon.
Explorers	Open	Open	Small, explorer-type satellites will be designed for experimental objectives. The missions will be scheduled as suitable objectives are suggested.
Sounding Rockets and Balloons	Open	Probe	The Sounding Rocket and Balloon program involves experiments in the areas of aeronomy, solar physics, astronomy, energetic particles and magnetic fields, micrometeoroids and cosmic dust, planetary observations and biology.
Tiros	Open	Satellite	The Tiros spacecraft, operable for 6 months, will be modified slightly to accommodate advanced meteorological instrumentation.

Reliable electrical connections



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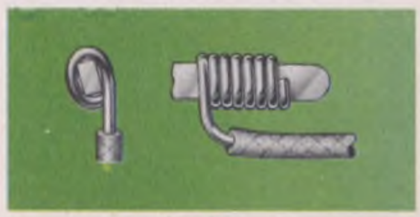

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ON READER-SERVICE CARD CIRCLE 38

Plotting the ocean's profile requires involved instrumentation. Today's constraints include bandwidth, data recovery and calibration.

The prime objective of oceanographic research is to obtain sufficient measurements to develop a model of the undersea environment. The shortcomings of present instrumentation systems, however, limit the oceanographer to single point measurements made at widely differing times and places. These measurements are integrated into an over-all profile, the accuracy of which is questionable because of the time difference and distance between the individual measurements.

There are a number of promising large-scale instrumentation systems, any one of which is capable of making simultaneous measurements over a wide area. These projected systems will be automated and capable of unattended operation for a year. Electronics promises wide application in these systems for measuring, processing, recording and transmitting. Improved reliability is the main advantage electronics will offer to the designer of oceanographic instrumentation.

Surprisingly, in trying to develop these electronic systems, the designer is severely restricted by four main engineering constraints:

- Bandwidth requirement.
- Data recovery.
- Navigation inaccuracy.
- Instrument calibration.

Present approaches to overcoming these constraints are economically unfeasible. Possible future solutions involve techniques that are far beyond the present state of the art.

Bandwidth is a major problem

Obtaining sufficient information to make a reasonable approximation of just a few square miles of ocean requires a tremendous amount of data. Collection of this much data dictates a frequency bandwidth far exceeding that available.

For example, to measure only the basic parameters of temperature, pressure, salinity, and sound velocity at a single sampling point requires four separate sensors, each with a 1 kHz bandwidth. To obtain a continuous profile from the ocean's surface to the bottom requires a string of 75 sampling points at 200-foot intervals. Thus, the measurement of these parameters at a single point in the ocean requires a total of 300 sensors and a bandwidth of 300 kHz. At one-mile intervals in an area only 10 miles by 10 miles square, 30,000 sensors and a bandwidth of 30 MHz would be required. To measure these parameters just along the surface area of the continental shelf adjacent to the United States, some 850,000 square miles, would require a bandwidth far into the gigahertz region.

Oceanographers are looking for buoy-contained data-transmission equipment capable of multiplexing 300 signals into a transmitted signal of minimal bandwidth. The use of adaptive processing to eliminate the transmission of unchanged parameters is being studied as a means of reducing the problem. The increased use of

Instrument package developed by Bissett-Berman Corp. for measuring salinity and temperature at various depths.

Dr. Alan Berman, Director, Hudson Laboratories, Columbia University, Dobbs Ferry, N. Y.

In the Scott 344 transistor FM stereo tuner/amplifier, Allen-Bradley hot molded resistors provide excellent gain stability, low noise, at top operating voltages.

*** "Based on our use of more than 30,000,000 Allen-Bradley hot molded resistors over the past 18 years, under a continuous re-evaluation program for all component parts."**

The known reputation of Scott hi-fi equipment is based on their unquestioned engineering excellence and their rigid quality standards. And Allen-Bradley hot molded resistors have played an important role in this achievement.

The consistently high quality of Allen-Bradley resistors—year after year, and million after million—is the result of an *exclusive* hot molding process developed and used only by Allen-Bradley. It produces such uniformity that the long term performance of Allen-Bradley resistors can be accurately predicted . . . and catastrophic failures *never* occur.

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HOT MOLDED FIXED RESISTORS are available in all standard EIA and MIL-R-11 resistance values and tolerances, plus values above and below standard limits. Shown actual size.

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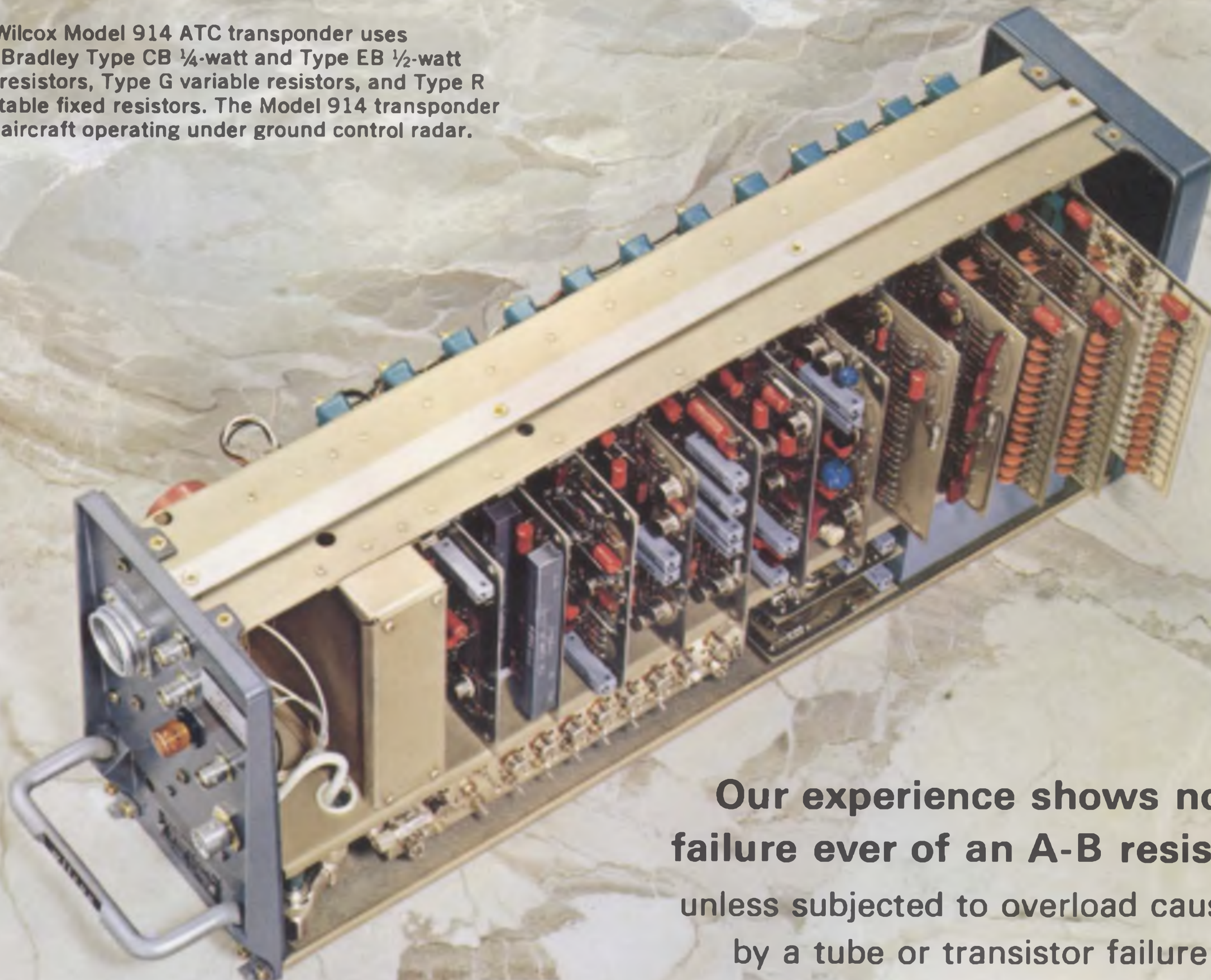
61-07-6E

This Wilcox Model 914 ATC transponder uses Allen-Bradley Type CB ¼-watt and Type EB ½-watt fixed resistors, Type G variable resistors, and Type R adjustable fixed resistors. The Model 914 transponder is for aircraft operating under ground control radar.



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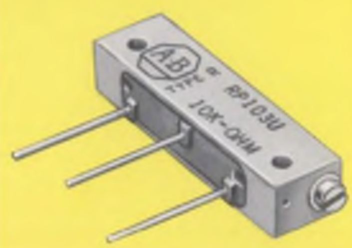
Type R Hot Molded Adjustable Fixed Resistors are rated ¼ watt at 70°C. Supplied in resistance values from 100 ohms to 2.5 megohms.



Type G Hot Molded Variable Resistors are rated ½ watt at 70°C. Resistance values from 100 ohms to 5.0 megohms.

"No failure ever" is an impressive record, especially since Allen-Bradley fixed and variable resistors have been used in Wilcox transponders for around ten years.

The reason for this consistently high performance is the unique hot molding process developed and used only by Allen-Bradley. In fixed resistors, it produces such complete uniformity that long term A-B resistor performance can be accurately predicted. Catastrophic failures don't occur with Allen-Bradley hot molded resistors.

Use of the hot molded resistance element in the Allen-Bradley Type G variable resistors assures very smooth operation—there are never any abrupt changes in resistance during adjustment. The Type G controls have a very low initial noise factor, becoming lower with use.

Type R adjustable fixed resistors also have a solid molded resistance track. Adjustment of resistance is so smooth, it approaches infinite resolution. Settings will remain fixed under severe vibration or shock. The Type R molded enclosure is dustproof and watertight—it can be potted after adjustment.

For more complete details on the full line of A-B quality electronic components, please write for Publication 6024: Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee, Wisconsin 53204.

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QUALITY ELECTRONIC COMPONENTS

digital-coding techniques, as recommended by the Intergovernmental Commission on Oceanography, may be a possible solution. Another might be the use of satellites to monitor the buoys. This technique would solve the shortage of vhf bandwidths by moving the transmission into the less crowded uhf region. But this is not possible now because of line-of-sight limitations on ground stations.

Data recovery is inadequate

Assuming that a method of achieving the bandwidth is available, data recovery would still be a major constraint. Signals may be sent back to shore or ship through hard copper cables or to a surface buoy for electromagnetic transmission. (Acoustic links do not have the required bandwidths.) While the cable route may appear to be relatively simple, it turns out to be a very expensive procedure since it requires underwater repeaters, multiple conductors or broadband coaxial systems. It may run as high as $20,000 to $30,000 per mile. High-power transmitters capable of long-distance broadcasting for unattended periods of up to a year are needed. But such transmitters, suitable for buoy use, are barely attainable by the present state of the art. No frequency channel is good for all ranges, all latitudes and all seasons.

In addition to transmitters, problems exist with the antennas and radiators. To provide worthwhile information, the data-dropout rate of the transmitted signal should not exceed 5% for any expected combinations of wind, weather, sea and ionospheric conditions. The antenna must provide a uniform radiation pattern independent of the irregular and non-static ground plane resulting from wave motion. Violent antenna swings must not result in great signal variations. Transmission must continue even after the antenna and insulators are doused with sea water, an excellent conductor.

What oceanographers require is an unattended transmitting buoy, able to accommodate several hundred individual sensors, digital processors for data, and a high-power transmitter with uniform signal radiation. Digital processors capable of interrogating the sensors and converting the measurements to a digital format for storage and analysis by computers are required. The processor should be capable of responding to different commands from shore to change its operating conditions as needed.

The two prototype long-range unattended buoys, now under development for the Office of Naval Research by General Dynamics/Convair,

Diver in scuba gear goes over the side to implant instrument package on the ocean floor at depths of 30 to 40 feet. At greater depths, mechanized techniques are used to deposit instruments on ocean floor.

show promise of meeting the oceanographer's requirements. These buoys will be capable of transmitting over 100 channels of oceanographic data and 10 channels of meteorological data over minimum distances of 2500 miles for unattended periods of up to a year. The first of these prototypes is already in place off the coast of Florida, undergoing tests of its seaworthiness and communication performance.

Navigation systems must be improved

The relative inaccuracy of present navigation equipment precludes knowledge of a ship's exact position, needed when making measurements, recovering samples and placing buoys. For oceanographic measurements to be meaningful, they should be accurate to within a few feet of an exact geodetic location.

The accuracy of currently available navigation equipment is shown in the table. These figures are quite optimistic and represent the best that can be obtained under ideal conditions with well-calibrated equipment and trained operators. The ultimate accuracy with which one can locate an instrument is far different. The geodetic location of an instrument in deep water, unless it is very close to the ship's hull, cannot be known within an accuracy of 300 feet.

The precise locations of unattended buoys are needed both to insure their recovery and to allow their data to be related to an exact oceanographic station. This is particularly important since it is difficult to maintain buoys at a single point because of the catenary forces on any long buoy cable. These forces are due to the effect of currents on the projected area of the buoy's cable. A 1-inch thick cable long enough to reach the ocean's bottom, an average depth of 15,000 feet, has a projected area the size of a ship's hull. An ocean current of only 1 knot would generate a sidewise force on the cable sufficient to displace the buoy by 300 feet. With changes in the direction of the current, the buoy will float somewhere in a circle 600 feet in diameter.

One might hope to overcome these problems by increasing the tension in the cable so that the vertical lift forces in the system are large compared to any horizontal forces that might arise. This is a tail-chasing problem. If the cable is made thicker to sustain greater tension, its projected area being pushed by currents also increases. Such considerations force oceanographers on a never-ending search for cables with better tensile properties.

Flotation buoy built by Geodyne Corp. supports three current meters and three temperature recorders below the ocean's surface. A wind speed recorder and navigation light are mounted topside.

Accuracy of present navigation systems

System	Accuracy
Inertial	100-300 ft
Decca	200-400 ft
Omega	300-500 ft
Loran C	300-500 ft
Acoustic beacon (underwater)	400-1000 ft
Satellite	600-2000 ft
Loran A	600-3000 ft
Celestial	1-2 miles

Oceanographers are seeking a navigation system with an accuracy equal to that of an inertial system, but at a fraction of the cost. What is needed is a low-cost version of the $500,000 Ship's Inertial Navigation System (SINS) found on the Polaris submarines. This system would be used on both survey ships and unattended buoys.

Self-calibrating instruments sought

The final main engineering constraint on equipment used for oceanographic research is calibration. As remote, unattended instruments age, they tend to drift off calibration in various unpredictable directions and magnitudes. Present self-calibrating instruments do not provide the absolute reference required. Unless expensive primary and secondary standards are included in the instrument package, it is impossible to obtain an absolute reference.

Oceanographers are perpetually looking for drift-free, hysteresis-free instruments capable of being calibrated once and then holding their calibration during periods of use.

Electronics promises increased reliability

Although the history of electronic equipment developed for oceanographic research has been something less than fruitful, the future holds great promise. Increased reliability is the primary contribution electronics has to offer to oceanography. Techniques borrowed from the space program are being used to improve the reliability of oceanographic instrumentation.

Microelectronics is the key to the future success of electronics in oceanography. These circuits are certain to enjoy widespread use in oceanographic equipment due to their inherent reliability. Lower power requirements and smaller size make these circuits particularly attractive for unattended buoy duty. Since the circuit elements are combined in a single block, the temperature and pressure effects that are the paramount problem with discrete components become less influential in affecting the circuit characteristics.

Underwater instrument measures tidal currents near the ocean's floor. Electronics are used for recording the data and telemetering it back to the surface.

Who says it costs

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and a leg to get 22 watts at 450 mc... or 10 watts at 960

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The basic specifications of the 1N4885 are: Efficiency 70%, Breakdown Voltage 150 volts, Series Resistance 0.7 ohms and a Capacitance Range of 29 to 39 picofarads. The basic specifications of the 8458 are: Plate Voltage 600 volts, Plate Current 120 mA, Screen Voltage 180 volts and a drive power of approximately 3 watts.

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For complete information, including an applications report on 8458 driver circuits and 1N4885 frequency-multiplier circuits and filter networks, write: Amperex Electronic Corporation, Semiconductor and Receiving Tube Division, Department 371, Slatersville, Rhode Island 02876.

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ON READER-SERVICE CARD CIRCLE 39

Chips falling the right way is the semiconductor theme in '66. Integrated and discrete devices may dominate the industrial/consumer market.

ICs: Industrial impact immense

Bryant C. Rogers, Industrial Marketing Manager, Fairchild Semiconductor, Mountain View, Calif.

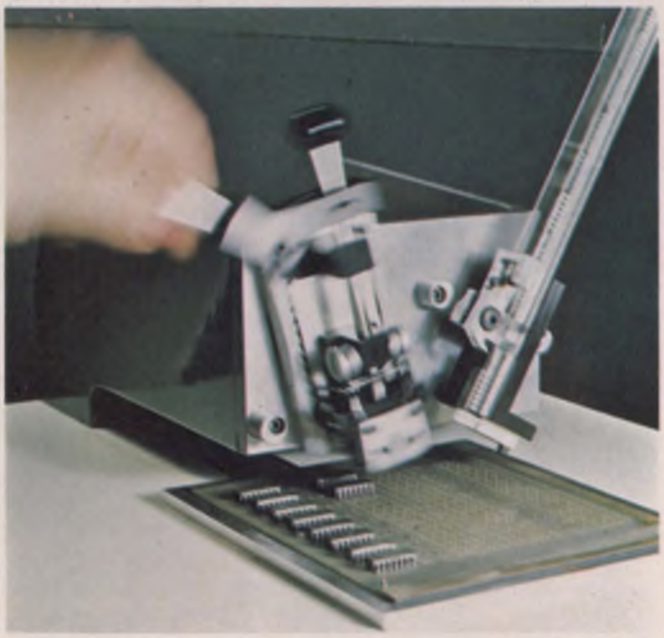
The most significant strides by semiconductors into the industrial and consumer markets in 1966 will be made by integrated circuits. These will be of the digital- and linear-amplifier varieties, with the former dominant. Discrete devices will also find their way into many analog, power-switching control and audio-equipment applications.

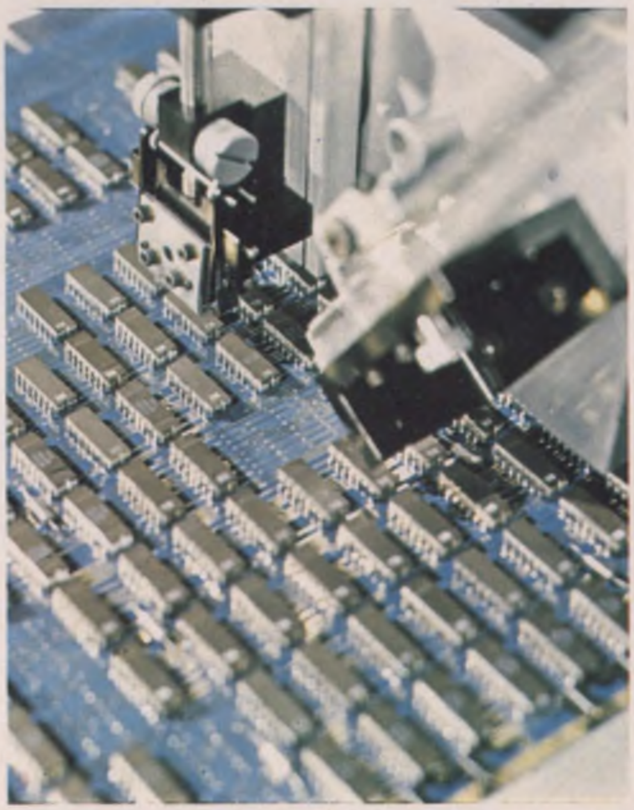
Typical of the areas that are turning to solid-state are test- and measurement-equipment, process-control systems and machine-tool (numerical) controls. In these applications, many of the digital and analog functions now being performed by low-power-level relays, switches and vacuum or gas tubes are already outmoded.

Moreover, the increasing reliance on computers and other digital-type signal-processing equipment is having a major effect on analog-type instruments and sub-systems. The latter group, formerly operated independently, must now interface with digital systems. Conversion of the analog types to digitized units is the most practical solution. However industry's growing acceptance of electronic controls and computer systems would not, in itself, ensure a strong role for integrated circuits (ICs).

Surprisingly, the strongest reason for the impending shift is lower cost. Small size doesn't count for much in a spacious plant or laboratory. Improved reliability is an asset, but good industrial equipment already operates at about 98% reliability. Integrated circuits would add only 1 to 1.5% to this figure. Performance would be better with microelectronics, but in most cases, the improvement would be far beyond what is actually needed.

Economics, then, is the only factor strong enough to persuade industry to choose the integrated-circuit route. There are several important ways in which these devices lead to lower costs.





Don't let the chips fall where they may! Dual, in-line integrated-circuit packages permit the user to design equipment assemblies. The semi-automatic inserting tool quickly and easily places IC packages directly on printed-circuit boards, lowering manufacturing cost and time.

ICs cut costs

Because of their pricing, integrated circuits lower the cost of components needed. Design time is also greatly reduced because the integrated circuits are pre-engineered units requiring little or no start-from-scratch design. Selection and interface problems will now consume the engineers' hours, rather than detailed circuit design. The devices also lower manufacturing time and costs—they are easy to assemble, have fewer leads to solder and reduce the chance for production errors (because they don't require internal connecting). By reducing the lead time between design and production, integrated circuits also lower marketing costs.

Inventory problems, with their accompanying cost headaches will similarly be overcome. The quantity of components to be kept in stock will be reduced by 80% to 95% with ICs. Finally, they will make the purchasing function more efficient. Instead of thousands of different types of transistors, resistors, etc., only a few basic IC types need be purchased.

This year, integrated circuits will be used by industrial designers to construct basic counters, shift registers, generators, synthesizers and a variety of test instrumentation systems. The design of much of this equipment will be characterized by the assembly of completely engineered sub-systems onto printed-circuit cards. By the end of 1966, virtually all new industrial equipment containing digital elements and a majority of industrial systems with analog needs will make use of integrated-circuit technology.

Coming up: More ICs, higher ratings

Donald B. Hall, Manager of Industrial Applications, Texas Instruments Inc., Dallas, Texas

Two major achievements in solid-state capabilities will spur the drive into industrial and consumer areas this year.

One will be greater variety and expanded lines of low-cost integrated circuits (ICs).

The second involves improved performance levels for discrete semiconductors. This should result in the one-to-one replacement of tubes and traditional electromechanical components. Much higher ratios (more than 2:1) have been needed up to now.

The move of ICs into industrial systems will be due mainly to:

- Increasing use of computer-based systems for industrial machinery and processes. ICs are now the heart of the modern computer.
- The introduction of faster, more sophisticated digital-type integrated circuits.
- Additions to the ranks of linear-and analog-type integrated circuits.
- The rise of MOS and other field-effect-type integrated circuits.
- Complex-function integrated-circuit product innovations. These new ICs will not be exclusively either digital or linear (analog). They will be used for higher order mathematical operations (such as fractional, square, cubic, etc., functions).

Improved ratings for discrete semiconductors will also have a major impact on the industrial and consumer markets. In these areas, such traditional devices as line-operated tubes and electromechanical components have managed to hold their own. This is largely because of the large-signal-handling limitations of semiconductors.

Now the tide has turned. It no longer takes some 2-1/2 semiconductors to replace a single vacuum tube. Technological advances, particularly in the breakdown-voltage and power-handling characteristics of solid-state devices, have brought this exchange ratio to unity in many cases. Improvements in bandwidth, isolation and high-frequency performance, along with higher switching speeds, can also be expected in '66.

These capabilities have also been extended to the high-power and electrical-control applications areas. The SCR family of devices and a number of power transistors can now be substituted for relay, switch and autotransformer-operated power-handling systems on a one-to-one basis.

In addition, FETs are now available with tube-type ratings. This will accelerate their replacement of triodes and pentodes in any amplifying and signal-processing applications, especially in the realm of consumer entertainment equipment.

For example, in the uhf tuner stages of television sets, semiconductors are preferred because of their price and the performance they offer.

Semiconductors also offer design simplicity in information processing.

It should be realized that the continued semiconductor penetration of the industrial and consumer markets is largely due to packaging concepts, rather than to exclusive improvements of electrical characteristics.

The packaging effort may be looked upon as making high performance available at an economical price.

Every major type of solid-state device is now available in a low-cost package. The majority of these feature either plastic or epoxy encapsulation. It is interesting to note that these units were not in the main derived from the fallout of military-type semiconductors. Rather, they are the deliberate, well-planned result of making the unique characteristics of the devices available in a form and at a cost that are suitable to industrial and consumer needs.

To continue the advancement of semiconductors in the industrial market, manufacturers will have to overcome their reluctance to make changes when business is booming.

FETs: Variety keynotes industrial biz

Charles H. Blankenship, Manager of Applications Engineering, Siliconix, Inc., Sunnyvale, Calif.

Field-effect devices are aiming at an expanded role in the industrial and consumer markets during the coming year. This will be achieved by the introduction of new and improved units for digital and analog applications and low-cost FETs for consumer equipment.

1966 will also see the beginning of a gradual FET takeover in large-output-signal linear voltage amplifiers, where vacuum tubes have so far managed to hold off the semiconductor advance. Further, the junction FET itself may very well become the most popular small-signal device in the electronics market.

The major activity will be focused on:

- Improvements in device parameters.
- Greater assortments of junctions and MOS FETs.
- Increased use of the lesser-known field-effect characteristics.
- Continuation of the decreasing-price trend, mainly due to expanded volumes and low-cost-packaging advances.

Device technology will aim at improving breakdown levels (particularly BV_{GDS}), raising the g_{fs}-to-C_{iss} ratio and lowering the already low noise figures. Values for the ON resistance (r_{ds}) and the gate-leakage current (I_{GSS}) will also diminish.

Adding to the already-mushrooming number of devices will be such items as FET-bipolar combinations, cascoded FETs and MOSs, complementary FET pairs, higher stability MOS units, matched FETs and a number of multi-gate packages. There will also be a host of new integrated circuits incorporating FETs, most probably of the analog-switching variety. MOS-type ICs will also be available in greater numbers, particularly for digital applications.

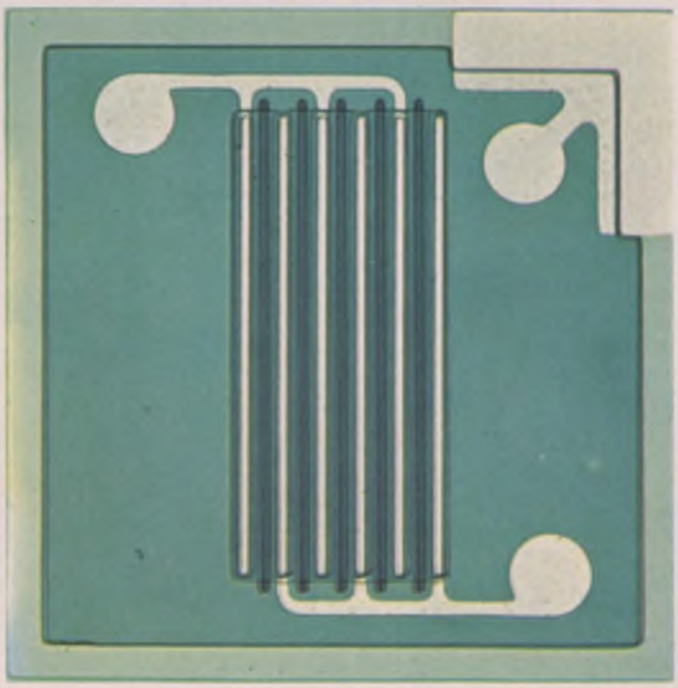
Even though FETs can be found today in some commercial receiving and amplifying equipment, their across-the-board drive into industrial and consumer systems will make significant strides this year. Particular emphasis will be placed on audio, RF and voltage-controlled resistor applications.

Variety keynotes FET biz

The key to the expansion of FET applications lies in greater advantage being taken of its characteristics. Although most of these are well known, they have not always been put to optimum use. Moreover, some FET types will be specified for a definite (rather than a general) application wherein one or more of its key parameters will be closely toleranced for this specific application.

High-input-impedance is the most widely recognized FET characteristic. It is especially useful for accommodating high-impedance signal sources and reducing loading effects on RC networks and tuned circuits. The FETs low-noise-figure attribute, which is not as well known, is particularly important for accommodating wide-ranging generator impedances and, of course, in all signal-processing applications. These two features are largely responsible for the growing FET role in receiving and amplifying applications. Of major note here are RF amplifiers to 600 Mc, FM receivers, microphone audio amplifiers, pre-amps and front-end IF and video amplifiers.

The well-known FET square-law transfer



Reaping the beneFETS . . . The diversity of field-effect devices and their close resemblance to vacuum tubes contribute to their suitability for across-the-board industrial and consumer applications. Shown are an integrated FET pair for IF stages (left) and an analog switching FET for transducer systems (right).

function will be put to more extensive use to cut down on harmonic and intermodulation distortion in Class A amplifiers. It will also be widely employed in multiplier and mixer-modulator applications.

The voltage-controlled resistance property of FETs under small-signal conditions offers a wide, dynamic control range. As a feedback element, it can be used as a modulator and to regulate gain (agc systems, for example), frequency or phase-shift.

Few engineers realize that the FET makes an excellent, two-terminal constant-current source. This property is useful in linear waveform generation and timing circuits. Analog switching applications are well met by the lesser known zero-offset-voltage FET characteristic. In addition, switching and driving circuitry is less complex. Use of FETs in multi-channel analog switches and drives will increase.

The well-known zero-temperature-coefficient feature of FETs will also be put to wider use. Single-ended and differential dc-amplifier stages, particularly for high-accuracy instrumentation systems, are outstanding examples of this property. The high transconductance figure of FETs, when operated with low drain currents (below 0.1 μA, is ideally suited for micropower-amplifier applications. Industrial transducer needs will also be satisfied by FETs functioning as amplifiers or, as with the photo-FET, as the transducer itself.

The impact of batch processing

Leo L. Lehner, Manager of Market Development, Motorola Semiconductor Products, Inc., Phoenix, Ariz.

Today, most consumer and industrial electronics manufacturers buy discrete components and assemble their own subsystems or modules. Integrated circuits, however, do find their way into military and space applications. But it will be a different story by 1970.

By that time, don't be surprised to see integrated circuits dominating military, space and industrial systems and even consumer products.

But what about the coming year? The fate of systems manufacturers, supplying products from electronic controls to TV sets, may well depend on their own course of action during the transition from a discrete-component assembler to a packager of integrated circuits. Batch-processed circuit modules, combining deposited-film circuits with semiconductor dice, offer an attractive intermediate step.

Mass production and the batch process

The steady decline in semiconductor prices can be traced to a different approach to "mass production" of integrated circuits. High-speed operations are usually performed on each assembly, one at a time, as the assemblies flow along a production line in single-file order. Semiconductor production, however, uses many processes that are inherently very slow and that require ultra-precise geometric control of microscopic structures.

Batch processing, introduced with the advent of the mesa transistor, solved both problems at once by applying each process step to thousands of transistors simultaneously while the individual devices were still part of a few large, wafer substrates. Within a very few years, this batch processing became so highly developed that the cost of the dice became negligible compared to the cost of the packages in which they were to be mounted. The plastic package was then developed, and this not only reduced the cost of the package's piece parts but also made possible an extension of batch processing to packaging.

How good are plastic semiconductors?

Plastic-encapsulated semiconductor devices for consumer and industrial uses range from complex, high-speed switching transistors to low-frequency audio transistors for hearing aids. The progress in these devices has been such that, in some cases, plastic devices outperform their metal can (military) counterparts. Before the plastic transistor, current gains specified over 400 minimum were unheard of; now they are common in stereo and hi-fi equipment.

In addition to the transistor, designers can purchase plastic encapsulated rectifiers, zeners and detector diodes, as well as SCRs, power transistors and integrated circuits.

Semiconductor pricing bottoming

The "value explosion" in the semiconductor industry has been so powerful that the production costs for many devices are approaching a negligible level, as compared with the overhead. As a result, today's lowest priced standard devices are nearing the bottom of a long price spiral. As the bottom of the device price spiral is reached, the prices of many more types of electronic equipment will become independent of semiconductor prices.

Consider a computer using 5000 transistors and having a total value of $150,000. Since the cost of the transistors used is already well under $1 each, a reduction to zero cost would have no important effect on the cost of the computer.

Batch-processed circuit modules

The monolithic integrated circuit is the ultimate extension of the batch process. Unfortunately, many processing problems remain to be solved before the full economic impact of integrated circuits can be felt. This is particularly true with those circuits requiring high power-handling capability because of the defect and transverse-effect problems in large area dice. It is also true that several of the techniques developed to obtain increased power-handling capability with small dice are incompatible with present integrated-circuit approaches.

Deposited-film circuits, on the other hand, provide the benefits of batch processing and can also use any desired combination of existing semiconductor dice. The result of this capability is likely to be an evolutionary process in which monolithic integrated-circuit dice are gradually incorporated into complete, deposited-film circuits, starting with the low-level sections and eventually becoming so inclusive as to eliminate the film-circuit completely.

The systems manufacturer's choice

Because of the inherent cost and performance advantages of batch-processed circuit modules, the equipment manufacturer in both the consumer and industrial markets must soon face a major change in the nature of his business. He will be not a manufacturer of circuits, but the designer, manufacturer, packager and marketer of complete systems. While many systems companies are likely to undertake the deposited-film-circuits approach to stay in the circuit-manufacturing business during the immediate future, very few can be expected to expand fully into integrated-circuit production, thereby becoming new members of the semiconductor industry.

By far, the most critical decision to be faced by electronic-systems manufacturers is the "build or buy" choice as deposited-film, batch-processed circuits become technically and economically competitive with conventional, discrete-component circuits. Although production facilities for batch-processed modules represent a relatively modest investment, companies must decide whether they will be able to follow through as these same modules evolve into completely integrated circuits. With integrated-circuit technology advancing at an increasing rate, the risk of early obsolescence for a circuit-module manufacturing facility becomes evident.

The semiconductor industry does not face a comparable risk because module business, which does pass into the fully integrated phase, will continue to be replaced by business in "first phase" modules for other systems which are just beginning the evolutionary process. Only when all the limitations of fully integrated circuits have been solved, will the deposited-film circuit become obsolete. Another factor favoring the semiconductor industry as the source for circuit modules is their tremendous advantage of having an in-house source for all semiconductor dice.

The economic outlook for the individual consumer- or industrial-electronics company will largely depend upon the wisdom of these choices as it faces its ultimate withdrawal from the circuits-manufacturing business. In many ways, these decisions resemble those that were required as the same companies faced the necessity of converting from electromechanical or vacuum-tube-based systems to semiconductor systems.

Put a computer on a chip? Microelectronic arrays are doing it. Faster diffused epitaxial devices compete with MOSs.

MOS arrays have more on a chip

Dr. J. Leland Seely, Associate Director, Research and Engineering, General Instrument Corp., Hicksville, N. Y.

Within less than two years, integrated circuits have been graduated from the elementary gate, flip-flop and buffer to the metal oxide-semiconductor (MOS) array with 200 to 800 devices on a single chip.

The electrical characteristics of the enhancement-mode MOS make it ideal in the areas of integrated multiplexers, digital logic and choppers. These characteristics are: extremely high input impedance, high noise immunity, ability to dc couple without level shifting and lack of inherent off-set voltage. But even more important is the ease with which complicated arrays of devices can be interconnected and batch fabricated. The entire integration process involves only four masking operations and one diffusion. Because the process has fewer and less critical operations than conventional integrated circuits, it follows that for comparable manufacturing skill, MOS wafers are less costly.

Two other factors excite potential customers. First, the simplified process gives rise to higher yields, which make much more complicated arrays possible on a single chip. This results in saved space and reduced packaging cost. Second, by using the more complicated arrays, external interconnections are greatly reduced. This results in increased reliability.

MOS vs monolithic arrays

Because of the very broad range of applications for MOS arrays, it's a difficult job to decide just which circuits to integrate. The novice design engineer behaves much like a hungry teenager in a pastry shop. There are so many good things to choose from that he doesn't know which one to pick. He may therefore be careless in his choice, thinking that anything he decides upon will be worthwhile. Such is not the case for a number of reasons.

If the circuit is too simple, yields are very high for both conventional integration circuits and MOS. Chip cost then becomes almost negligible compared to package and testing costs. Then the MOS loses its advantage. If the circuit is too complicated, yields reach the vanishing point and the chip becomes very costly. It may then be less expensive to build up the circuit from standard parts.

With the present MOS technology, digital circuits are limited in frequency to 1 or 2 MHz. Output impedance presents another problem.

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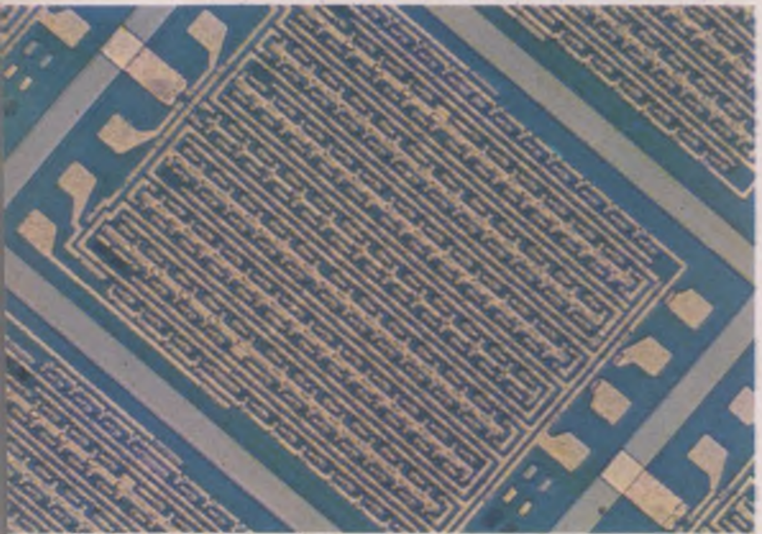
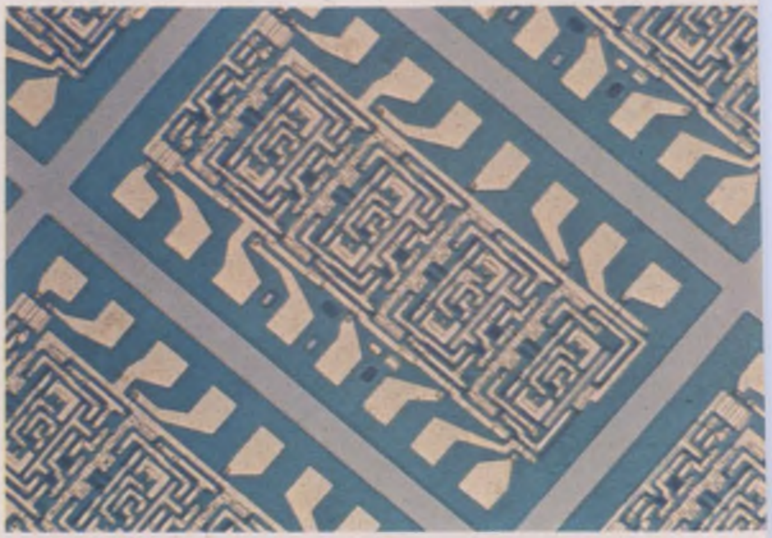


90-bit shift register contains 540 transistors on an 80- x 58-mil chip, deposited with MOS techniques.



Up-down counter has four stages. Its 115 transistors are placed on a chip of 76- x 48-mil dimensions.

Monolithic arrays offer high speed

Richard Lewis, Jr., Manager, Marketing Services, Westinghouse, Elkridge, Maryland.

Logic arrays formed with diffused planar-epitaxial techniques appear to be the answer to tomorrow's computing-speed requirements—provided that interconnection problems are solved. The use of MOS arrays appears limited because of their relatively slow speeds (100 ns to 1 μs), compared with diffused arrays (5-10 ns).

The ability to perform computer sub-functions on a single chip is not really a remarkable technological breakthrough in the same sense as the development of the pn junction or the MOS transistor. It is rather a logical extension of the state-of-the-art in diffused planar-epitaxial technology.

The real gains from the use of arrays are in the area of nanosecond logic. There, 1 ns switching speeds can never be achieved by connected groups of elemental gate circuits in many separate packages. Diffused planar-epitaxial arrays, performing complete arithmetic functions in a monolithic block, may achieve these speeds of the future.

The economical availability of such arrays to industry depends on several factors:

- Achievement of better yields at the wafer stage.
- Development of practical multiple-layer interconnects.
- Availability of packages with enough pins to provide the required communication with the array.
- Ability to produce logic functions, or sub-computers, which are useful to a significant percentage of present users of integrated logic circuits.

Multi-layered connections offer flexibility

The primary contributor to the success of the present work in diffused planar-epitaxial arrays is the capability of putting multiple layers of interconnections on the surface of the chip. It makes possible very complex circuit configurations.

Conventional integrated circuits use three types of interconnections: a metal layer, deposited on top of the passivating oxide; the substrate, which serves as the ground plane where the silicon chip is bonded to a conducting mounting state in the package, and conducting paths diffused into bulk silicon.

While the flexibility offered by these three interconnection techniques is satisfactory for most requirements, really complex arrays call for one or more additional interconnect planes. Multilayer metallic interconnects appear to be one solution using metallic conducting layers insulated from each other by glass. Metals such as gold and platinum alloyed with chromium, molybdenum or titanium are used. Although two layers seem sufficiently flexible to meet present needs, many layers are possible.

Arrays cut system cost, hike reliability

The principal advantages of complex arrays are reduced component count and assembly cost and increased system reliability resulting from fewer packages and interconnections. Arrays have a clear advantage over simpler circuits, since system-cost is much more closely related to the num-

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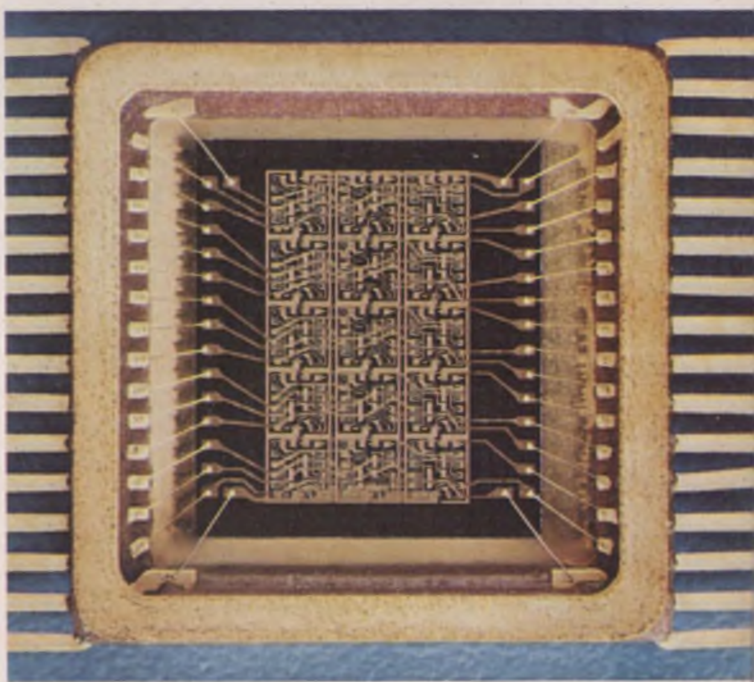


High pin count is combined with complete access to circuitry in this quintuple "D" flip-flop. It requires two layers of interconnections to handle the 30 DTL gates on a 220- x 250-mil chip.

MOS arrays

since it is difficult to obtain less than 1k. Circuits requiring a large number of input and output leads are difficult to produce because the lead bonds take up so much chip area and testing and packaging problems are multiplied.

In addition to the above factors, economic feasibility is strongly dependent on the volume of circuits to be produced, since many engineering hours must be spent in designing the photographic masks used in processing the circuits. Once the masks have been made, the circuits can be batch processed; if only a few circuits are needed, engineering costs per circuit can be quite high. This points out a rather basic problem: As the circuit becomes more complicated, the engineering becomes more expensive but the number of required circuits decreases.

Serial shift register appropriate

An ideally suited circuit for integration is a serial shift register. It has few input and output lines, a repetitive-type circuit pattern, which fits together in a compact manner on a chip, and it finds use in many applications. These arrays are now commercially available in a number of variations. Reversible counters, decade counters, binaries, multichannel multiplexers, dual full adders, gates and a host of custom logic circuits are presently being produced on single chips.

The most complex array made to date on a single chip is a complete digital differential analyzer (DDA). Other versions of DDAs are being made on two and three chips to provide more flexibility in use. These circuits, involving 500 to 800 devices plus complicated interconnections to these devices, represent the limit of present technology. Circuits containing 200 to 300 devices are considerably more practical. For those seeking complete computers on a single silicon wafer, the time is not yet here.

As is usually the case with any technology, the MOS has advanced rapidly to the point where it depends upon the state of the art of various related technologies. As an example, the future development of complete MOS systems is intimately related to packaging developments. Inexpensive, but reliable, means must be found to interconnect chips containing complex circuits without resorting to separate flat packs. One might think that a flip-chip technique might be successful where the chips are ultrasonically bonded to a metalized pattern contained on a mother board and then simply passivated with no further packaging involved. Instead, this is complicated by the fact that MOS surfaces are sensitive to contamination and "simply passivating" is easier said than done.

Computers design photo masks

Waiting for breakthroughs in related technologies can be a slow and unpredictable process. The more immediate spurts of progress will come about by applying the existing technologies to the design and fabrication of arrays. For example, computers can help in the design of the photographic masks used in making MOS arrays.

Until recently, all masks had been designed by engineers who had to calculate device sizes, make a master drawing containing all the devices and their interconnections, and check additional propagation delays from stray capacitance related to a specific geometrical layout of the devices. Then they had to shift the layout around to minimize wasted area and make a finalized master drawing. From the master drawing, four separate rubylith masks were cut by a coordinateograph operator. These rubyliths were photographically reduced in size and ended up as working plates used in the actual processing of MOS arrays. Some of the above steps are already being done by computers.

How complicated are MOS arrays?

One other aspect of the use of computers in

Monolithic arrays

ber of packages than to the number of logic functions.

Present IC price lists show that three to six gate functions may be purchased in single packages for very little more than similarly packaged single or dual gates.

Beyond this complexity in current units, there is a rise in the cost per function as the yield drops off. At present, arrays of approximately 30 gates per package appear to be the optimum complexity level. Further improvements in yield and packaging will raise this number perhaps to several hundred gates in each array.

Reliability is significantly improved simply because complex arrays reduce the number of interconnections. Consider the rather ponderous method by which a digital system is now constructed. An integrated-circuit manufacturer forms from 200 to 1000 circuits on a wafer. Then he breaks these apart into individual dice, mounts them in headers or flat-packs and sells these packaged circuits to a systems manufacturer. This manufacturer then assembles the packages to accomplish the required logic function in his system.

Besides creating an interconnection problem, this method is grossly inefficient. Obviously, it would be in the best interest of all parties if the circuits were interconnected within a single package to perform a function rather than being broken apart and packaged separately.

designing MOS arrays deserves mention. As previously stated, acceptable yields are obtained for circuits containing 200 to 300 devices.

If P_g is the probability that any single device is good, than P_g^{200} is the probability that 200 devices in the same circuit are all good. If "acceptable yield" is taken to mean at least 10%, then:

$$P_g^{200} = 0.1, \qquad (1)$$

which means that P_g is 99.5%. Then the probability that a device is bad is:

$$P_b = 1 - P_g = 0.5\% \qquad (2)$$

The probability that two adjacent devices are both bad is:

$$P_b^2 = (0.5\%)^2 = 2.5 \times 10^{-5}$$

If means were provided to connect either one of the two adjacent devices into the circuit and a yield of 10% is still taken as acceptable, then N, the number of devices which can be connected into the circuit, is given by:

$$(1 - 2.5 \times 10^{-5})^N = 0.1 \qquad (3)$$

$$N = 40{,}000$$

If the wafer is probed to determine which of the two devices is good and this information is given to a computer, the computer could then design an interconnect mask to fit the given wafer. By this double redundancy, the maximum feasible number of devices per circuit is increased 200 times.

Computers reproduce themselves

With this in mind, it's easy to let one's imagination run wild concerning what the future may bring. For instance, suppose programs are worked out such that the design engineer can feed his logic equations into a computer and get out a complete set of masks for an integrated circuit having the proper transfer function. Suppose, further, that the wafer processing can be automated, which doesn't require too much imagination. Then one computer could practically give birth to another.

This proliferation would lower machine time costs to the point where it would be practical to use computers to design almost any integrated circuit, including those involving very limited production quantities. Under these circumstances, the design engineer would completely by-pass engineering service groups. Instead, he could go directly to the computer-processer unit, deposit his equations, and pick up his circuits! Although this is an over-simplification and a bit far-fetched at present, MOS technology offers the first real hope that it may eventually become a reality.

What happens to the engineer?

Coming down to earth now, consider the question, "With the advent of MOS arrays, what happens to the practicing design engineer?" The answer is, he will be working harder than ever and will be more in demand. At present, the only really practical way to make complicated custom arrays is for the design engineer and the integrated-circuits engineer to educate each other as to what is required and what compromises can be made to get an acceptable circuit yield. In practice, it's only a few hours before the designer learns how to implement his equations with MOS arrays. Once he has mastered this, whole new areas of design are open to him.

In summary, a lot has been expected of MOS arrays. Their development has been phenomenally rapid because use has been made of well-advanced existing technologies. Economic pressures as well as the ability to make extremely complex arrays have also speeded development.

Arrays are now limited to 500 to 800 devices, with 200 to 300 devices being considerably more practical. The use of computers holds a promise of extending this limit to more than 40,000. Computers may also be used to automatically fabricate circuits directly from logic equations. Design engineers will have some learning to do to keep up with the times. But rather than replaced, they will be working harder than ever.

What to array?

This happy contemplation has its pitfalls. There is no unanimity of opinion among IC manufacturers or users on what computer or sub-computer should be so arrayed. Such circuits have been suggested as a two-bit adder-subtractor, a four-bit ripple counter, a four-bit decade counter, a six-bit shift register, a 16-state decoder, and so on—all in the complexity range of 24 to 40 gates per chip and requiring from 16 to 24 pins.

As arrays become more complex, it becomes necessary to make a trade-off between complete access with a high pin count and high cost, and limited access with minimal pin count and lower cost.

Two examples illustrate the knotty problem facing manufacturers—how much flexibility?

One example of complete access is the quintuple "D" flip-flop (shown), consisting of 30 DTL gates on a 0.220 x 0.250-inch chip. This array requires two layers on interconnections and all 32 pins of a 3/8 x 3/8-inch flatpack for communication.

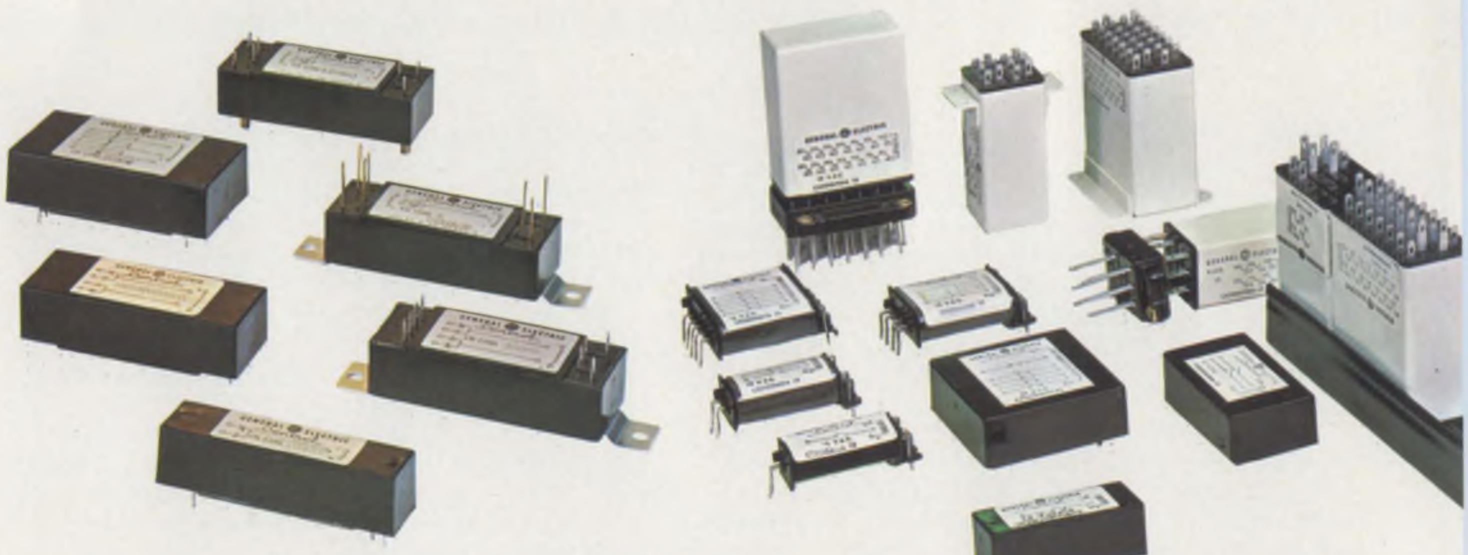
At the other extreme is a 108-gate multi-bit TTL shift register (not shown). Although it is one of the largest arrays produced to date, it requires only a unilayer interconnect and seven pins from its 3/8x1-inch flat-pack when only serial access to the register is required. Were parallel readout also desired, a read gate terminal and outputs from each stage would be necessary at a cost of 20 more access terminals.

standard

CR120 TYPE G
REED SWITCH RELAYS

small

CR220 TYPE G
REED SWITCH RELAYS



Leader in...

CONTROL INNOVATION

miniature

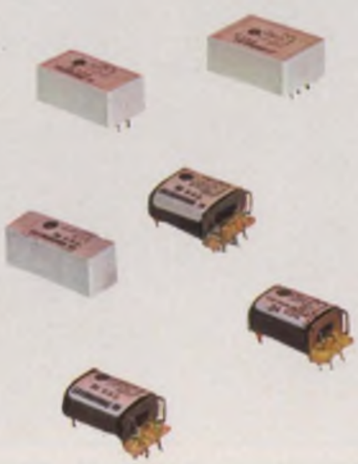
CR120 TYPE M

REED SWITCH RELAYS

OVER 500 G-E REED SWITCH RELAYS IN INDUSTRY'S WIDEST RANGE OF MOUNTING, TERMINAL, AND CONTACT ARRANGEMENTS

With General Electric's broad range of attractively packaged reed switch relays, you get application freedom never before possible: ■ **six mounting configurations**—open printed circuit, enclosed printed circuit, tube plug-in, bracket, channel and stud mounted ■ **four termination types**—printed circuit solder, solder tab, quick-connect and wire wrap ■ **four contact types**—A, B, C and K ■ **five relaying functions**—straight relaying, magnetic latching, electric latching, current sensing and timing ■ Grand total: over 500 different General Electric reed switch relays (easily industry's most complete line). Add the many factory modifications to these basic relay forms and your selection is virtually unlimited. ■ You'll also get exceptional life and speed from any one of these relays. Average life is 200,000,000 operations. Speeds range as fast as 600 microseconds (including bounce). ■ Call your G-E Sales Engineer today for more information. He'll also give you application assistance. Or write to Section 811-68, General Electric Company, Schenectady, New York, and ask for Publication GEA-7396A.

CONSTRUCTION INDUSTRIES DIVISION



Progress Is Our Most Important Product

GENERAL ELECTRIC

ON READER-SERVICE CARD CIRCLE 40

Computers aid circuit design and eliminate much engineering drudgery. How far along is this effort and what will it really do?

The coming year will see a continuing increase in the use of computers for analyzing and designing electronic circuits. Not only will newer and more sophisticated automatic programs be developed, but more and more circuit designers will begin taking advantage of these powerful tools. The prospects for the near future are that:

- The most impressive progress will be in transient-analysis programs. Improvements in efficiency and convenience will be emphasized.
- Progress in automatic design programs will probably be limited to fixed-topology programs.
- The problem of the availability of transistor equivalent-circuit parameters will remain, but it will be alleviated by stored-model features.

The past year has witnessed a significant increase in computer-aided analysis and design of circuits.

A prime factor in this increase has been the refinement and dissemination of automatic programs that remove most of the time-consuming and error-prone operations inherent in individually prepared programs. In effect, these automatic programs make the circuit designer virtually independent of the computer programer.

The great majority of automatic programs now in existence are oriented toward the analysis, rather than design, of circuits. This does not, however, preclude their use in the design process. Analysis programs may be used to check the progress of a design at intermediate phases, or the specifications for an active element may be determined as a result of a series of analysis runs.

An automatic circuit-analysis program can be defined as one that does not require the user to write any circuit equations or do any real programing. All information is entered according to an easily learned format that describes the necessary topological and quantitative information to the computer. The basic objectives of this type of

S. R. Sedore, Staff Engineer, IBM Corp., Owego, N. Y.

Fig. 1. **Automatic programs** allow the circuit designer to use computers for the design and analysis of his circuits with a minimum of programming. Dc, ac and transient automatic programs are available.

Published by The Deutsch Company • Electronic Components Division • Municipal Airport, Banning, California

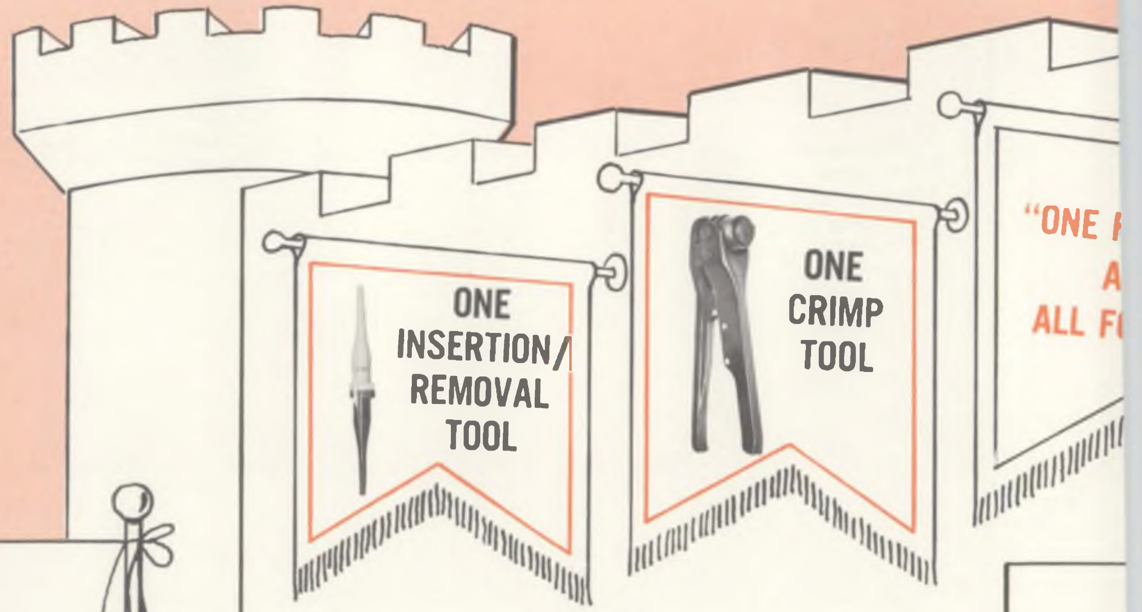
Deutsch Deflections

This Issue Ferrets Out Fearless Fighters

The Deutsch rear-release contact retention system has more one-for-allness than even the three Musketeers and their side-kick d'Eutschman d'Artagnan.

Talk about togetherness! Take a peek at this wide variety of peerless products that feature *one* contact retention system for *all* applications . . . *one* crimp tool for *all* rear-release connector styles.

This gallant group (DBA Series, 460 Series, 450 Series, TJ Series) fits into any system without a fight. They stand shoulder-to-shoulder with one, expendable, fail-safe insertion/removal tool . . . they share-and-share alike one contact retention system . . . their camaraderie knows no bounds with one (MIL-T-22520) crimp tool and one assembly procedure. For information you'll treasure, join the fracas on the inside pages.



TOUCHÉ WITH THE DBA

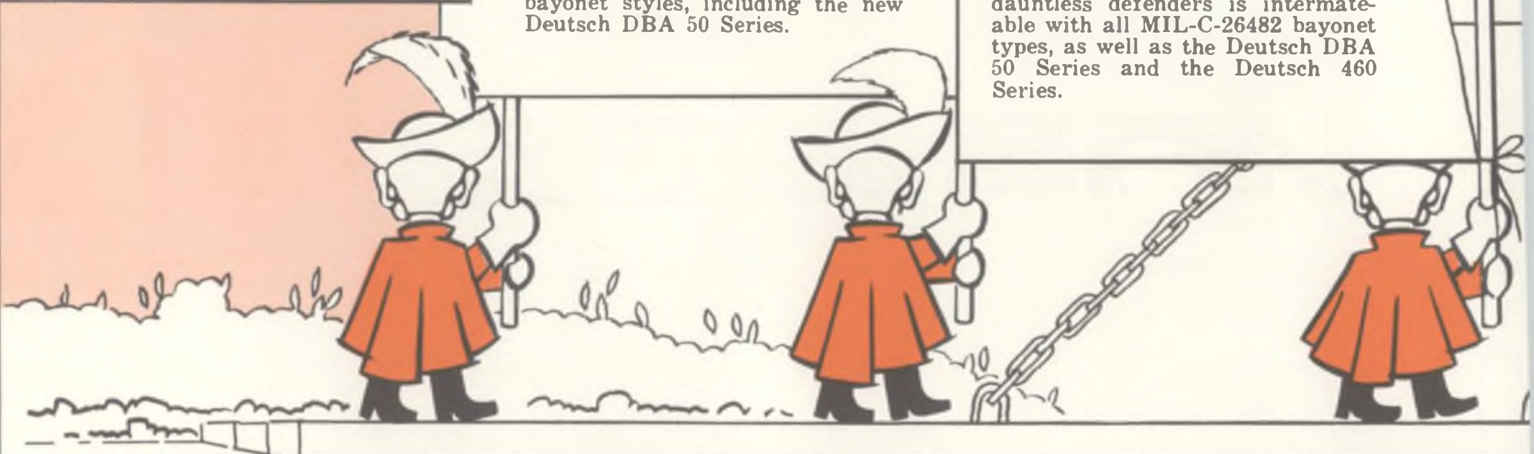
The first connector and contact series to qualify to NAS 1599 and 1600! Like Dumas' dandies, these high-performers always come through no matter what the odds. The DBA 30 Series threaded coupling intermates and interchanges with existing MIL-C-26500 connectors; the DBA 50 Series bayonet coupling intermates and interchanges with existing MIL-C-26482 connectors; and the DBA 70 Series intermates and interchanges with applicable MIL-C-26482 push-pulls.

DON'T BE FOILED BY HARSH ENVIRONMENTS

Try the DBA Series' comrade-in-arms: the 460 Series. This bayonet coupling MIL-C-26482 type provides high-temperature Silicone inserts and seals to parry the toughest environments, and for even further harmony-in-the-ranks is intermateable with all MS 3120 through 26 bayonet styles, including the new Deutsch DBA 50 Series.

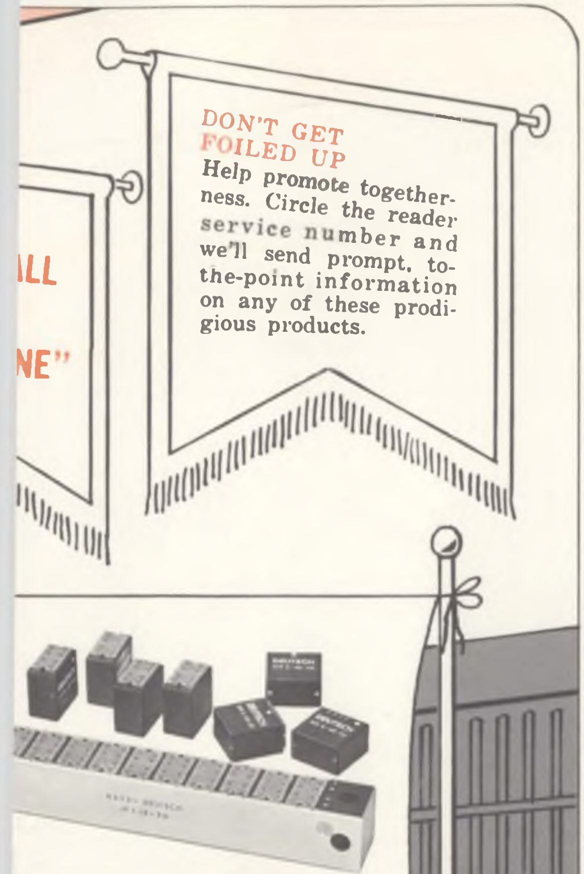
STOP DUELING WITH NON-ENVIRONMENTAL APPLICATIONS

The new, low-cost, Deutsch 450 Series is built to baffle rough treatment during contact insertion and removal . . . stops the need for further fencing. The 450 Series is ideal for ground-support applications . . . and like the share-alikeness of our dauntless defenders is intermateable with all MIL-C-26482 bayonet types, as well as the Deutsch DBA 50 Series and the Deutsch 460 Series.



RALLY 'ROUND OUR FLAGS

These problem solvers give you the sharpest method of upgrading your systems ever unfurled . . . nothing is too adventuresome for our DBA Series, 460 Series, 450 Series and TJ Series! This fearless foursome withstands environmental or non-environmental attacks from all quarters — they provide a doughty defense with the same rear-release contact system, a common crimp tool for all series, identical assembly procedures, and a single, expendable, fail-safe insertion/removal tool . . . *one* concept for *all* applications.



:RMINAL STRIP USERS
IN THE FRAY

ıe new Deutsch Environmental ɾrminal Junction Series overcome ɜir avoirdupois-prone adversaries th the versatility of modular con-ɾuction, the simplicity of crimp ɾminated insertable/removable ntacts, and the same tooling and sembly procedures found in the BA, the 450, and the 460 Series. ıese lightweight luminaries up-ade your systems, and save you ring time, weight, and costs . . . e also available in non-environ-ental styles, and in a wide variety busing configurations.

DEUTSCH CHAMBER OF HORRORS

by

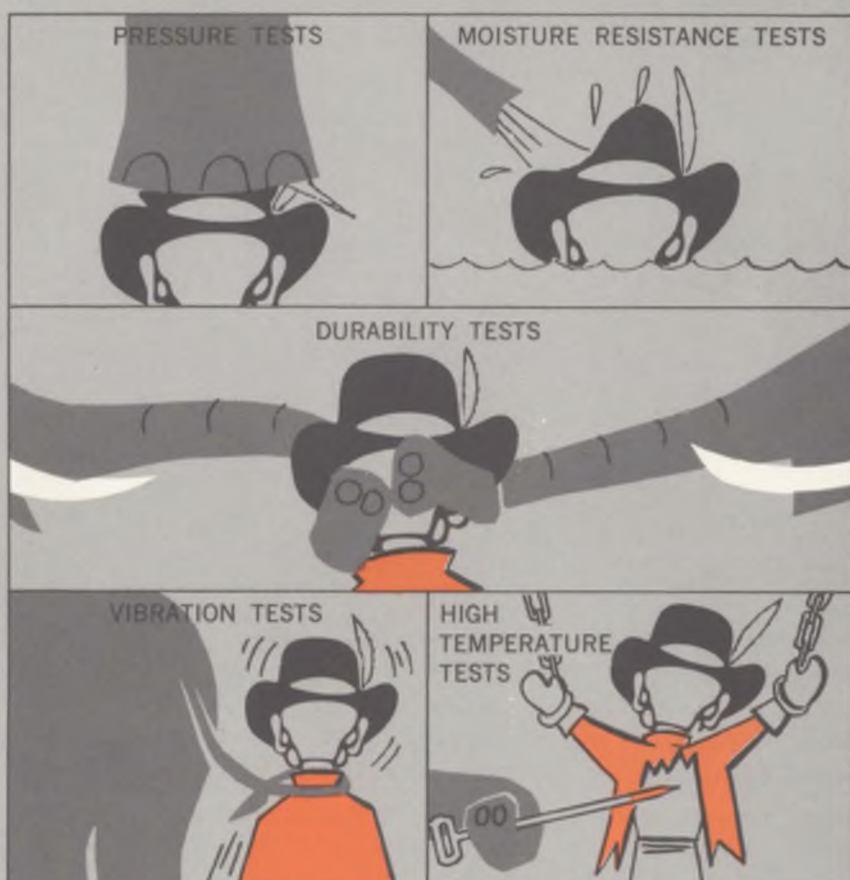
E. Deutschman Poe

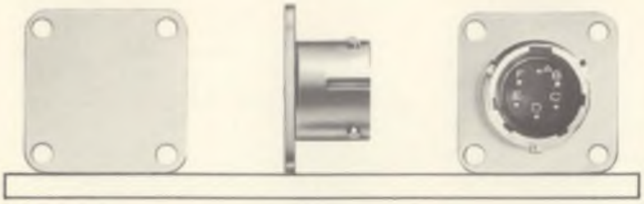
Once during the midnight gloom, while I pondered in the tomb,
Over many a quaint and curious spec never seen before —
While I nodded, nearly napping, suddenly came a ghastly tapping,
A nerve defying hollow rapping, rapping behind the test lab door.
"Tis the lab attendant," I muttered, "tapping behind the test lab door —"
Only this, and nothing more.

At the specs I stood there peering, choosing inserts and shells unfearing,
'Til again I heard the tapping, somewhat louder than before.
Are connectors being tortured; being cooked, whacked and ruptured;
Being frozen, shook, and fractured? — here I opened wide the door.
Upon the rack, in vacuum bottles; bathed in fire upon the floor —
Were connectors being tested, tested evermore.

The attendant's face so cheerful, as he performed these actions fearful
Scared me — filled me with shivering terrors never felt before;
So that now to stop the beating, horrified I stood repeating
"Stop this punishment," entreating that he leave the test lab floor.
That he leave forever behind him the tools of torture that he bore —
All he said was "Nevermore."

Then I knew what he was doing, why those tortures he kept pursuing,
And gladly now I watched as I reached for the test lab door.
For Deutsch connectors we defile to see if they meet environments vile,
And each that faces these tests awhile, tomorrow will join thousands more
Of Deutsch connectors that never fail though they are battered by the score.
Then quoth the lab attendant, "Failed Nevermore."





PLAN AHEAD
With Bused Contacts

Whether you prefer short shorts, several snorts, planned shorts, or heavy shorts, Deutsch Hermetic Shorting Receptacles provide something within everyone's reach in a variety of shell sizes, insert configurations, clocking positions, and plating — with or without interfacial seals.

As part of the Deutsch DTK Series of pre-wired hermetic receptacles, they not only provide a space-saving short cut from where you are to where you want to be . . . they pyramid reliability through simplified circuitry — contacts are bused to your specifications.

They are intermateable with all bayonet lock MIL-C-26482 plugs (MS 3126) and complement the existing Deutsch hermetic line of bused receptacles . . . all tailored to your individual needs.

The next time you want to be wired in the right places, don't short-circuit your local Deutschman.

MORE-MORE-MORE CONNECTORS TO NAS 1599-1600

THREAD COUPLING NAS 1599 CONNECTORS (INTERMATEABLE AND INTERCHANGEABLE WITH MIL-C-26500 TYPES):

DEUTSCH PART NO.	NAS PART NO.	DESCRIPTION
38041-22-55P/S*	NAS1641R22T55P/S*	Flange Mount Receptacle
38041-22-19P/S*	NAS1641R22T19P/S*	Flange Mount Receptacle
38041-18-31P/S*	NAS1641R18T31P/S*	Flange Mount Receptacle
38041-16-24P/S*	NAS1641R16T24P/S*	Flange Mount Receptacle
38041-14-7P/S*	NAS1641R14T7P/S*	Flange Mount Receptacle
38041-14-4P/S*	NAS1641R14T4P/S*	Flange Mount Receptacle
38041-12-12P/S*	NAS1641R12T12P/S*	Flange Mount Receptacle
38041-10-5P/S*	NAS1641R10T5P/S*	Flange Mount Receptacle
38042-16-24P/S*	NAS1642R16T24P/S*	Single Hole Mount Receptacle
38042-14-7P/S*	NAS1642R14T7P/S*	Single Hole Mount Receptacle
38042-14-4P/S*	NAS1642R14T4P/S*	Single Hole Mount Receptacle
38042-12-12P/S*	NAS1642R12T12P/S*	Single Hole Mount Receptacle
38042-10-5P/S*	NAS1642R10T5P/S*	Single Hole Mount Receptacle
38043-22-55P/S*	NAS1643R22T55P/S*	Plug Connector
38043-22-19P/S*	NAS1643R22T19P/S*	Plug Connector
38043-18-31P/S*	NAS1643R18T31P/S*	Plug Connector
38043-16-24P/S*	NAS1643R16T24P/S*	Plug Connector
38043-14-7P/S*	NAS1643R14T7P/S*	Plug Connector
38043-14-4P/S*	NAS1643R14T4P/S*	Plug Connector
38043-12-12P/S*	NAS1643R12T12P/S*	Plug Connector
38043-10-5P/S*	NAS1643R10T5P/S*	Plug Connector

BAYONET COUPLING NAS 1599 CONNECTORS (INTERMATEABLE AND INTERCHANGEABLE WITH MIL-C-26482 TYPES):

38050-22-55P/S*	NAS1650R22B55P/S*	Narrow Flange Mount Receptacle
38050-22-41P/S*	NAS1650R22B41P/S*	Narrow Flange Mount Receptacle
38050-20-41P/S*	NAS1650R20B41P/S*	Narrow Flange Mount Receptacle
38050-18-32P/S*	NAS1650R18B32P/S*	Narrow Flange Mount Receptacle
38050-16-26P/S*	NAS1650R16B26P/S*	Narrow Flange Mount Receptacle
38050-16-8P/S*	NAS1650R16B8P/S*	Narrow Flange Mount Receptacle
38050-14-19P/S*	NAS1650R14B19P/S*	Narrow Flange Mount Receptacle
38050-14-15P/S*	NAS1650R14B15P/S*	Narrow Flange Mount Receptacle
38050-14-12P/S*	NAS1650R14B12P/S*	Narrow Flange Mount Receptacle
38050-10-6P/S*	NAS1650R10B6P/S*	Narrow Flange Mount Receptacle
38053-22-55P/S*	NAS1653R22B55P/S*	Plug Connector
38053-22-41P/S*	NAS1653R22B41P/S*	Plug Connector
38053-20-41P/S*	NAS1653R20B41P/S*	Plug Connector
38053-18-32P/S*	NAS1653R18B32P/S*	Plug Connector
38053-16-26P/S*	NAS1653R16B26P/S*	Plug Connector
38053-16-8P/S*	NAS1653R16B8P/S*	Plug Connector
38053-14-19P/S*	NAS1653R14B19P/S*	Plug Connector
38053-14-15P/S*	NAS1653R14B15P/S*	Plug Connector
38053-14-12P/S*	NAS1653R14B12P/S*	Plug Connector
38053-10-6P/S*	NAS1653R10B6P/S*	Plug Connector

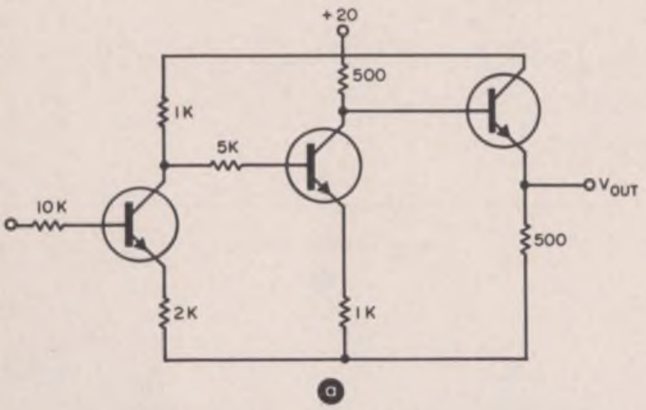
NAS 1600 ELECTRICAL CONTACTS:

0641-1-2059	NAS1662-20	Crimp Type Pin Contact
0602-11-2059	NAS1663-20	Crimp Type Socket Contact
0641-2-1659	NAS1662-16	Crimp Type Pin Contact
0602-16-1659	NAS1663-16	Crimp Type Socket Contact
0641-3-1259	NAS1662-12	Crimp Type Pin Contact
0602-18-1259	NAS1663-12	Crimp Type Socket Contact

NAS 1599 BACKSHELLS, IN A VARIETY OF SIZES AND TYPES:

38002-22	NAS1665-22	Backshell, Straight, Less Strain Relief
38002-20	NAS1665-20	Backshell, Straight, Less Strain Relief
38002-18	NAS1665-18	Backshell, Straight, Less Strain Relief
38002-16	NAS1665-16	Backshell, Straight, Less Strain Relief
38002-14	NAS1665-14	Backshell, Straight, Less Strain Relief
38002-12	NAS1665-12	Backshell, Straight, Less Strain Relief
38002-10	NAS1665-10	Backshell, Straight, Less Strain Relief
38003-22	NAS1666-22	Backshell, Straight, Strain Relief
38003-20	NAS1666-20	Backshell, Straight, Strain Relief
38003-18	NAS1666-18	Backshell, Straight, Strain Relief
38003-16	NAS1666-16	Backshell, Straight, Strain Relief
38003-14	NAS1666-14	Backshell, Straight, Strain Relief
38003-12	NAS1666-12	Backshell, Straight, Strain Relief
38003-10	NAS1666-10	Backshell, Straight, Strain Relief
38001-22	NAS1667-22	Backshell, 90°, Strain Relief
38001-20	NAS1667-20	Backshell, 90°, Strain Relief
38001-16	NAS1667-16	Backshell, 90°, Strain Relief
38001-14	NAS1667-14	Backshell, 90°, Strain Relief
38001-12	NAS1667-12	Backshell, 90°, Strain Relief
38001-10	NAS1667-10	Backshell, 90°, Strain Relief

*Alternate Positions as Approved by NASC.



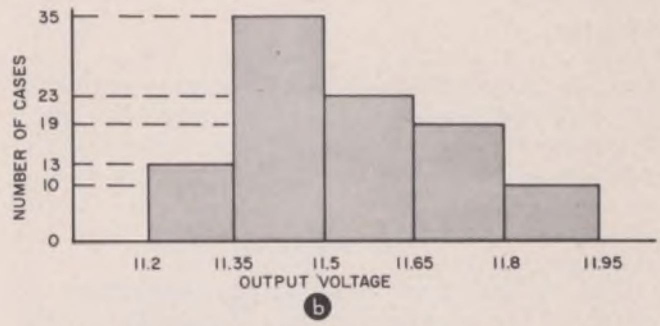


Fig. 2. **Dc program** was used for this circuit to determine the change in output voltage caused by various values of transistor beta. Statistical analysis feature was used.

program are to free the circuit engineer from dependence on the computer programer (who often does not speak in the same technical language) and to increase substantially the speed of problem preparation. Obviously, it is much easier to code the topology of any network than to write and program the mesh or nodal equations of that same network.

Dc programs for algebraic equations

Three distinct types of automatic programs are available: dc, ac and transient. The dc programs are intended to handle linear and nonlinear algebraic equations. If the problem consists only of resistors and constant voltages and current sources, the resulting linear algebraic equations can be solved in just one solution pass. If nonlinearities are added in the form of diodes or transistors, iteration techniques are employed to achieve a solution in a minimal number of passes. A statistical-analysis feature is included that permits random choice for any parameter from a variety of probability-density functions. Since no capability for a differential equation solution is included, capacitors and inductors cannot be handled in this type of program.

As an example of the application of a dc program, consider the circuit shown in Fig. 2a. This three-stage, dc-coupled amplifier is designed to produce an output of approximately 11.5 volts, if $\beta=40$ for all transistors. The objective is to determine the change of output voltage if the transistor betas are allowed to assume any value between 30 and 50. The statistical-analysis feature was used to obtain results for 100 cases, with the three transistor betas for any individual case randomly chosen from a uniform probability-density function.

The output format was chosen to divide the results into five increments. These results are shown in bar graph form (Fig. 2b). Note that in 13 cases, the output voltage fell between 11.2 and 11.35 volts, while the most common increment was from 11.35 volts to 11.5 volts. A nominal solution was also obtained for $\beta_1 = \beta_2 = \beta_3 = 40$, which was 11.53 volts.

Solutions for all the other nodal voltages in the circuit were also obtained from the same run. In this example, all the resistors were held at their nominal value, but any of them could have been varied as well. These solutions, including set-up and output time, required 4.8 minutes of 7090 computer time. Up to 100,000 cases at a time may be run with the statistical analysis feature, and each case may contain up to 50 modes.

Ac programs aimed at steady states

General ac programs are intended to produce the steady-state ac solution for linear networks. Transistors are accommodated by linear small-signal equivalent circuits, while nonlinear components are not permitted. A typical mode of operation is for the program to set up the matrix equation $I_s = AV$, where A is the nodal-admittance matrix computed at a given frequency; V is the vector of unknown nodal voltages, and I_s is the source vector. The inversion of A permits the solution: $V = A^{-1} I_s$.

The user may specify a number of source frequencies and obtain as output the amplitudes and phases of the nodal voltages. Some programs also yield outputs of such parameters as input impedance and circuit gain. Only one inversion and one pass through the equations are necessary for each frequency. As a result, a statistical-analysis feature is quite feasible. Up to 100,000 variations in component sizes may be run. Typical ac programs will handle networks of about 50 nodes.

Transient programs for time history

In contrast with the two other types of programs, the general transient program [1,2] must produce a complete time history of all the voltages and currents in the network. This can and often does require thousands of solutions for a single problem. A complete discussion of the organization and formulation that go into the development of an automatic transient program would require lengthy excursions into network topology, matrix theory and numerical analysis; however, a brief description may be given with the aid of Fig. 3.

It can be shown[3] that a knowledge of all capacitor tree-branch voltages and inductor-link (or chord) currents in any network is sufficient to solve for all currents and voltages in that network at any instant in time. At time t_0 of the transient problem, these quantities are inserted as initial conditions and all the other network's quantities are obtained. Let any one of the quantities to be found be defined as $Y(t)$, as shown in Fig. 3a. The solution at t_o is known $[Y(t_o)]$, and it is desired to obtain $Y(t_1)$. This is possible if the initial conditions have been updated so that they are valid at time t_1.

The updating of the initial conditions is achieved by determining the derivative of the initial conditions at t_o and integrating numerically. The process is described in flow form in Fig. 3b. The process is repetitive, and the problem "steps along" in increments of time until the problem duration, t_f, which is specified by the user, is reached.

Since computer time is expensive, an examination of the factors that control solution time is in order. The two major factors are the number of time steps required to complete the problem and the amount of computer solution time required per step. The number of time steps is governed by the problem duration required for the particular transient the user is interested in, as well as the size of the average individual time step actually taken. It is clear the user would prefer that the average time step be as large as possible. However, this is determined by the type of integration routine used and a number of circuit-dependent considerations, such as time constants and forcing functions. The amount of computer time per step is determined essentially by the number of derivative evaluations required per step and by the number of circuit elements present.

As a measure of the present efficiency of a transient program, a three-stage transistor circuit involving 13 differential equations and 25 passive elements was run for a problem duration of 5μs in 3.8 minutes of 7090 solution time. Based on the amount of solution time required for this circuit, it is obvious that a true statistical analysis, which would analyze thousands or even hundreds of variations of a circuit, would be quite impractical with present techniques and computers.

It should be mentioned that the transient program can be used to solve dc and ac problems, while the converse is not true. However, efficiency is often sacrificed if a dc or ac problem is run on a transient program.

Very definite improvements in transient programs will be made in 1966. Solution times will be significantly improved by reducing the amount of computer time per step. Also, improved integration routines will possibly permit a solution of the general transient problem in fewer steps than presently required. This reduction in solution time for the individual problem will establish the feasibility of a rerun feature, which will allow time for checking parameter variations in a given circuit. True statistical analysis in transient programs is still some time away, however.

An important factor to consider when choosing between transient programs is flexibility. There should be as few restrictions as possible on the user's choice of an equivalent circuit to represent any active device. The analyst should be free to insert equivalent voltage and current generators at any point in a network and to use any network functional dependence in their representation. The ability to represent nonlinear passive elements is also of great importance.

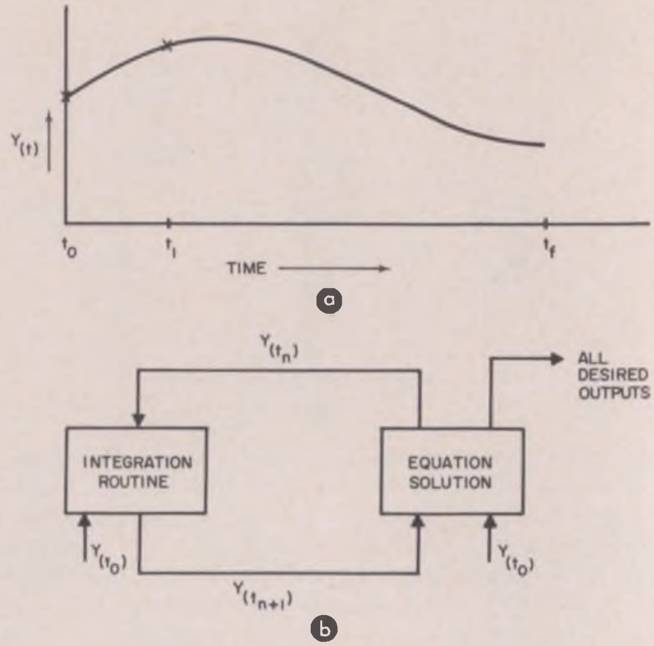


Fig. 3. **Transient programs** solve for network quantities in a series of individual time steps. For each step the initial circuit conditions are updated, and then an integration routne is carried out.

Graphical inputs being developed

A very interesting development, which is of comparatively recent origin, permits the circuit designer to enter input data to the computer graphically. That is, the network configuration may be drawn on the face of a cathode-ray tube. This step removes the necessity of entering the network topology in the conventional card format. Although the feature is not presently available on the open market, a working prototype exists that is compatible with the programs previously described. This consists of an operator console, a film recorder and a film scanner that work in conjunction with the computer. During the coming year, this feature is expected to be available in the form of an auxiliary attachment intended for use with the new IBM 360 computer system.

Few design programs available

As previously mentioned, the great majority of circuit analysis programs in existence today are oriented toward the analysis problem rather than the design problem. The perfect program from the designer's view point would be one in which the designer specifies the input and the desired output, and the program yields an optimum topology complete with optimum parameters. No such program exists, nor is it likely to in the near future.

The progress that has been made to date with automatic design programs has been with fixed-topology formats. That is, the user specifies the non-reactive topology and the desired values for certain dc nodal voltages. Then the program puts out a set of resistor values that are compatible. This type of program is just beginning to appear; consequently, it has not seen widespread service.

Equivalent circuits pose problems

Anyone who has ever undertaken any but the most trivial analysis or designs involving active devices has had the necessity of providing equivalent circuits, or models. Simpler problems permit the use of the small-signal class of equivalent circuits, for which approximate parameters may often be found in manufacturers' data sheets. These models become useless whenever cutoff, saturation or even large signal swings occur. The engineer must then turn to more comprehensive equivalent circuits, with their added problems.

The difficulty lies not so much in the choice of a large-signal model,[4,5] but rather in the availability of the parameter values. Those who have access to well-equipped laboratories can readily measure the necessary parameters; however, not all engineers are in this fortunate position. This deficiency inhibits the use of computer programs in many installations, whether digital or analog, automatic or not. It is not that the component-data situation is any worse today than in the past; it is just that much more can now be done with these data, so their lack is more acutely felt. A partial remedy may be in the stored-model feature, which will be contained in the larger transient programs. Such a feature will often make available nominal equivalent-circuit parameters.

References:

1. "Automated Digital Computer Program for Determining Responses of Electronic Systems to Transient Nuclear Radiation," Volume II, International Business Machines Corp., Space Guidance Center, IBM File No. 64-521-5, Owego, N. Y., July 1964.

2. R. H. Cushman, "Computer speeds circuit design reviews," *Electronic Design*, February 15, 1965, p 12.

3. T. R. Bashkow, "The A Matrix, New Network Description," *Trans. IRE* (Prof. Group on Circuit Theory), Volume CT-4, 117-119, September, 1957.

4. K. G. Ashar, H. N. Ghosh, A. W. Alridge, and L. J. Patterson, "Transient Analysis and Device Characterization of ACP Circuits," *IBM Journal*, Volume 7, July, 1963.

5. R. Beaufoy and J. J. Sparkes, "The Junction Transistor as a Charge Controlled Device," *Automatic Telephone and Electric Company Journal*, October, 1957, XIII, 310-327.

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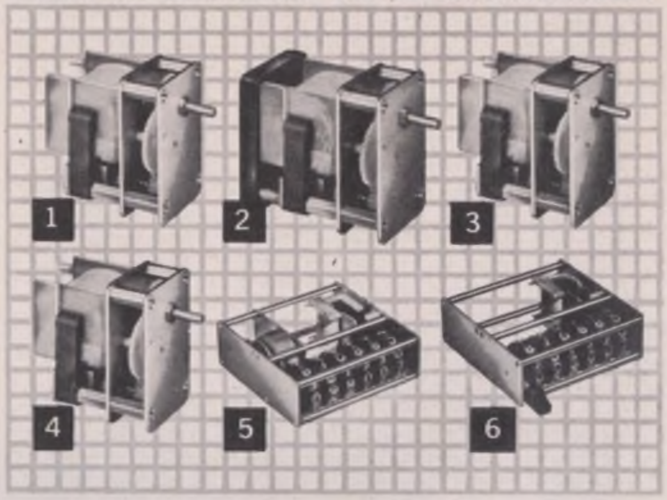

TI to help you and reduce costs

Fourteen new transistors extend silicon planar power line to 30 amps

A broad new family of NPN silicon power transistors extends TI's planar-epitaxial product line to meet your power requirements from 50 mA to 30 amps.

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This new fourteen-device family includes two one-amp units (2N4000-01); eight five-amp units (2N3418-21, 2N3996-99); and four 30-amp units (2N4002-05). Package choices include TO-5, standard and insulated 7/16" stud, TO-63 and dime-size *Thin-Pac** package. Circle 197 on Reader Service Card for data sheet.

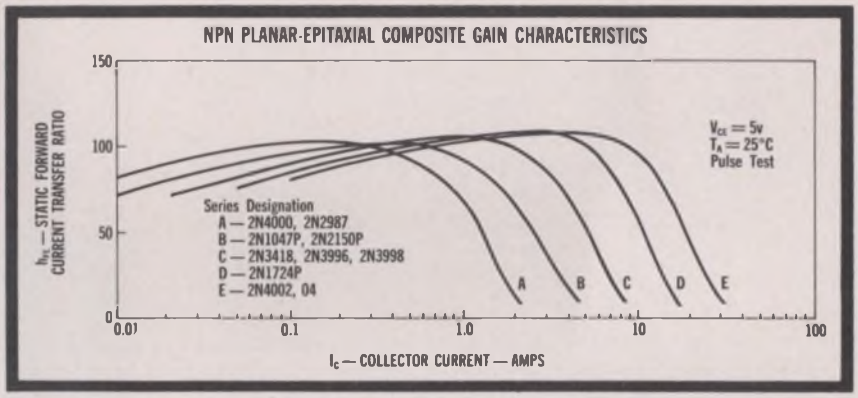

Figure 4: Uniform beta of five families of planar-epitaxial NPN silicon power transistors

Planar unijunction offers low leakage, high reliability for timing circuits

Now you can build more accurate timing circuits with significantly lower power requirements when you employ TI's new 2N3980 planar silicon unijunction transistors.

You achieve high accuracy because of extremely low leakage — 2 nA at 30 volts (several orders of magnitude lower than the best conventional grown unijunction transistors). Greater circuit simplicity is an inherent advantage with unijunction transistors. TI's new planar device allows you to reduce capacitor size as well, because of its exceptionally low leakage characteristics.

These features, combined with planar high reliability and compact TO-18 package, represent an important state-of-the-art advance in unijunction technology. Circle 198 on Reader Service Card for detailed information.

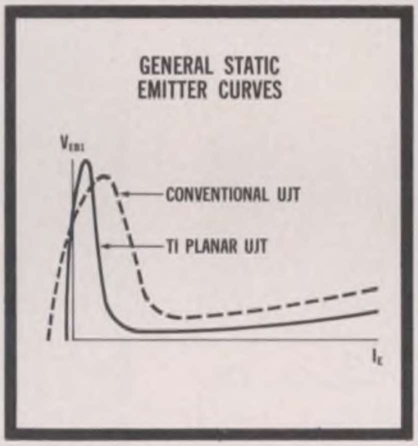

Figure 5: Comparison of curves shows improved leakage, valley current and saturation characteristics of 2N3980 planar unijunction

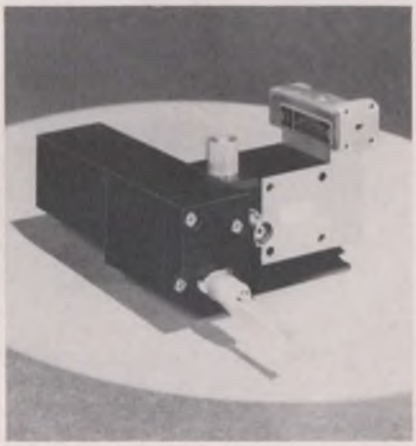

Figure 6: TI K_u-band preamplifier-converter employs TIXV07 varactor diode to achieve 2.5 dB noise figure

New Schottky-barrier varactor diodes offer 2.3 dB NF at 16.5 GHz, f_T to 500 GHz

Low noise, high tunability and low pump power requirements are characteristics of K_u-band parametric amplifiers that employ TIXV05-07 varactor diodes. This makes possible radar, communications and telemetry equipment that performs better and costs less.

TIXV05-07 varactors are Schottky-barrier, planar-epitaxial, gallium-arsenide units encased in beryllium oxide microwave pill packages.

Low noise permits greatly increased receiver sensitivity, providing increased useful range and/or reduced transmitter power requirements.

High electronic tunability—over 900 MHz in the preamplifier/converter shown in Figure 6 — permits simplified design.

Low pump power requirements — as low as 10 mw in the unit shown — permits the use of a low voltage klystron or an all-solid-state pump. Circle 199 on Reader Service Card for data sheet.

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A large-signal FET amplifier? Yes.

In addition to small-signal applications, the FET can be designed to outperform both tubes and bipolars.

If you've limited your large-signal voltage-amplifier designs to vacuum tubes or bipolar transistors, you've missed the boat. Field-effect transistors (FETs) are capable of large-signal amplification, in addition to their conventional, small-signal role, to degrees which may pale competing device approaches.

Measured by such basic amplifier criteria as gain, noise and distortion levels, input impedance and isolation, your device dollar takes on new dimensions when you settle on the FET. Moreover, the FET amplifier does not require cascoded stages or multiple feedback loops to achieve this performance. It is the natural result of the FET's unique properties if the design is tailored to the Q-point and load, instead of the pinchoff voltage and transconductance. In addition, it entails a tube-level supply and gate bias that are determined by the distortion, rather than the output- and input-voltage swings, respectively.*

Establishing the ground-rules

Before proceeding with the design and performance criteria for FET voltage amplifiers, a brief run-through of amplifier qualities is in order. To begin with, a true voltage amplifier is characterized by a very high input impedance. This feature is inherent in the vacuum tube and FET cases and can be obtained by relatively costly, complex circuit-staging with bipolar transistors.

Amplifier gain, the ratio of output voltage to input voltage, is a popular measure of device

*The latter two design criteria were discussed in detail in a recent article. See "Linear voltage amplifiers: FETs can surpass bipolars, pentodes," ELECTRONIC DESIGN, Dec. 20, 1965, p 20.

Table 1—Comparison of amplifying devices

	Tube	Transistor	FET
Device used, 1st stage	ECC83	2N1192	DNL-1.8A
Device used, 2nd stage	ECC83	2N1193	DNL-1.8A
Gain, dB	40	40	40
Output noise level, dBV	—66	—72	—74
Maximum output at 1% distortion, dBV	+26	+13	+31
Distortion at 30 volts, %	in heavy overload		0.06
Overload to noise ratio, dB	92	85	105

An undistorted view of FET amplifiers. Author Rheinfelder observes the superior gain, noise and distortion characteristics of a FET voltage amplifier in a Phono-Equalizer application. It is superior to tubes and bipolars.

William A. Rheinfelder, Applications Consultant, Dickson Electronics Corp., Scottsdale, Ariz.

performance in these voltage applications. Given three equivalent circuits, each incorporating one of the three devices, some index of the relative merits of each can be obtained by looking at the quality of the output when the gain of each is made the same. These qualities are assessed by observing the noise, distortion and load conditions prevalent at the output (Table 1).

The tabular results were taken from a Phono-Equalizer circuit, which is a common two-stage audio amplifier. The circuits were identical, save for the type of device used and minor circuit details peculiar to each. Performance factors, set-up, operating conditions, procedures and adjustments were the same for all cases.

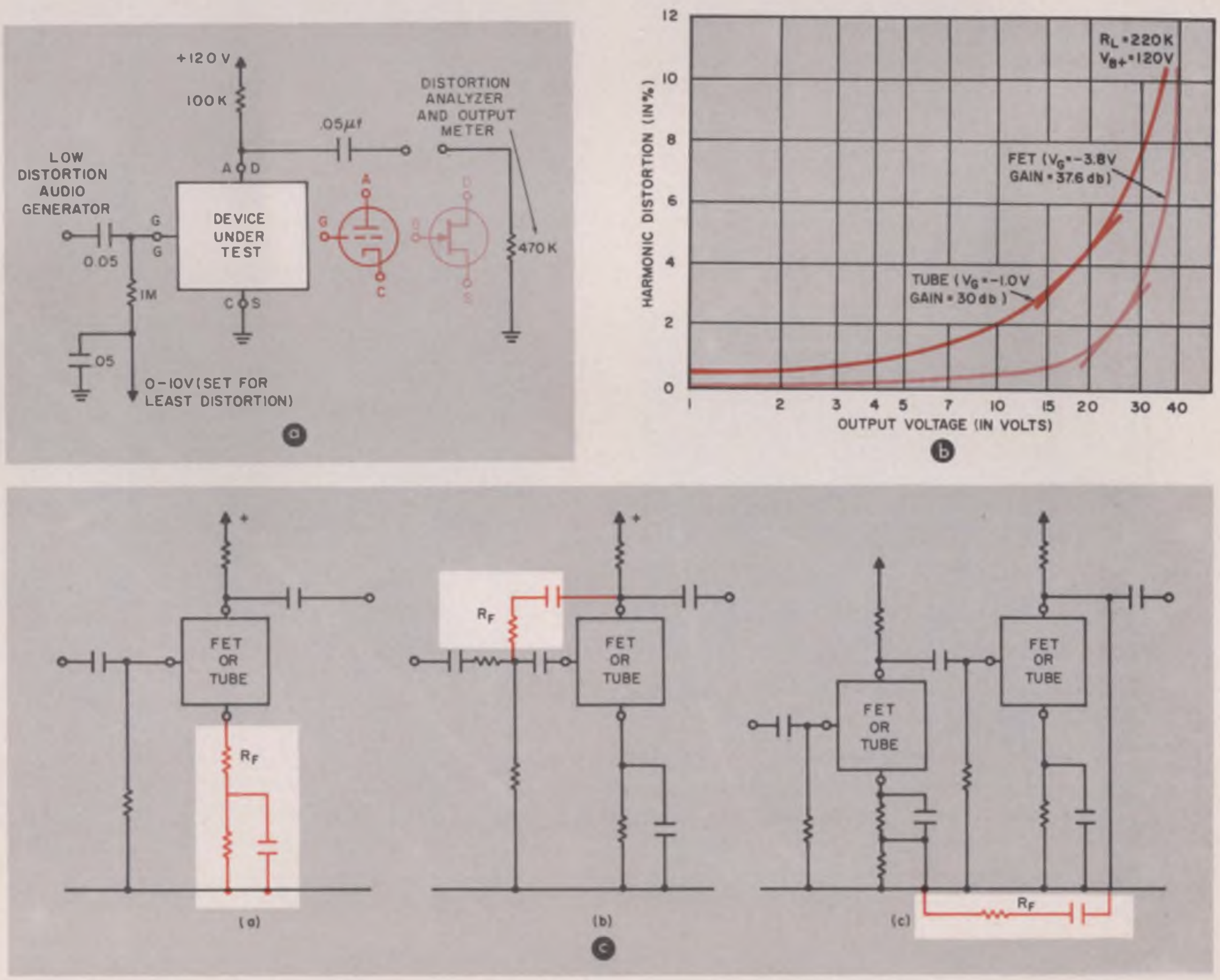
Note that the FET is clearly superior to the other devices, across-the-board. The tube exhibited better output and overload characteristics than the bipolar, but these were accompanied by poorer noise behavior. Also, bear in mind the well-known virtues of solid-state devices when contrasted with vacuum tubes like size, heat, power, life and shock resistance.

In addition, the term "voltage amplifier," in this case, refers to resistance-coupled dc and capacitive-coupled ac circuits, extending from the audio range to a few megahertz. The discussion does not apply to high-frequency voltage amplifiers. The input impedance of FETs and bipolars takes on a different meaning in that case, inconsistent with the amplifier requirements mentioned above.

In high-frequency amplifiers, the input and output capacitances are made part of tuned circuits. Moreover, feedback capacitances, if undesired, are typically neutralized out. Although FETs and bipolars are capable of voltage amplification to a few hundred megahertz and beyond, the conclusions made should be limited to amplifier circuits that level off at a few megahertz.

A clearer view of distortion

Since the tube and the FET exhibit better distortion characteristics than the bipolar, let us examine this aspect of their performance in detail. The test circuit used for determining this characteristic appears in Fig. 1a. Note that the Q-point location and biasing arrangement for the FET



1. **Distortion in amplifying devices** is measured by this test circuit (a). Comparing the test results for a 12AT7 tube and a DNL-Q-A FET (b), it is evident that the FET shows less harmonic distortion. Feedback arrangements (c) may be used to improve the distortion characteristic of the tube, but lower gain results. Shown are series-current feedback (left), shunt-voltage feedback (middle) and series-voltage feedback (right).

followed the design prescription outlined in an earlier work.[1] The test conditions used were similarly standardized and call for a 120-volt supply for both devices.[2]

The measurements obtained from a 12AT7 tube and a DNL-Q-A FET were plotted and appear in Fig. 1b. In both cases, the bias levels were optimized for minimum distortion.

The vacuum tube shows the typical gradual increase in distortion, consisting mainly of second, but also a good deal of third, harmonics. The FET, in contrast, shows very small distortion levels until the overload area is approached. Virtually no second harmonic is present. A very low-level third harmonic of about the same magnitude as that found in the tube case appears.

The extreme linearity of the FET at low levels was traced to the input circuit. While the tube also shows a gradual increase in distortion at the grid (due to the normal grid current [3]), the signal at the FET gate stays clean. Less than 0.01% distortion is exhibited all the way to the point where the output is heavily overloaded (marked by clipping of the sine wave). Distortion may be generated in the gate circuit by overdriving the gate, but this undesirable effect would occur only if the voltage gains were excessively low. Since FETs typically have a gate-overdrive safety margin of at least 10 dB, distortion is confined to the FET output circuit.

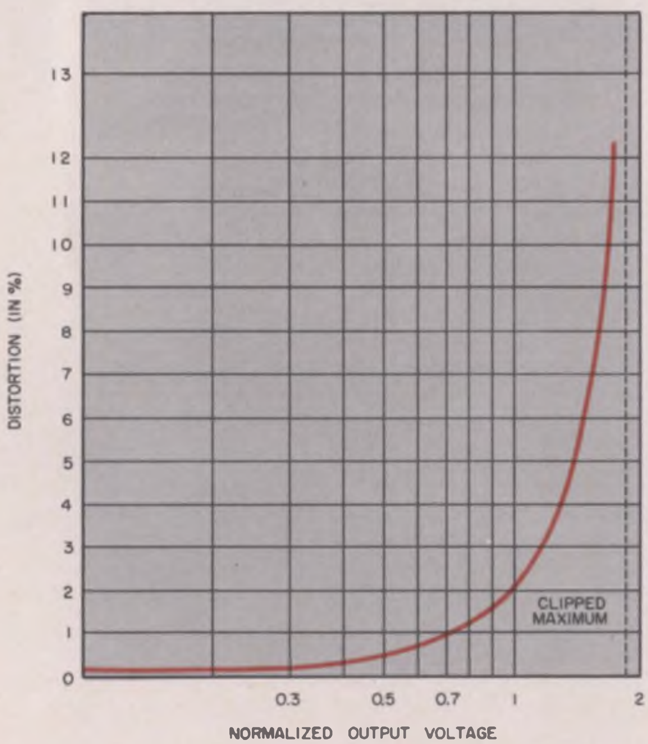
In bipolars, most of the distortion is produced in the base-emitter junction; the collector distortion is virtually the same as that measured directly at the base. This applies up to the point where output overload occurs. At this location, the onset of additional collector distortion occurs. The relatively high distortion is unavoidable because of the inherently nonlinear input characteristic of the transistor. It is due to the forward-biased diode operated in a current mode and associated with a small load resistance.

Feedback lowers distortion level

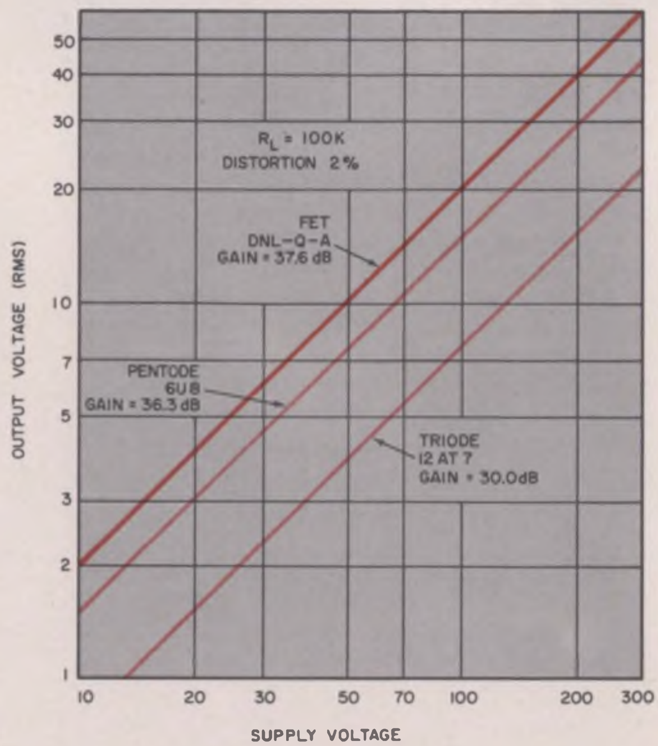
Negative feedback may be used below the overload point to reduce distortion, but this is accompanied by a sacrifice in gain. For example, the tube characteristic (Fig. 1b) may be made to approximate the overload curve of the FET by using feedback networks (Fig. 1c) to provide 12 dB of negative feedback. However, the tube's gain picture suffers markedly. Originally a gain 7.6 dB below that of the FET was evident; with the feedback, the gain is further reduced to 20 dB below the FET level. Also note that the knee of the overload curve for FETs occurs at 2% harmonic distortion. For the tube, this point is reached at the 4% distortion level (Fig. 1b).

Overload is an output level producing 2% harmonic distortion, such as 25 volts in Fig. 1b. A normalized overload curve is obtained by making the 2% distortion level equal to unity output voltage. It is then possible to read distortion for different output levels under widely varying conditions. FETs are therefore specified for output capabilities at 2% distortion to obtain the highest test accuracy. Overload voltages for different distortion levels are then easily obtained from the normalized FET overload curve (Fig. 2).

For example, how much signal is available from



2. **Normalized overload curve of FET** may be used to determine output signal for a given distortion level. Unity output voltage (normalized) occurs for 2% distortion. Note that clipping of the output occurs at 1.8 volts.



3. **Maximum output voltage for FETs** and tubes as a function of supply voltage shows that the FET provides more gain when the distortion level for all amplifying devices is normalized at 2%.

a FET circuit at 5% distortion when the overload level (2%) is 8.0 volts? From Fig. 2, the multiplication factor is 1.38, therefore 11.04 volts produce 5% distortion.

A pentode has a somewhat higher output level than a triode, but it, too, shows more distortion in the input circuit than the FET. Comparative maximum output signals for different supply voltages, using the test set-up as before, clearly indicate the FET's superiority (Fig. 3).

Output capability is also affected by load resistance, but to a lesser extent than with supply changes. In Fig. 4, FET-overload characteristics for different load resistances are plotted. The supply voltage was kept constant at 120 volts. The diagonal loading was also maintained constant by making the ac-coupled load resistance five times the dc load resistance in the drain.

Note that "diagonal loading" results when the ac resistance of a circuit is less than the dc resistance. This causes a rotation of the load line in the output characteristics. For example, a circuit working into a 100 kΩ load with an ac-coupled load resistance of 300 kΩ results in a dc load of 100 kΩ and an ac load of 75 kΩ. The resulting rotation of the load line produces increased distortion. The diagonal-loading term is commonly used with amplifiers and detectors.

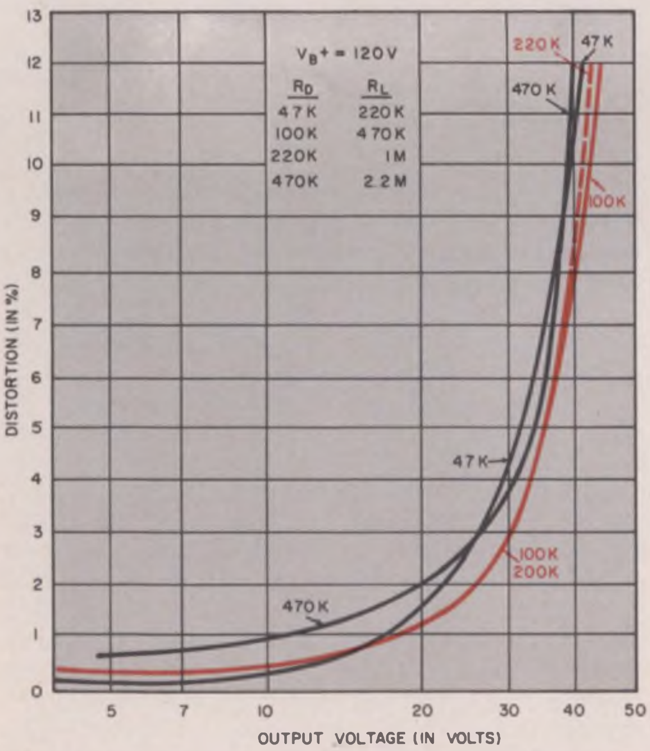
Figure 4 indicates that optimum performance is obtained with a load resistance of 100 kΩ. The 220 kΩ load produced results which were nearly as good. Although the larger load resistance yields increased gain, decreases in bandwidth and bias stability also result. Thus, for most applications, the 100 kΩ value is preferable.

Although optimum load resistance is independent of supply voltage, the maximum output signal is directly related to the supply, because FETs show no distortion in the input circuit. The maximum (clipped) peak-to-peak output voltage is equal to the supply-voltage level minus the "bottoming" voltage which occurs for zero bias on the gate. For specific distortion levels, maximum output voltage may be read from a plot of maximum output vs supply level, with total harmonic distortion as the parameter (Fig. 5).

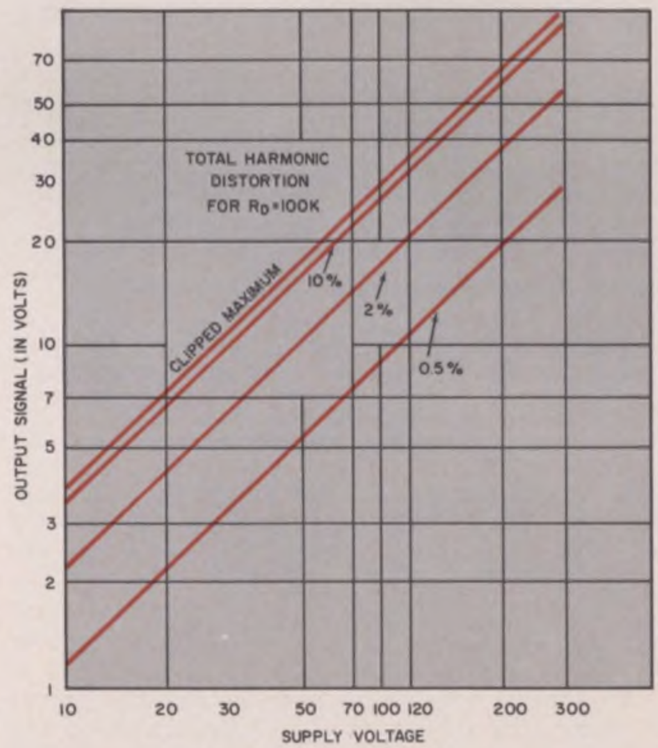
Breakdown determines overload

When the breakdown voltage is equal to, or larger than, the supply voltage, the output voltage is said to be supply limited. Breakdown refers to BV_{DS}, when biased at twice the normal operating point to allow for peak signal swings. In practice, a gate voltage of −15 volts is used and the drain voltage is read with a supply of 120 volts and a drain resistance of 100 kΩ.

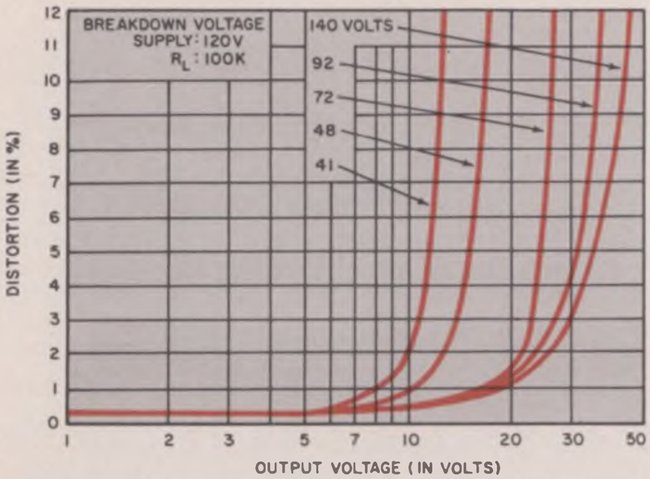
The effect of lower breakdown voltages on the output capability is clearly demonstrated when units with differing drain-to-gate breakdown voltages are driven to overload (Fig. 6). It is interesting to note that the breakdown itself causes no distortion but rather clamps the positive-going signal to whatever breakdown voltage the device has. After clamping occurs, the output signal only increases toward the bottoming region as the drive is increased. When bottoming is reached, overload is achieved by clipping the negative-going waveform. Up to that point, the distortion is very low (typically 0.01%), even



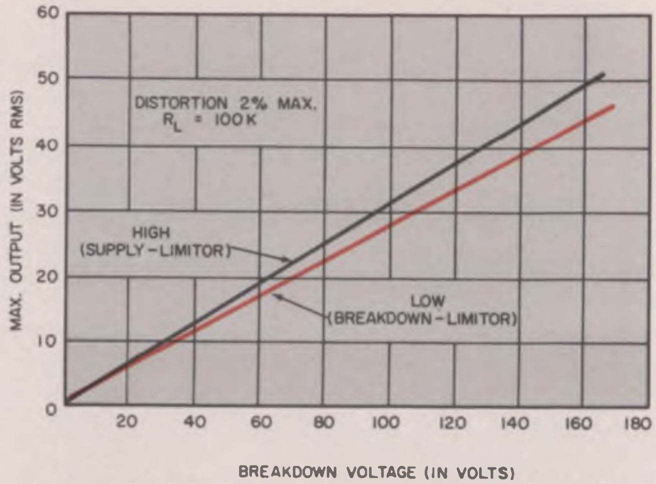
4. **FET overload characteristics** as a function of load resistance show that 100kΩ is the optimum drain resistance for combined, optimum gain-distortion. Larger loads yield increased gain at the expense of bandwidth.



5. **Maximum output signal in FETs** is a function of supply voltage. For FETs with breakdown voltages in excess of the supply, the amplifier is supply-limited, rather than breakdown-limited. Note the excellent linearity.



6. **Output voltage in FETs** as a function of breakdown (BV_{DS}) shows that for a specified output, harmonic distortion is larger in the lower breakdown units. The breakdown itself produces a clamping effect.



7. **The breakdown voltage-overload characteristic** shows that higher outputs are achieved when supply-limited FETs are used instead of breakdown-limited FETs. In the test, the supply voltage was to be twice the breakdown level.

though the unit may be operating in its breakdown region with the top of the waveform clamped.

Breakdown voltage is somewhat dependent upon the Q-point of a particular unit. Also, bear in mind that the drain-voltage level is normally 45% of the supply voltage's magnitude. Therefore, in breakdown-limited applications, output voltage may be accurately predicted by consulting a breakdown-overload curve (Fig. 7). Note that the increase to high distortion levels is more rapid in breakdown-limited FETs than in supply-limited units. These considerations are of major importance to large-signal voltage-amplifier applications. In small-signal uses, a breakdown-voltage figure of about one-half of the supply voltage is adequate.

As is indicated by all the curves, particularly Figs. 3 and 5, FETs make superior large-signal voltage amplifiers. For example, in hi-fi applications, better performance is immediately available by using FETs, even for the driver stages, which power the push-pull, audio-output tubes.

Gain characteristic is flat

The gain of a FET amplifier may be expressed by the familiar formula used for pentode circuits:

$$A = \frac{g_m R_o R_L}{R_o + R_L} \approx g_m R_L, \qquad (1)$$

where A is the voltage gain, g_m is the transconductance, R_o is the output resistance (the internal dynamic resistance of the FET) and R_L is the load (drain resistance). In most cases, $R_o >> R_L$.

This formula permits the calculation of voltage gain when the transconductance for a specific operating point is known. But the formula fails to shed light on how to achieve optimum gain. This is because g_m is a function of both drain voltage and drain current and R_L is related to the supply voltage. Therefore, gain as a function of supply voltage and load must be supplied (Fig. 8).

Using the previously determined optimum load resistance (100 kΩ), the gain changes 3 dB with the doubling of supply voltage (Fig. 8a). This gain increase for every 2:1 increase in supply voltage is identical to the change with vacuum tubes,[4] and can be attributed to the 3/2 power law of the FET.

Changes in gain with load resistance (Fig. 8b) demonstrate a slope of 3.5 dB per doubling of load to the point where the load resistance reaches the same order of magnitude as the output resistance (normally 1 MΩ). These characteristics, added to the biasing and overload considerations, clearly indicate that FETs should be operated at considerably higher voltages than those commonly used with bipolar transistors.[5] A supply-voltage level of 120 volts is now used as a standard.

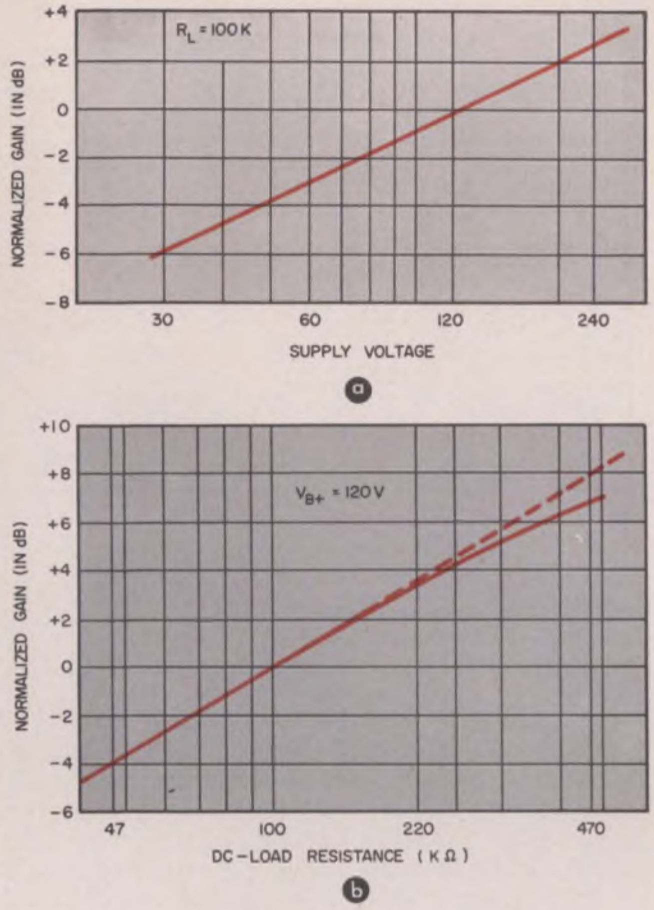
Instead of measuring g_m and R_o separately, it is more meaningful to specify the effective transconductance g_m' defined by

$$g_m' = g_m R_o/(R_o + R_L). \qquad (2)$$

The value of g_m' for a given circuit is readily obtained by dividing the voltage gain by the load resistance. However, the gain picture remains incomplete until mention is made of bandwidth. In particular, the frequency response of RC-coupled FET voltage amplifiers is almost entirely determined by the Miller effect.[6]

To demonstrate this, a typical FET amplifier stage was placed in a special circuit-capacitance test circuit (Fig. 9). A built-in source-follower was used to drive a shielded-cable-coupled Ballantine VTVM. The input coupling capacitor of the source-follower was soldered directly to test points A, B and C with a minimum of lead length. The 100-kΩ resistance between A and B simulated the previous stage's drain resistance. With biasing established at the normal Q-point, the frequency response and individual circuit capacitances under normal operating conditions were determined. The results are given in Table 2.

The circuit interelectrode capacitances were computed by setting up the equations for the input and output Miller effect for both stages and

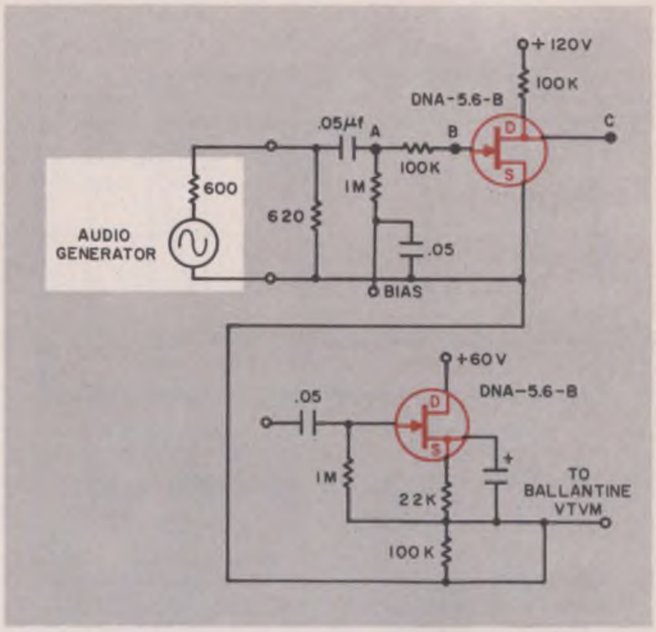


8. **Gain is a function of both supply voltage and load resistance.** Normalized gain vs supply-voltage curve (a) shows a 3-dB increase in gain with a doubling of the supply, because of the 3/2 FET power law. As a function of load (b), the gain increases by 3.5 dB for each doubling of the load resistance. Note that the ac-coupled load is five times the dc load resistance.

allowing for gain variations at the various test frequencies. Examination of the results indicates values virtually identical to those obtained with triodes. For example, a 12AT7 tube is listed with a grid-to-plate capacitance of 1.7 pF as typical. The frequency response of the FET is therefore very close to what is commonly achieved in conventional triode circuits. Because of the larger gain of FETs, the Miller effect produces somewhat higher input capacitances than in the triode case. Development efforts are aimed at producing an FET with an added shielding electrode to achieve lower feedback capacitances (particularly drain-to-gate). The best capacitance figures are comparable to those obtained with present-day pentode tubes (Table 3).

Data sheet specs incomplete

Based on the characteristics of FETs discussed above, many current data sheets are inadequate for voltage-amplifier applications. Since these applications constitute a considerable share of the market, a more applicable designer's data sheet was developed which took cognizance of the specifically designed testing techniques discussed above. Note that such conventional FET terminol-



9. **Frequency response in FET amplifiers** is similar to results obtained with triodes. Circuit-capacitance test set-up is used to measure interelectrode capacitances and their

Table 2—FET frequency response*

I Low frequency gain	35 dB
3 dB down from B to C at	242 kHz
3 dB down from A to B at	16.2 kHz
II Gain at 16.2 kHz, B to C	35 dB
$(A_1 + 1)$, numeric (multiplier for Miller-Effect computations)	57
III Gain at 242 kHz, B to C	32 dB
$(A_2 + 1)$, numeric	41
IV Total input capacitance	98 pF
Total output capacitance	6.4 pF
C_{gd}, gate-to-drain capacitance	1.65 pF
C_{gs}, gate-to-source capacitance	4 pF
C_{ds}, drain-to-source capacitance	3 pF

*This table refers to FET amplifier frequency response (Fig. 9)

Table 3—Comparison of typical capacitances

Capacitances	Triode (12AX7)	Pentode (6AU6)	FET (DNL-1.8-B)
Plate to grid/ (drain to gate), pF	1.7	0.0035	1.65
Input to ground, pF	1.6	5.5	4
Output to ground, pF	0.46	5.0	3
Gain (typical)	65	100	100
Miller-effect, pF	111	0.3	165

Table 4—Typical FET operating characteristics

Supply voltage, V_{DD}	120	120	volts
Drain resistance, R_D	100	220	kΩ
AC-coupled load,[1] R_G	.47	1.0	MΩ
Drain current, i_D	0.6	0.3	mA
Source resistance, R_S	See Data Sheet		—
Voltage gain,[2] G_V	32.5	36.5	dB
Output voltage[3] E_o	24	24	v_{rms}
Output voltage,[4] E_o	40	40	v_{rms}

Notes
1) or following gate resistance.
2) for units with gain code B. Add 5 dB for code A. Subtract 5 dB for code C.
3) at 2% total harmonic distortion
4) at 10% total harmonic distortion

ogy as pinchoff voltage, shorted-gate drain current, transconductance and other parameters measured with zero gate bias are not very useful in amplifier design (although they are of immeasurable value in switching-circuit design). Generally, breakdown voltage, Q-point and gain in a standard test circuit fully classify a FET amplifying device. This information should be supplemented by typical operating conditions, similar to the old tube practice (Table 4).

Observe that the remarks made in this discussion are applicable to small-signal as well as large-signal amplifying applications. They hold true for both *n*- and *p*-channel-type FETs and MOS devices, providing that the breakdown voltage of the unit under consideration is 60 volts, minimum. For large-signal applications, 110 volts is the desirable breakdown voltage figure.[7-9] Note also that *n*-channel units generally exhibit higher gain and lower capacitance characteristics than the *p*-channel types. ■ ■

References:

1. W. A. Rheinfelder, "Biasing Considerations for FET Voltage Amplifiers," Dickson Engineering Report #2, Dickson Electronics Corp., Scottsdale, Ariz.
2. See Data Sheet Specifications of Dickson Q-Series FETs.
3. *Radiotron Designer's Handbook* (4th ed: Harrison, N. J.: Radio Corp. of America, 1952), p 18.
4. *Ibid*, p 37, Eq. 14.
5. W. A. Rheinfelder, *op. cit.*
6. W. A. Rheinfelder, "RF-Amplifiers: Solving the Stability Problem," ELECTRONIC DESIGN, Part 1: Dec 20, 1963, p 36; Part 2: Jan. 6, 1964, p 72.
7. "High Quality Phono-Equalizer using FETs," Dickson Engineering Report #7, Dickson Electronics Corp., Scottsdale, Ariz.
8. "Hi-Fi Drive Circuits Using FETs," Dickson Engineering Report #9, Dickson Electronics Corp., Scottsdale, Ariz.
9. "Convert Your Hi-Fi to Solid State the Easy Way With FETs," Dickson Engineering Report #10, Dickson Electronics Corp., Scottsdale, Ariz.

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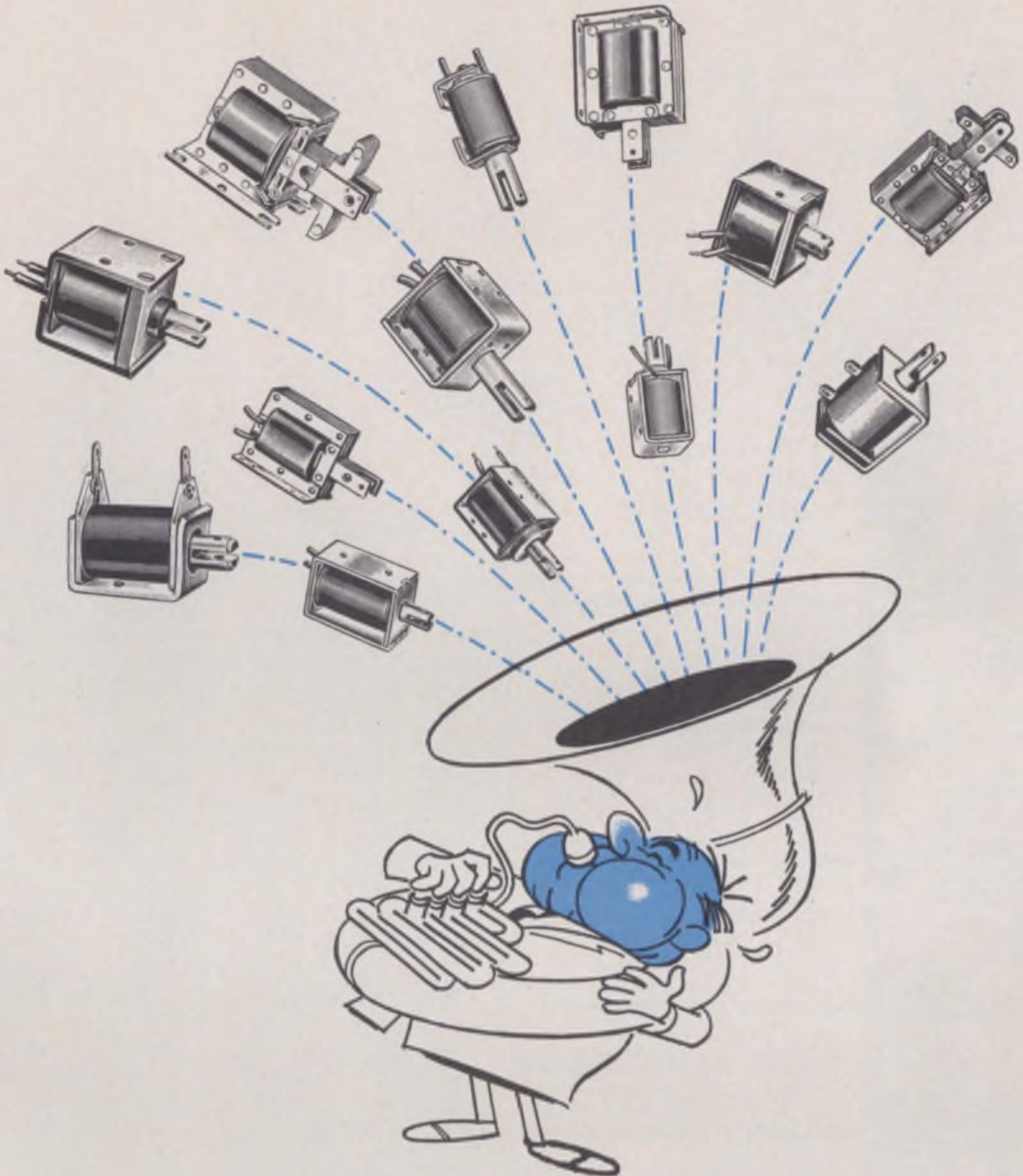

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This technique avoids the use of feedback stages to stabilize the gain, thus resulting in cost and component savings. It also dispenses with the need for measuring and selecting transistor types.

The method is applicable to differential as well as single and multi-stage amplifiers. It develops a gain-frequency response which exhibits a single pole and a single zero. Moreover, the frequencies at which the pole and zero occur are independent of one another.

Basics of multistage amplifiers

Multistage transistor amplifiers are frequently designed to make individual stage-gains roughly proportional to the βs of the transistors. With the wide variation of transistor βs from unit to unit, the over-all gain of these amplifiers (when using randomly selected transistors) is indeterminate. Individual-stage feedback can be used to stabilize the gain of a multistage amplifier, but this complicates the circuit. Over-all feedback can also be used to stabilize the gain. This, too, may prove to be a difficult method, because of the need to maintain loop stability at high frequencies in the face of uncertain transistor high-frequency characteristics.

By treating the transistor as a voltage, rather than a current, amplifier, it can be shown that the gain is primarily a function of the circuit and not of the transistor. In this type of design, the problems involve understanding and controlling the factors affecting transistor-voltage gain and then minimizing interstage-loading. This is done so that the gain of a multistage amplifier is merely the product of the individual-stage gains. The method is applicable to frequencies from dc to the $f\alpha$ cutoff.

For low-frequency operation, the equivalent circuit of Fig. 1a is appropriate. It includes the low-frequency, common-base current-transfer factor α_o, the base-spreading resistance, r_b', the emitter-diffusion resistance, r_e, and the reverse-voltage transfer-factor, μ_o. A series bulk-emitter resistance is not included, since it is much smaller than r_e at the emitter-current levels considered.

In addition, the resistance generally shown in shunt with the $\alpha_o I_e$ current source is omitted, since it is of too high a value (in most transistors) to have any significant effect on circuit operation. Note that V_{cb} voltage source is not the voltage from the collector to the external base connection b', but rather to b, a point more nearly representing the actual base potential level.

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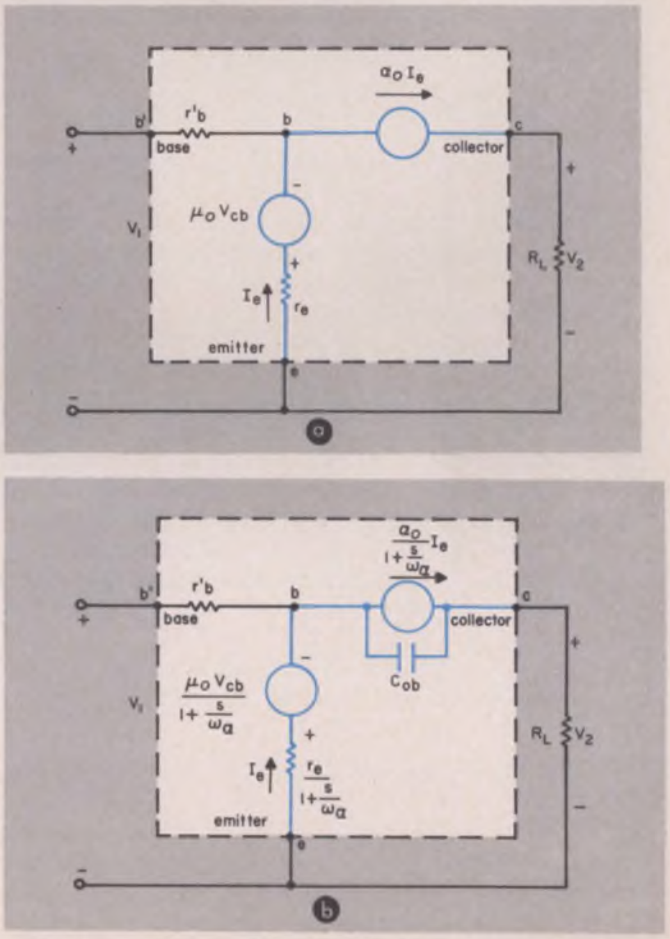


1. **Simple T-type equivalent circuit** for a low-frequency transistor-amplifier stage (a) is used to develop the gain and frequency response. The frequency-dependent parameters of transfer current, transfer voltage and diffusion resistance must be modified by the $(1 + s/\omega\alpha)$ for frequencies approaching cutoff (b).

W. E. Earle, Research Engineer, The Foxboro Co., Foxboro, Mass.

(continued from p 111)

At high frequencies, μ_o, α_o and r_e exhibit phase lags and should be replaced by $\mu_o/(1+s/\omega_\alpha)$, $\alpha_o/(1+s/\omega_\alpha)$ and $r_e/(1+s/\omega_\alpha)$, respectively. Here ω_α is the α cutoff frequency and $s = j\omega$. The collector-to-base junction capacitance, C_{ob}, should also be included at high frequencies, giving the complete high-frequency equivalent circuit (Fig. 1b).

Small-signal, low-frequency gain

The low-frequency voltage gain of a common-emitter transistor amplifier stage, as calculated from the equivalent circuit (Fig. 1a), is:

$$G_V = \frac{V_2}{V_1} = \frac{-\alpha_o R_L (1 - \mu_o)}{\mu_o \alpha_o R_L + r_e + \dfrac{r_b'}{\beta_o + 1}}, \tag{1}$$

where β_o is the low-frequency common-emitter current gain, related to α_o by $\beta_o = \alpha_o/(1-\alpha_o)$.

Assuming that $\alpha_o \approx 1$, $\mu_o << 1$ and $r_b'/(\beta_o+1) << r_e$,* Eq. 1 becomes:

$$G_V = \frac{-R_L}{\mu_o R_L + r_e}. \tag{2}$$

Inasmuch as $r_e = kT/qI_e$, then by choosing I_e and specifying that $r_e >> \mu_o R_L$ (make r_e fives times larger at least), Eq. 2 can be rewritten in a more convenient form as:

$$G_V = -\frac{qI_e}{kT} R_L = -\frac{R_L I_e(\mu A)}{25{,}900} \text{ (at 27°C)}, \tag{3}$$

subject to the constraint that $G_{V\,max} = -200$. Note also that $\mu_{o\,max} \leq 1 \times 10^{-3}$ for most silicon transistors. Thus, following Eq. 3, a known voltage gain for a single transistor amplifier can be guaranteed without actually measuring the values of the transistor parameters.

For a multistage amplifier, the collector's load resistor, R_L, of each stage is paralleled by the input resistance R_{in} of each succeeding stage. Hence, for Eq. 3 to remain valid for each stage of a multistage amplifier, the loading effect of a succeeding stage must be small. This requirement is generally satisfied if $R_{in} > 5R_L$ of the preceding stage.

Referring again to Fig. 1a, and assuming that $r_b'/(\beta_o+1) << r_e$, it can be shown that the input impedance of a common-emitter stage is given by $R_{in} = (\beta_o+1)(r_e+\mu_o R_L)$.

Since it has already been suggested that $\mu_o R_L << r_e$, then this can be simplified to:

$$R_{in} = (\beta_o + 1) r_e. \tag{4}$$

Using Eq. 4, the condition that $R_{in} \geq 5R_L$ becomes:

$$(\beta_o + 1) r_e \geq 5R_L \tag{5}$$

or, at 27°C:

$$\frac{5180(\beta_o + 1)}{I_e\,(\mu A)} \geq R_L \tag{6}$$

By satisfying Eq. 6 for each stage of a multistage amplifier, the over-all low-frequency gain will simply be the product of the individual-stage gains as calculated from Eq. 3.

High-frequency considerations

At higher frequencies (up to ω_α), the frequency dependencies of α_o, μ_o and r_e, and the collector-to-base capacitance must be included in the gain equation. The frequency-dependent voltage-gain expression, as derived from the high-frequency equivalent circuit (Fig. 1b), may be written as:

$$G_V = -R_L \Big/ \left\{\left[r_e + \frac{r_b' R_L C_{ob}}{\omega_\alpha} s^2\right] + s\left[r_b' r_e C_{ob} + r_b' R_L C_{ob} + \frac{r_b'}{\omega_\alpha} + R_L r_e C_{ob}\right]\right\}. \tag{7}$$

Eq. 7 is based upon the following assumptions: $\mu_o << 1$, $\alpha_o \approx 1$, $r_e >> r_b'/(\beta_o + 1)$ and $\omega r_e C_{ob} << 1$ (for $\omega < \omega_\alpha$).

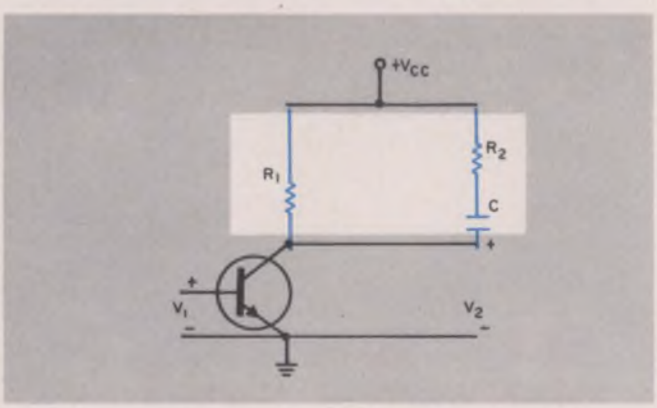
If the requirement that the gain equation contain only one pole for frequencies up to ω_α is now introduced, then the s^2 term of Eq. 7 must be made negligible compared to r_e at $\omega = \omega_\alpha$. This requirement is satisfied by making:

$$r_e \geq 5\, r_b' R_L C_{ob} \omega_\alpha. \tag{8}$$

With $r_b' \leq r_e$ (an assumption that is usually valid for a small-signal transistor operating at an emitter current of 1 ma or less), it follows that $r_b' C_{ob} \leq r_e C_{ob}$. However, it has already been stated that $r_e C_{ob} \omega_\alpha << 1$, making $r_b' C_{ob} << 1/\omega_\alpha$. This allows the $s r_b' r_e C_{ob}$ term in Eq. 7 to be neglected for frequencies up to ω_α. In addition, from Eq. 8, $(r_b'/r_e) R_L C_{ob} \leq 1/5\omega_\alpha$, which means that the $s r_b' R_L C_{ob}$ term can also be neglected. With these simplifications, Eq. 7 becomes:

$$G_V = \frac{-R_L}{r_e\left[1 + s\left(R_L C_{ob} + \dfrac{r_b'}{r_e \omega_\alpha}\right)\right]} \tag{9}$$

Using the assumptions made above, it can be seen (in Eq. 9) that $R_L C_{ob} >> r_b'/r_e \omega_\alpha$ for $R_L C_{ob}$



2. **Complex-load network** consisting of RC pair replaces ordinary load, R_L. This modification makes the frequency response of the amplifier independent of variations in the transistor parameters.

*This is generally true for $I_e \leq 1$ mA, as can be verified by referring to transistor specification sheets for $h_{ib\,max}$.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$\geq 1/\omega_\alpha$. Moreover, for $R_L C_{ob} < 1/\omega_\alpha$, the maximum value of the "s" coefficient is approximately equal to $1/\omega_\alpha$. If the operation is actually confined to frequencies slightly below ω_α (and this will generally be desirable due to the presence of a large, non-RC type phase lag near ω_α),[1] then for

$$\omega < \omega_\alpha, \tag{10}$$

Eq. 9 can be reduced to the simple gain expression:

$$G_V = \frac{-R_L}{r_e(1 + sR_L C_{ob})} \tag{11}$$

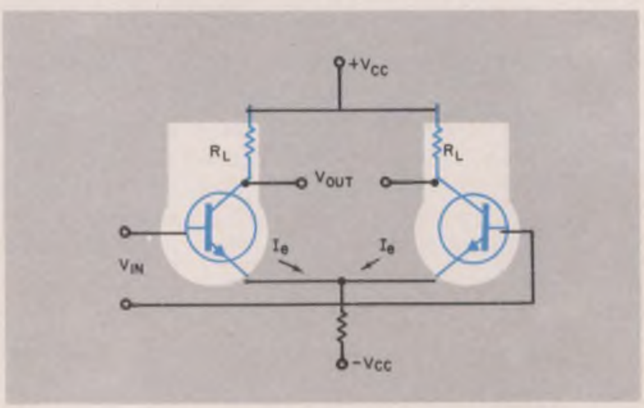
Controlling the frequency response

One way to modify Eq. 11 into a gain expression having a predetermined frequency response is to make it independent of the frequency for $\omega < \omega_\alpha$. This is possible by choosing R_L such that $R_L C_{ob} \leq 1/5\omega_\alpha$. Then R_L is replaced with the RC network shown in Fig. 2. With this complex impedance and the assumptions that $R_2 \leq R_L$ and $(1/\omega_\alpha C) << R_L$, the gain expression (for $\omega < \omega_\alpha$) becomes:

$$G_V = -\frac{R_1}{r_e}\frac{(1 + CR_2 s)}{[1 + C(R_1 + R_2)s]} \tag{12}$$

At any given temperature, Eq. 12 is independent of the transistor parameters within the limits of the assumptions used in the derivation. It features the ideal characteristic of a single-pole frequency and a single-zero frequency, each of which can be chosen independently.

As with operation at low frequencies, interstage loading at high frequencies must be minimized if the multistage gain is to be equal to the product of the individual stage gains. The calculation of the frequency-dependent common-emitter input impedance results in a Z_{in} consisting of r_b' in series with a parallel RC network. This parallel RC network is composed of the input diffusion resistance, $r_e(\beta_o + 1)$, and the sum of the diffusion capacitance $1/r_e \omega_\alpha$ and the "Miller Effect" capacitance $C_{ob}(G_V + 1)$. However, at high frequencies, the diffusion resistance can be neglected and the input impedance can be considered to be largely a capacitive reactance of the value:



3. **Differential amplifier-stage gain ($G_V = -R_L/r_e$) can also be designed to be independent of transistor beta variations. Each stage's collector resistance (R_L) is replaced by the appropriate RC network.**

$$X_c = \frac{1}{\omega[C_{ob}(G_V + 1) + 1/r_e\omega_\alpha]}. \tag{13}$$

This reactance is in series with r_b'. Generally, r_b' is negligible in comparison to X_c.

To minimize interstage loading, X_c should be at least five times larger than the preceding stage's load impedance at all desired operating frequencies. Usually the RC network used to characterize the frequency response of the preceding stage will also guarantee a sufficiently low source impedance to the succeeding stage. This will permit interstage loading to be small at all frequencies. It is desirable, nevertheless, to make a few trial calculations just to be certain that this loading is, in fact, negligible. If the loading is not negligible, then the circuit should be redesigned by altering the collector RC networks and by selecting different transistor types until the loading requirement is satisfied.

The multistage gain of an amplifier for all frequencies below f_T is then merely the product of the individual stage gains as given by Eq. 12. If the poles and zeros of each stage are chosen such that all but one pole and one zero cancel in the multistage gain-expression, then the over-all transfer function will be that of a single-order RC cutoff network. The adaptation of these design procedures to a differential amplifier is straightforward. The principle differences are that input and output impedances become doubled and the RC frequency network in Fig. 2 is connected between collectors, rather than from collector to power supply.

Determining maximum gain

Following the design suggestions presented, the maximum low-frequency voltage gain per stage for a differential amplifier consisting of n identical stages may now be determined.

A balanced, differential stage (Fig. 3) has a differential voltage gain of:

$$G_V = -\frac{R_L}{r_e}, \tag{14}$$

where r_e is the emitter's diffusion resistance for one transistor. Although the input signal to each transistor of a differential stage is one-half of that of a single-ended stage, the use of two collector load resistors results in the same gain expressions for both differential and single-ended stages (Eq. 14).

The input impedance to a differential stage is twice that to a single-ended stage. However, this doubled input impedance is in parallel with twice the value of the load resistance of the preceding stage, thereby leaving unchanged the interstage loading requirement (Eq. 5). Since R_L in Eq. 14 and R_L in Eq. 5 are identical for this problem, the the equations can be combined to give:

$$G_{V(max\ per\ stage)} = 0.2(\beta_o + 1), \tag{15}$$

which is the desired solution.

Step-by-step multistage design

Using two stages of the amplifier problem discussed above, the component values needed to obtain maximum low-frequency voltage gain can be determined. A single-order RC type frequency-response characteristic and unity gain for frequencies above 1 MHz are required. The transistors are type 2N1711, operating with an emitter current of 100 μA.

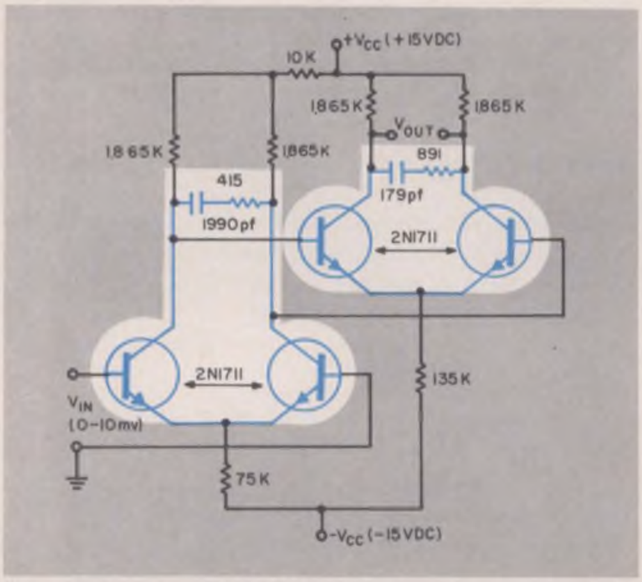
From the 2N1711 data sheet, the dc-β at I_e = 100 μA is a minimum of 35. This value for β_o yields:

$G_{V(max\ per\ stage)} = 7.2$ and $G_{Vmax(both\ stages)} = 51.8$.

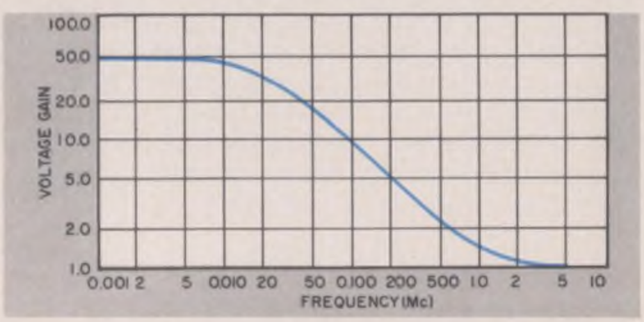
Using Eq. 6:

$$R_L = \frac{5180(\beta_o + 1)}{I_e(\mu A)} = 1865 \text{ ohms}$$

The RC networks across the first- and second-stage collectors (Fig. 4) designed to attenuate the over-all gain from 51.8 at low frequencies to unity at high frequencies, are determined from Eq. 12. It is assumed that the networks across the first and second stages attenuate the high-frequency gain by factors of 10 and 5.18, respectively, with the 1-MHz cutoff occurring in the second stage Since the second-stage network only attenuates the second-stage gain by a factor of 5.18, the high-frequency gain of the second stage is given by Eq. 12:



4. **Multistage amplifier network** achieves maximum low-frequency gain and predicted frequency response without measurement of transistor parameters.



5. **Single-order RC-type cutoff characteristic** to beyond 1 MHz is exhibited by the amplifier in Fig. 4.

$$G_{V(hf)} = -\frac{7.2}{5.18} = \frac{R_1 I_e(\mu A)}{25,900}\left[\frac{R_2}{R_1' + R_2}\right], \quad (16)$$

where R_1 is R_L or 1865 ohms. The resistor R_1' represents $2R_L$ or 3730 ohms. The discrepancy arises because the low-frequency voltage gain is expressed in terms of the load resistance, R_L, for a single-ended stage. However, the high-frequency gain depends on the relationship between R_2 and the sum of the two load resistors, $2R_L$. Thus, solving Eq. 16 gives $R_{2(second\ stage)}$ = 891 ohms. To obtain an attenuation factor of 10 in the first stage, a similar application of Eq. 12 results in $R_{2(first\ stage)}$ = 415 ohms.

The high-frequency break point of 1 MHz corresponds to the zero of Eq. 12, or $\omega R_2 C = 1.0$. This makes $C_{(second\ stage)}$ =179 pF and establishes a pole for the second stage at 193 kHz. If the frequency of the zero of the first stage is to equal the pole frequency of the second stage (193 kHz) so as to achieve the effect of a single-order RC-type cutoff characteristic, then the solution of the expression $\omega C R_2 = 1$ for the first stage yields $C_{(first\ stage)}$ = 1990 pF. The frequency-response characteristic of the circuit appears in Fig. 5.

Before accepting this design as final, the following four conditions should be verified.

1. $G_{V(per\text{-}stage)} \leq 200$
2. $I_e \leq 1$ mA
3. $\frac{f_T R_2 C_{ob}}{2} \leq 0.0315$*
4. $\frac{R_2 C f_T}{2} \geqslant 0.159$†

Conditions 1 and 2 are obviously true. For conditions 3 and 4, a knowledge of C_{ob} and f_T is necessary. C_{ob} from the 2N1711 data sheet is stated as a maximum of 8 pF, but f_T is not given at the chosen emitter current.

However, if a capacitance bridge is available, the determination of f_T is not difficult. By measuring h_{ie} as a parallel RC combination at the chosen emitter current, f_T can be calculated from the relationship:†

$$f_T = \frac{I_e(\mu A)}{2\pi C_p(25,900)}, \quad (17)$$

where C_p is the measured value of parallel capacitance and $\beta_o >> 1$. The test frequency used in measuring C_p is not critical, provided that it is lower than f_T. For the 2N1711 at I_e = 100 μA, C_p is typically 120 pF, giving an f_T of about 5 MHz. With a 5-MHz f_T, conditions 3 and 4 are both satisfied, justifying the design in Fig. 4 for frequencies up to f_T. ■ ■

Reference:

1. D. E. Thomas and J. L. Moll, "Junction Transistor Short-Circuit Current Gain and Phase Determination", *Proc. IRE*, June, 1958, pp 1177-1184.

*The factor of ½ is used for a differential amplifier. For single-ended amplifiers, this factor is omitted.

†This relationship can be derived from the definition of f_T, using the equivalent circuit in Fig. 1b.

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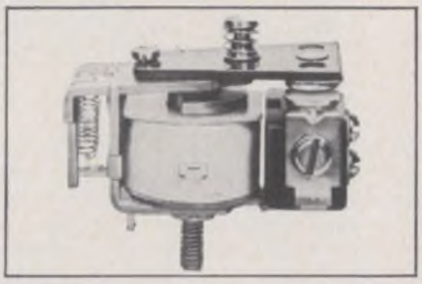

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Switch high power with diodes mounted like the spokes of a wheel and shunting a coaxial line. The device can cover wide bands of microwave frequencies.

Need a high-power microwave switch to cover a broad frequency band?

Take a conventional low-pass filter. Replace its shunt capacitors with *pin* or varactors diodes, its series inductors with short, high-impedance transmission lines and you can end up with a broadband microwave switch or limiter. If instead of one diode, many diodes are mounted in a radial fashion, the device not only will keep its broad band, but will handle high power as well.

Of course, the design is not at all as simple as we made it sound. The many problems like matching, proper biasing, loss reduction and ways to solve them are the subject of this article.

The design approach naturally separates into two parts:

- Providing broad band.
- Increasing power-handling ability.

The broadband design procedure is straightforward and is based on the Chebyshev approach. It yields broader band than the maximally flat, or Butterworth, design with the same shunt capacitance value. The price paid for the wider low-loss band is ripple in the operating frequency range.

The switch has the form of a cascaded pi[1] network (Fig. 1a), with response curves like those in Fig. 1b. During reverse and zero biases, the diodes complete the low-pass filter, which is designed for a high cutoff frequency. The signal suffers very little attenuation. However, when a forward bias is applied to the shunt diodes, they appear as low inductive reactances. This obviously destroys the matched-filter structure and severely attenuates the propagating signal.

Parasitics cut down diode capacitance

Though the design of Chebyshev filters is quite conventional, several practical factors must be considered before the diodes are selected:

- Parasitic capacitance of the package, C_p, shunting the diode in Fig. 2.
- Parasitic series inductance, L_s, that causes an apparent increase in the junction capacitance.
- Capacitance resulting from structural discontinuities. The abrupt change in the diameter of the coaxial line increases the capacitance of the transmission line. This physical discontinuity is shown in Fig. 3.
- Capacitance per unit length of the coaxial line over the region occupied by the diode package.

Since the total capacitance of the switch or the limiter is a fixed quantity, these added capacitances decrease the needed junction capacitance of the diode. The junction capacitance is directly proportional to the area of the diode, which, in turn, determines its power-dissipating ability. The conclusion is clear: Keep C_p and L_s as low as possible. (Obviously the best solution would be to discard the package and put the semiconductor chip directly into the transmission line. Even though some experimental work is in progress, there is much to be done in this area before practical designs can be achieved.)

The basic design concept of a wideband, high-power *pin* switch or limiter involves, then, a classical low-pass filter with shunt capacitances and series inductances. The table gives constants for the calculation of the various values of L and C once the cut-off frequency, f_{co}, and the characteristic impedance valve, Z_o, are known. Several sets of constants are given for various values of maximum bandpass ripple. The ripple determines the theoretical maximum vswr that will be encountered in the frequency range of interest. For example, a 0.2-dB ripple characteristic implies a maximum vswr of 1.54. The ripple in decibels is $-10 \log_{10} (1-\rho^2)$, where ρ is the reflection coefficient.

Note that increasing maximum bandpass ripple or decreasing Z_o yields higher capacitance values. This is the key factor in increasing the power-handling ability of the device, since larger junction areas can be used.

As for the inductance values, short sections of high-impedance line can supply them. The electrical length of these line sections must be less than one-eighth of a wavelength at the cut-off frequency to insure that they act as true lumped inductances. This condition is usually satisfied if the inductive sections have a characteristic impedance value, Z_{ol}, of at least twice Z_o. Once Z_{ol} is selected, the required lengths may be calculated:

$$L_n = \frac{g_n Z_o}{\omega_{co}}, \tag{1}$$

Robert H. Brunton, III, Project Engineer, Microwave Associates, Inc., Burlington, Mass.

$$C_n = \frac{g_n}{\omega_{co} Z_o},$$

where:

C_n = capacitance required for each capacitor in filter, in pF.

L_n = inductance of line segments required for filter, in nH. It must be greater than or equal to $2Z_o$.

g_n = Chebyshev constant from table,

f_{co} = cutoff frequency, $\omega_{co}/2\pi$

The inductance per inch of transmission line is given as:

$$L = 0.085\ Z_o\ nH/in$$

The value of Z_o usually chosen for low-pass filter switches and limiters is less than 50 ohms. To prevent a mismatch to the line, it is necessary to design input and output impedance transformers.[2] The simplest approach is to use quarter-wave transformers, since these consist of cascaded sections of transmission lines. The design is straightforward—each section must be one-quarter wave-length long at the center frequency. The result is a broadband impedance transformer that may match 50 ohms to 25, 12.5 and 6.25 ohms in several steps.

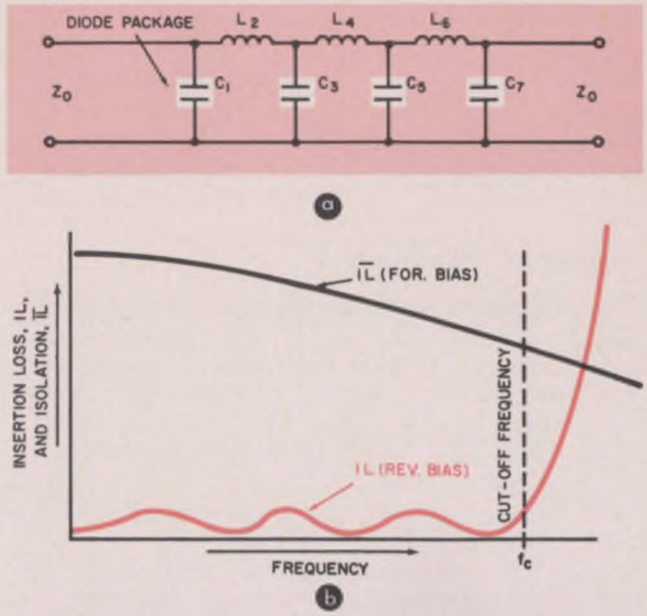
Biasing method depends on diodes

There are two accepted methods of bias: (1) The common-bias technique and (2) individual biasing of all diodes.

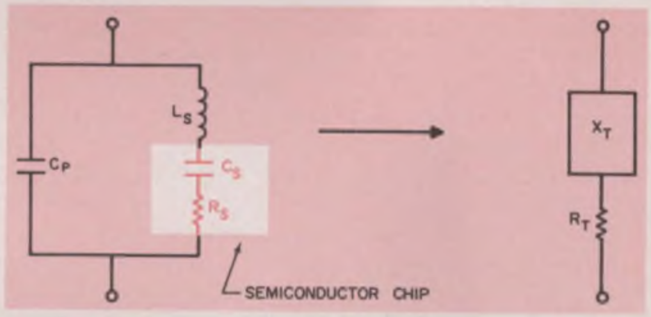
Common biasing may be used when the diodes are well matched. A broadband bias tee feeds the

Chebyshev constants for various ripple values of a lowpass filter.

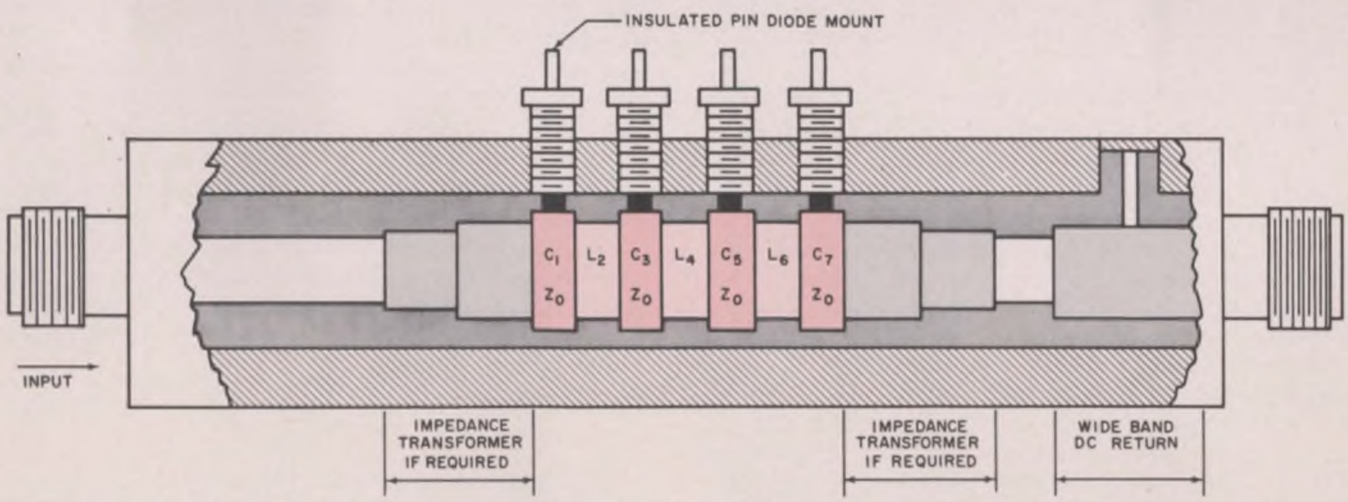
db ripple	$g_{1(C)}$	$g_{2(L)}$	$g_{3(C)}$	$g_{4(L)}$	$g_{5(C)}$	$g_{6(L)}$	$g_{7(C)}$
0.01	.797	1.392	1.748	1.633	1.748	1.392	.797
0.1	1.181	1.423	2.097	1.573	2.097	1.423	1.181
0.2	1.372	1.378	2.276	1.50	2.276	1.378	1.372



1. Broadband switch has low-pass filter structure (a). When diodes are reverse-biased, the structure acts as a low-pass filter and the insertion loss is small (b). During forward bias, the diodes appear as inductive elements, and because the matched condition is destroyed, the signal will be greatly attenuated.



2. Equivalent circuit of diode and its package illustrates the parasitic reactances that have to be considered. Both C_p and L_s increase the apparent capacitance of the diode package. Therefore the larger these values, the smaller is the actual capacitance of the diode, C_s, needed for a given design, since the total capacitance is a fixed quantity.



3. Construction of switch or limiter may include two or more impedance transformers. Some parasitic capacitance results from the abrupt change in the diameter of the line between a diode package and the inductive transmission-line segments. The low-pass filter structure is built with seven elements, as in Fig. 1.

bias voltage to the center conductor and, if the diodes are matched, each will be equally biased.

Individual biasing of the diodes insures equal bias even though the diodes are not well matched. Also, this method is preferred for maximum power handling, since each diode is assured of sufficient bias—the current distribution will be equal.

Designing for high power

The design considerations for extending the power-handling ability of diode switches and limiters must be approached from two directions:

- Optimizing the physical and electrical circuit with respect to the diodes used.
- Not exceeding the temperature limits of the diodes.

Although these two points are related, they are best treated separately.

Under a forward-bias condition (high loss), the same rules apply to both switches and limiters. However, the switch must sustain high power under reverse bias, or low-loss state, while limiters don't.

We are going to show that diodes can and must be mounted radially to achieve high power-handling capability in both switches and limiters. Furthermore, the conditions for high-power operation for switches under reverse bias will turn out to be the same as for forward-bias.

Mounting many diodes radially around the center conductor will obviously change impedance levels, isolation, insertion losses and other vital parameters. The proper design approach may be evaluated through the exact equivalent circuit of a diode shunting a transmission line (Fig. 4).

Assume that low RF-power conditions exist. Then $R_p >> Z_o$. The capacitance, C_T, does not contribute to the loss since it has been incorporated into the filter structure. Therefore, the power dissipation is due solely to dissipation in R_p:

$$P_d = \frac{P_{in} Z_o}{R_p}, \qquad (2)$$

where P_{in} is the incident power, P_d is the dissipated power and P_{in} Z_o represents the square of the line voltage across the effective shunt resistance of the diode.

If more than one diode is placed in shunt at the same physical location, then:

$$P_{dt} = \frac{P_{in} Z_o N}{R_p}, \qquad (3)$$

where P_{dt} represents the total power dissipated by all diodes.

As would be expected, the power dissipated increases with increasing N, the number of diodes employed, for a constant line impedance, Z_o. This appears as a higher insertion loss.

To overcome this increase in insertion loss, Z_o can be decreased so that Z_oN remains constant in Eq. 3. Therefore, the insertion loss of a single diode in a 50-ohm coax line is comparable to five similar diodes in a 10-ohm line. It is necessary, of course, to have appropriate transformers to change the 10-ohm coaxial section back to 50 ohms at both input and output ports.

So far we have established the fact that the paralleling of diodes can be made independent of insertion loss.

Next, high-power isolation during forward bias must be considered. In this case, both the diode switch and the limiter closely approximate short circuit. Here, twice the line current for a specific input power will flow through the diode and contribute to the power dissipated in R, as shown in Fig. 4b. For a single diode shunting a transmission line under isolating conditions, the power dissipated within the diode, $\overline{P}_d$, can be expressed as:

$$\overline{P}_d = \frac{4P_{in} R_s}{Z_o} \qquad (4)$$

where the term $4P_{in}/Z_o$ represents the square of twice the line current $(2\ I_{line})^2$. As in the low-insertion-loss case, the paralleling of diodes will now be assumed. The total dissipated, $\overline{P}_{dt}$, is given:

$$\overline{P}_{dt} = \frac{4P_{in} R_s}{Z_o n} \qquad (5)$$

This equation shows that, as in the low-level case, the dissipated power can be kept the same if Z_oN remains a constant.

Therefore, increasing the number of diodes to N and keeping the product NZ_o constant increases the switch or limiter power-handling capability. The effect of the approach may be summarized as:

- Insertion loss can be kept low.
- Power-handling capability of the switch or limiter is increased by the factor N.
- Power dissipated per diode is the same as in the single-diode case.

If the switch or limiter in Fig. 3 has a 1.0 kW peak power-handling capability, it could be increased by a factor of ten by reducing Z_o to one-tenth of its value and by using 10 diodes per stage.

Switches: reverse bias causes problems

With switches, an additional difficulty arises. The *pin* diode must sustain high power under reverse-bias conditions.

Experimental results indicate that about 80% diode reverse-voltage breakdown rating should be used when determining the maximum line voltage for a given diode.

In the reverse-bias state, Fig. 4a, assume again that $R_p >> Z_o$. Thus, dissipation losses are low and C_T is incorporated in the low-pass filter structure. Assuming a transmission-line impedance, Z_o, and a maximum RF voltage rating, E_m, for the diode, we can express the maximum power-handling capability as follows:

$$P_m = \frac{(E_m)^2}{Z_o}. \qquad (6)$$

The maximum power rating, P_m, can be increased by lowering the characteristic impedance, Z_o. For example, if a specific diode can handle only 1 kW in the reverse-bias state when shunting a 50-ohm line, 5 kW can be handled by simply lowering Z_o to 10 ohms. It is assumed that the RF voltage appears across the *pn* junction and only a negligible amount drops across L_s. At higher frequencies, this assumption is not exactly true, hence a voltage larger than line voltage will be across the diode junction. This will tend to decrease the power-handling capability.

The analysis shows that, for reverse bias, power-handling capability can be increased by the following two modifications:

- Using N diodes at the same location.
- Reducing Z_o for the single diode case by the factor N.

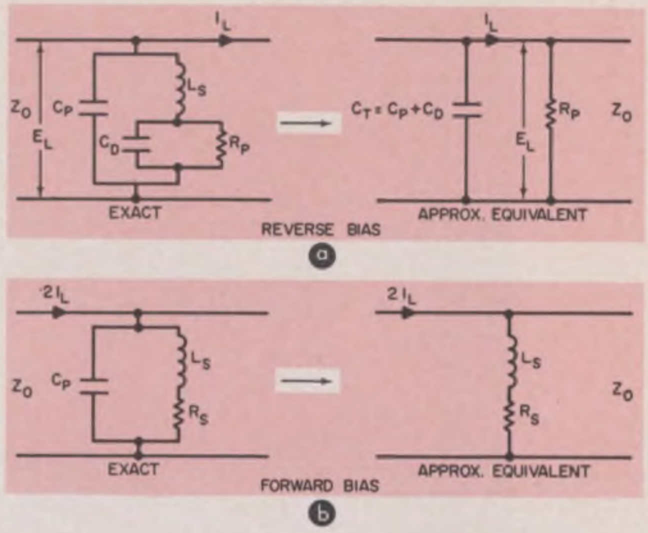
Note that this approach increases the power-handling capability by the factor N for both the forward- and reverse-bias states. It reduces the RF voltage across the diodes during reverse bias and keeps the power dissipation per diode constant during forward bias.

The insertion loss will also remain constant, since the lowering of R_p, as shown in Fig. 4a, is accompanied by a corresponding reduction in Z_o. This relation is expressed as:

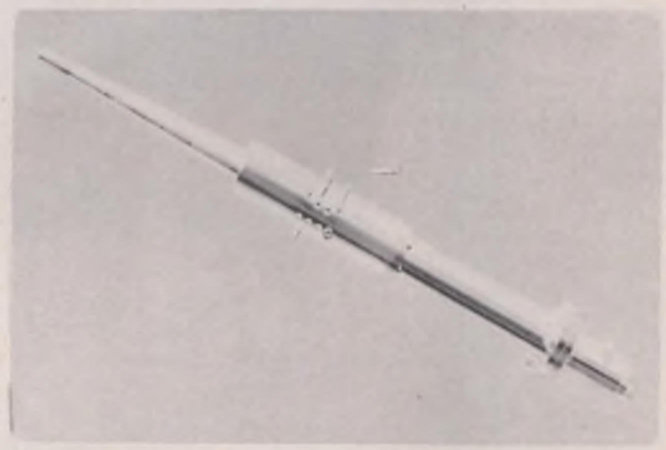
$$IL = 1 + \frac{g^2 + 4g}{4}, \qquad (7)$$

where IL is the dissipative insertion loss and g is the normalized shunt conductance, Z_oN/R_s. By keeping NZ_o constant, as was previously stated, the insertion loss will not change.

The temperature rise of a diode junction due to the RF energy applied is the other criteria that determines the power-handling capability of the diode. It is generally assumed that the maximum permissible junction temperature is 200°C and that a sufficient safety factor exists when the diode junction is operated at not more than 150°C. Thus, it is important to know the peak temperature which a diode will reach under operating conditions. Knowledge of the thermal resistance is highly desirable for diodes used in switches.[3]



4. Exact equivalent circuits of the diode shunting the transmission line are needed to find the power-handling capacity during forward and reverse bias.



5. Radial mounting of diodes in a microwave switch or limiter increases the device's power-handling capability. This coaxial switch covers the frequency range of from 1 to 4.5 GHz and can switch 30 kW peak and 30 watts average power in 200 ns.

Switch handles 3 kW peak power

Consider the following specifications: A switch is needed to cover the frequency range from 1 to 4.5 GHz at a peak input power of 30 kW and with a ripple factor of 0.2.

The filter will consist of seven elements, as shown in Fig. 1. The values of the capacitances and inductances can be found with the aid of the table and Eq. 4, once the cut-off frequency has been established.

Let the cut-off frequency be 4.8 GHz. The line impedance should be 6.25 Ω to prevent the line voltage from exceeding 500 volts at peak power. Let $C_1 = C_7$, $C_3 = C_5$ and $L_2 = L_6$. This arrangement maintains matched conditions.

From the table:

$g_1 = 1.372$, $C_1 = C_7 = g_1/(\omega_{co} Z_o) = 7.3$ pF.

$g_3 = 2.276$, $C_3 = C_5 = 12.0$ pF.

$g_2 = 1.378$, $L_2 = L_6 = g_2 Z_o/\omega_{co} = 0.29$ μH.

$g_4 = 1.50$, $L_4 = 0.31$ μH.

The switch uses 28 silicon pin diodes, type MA-4573A2. The diodes are grouped into four sections of six, eight, eight and six and mounted radially (Fig. 5.) in a 7/8-inch coaxial transmission line.

The actually used typical junction capacitance of the diodes was 0.65 pF. This led to a lower-than-calculated value of the over-all capacitance for each section and compensated for the package parasitics.

Test results showed that the capacity per section should be about 60% of the calculated values.

The switch has a maximum switching speed of 200 ns and can handle 30 kW peak and 30 watts average power. Its insertion loss is 1.1 dB and isolation was measured as 33 dB. ■ ■

References:

1. S. B. Cohn, "Direct Coupled Resonator Filter," *Proc. IRE*, Vol. 43, Feb., 1957, p 187-196.
2. L. Young, G. L. Matthaei, "Microwave Filters and Coupling Structures," Stanford Research Institute Project, Report No 4, January, 1962.
3. K. Mortenson, "Study of Utilization of Microwave Interaction in Semiconductors," Microwave Associates, Inc., Contract No. AF33 (657)-10001, Project No. 4460, Task No. 446001, Final Report, November, 1964.

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Transmission losses of signals in the optical and infrared region can be read off quickly and quite accurately from this graph.

Optical design, particularly in the infrared region, often requires a quick estimate of the amount of radiation transmitted through various optical materials. This optical-transmission nomograph supplies the answer—only one multiplication and the location of one point is needed.

Consider the case when several materials are used in layers. Instead of calculating the effect of each material with the equation below, losses can be read off directly from the graph.

The percent of transmitted radiation for any particular material is dependent upon (1) the absorption of the radiation by the material and (2) the amount of radiation reflected from the material's surfaces. The reflection, in turn, is a function of its refraction index.

The graph is based on the following equation. It is valid throughout the optical-infrared spectrum, if the angle of incidence is within 10 degrees of the normal to the surface:

$$100t = \left[1 - \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2\right]^2 e^{-\alpha x}. \quad (1)$$

Thomas E. Lusk, Research Physicist, General Electric Co., Cleveland, Ohio

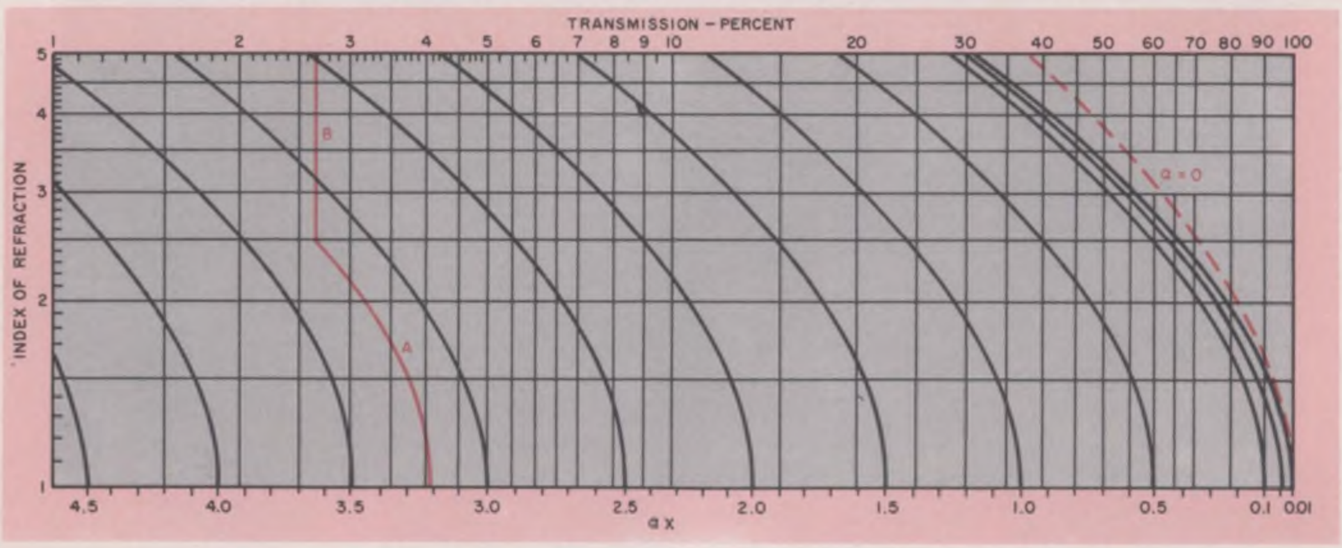
The symbols in this equation represent:

t = transmittance
α = absorption coefficient
x = thickness of material
n_2 = index of refraction of the material
n_1 = index of the material in which n_2 is immersed.

The equation is valid if the angle of the incident radiation is within about 10 degrees of the normal to the surface. This is not really a limitation, since the field of view is usually narrow.

To use this nomograph, the product of the thickness and the absorption coefficient of the material at the wavelength of interest must first be determined. If this product is between 4.5 and 0.0085, the transmission will be between 1.0% and 100%, which is the range of this nomograph. Since, for most practical cases, the absorption coefficients are between approximately 10 mm^{-1} and 0.01 mm^{-1}, the thicknesses which lie within the range of this nomograph vary from 0.85 mm to 450 mm.

For absorption-coefficient values much below 0.01 mm^{-1}, the absorption becomes negligible and the transmission losses are essentially due to Fresnel reflection. In this case, the percentage of transmission can be approximated by:



$$100\,t = 2n/\,(n^2 + 1), \qquad (2)$$

where n is the index of refraction, the material is in air and the light is almost normally incident upon it.

In this case—that is, for zero absorption—the amount of transmitted energy can be determined with the lowest curved line of the graph. The intersection of this curve with a vertical line, representing the value of the refraction index, is a pivot for drawing a horizontal line to the transmission ordinate, giving the percentage of transmitted energy.

When absorption is present, the procedure is basically similar, except that a different curve is needed. The curve originates from a point that represents the product of the sample's thickness, x, and its absorption coefficient, α.

For example, find the percentage of transmission for a material with a thickness of 2.2 mm, an absorption coefficient of 1.5 mm^{-1} and an index of 2.5. Multiply x times α, to obtain 3.3.

Locate 3.3 on the αx scale and draw a line parallel to the curved lines (color line on nomograph) until it intersects the line for a 2.5 refractive index. Draw a straight line from this point horizontally to the transmission scale. The transmitted energy is 2.7% of the incident value.

Finding the absorption coefficient

The nomograph can also be used to find the absorption coefficient of a material if the thickness and the percentage of transmission are known.

This is accomplished by finding the intersection of a horizontal line from the transmission scale and a vertical line from the index of refraction scale. Move this point parallel to the curved lines to the αx scale. Dividing this αx value by x, the material thickness, gives α, the absorption coefficient.

This value of the absorption coefficient may then be used to find the transmission of all other thicknesses of the same material at the chosen refractive index.

This nomograph may be used when the problem is to select a detector for a system. This requires a knowledge of the target's size, the amount and the spectral distribution of the emitted radiation, the distance to the target, the absorption of the atmosphere, the amount of radiation transmitted by the collecting optics and the absorption characteristics of the detector. Usually, the system designer can only control the collecting optics and, to some extent, the absorption characteristics of the detector. This puts a heavy burden upon the proper selection of the optical materials.

Many optical systems are protected with a dome of material that transmits the spectral range of interest. Or, the detector is immersed in a lens to increase its performance. Here the designer has to compromise between optimum detector performance and the thickness of the source material which effects its structural strength and refractive properties. ■ ■

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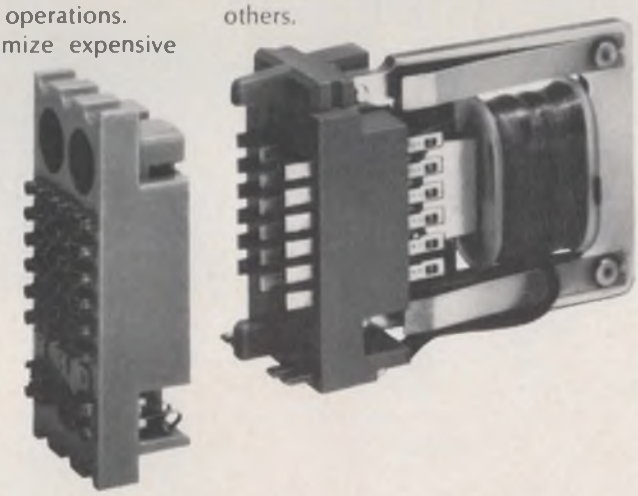

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ON READER-SERVICE CARD CIRCLE 149

Transmission-gate circuit processes video signals

A simple, three-stage transmission-gate circuit uses pulse logic to attenuate unwanted portions of a video signal. The circuit, which has a 7-MHz upper 3-dB point, also features a combination balancing-offset adjustment.

Its signal-attenuating capability is derived from a voltage divider consisting of R_s and the Q_2-CR_1 combination (Fig. 1a). The input to the gate is a 5-volt pulse which turns Q_3 on. This places Q_2 in the OFF state and permits the video to pass without attenuation.

When the gate input falls to zero, Q_3 is turned off. This permits Q_2 to be biased into saturation, thus presenting a low impedance between point *M* and ground. In this state the attenuation is 30 dB min (Fig. 1b).

Thus, by opening and closing the gate at appropriate intervals, unwanted portions of the video are removed and desirable portions remain intact. The 5k potentiometer in the base of Q_1 permits the gate level to be adjusted to fit the dynamic range of the input video.

Jack K. Hickman, Apparatus Engineer, Texas Instruments Inc., Dallas, Tex.

VOTE FOR 110

(continued on p 130)

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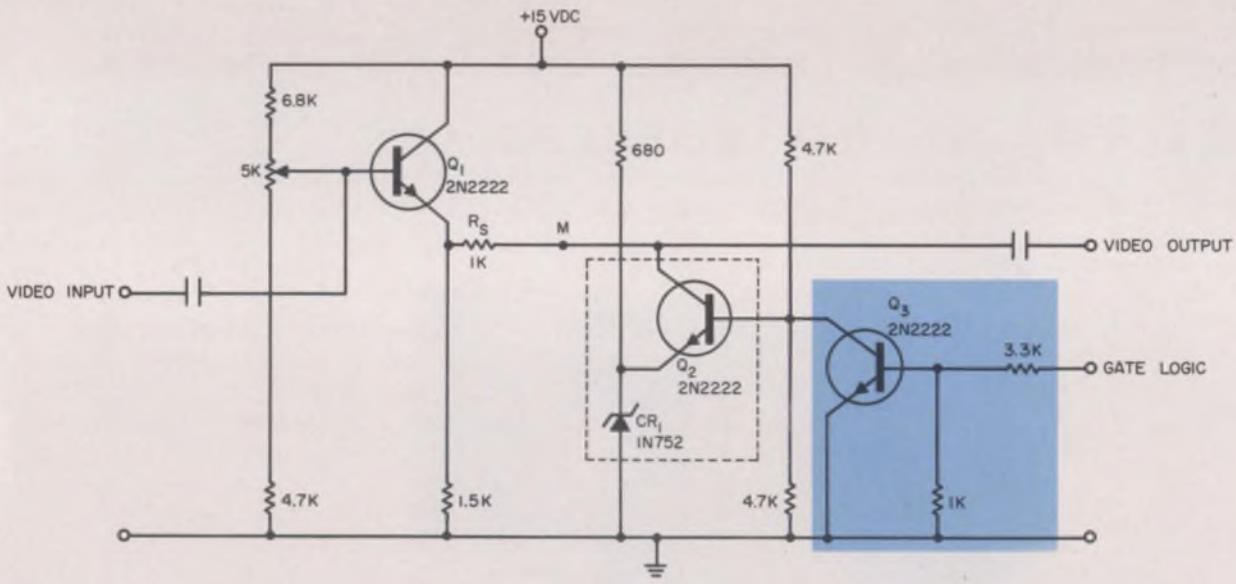
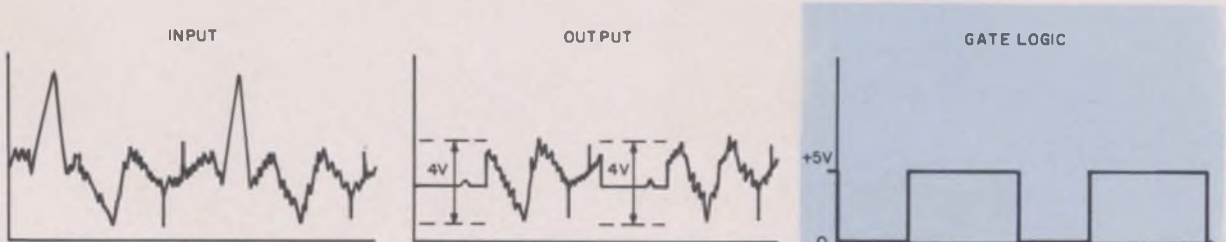


a



b

Pulse logic applied to the gating transistor, Q_3, of this video signal processor (a) determines which portions of the input video are attenuated. **Q_2** and **CR_1** form an inserted attenuator when **Q_3** is OFF. Waveforms are in (b).

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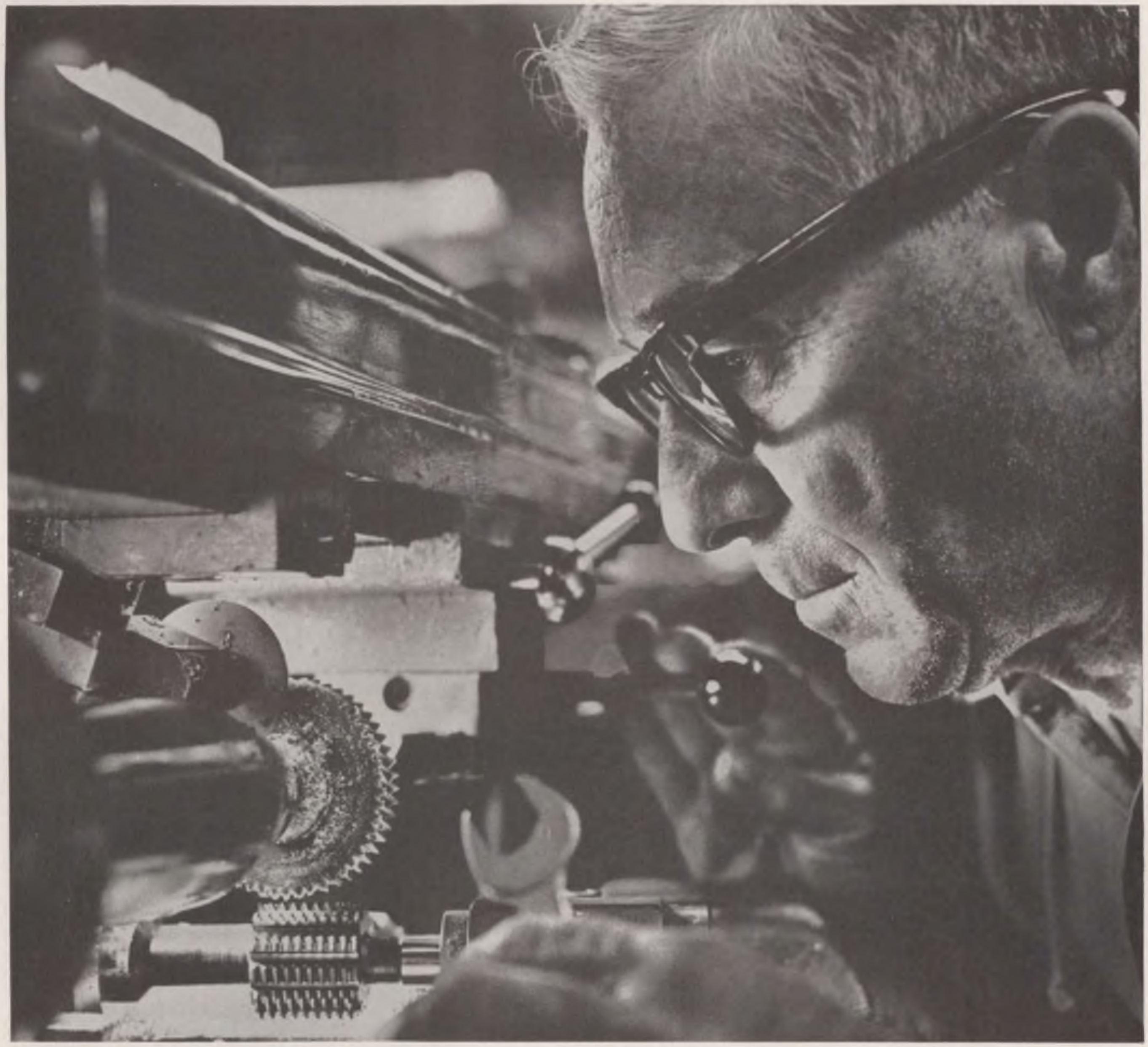

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Bipolar current source simplifies triangle generator

A bipolar current-source concept, when applied to the charging network of a triangle-wave generator, provides a constant amplitude output over a wide frequency range. Moreover, this design approach requires less components than competing arrangements.

Triangle generators have a wide variety of applications. To cite two, the determination of the dynamic linearity of amplifiers as a function of frequency, and as a function generator for analog computers.

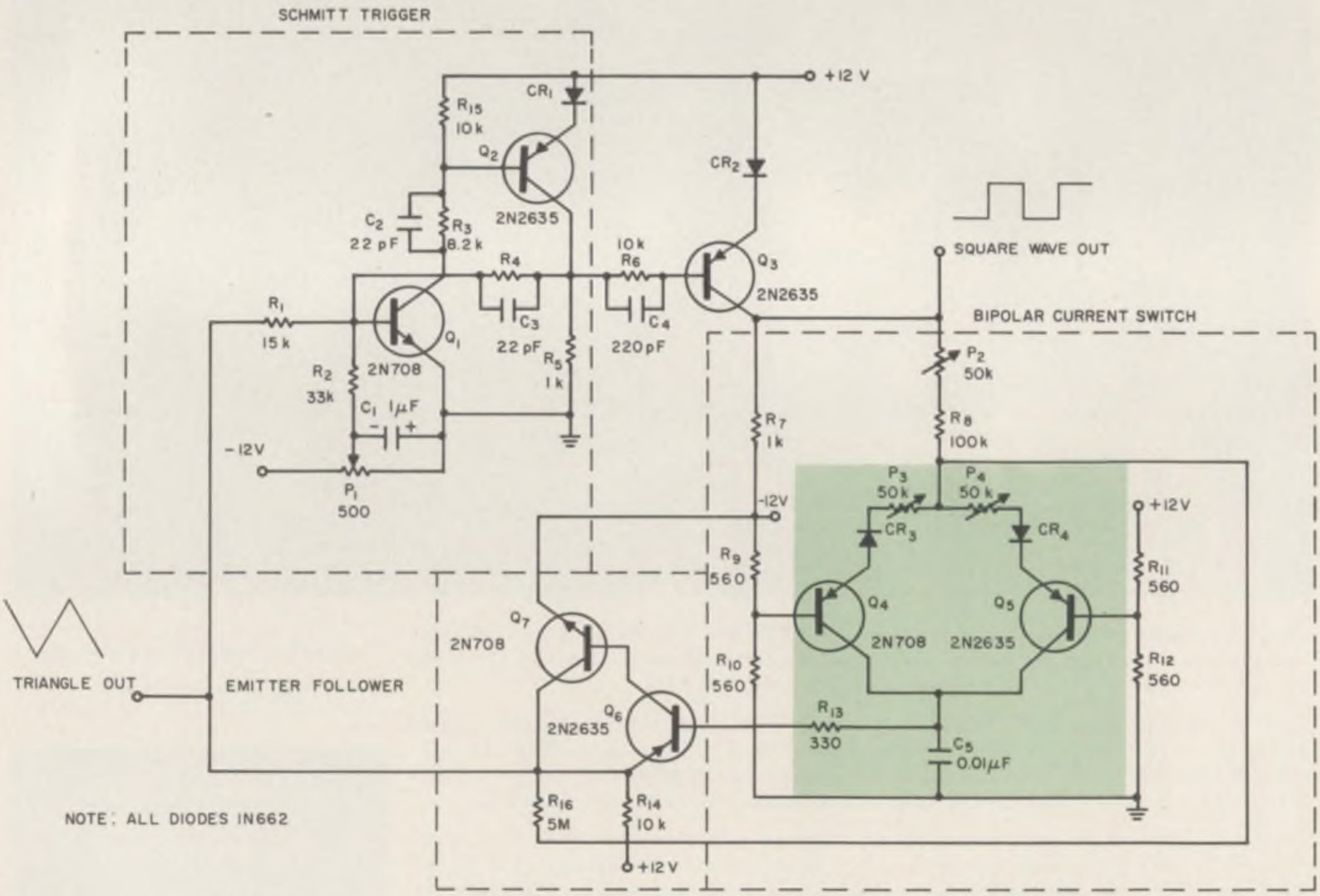
The conventional design of the generator converts a sine wave into a square wave. This square wave is then integrated and amplified. The amplitude of the triangle is maintained constant by compensating for changes in the integrator's output voltage. This is achieved by using a dc voltage proportional to the frequency and feeding it to the integrator. This circuit scheme used 14 transistors.

Another standard design approach to triangle generators entails the use of two current sources. Each current source charges a capacitor in only one direction. A peak detector then turns off the charging source and turns on a constant-current sink which charges the capacitor in the reverse direction until another peak detector is turned on. The frequency may be varied by changing the capacitor values. The slope of either side of the output is varied independently by two resistors. This design used 10 transistors and one unijunction transistor.

A bipolar current source concept can be used to generate a constant-amplitude triangular wave form over a frequency range of 250 to 1. The circuit has provisions for varying the positive or negative slope at any given frequency. In addition, it provides a square wave output. The circuit uses only seven transistors to achieve this (Fig. 1).

The bipolar current source is made up of two transistors, an npn and a pnp. Depending on the polarity, the transistor will act as a constant current source charging a capacitor to a positive voltage, or as a constant current sink charging the capacitor to a negative voltage. The Schmitt trigger has a large hysteresis. When the voltage on the capacitor is positive enough to exceed the trip point of the Schmitt, the polarity on the bipolar current source is reversed and the voltage on the capacitor reverses direction.

Due to the hysteresis of the Schmitt, the voltage on the capacitor has to drop 5 volts (approximately) in order to turn off the Schmitt. Once turned off, the polarity of the bipolar current source is



1. **Bipolar current sources** (color) are used in the charging network of a triangle generator. The output has constant amplitude over a 250:1 frequency range, since the Schmitt trigger's hysteresis is constant.

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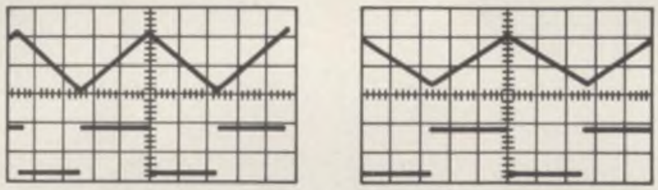
reversed and the cycle is repeated. An emitter-follower is used to decouple the capacitor from the Schmitt. The bipolar current source uses one potentiometer to drive the current through the capacitor in either direction. Thus the output is symmetrical over a wide frequency range. Since the Schmitt's hysteresis is constant, the amplitude of the output triangle wave does not change.

Q_1 and Q_2 make up a complementary Schmitt trigger. Q_3 functions as a switch to apply positive or negative polarity to the bipolar current switch, Q_4 and Q_5. The bipolar current switch charges C_5 in either the positive or negative direction. Q_6 and Q_7 are emitter-followers which decouple C_5 from the Schmitt.

Assume that Q_1 and Q_2 are off, and Q_3 is on. The voltage at the base of Q_4, established by the dividing action of R_9 and R_{10}, is −6.0 volts. Since the voltage at the collector of Q_3 is +12 volts, Q_4 is backbiased. The voltage at the base of Q_5



2. **Both triangular and square** waveforms are generated by the circuit of Fig. 1. Upper trace of top CRO picture shows output of emitter-follower; lower trace exhibits Schmitt output (vertical scale is 2 V/cm; horizontal 2 μs/cm). Upper trace of bottom CRO pattern shows emitter-follower output and square wave derived from Schmitt (scale here is 5 V/cm vertical and 2 ms/cm horizontal).

is +6 volts, thus Q_5 is turned on. Assuming for the moment that P_3 and P_4 are replaced by short circuits, the rate of charge of C_5 will be determined by the six volts across P_2. C_5 charges in the positive direction. At a positive voltage set by P_1, Q_1 turns on and enables Q_2 to conduct. When Q_2 is on, R_4 provides an additional source of current to Q_1. The voltage at the emitter of Q_6 now must drop low enough to buck the current through R_4 and R_2 to turn off Q_1.

The hysteresis expression is given by:

$$\Delta v = V_{cc}\ (R_1/R_4) \qquad (1)$$

This voltage differential is also the peak-to-peak voltage of the triangular waveform. With Q_2 on, Q_3 turns off and blocks Q_5, thereby turning Q_4 on. The direction of current is reversed and C_5 charges towards the opposite polarity. Since P_2 again determines the current, C_5 discharges at the same rate as it was charged. When the voltage on C_5 approaches the ground reference, Q_1 turns off, turning off Q_2. Q_3 then turns on, and turns Q_5 on and Q_4 off, to repeat the cycle.

The frequency of the operation is:

$$f = \frac{2}{\frac{\Delta v}{V_1} P_2 C_5} = \frac{2V}{\Delta v\, P_2 C_5}, \qquad (2)$$

where V_1 is the voltage across P_2 and Δ_v is the

amplitude of the triangular waveform. With P_2 shorted, P_3 and P_4 independently determine the slope. The frequency is then:

$$f = \frac{V_1}{\Delta v C_5}\left(\frac{1}{P_3} + \frac{1}{P_4}\right). \quad (3)$$

CR_3 and CR_4 insure that Q_4 and Q_5 will not break down when either transistor is in the off state.

To maintain linearity at low frequencies, the emitter-follower must not load C_5. R_{16} effectively neutralizes the shunting effect of the emitter-follower by feeding back a current to the emitters of Q_4 and Q_5. Key waveforms appear in Fig. 2.

Gilbert Marosi, Senior Engineer, Friden Inc., San Leandro, Calif.

VOTE FOR 111

Blueprint for rapid design of high-voltage vhf stages

The fact that vhf transistors are now available with high breakdown voltage ratings does not eliminate the output-limitation problem. For wide bandwidth vhf stages, the ac output swing is still dependent on the maximum power dissipation. Here is how to determine the maximum possible output for a given transistor.

First, select the transistor for high f_T, BV_{CBO} and collector-power rating. The transistor with the highest BV_{CBO} is not necessarily the best suited one because of frequency or power limitations. At a high bandwidth, it is likely (as will be shown) that full use of the BV_{CBO} of either transistor will not be possible because of collector-power limitations. Therefore, the higher f_T transistor is the logical choice. With all other factors equal, the higher collector-dissipation rating will become the governing selection factor in most cases.

Next, calculate the load resistance, R_L, and peaking inductance, L, according to the total collector circuit capacitance, C_o, and the desired upper frequency limit, f_2 (Fig. 1a).

With f_2 and C_o fixed, R_L may be calculated from:

$$R_L = 1/2\,\pi f_2 C_o \quad (1)$$

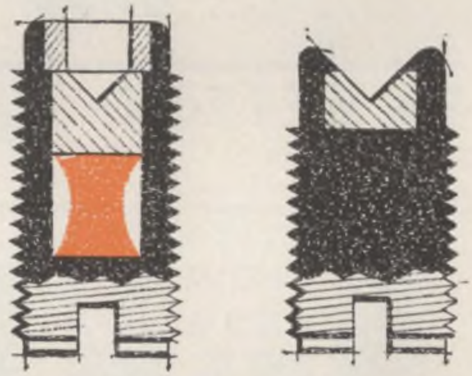
Maximally flat-response, shunt-peaking inductance ($m = 0.414$) is determined from:

$$L = m\,C_o\,R_L^2. \quad (2)$$

More complex peaking may be employed if desired. R_L should be as high as possible to minimize collector dissipation, to maximize gain and to permit maximum ac output. Negative feedback will help.

Then, plot collector power, P_c, vs collector voltage, V_c.

in meters



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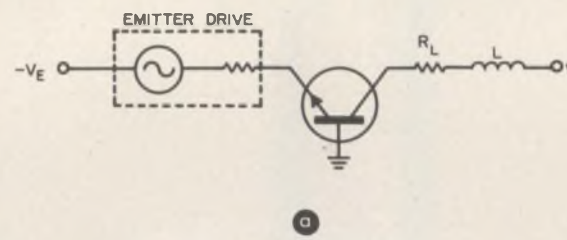
$$P_c = V_{cc} I_{cc} - R_L I_c^2 \qquad (3)$$

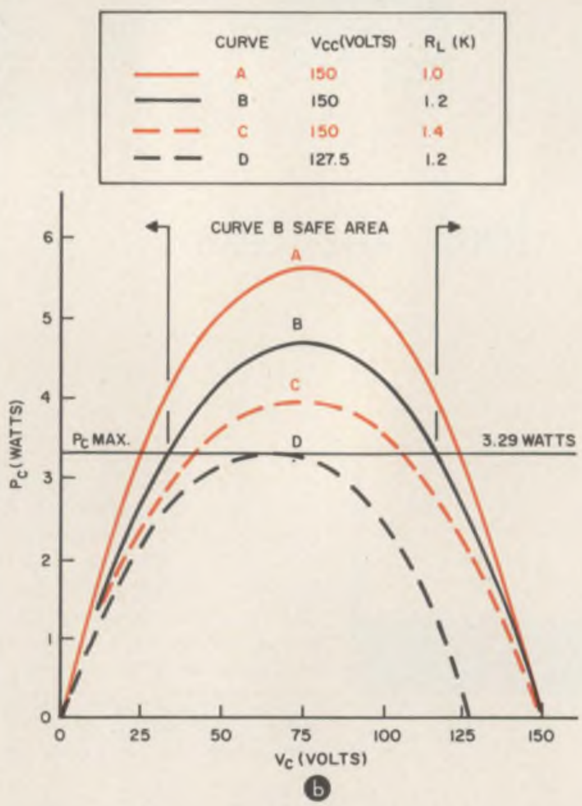
Substituting $(V_{cc} - V_c)/R_L$ for I_c:

$$P_c = (V_{cc}/R_L)V_c - (1/R_L)V_c^2. \qquad (4)$$

Plots of P_c vs V_c for various supply voltages and load resistances are shown in Fig. 1b.

The next design step is to determine the collector supply voltage, V_{cc}, and quiescent collector voltage, V_c. The collector supply voltage is limited by the collector breakdown voltage, collector dissipation rating and the class of operation. Common-base operation with a high-impedance drive permits collector voltages up to BV_{CBO} The class of operation (pulse or linear) determines the collector's quiescent current and voltage point. For linear operation at any voltage from zero to V_{cc}, the entire P_c vs V_c curve must be on or below the collector-power rating ($P_{c\,max}$) at a given temperature. The curve may go above $P_{c\,max}$ (curves A, B and C) if: (1) Collector voltage





High-voltage video-amplifier stages (a) are rapidly designed by a five-step, power-oriented procedure. The technique, which is based upon the collector dissipation curves (b), helps the designer to choose from a number of transistors and determines the maximum achievable output.

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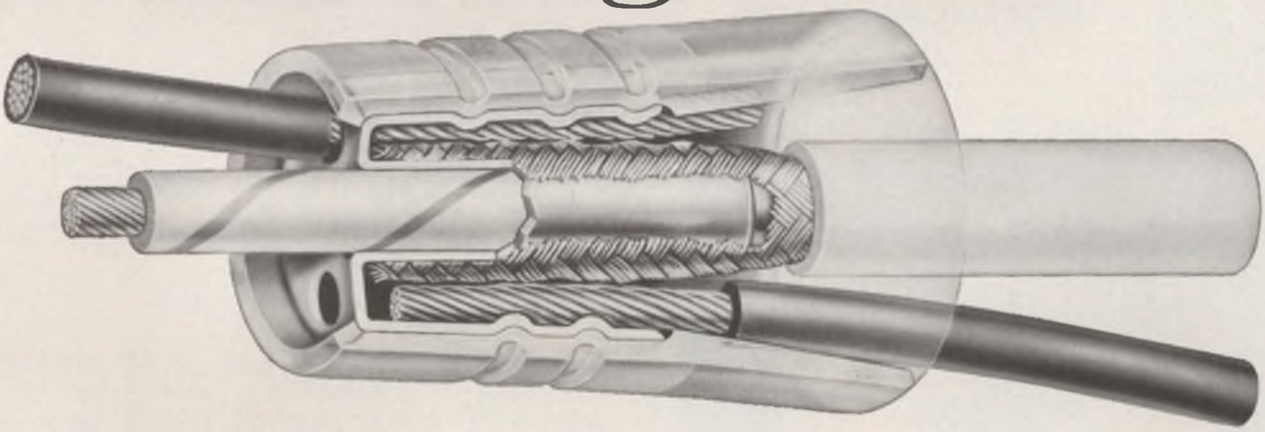

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excursions do not result in P_c above $P_{c\ max}$ for linear operation or (2) Duty-cycle time of pulse operation is such that the period of operation above $P_{c\ max}$ is short.

Finally, determine the maximum ac output voltage. For linear operation, $V_c = V_{cc}/2$ and the peak of the curve (curve D in Fig. 1b) falls on $P_{c\ max}$. Since $P_c = P_L$ at the peak:

$$V_c = \sqrt{P_{c\ max} R_L} = V_{cc}/2 \qquad (5)$$

The following example demonstrates this five-step design procedure.

1. The 2N3501 will be used for a high-voltage video-amplifier design. Collector dissipation rating, $P_{c\ max}$ is 5 watts at 25°C case temperature. This is derated to 3.29 watts at 85°C, the design temperature. A BV_{CBO} rating of 150 volts will be used. Upper frequency, f_2, is 10 MHz, and total collector circuit capacitance is 13.3 pF.

2. From Eq. 1:

$$R_L = 1/2\pi \times 10^7 \times 13.3 \times 10^{-12} = 1.2\text{k}.$$

Eq. 2 gives:

$$L = 0.414 \times 13.3 \times 10^{-12} \times 1200^2 = 7.95\ \mu\text{H}$$

3. Collector power vs collector voltage is plotted from Eq. 4 (curve B, Fig. 1b) for a supply voltage of 150 volts. Also, curve D is plotted for linear operation. From Eq. 5:

$$V_c = \sqrt{3.29 \times 1200} = 63.6 \text{ volts, and}$$
$$V_{cc} = 2 \times 63.6 = 127.2 \text{ volts.}$$

4. For pulse operation, the quiescent collector voltage may be set anywhere on the safe areas of curve B (Fig. 1b). The two points where the curve crosses $P_{c\ max}$ are calculated by solving Eq. 4 using the quadratic equation:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

This gives 34.3 volts and 115.7 volts. If a negative output pulse is desired, V_c is set between 115.7 volts and 150 volts. For a positive output pulse, set V_c below 34.3 volts. (An opposite polarity design can be made with a *pnp* transistor, such as the 2N3637.)

5. A pulse output equal to 150 volts (minus V_{SAT} can be obtained. With linear operation, however, the maximum collector excursion is 127.2 volts. Somewhat less should be used, depending upon the allowable amplitude distortion. The quiescent collector voltage should be selected according to standard linear-amplifier design and not necessarily as one-half of V_{cc}.

Howard F. Stearns, Senior Engineer, Sperry Piedmont Co., Charlottesville, Va.

VOTE FOR 112

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B. A. Ziegner, *Microwave Applications Engineer, Motorola Semiconductor Products, Inc., Phoenix, Ariz.*

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Innovations, techniques, guidelines of design, the "best" to come across the desks of *Electronic Design* editors, are featured in this useful volume. The selections feature outstanding ideas that have appeared in recent years in this popular department of the magazine. This attractively bound, hardcover edition will be given to 100 winners. (Retail value: $8.50.)

tickets between *and* PARIS

VIA AIR FRANCE

eligible!

January 4th, "FOCUS '66" issue.

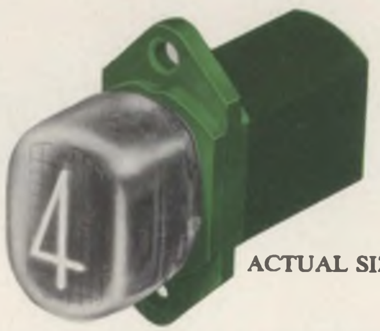
"Top Ten" contest

HERE'S ALL YOU HAVE TO DO TO ENTER:

Rate the ads appearing in the *FOCUS '66* issue of *Electronic Design* (January 4). Select the *"Top Ten"*. . . the ads that, in your opinion, will be best remembered by readers. Your choices will be measured against the 10 ads ranking highest in the "Recall-Seen" category of Reader Recall—*Electronic Design's* scientific method of measuring readership. In making your predictions, be sure to consider your 53,000 fellow engineers' interest in the subject matter of the ads, their effectiveness, impact, and attention-getting values.

Entry blanks and complete contest rules will appear in the January 4th issue. Don't miss this opportunity to win one of the many valuable prizes shown at left. The first prize winner will receive round-trip tickets for two, between New York and Paris via Air France!

This is the BCD decoder that ends make/buy decisions

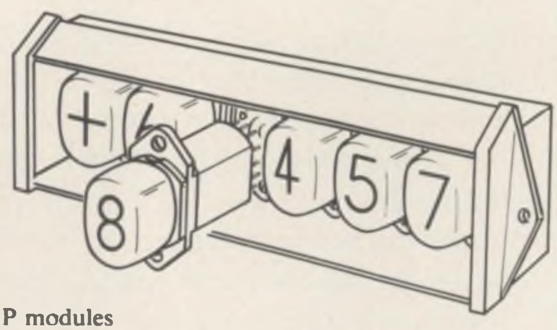


ACTUAL SIZE

Many users seem to think so.

We've built our numeric readout (the noteworthy NIXIE® tube, naturally!) into a handsome, compact package that not only gives you dependable low-level BCD-to-decimal conversion, but also enhances your most elegant design.

Most important, our BIP-8211P readout assembly carries a price tag so low that the savings in design, development, production, and testing will convince even the most parsimonious do-it-himselfer to reach for a P. O. instead of a slide rule.



Convenience? The decoder socket packs can be mounted in one of our bezel assemblies that handles up to 15 digits, mounts into your front-panel opening with just two screws, accommodates decimal points and colons.

Flexibility? It's odds-on that your own BCD circuits will drive the BIP-8211P without modification. But we also offer optional versions which accept just about any form of BCD, or one that gives you straight decimal-to-decimal driving, should that be what you need.

Reliability? Continuing environmental and life testing add up to dependable operation in severe environments of temperature, shock and vibration. All this and an enthusiastic Zero Defects Program, too!

Availability? We've tooled up a new production line that's turning out BIP-8211P modules in quantities large enough to make shipment possible in an interval no longer than the time it takes to process the paperwork. Need them even faster for bread-boarding or prototyping? They're priced low enough to order them now, and have them in arm's reach.

Got a BCD-decoding requirement? Leave it to Burroughs! You'll be glad—so will your comptroller — so will the user.

Write or call for full information.

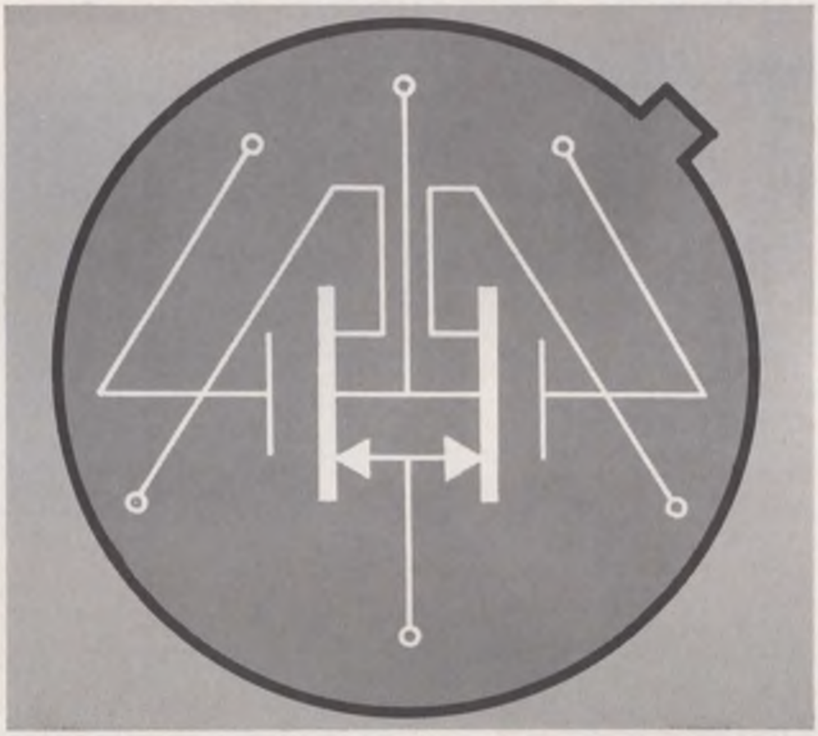
Burroughs Corporation / ELECTRONIC COMPONENTS DIVISION

PLAINFIELD, NEW JERSEY 07061

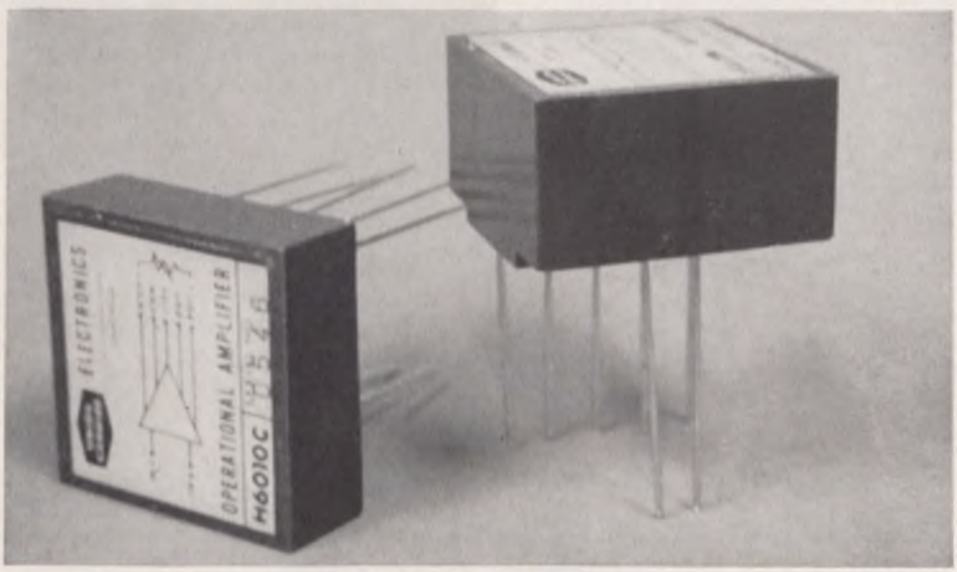
E|D Products

Keeping up with the latest in product innovations and useful design literature—a must for the successful engineer. Here are items that E/D editors think most likely to influence your designs.

A new low in FET on-resistance 144

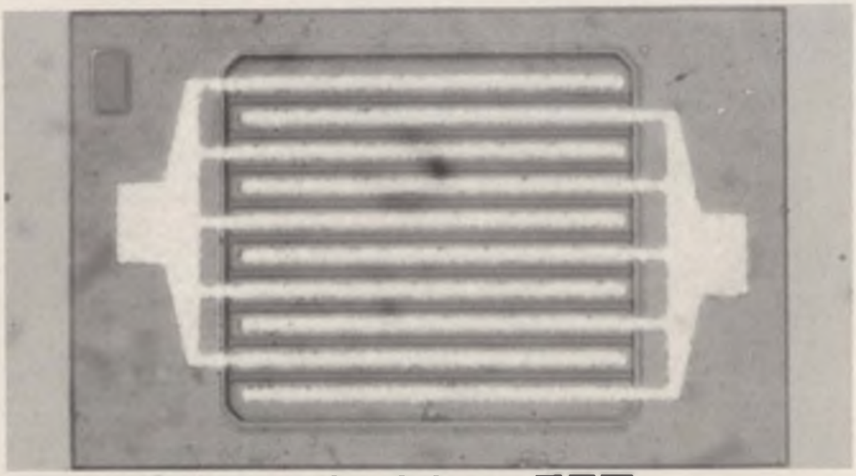


Low-level switching? This is the MOST 146



Union Carbide enters booming "economy" module market 150

Pick an ohm, 0.1 to 1k .. 150

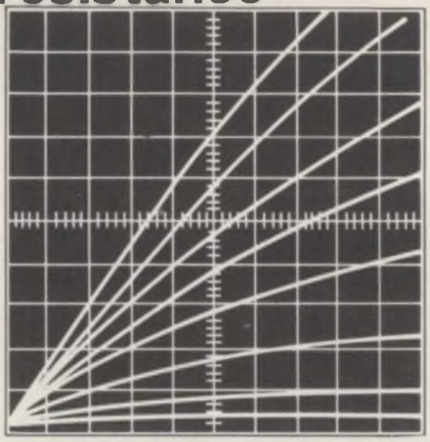


Junction switching FET has 30-ohm ON resistance

You'll have to wait a while for the perfect semiconductor switching element—one that gives zero ON resistance and infinite OFF resistance, switching from one to the other instantaneously. Meanwhile, a new device from Amelco may take a few of the kinks out of your multiplexing and other signal steering equipment designs.

The new n-channel junction FET, 2N4091, features an ON resistance (R_o) of only 30 ohms. This is coupled with an offset of virtually zero and an ON/OFF ratio of 10^{10}.

The low R_o pays off in two ways in switching and demodulating circuits: your initial signal loss is minimal and distortion through transistor heating is slight and easily compensated for. According to Amelco engineers, the zero offset can be taken literally. This means that the switching drive power is minimal. While the design concentrates on low-level applications, its switching capability extends to 75 mA.



The ON resistance vs gate voltage plot of the 2N4091 FET is shown in 1-V steps. Settings are 5 mA/cm horizontal and 0.2 V/cm vertical.

Two other devices in the family offer slightly higher R_{on}, I_{DSS} and switching time values. These are actually lower-priced "fallouts".

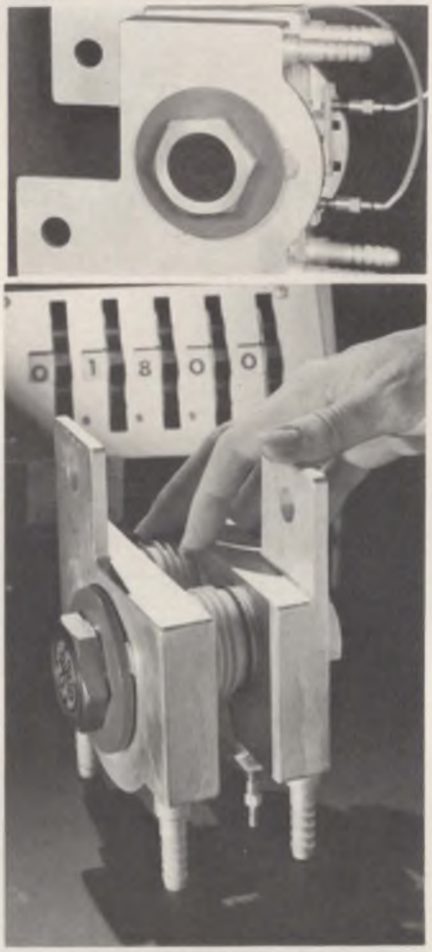
Price: $12.30 (in quantity). Teledyne, Inc., 1300 Terra Bella Ave., Mountain View, Calif. Phone: (415) 968-9241. TWX: (415) 969-9112.

Circle No. 278

Specifications

		2N4091	2N4092	2N4093
R_o	(ohms)	30	50	80
I_{DSS} min	(mA)	30	15	8
$I_{D(off)}$ max	(pA)	200	200	200
BV_{GSS} min	(volts)	40	40	40
V_P max	(volts)	10	7	5
C_{iss} max	(pF)	16	16	16
t_d max	(ns)	15	15	20
t_r max	(ns)	10	20	40
t_{off} max	(ns)	40	60	80

High-power SCRs rated to 1800 volts



Direct operation from 480-volt distribution lines is the featured capability of a series of SCRs for industrial applications. The water-cooled units have a power-handling capability of 1200 amps rms and a blocking rating of 1800 volts. This permits switching of 1.5-megawatt loads.

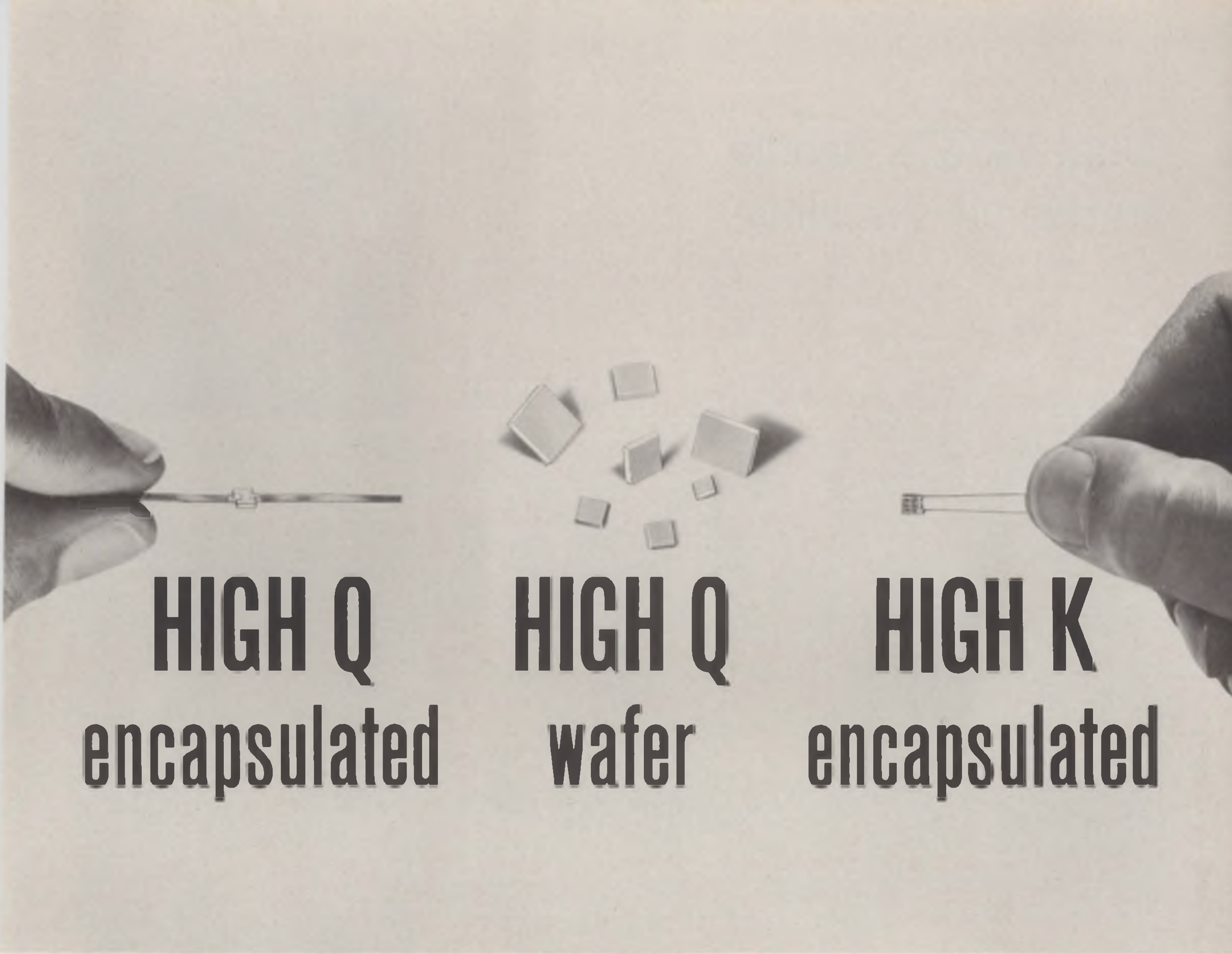
Applications for the new device are seen in such areas as large dc motor controls, MG set replacement, heating and lighting, plating operations and battery charging.

According to George B. Farnsworth, manager of marketing for the General Electric Semiconductor Products Division, the pressure-mounted, double-sided cooling system and an extra large silicon junction structure are responsible for the increased ratings.

Engineering samples of the 6 x 6 x 5-in. switch are available on a 90 day basis and an air-cooled version is presently under development.

General Electric Co., Semiconductor Products Div., Schenectady, N. Y. Phone: (518) 374-2211.

Circle No. 279



Now, JFD Uniceram® Fixed Capacitors Come THREE ways

High Q Uniceram High Q ceramic fixed capacitors offer a unique combination of small size, exceptional stability and a guaranteed minimum Q of 5000 . . . with up to ten times more capacitance per unit volume than competitive units . . . up to .206 mfd/in^3.

GLASS ENCAPSULATED—105 models, with capacitance values from 0.5 to 3000 pf, provide the ultimate in High Q, reliability and stability. All models meet or exceed requirements of MIL-C-11272B.

WAFERS—Uniceram High Q capacitors are also available as unencapsulated wafers with metalized edges. 88 low-cost units, with capacitance values from 0.5 to 3000 pf, offer the same outstanding electrical properties. These wafers are ideally suited for hybrid integrated circuits, can be soldered directly to printed circuit boards or used as discrete components.

High K ENCAPSULATED—A High K series of Uniceram ceramic fixed capacitors with up to 1 mfd capacitance per unit volume is also available. These glass encapsulated units meet or exceed requirements of MIL-C-11015C. Volumetric efficiency . . . up to 48 mfd/in^3.

WAFERS—Uniceram High K capacitors will soon be available as unencapsulated wafers, also.

WRITE FOR CATALOG UNM 65-2

ON READER-SERVICE CARD CIRCLE 64

JFD ELECTRONICS CORPORATION
THE AMERICA KNOWS BEST!

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JFD NEW YORK-NORTHERN, Damiano Pl., P. O. Box 96, New Hartford, N. Y. 13503
JFD MID-ATLANTIC, P. O. Box 5055, Philadelphia, Pa. 19111
JFD MID-ATLANTIC-MARYLAND, P. O. Box 7676, Baltimore, Md. 21207
JFD MIDWESTERN, 6330 W. Hermione St., Chicago, Ill. 60646
JFD MIDWESTERN-OHIO, P. O. Box 8086, Cincinnati, Ohio 45208
JFD WESTERN, 9 Morlan Place, Arcadia, California 91006
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JFD ELECTRONICS, EUROPE S A, 7 Rue de Rocroy, Paris, 10, France

Precision Piston Trimmer Capacitors ■ Metalized Inductors ■ LC Tuners ■ Ceramic Fixed and Variable Capacitors ■ Fixed and Variable Distributed and Lumped Constant Delay Lines

JFD 123

Dual MOSTs handle microvolt sampling

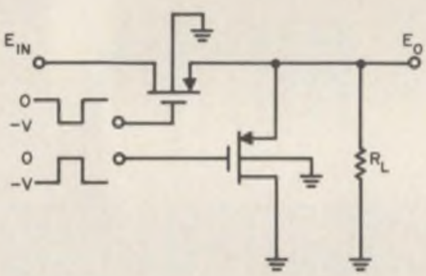
Two new p-channel MOS transistors, a result of the manufacturer's Planar II processing, are especially suited to low-level chopping and multiplex-switching applications. Each of the new devices, from Fairchild Semiconductor Division, features a dual-MOS arrangement in a hermetically sealed can.

The outstanding characteristic of these new devices, 2N4066 and 67, is a zero drain to source offset voltage. They also feature a high transconductance, low ON resistance and low leakage current, enabling them to serve as microvolt samplers with excellent results.

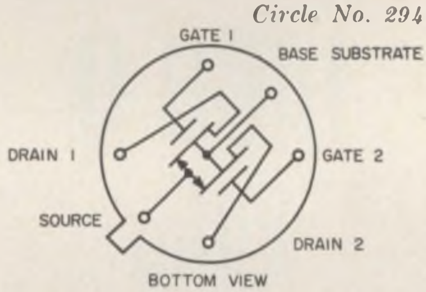
In addition, the dual arrangement permits the devices to serve in a variety of chopping and commutator configurations.

P&A: $11.30 (2N4066), $15.00 (2N4067) in 100 lots. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. Phone: (415) 962-5011. TWX: (910) 379-6435.

Circle No. 294



Shunt chopper design is simplified by the new 2N4066 and 2N4067.



A six-lead device, the 2N4066-67 is an integrated dual-MOST.

Specifications:

	2N4066	2N4067
Y_{fs}	1500 ohms (max)	2500 ohms (max)
R_{OS}	10^{13} (Min)	10^{13} (min)
I_{DSS}	0.5 nA (max)	0.5 nA (max)
$i_{G(f)}$	2.5 pA (max)	2.5 pA (max)
$r_{ds(on)}$	500 ohms (max)	250 ohms (max)
BV_{DSS}	30 V (min)0	30 V (min)
C_{iss}	7.0 pf (max)	7.0 pf (max)
C_{rss}	1.5 pf (max)	1.5 pf (max)

Four-layer diodes

A line of two-terminal bistable switches change from the high-resistance "OFF state to a low-resistance ON state when the applied voltage exceeds a specified voltage. Voltage ratings from 8 to 12 v are available in the line with typical turn-on time at 50 ns and turn-off at 100 ns. Holding current is 4 mA and forward voltage drop is 1 V.

P&A: $1.50-$1.70; stock. Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. Phone: 273-6900.

Circle No. 295

Power transistor

Designed as a power driving transistor for ferrite core memory units, the type 203-03 transistor handles cycling times as short as 1.2 μs. Maximum power dissipation at 25°C is 3.0 watts (case) and 0.8 watts (ambient). V_{EB} is rated 4.5 V maximum and V_{CB} is 50 V. Peak emitter current is 1.0 A.

This is an npn silicon planar device mounted in a standard three-lead TO-5 can. In a typical circuit. ON time is 14 ns and OFF time is 90 ns.

Marconi Co. Ltd., Chelmsford, Essex, England. Phone: Chelmsford 3221.

Circle No. 296

Germanium power family

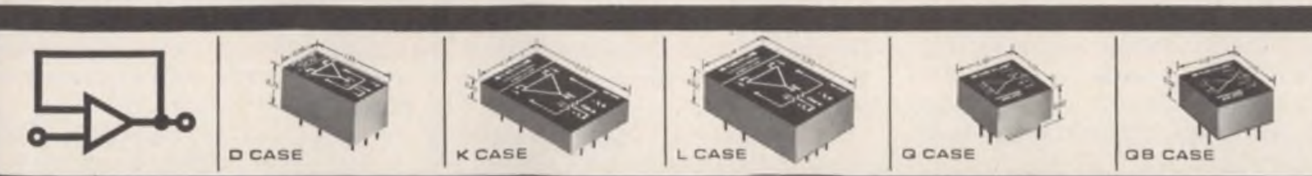
Over 175 types of pnp germanium transistors are represented in a family of TO-3 and TO-41 devices. Included in this family are the 2N1529-56, 2N2137-46 and the 2N3611-18 series.

Current range is from 0.5 to 10 A. Typical performance at 7 A is h_{FE} at 45, $V_{CE(SAT)}$ at 0.25 V, and $V_{BE(SAT)}$ at 1 V.

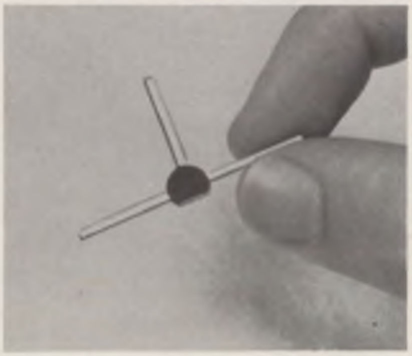
P&A: from $0.60; stock. Solitron Devices, 1177 Blue Heron Blvd., Riviera Beach, Fla. Phone: (305) 848-4311.

Circle No. 297

ON READER-SERVCIE CARD CIRCLE 219 ➤


D CASE
K CASE
L CASE
Q CASE
QB CASE

500 MHz transistor



The VX-3375 silicon planar npn transistor provides 5 watts at 500 MHz with a maximum junction dissipation of 11 watts through its berrylium oxide base.

In a lumped-element test circuit, the transistor delivered 6 dB gain at 500 MHz, a 5 watt output with 53% efficiency. In coax circuits, outputs beyond 100 mW at 2 GHz have been reported. The flat-pack device measures 0.280-in. in diameter and is 0.75-in. thick.

craft Corp., Vector Labs, South-
P&A: $60; stock. United Air-
ampton, Pa. Phone: (215) 357-7600.

Circle No. 282

Tape transport

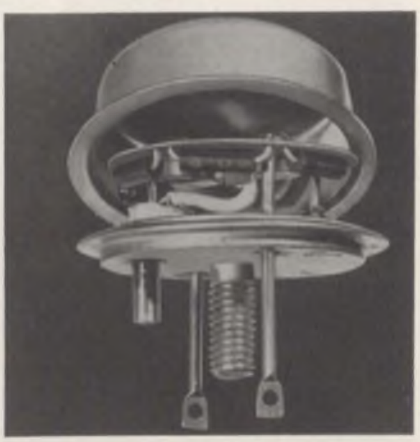
A solid-state magnetic tape drive mates with the PDP-7 and PDP-8

computers. The transport type TU55, has a reliability figure of less than one transient error per 10^{10} characters. Tape tension is controlled electromagnetically.

The transport uses 4-in. reels containing 260 feet of 3/4-inch Mylar sandwich tape. Recording density is 350±55 bpi and read-record speed, in either direction, is 97 ± 14 ips. Total information capacity per reel is 2.7 x 10^6 bits, arranged in duplexed three-bit characters.

Price: $2,350. Digital Equipment Corp., Maynard, Mass. Phone: (617) 797-8822 *Circle No. 283*

Senthesized zeners



Zener diodes of the Super/Reg line are now available with zener voltages of 3.9, 4.7, 5.6, 6.8 and 8.2 Vdc. These additions to the standard 75TE line are modules manufactured from military-grade circuit components and packaged in a TO-36 can. Connections are the same as those for a standard zener diode with the addition of a third, trim terminal. The third terminal provides voltage adjustment when needed.

P&A: $59.50 (sample quantities). Trio Labs, Semiconductor Div., Plainview, N. Y. Phone: (516) 681-0400. *Circle No. 284*

Economy 7-amp SCRs

Intended for power control in portable devices, the 40378 and 40379 SCRs feature 7-amp ratings in a low-profile package. The 40378 is rated for 120-volt operation and the 40379 for 240-volt lines. Both have a peak forward blocking voltage rating of 600 volts and a peak surge rating of 80 amps.

Price: $1.12 and $1.82. RCA Electronic Components and Devices, Harrison, N. J. Phone: (201) 485-3900.

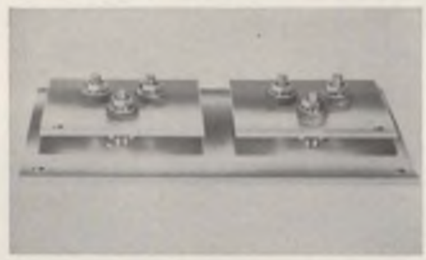
Circle No. 285

Bidirectional switches

Economical triggering circuits in four operating modes is possible with two developmental triacs. The devices, TA2676 and TA2685, are gate-controlled full-wave silicon switches designed for positive or negative gate-triggering. Both are packaged TO-66. The TA2676 can control up to 600 watts at 120 volts while the TA2685 controls up to 1.2 kV at 240 volts.

Price: $3.35 and $4.50. RCA Industrial Semiconductor Marketing, Sommerville, N. J. Phone: (201) 722-3200.

Circle No. 286



Rectifier stacks to 150 A

Silicon rectifier stacks with forward current ratings from 100 to 150 A are available in flat "sandwich" assemblies. Surge ratings range up to 4000 A. Suggested applications include replacement of selenium rectifiers and stud rectifiers in chargers and plating equipment.

P&A: $9.00-$15.00; stock. Electronic Devices, Inc., 21 Gray Oaks Ave., Yonkers, N. Y. 10710. Phone: (914) 965-4400.

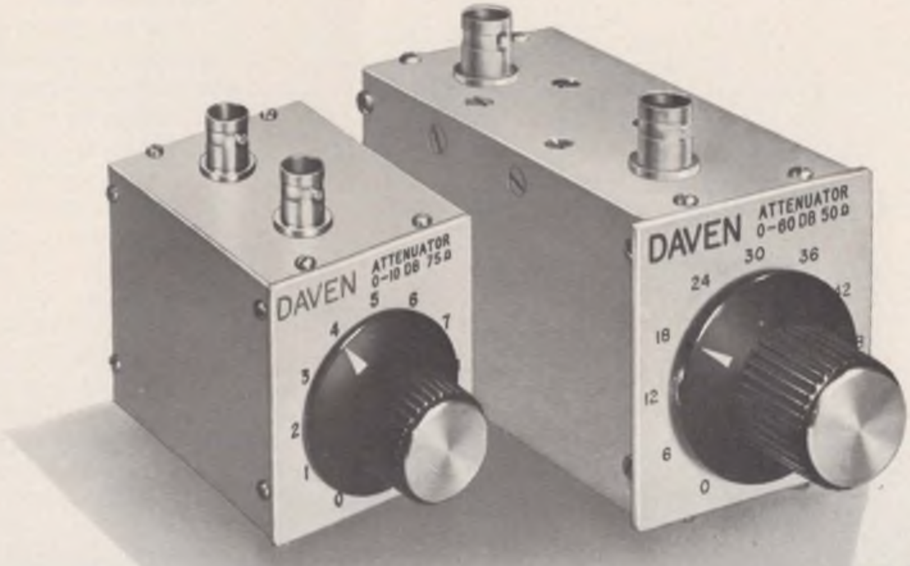
Circle No. 287

Transistor sink

Called Nickl-Sink, an economy heat sink line is designed for use in marginal circuit applications where only a small amount of heat dissipation is required. Made of tempered aluminum, the sinks will fit TO-5 cases, taking no more space than the can's weld flange.

P&A: $0.05 in quantity, stock. Thermalloy Co., 8717 Diplomacy Row, Dallas, Tex. Phone: (214) 637-3333.

Circle No. 288



underpriced!

High performance DAVEN Rotary RF Attenuators are underpriced!

Here's why:

◯ Only highest quality 1% deposited carbon non-inductive resistors are used throughout

◯ They meet vibration and shock conditions of MIL-STD—202C

◯ Basic switches are designed to meet MIL-S-3786A

◯ All metal finishes are per military specifications

Daven Rotary Coaxial RF Attenuators are made to high-priced specifications, yet are priced low. Use them in signal generators, in transmitters, for calibration of audio and RF equipment, or even in the testing of transmission lines. Their square design makes for easy packaging.

Choose from two models, both available in either 50 or 75 ohms impedance.

Model 10240 frequency response extends from DC to 500 Mc. Standard units can be supplied in 0-10 db in 1 db steps, 0-20 db in 2 db steps, or 0-30 db in 3 db steps. 0-30 db unit is rated DC to 400 Mc.

Model 10440 has frequency response from DC to 250 Mc (usable to 500 Mc); is available in either 50 or 75 ohms impedance. Standard units are 0-60 db in 6 db steps or 0-60 db in 10 db steps.

Write today for complete specifications and price.

954

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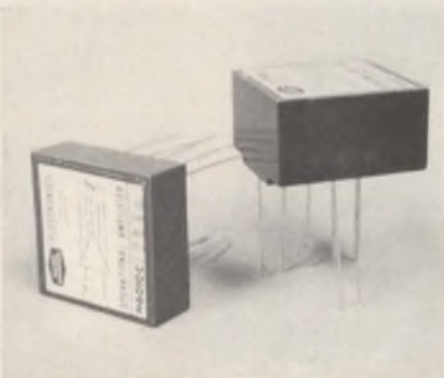
Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 65

Low-cost operational amp based on dual transistor



With a low-cost operational amplifier, based on their own monolithic dual transistor (ED Oct. 11, p 76), Union Carbide became the first major semiconductor manufacturer to offer a packaged industrial operational amplifier that reflects the new trend toward premium specs over a less-than-military temperature range. To date this area has been one of the "instant success" routes for small to medium-sized manufacturers who must buy their semiconductors.

This new unit, called the H6010, delivers an open-loop gain of 86 dB minimum—more than sufficient for most industrial applications. It is specified for −25° and +85°C.

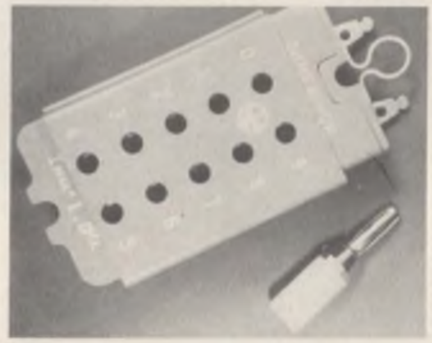
Two packaging options are available in the H6010. The standard seven-lead cube measures 1.5 x 1.5 x 5/8-in. For printed circuit use where 0.5-in. spacing is common, a low-profile package, 0.4-in. in height, has the same length and width.

P&A: $24 in quantities of one to four; stock. Union Carbide Linde Div., 365 Middlefield Rd., Mountain View, Calif. Phone: (415) 961-3300. TWX: (415) 969-9166.

Circle No. 293

H6010 specifications

Specification	Conditions	Min.	Typ.	Max.	
Open Loop					
Dc gain	R_L = 10 k	86	90	—	dB
Input resistance		150	250	—	K
Gain—bandwidth product	R_L = 10 k	5.0	6.0	—	MHz
Full power output frequency		—	75	—	kHz
Slewing rate		—	4.5	—	V/μs
Output voltage	R_L = 3.3 k, —25° to 85°C	±10	±11	—	volts
Output current		±3.0	±4.0	—	mA
Differential input					
Offset voltage			Adjustable to zero		
Offset current		—	25	50	nA
Drift	—25° to 86°C	—	±5	10	μV/°C
Input wideband noise		—	0.5	5.0	μV rms
Voltage drift	(constant temp)		10	30	μV/24 hr
Current drift		—	1.0	10	nA/24 hr.
Other					
Common mode rejection ratio		80	100	—	dB
Cutoff, inverting		5.0	6.0	—	MHz
Operating temp.		—25	—	+85	°C
Storage temp.		—65	—	+125	°C



Resistance decade boxes take a modular approach

A series of modular resistance boxes are designed to overcome many of the practical problems involved in laboratory use. Like any decade box, they provide a handy source of resistance for breadboarding, testing or just experimenting. They differ in both construction and in operation.

Called the Claro-Dec series, these modules cover a total range of 0.1 ohm to 900k in seven complementary ranges. Each can be used separately or they can be ganged in any configuration. The discrete steps are 0.1-9.9 ohm, 1-9 ohm, 100-900 ohm, 1-9 k, 10-90 k and 100-900 k.

Using all seven modules, the complete range can be covered in 0.1 ohm steps. Resistance is selected by simply inserting a banana-plug in one of the ten holes provided in the front of the 3 x 2 x 7/8-in. modules.

Each unit is provided with tongue-and-groove molding on each side as well as mounting notches at either end for ganged mounting.

P&A: $3.95; stock. Clarostat Mfg. Dover, N. H. Phone: (603) 742-1120. TWX: (603) 742-2038.

Circle No. 294

ON READER-SERVICE CARD CIRCLE 220 ➤

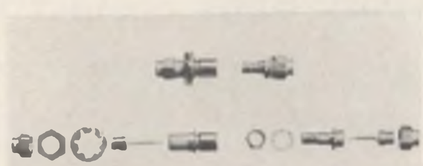
Rack/panel connectors

Users of miniature rack and panel connectors can now mount many identical units on a single frame without danger of mismating. Keyed-shell miniature connectors allow four different keying positions on each connector in the micro-ribbon 57 series. The new units are available with as many as 50 contacts in a mating face area approximately 2.4 x 0.61-in. Combinations of the basic keying positions further increase the number of like connectors that can be used on the same panel without mismating. Three types are available: cable to chassis units; cable to cable units; and right-angle shell units.

Connector bodies are molded of diallyl phthalate. Standard shells are cadmium plated brass with clear chromate treatment. Contacts are rated 5 amp 700 vdc at sea level; 200 vdc at 70,000 ft. Contact material is gold-plated silver.

Amphenol Corp., 1830 S. 54th Ave., Chicago, Ill. Phone: (312) 242-1000. TWX: (312) 656-7125.

Circle No. 750



Coaxial connector

Both 50 and 75 ohm types are available in a line of micro-miniature coaxial connectors. Three mating forms are included in the line: screw-on, push-on and slide-on. All are designed to conform to MIL-C-22557A.

Mi-kro Connector Corp., 40-90 21st St., Long Island City, N. Y. Phone: (212) 392-8810.

Circle No. 751

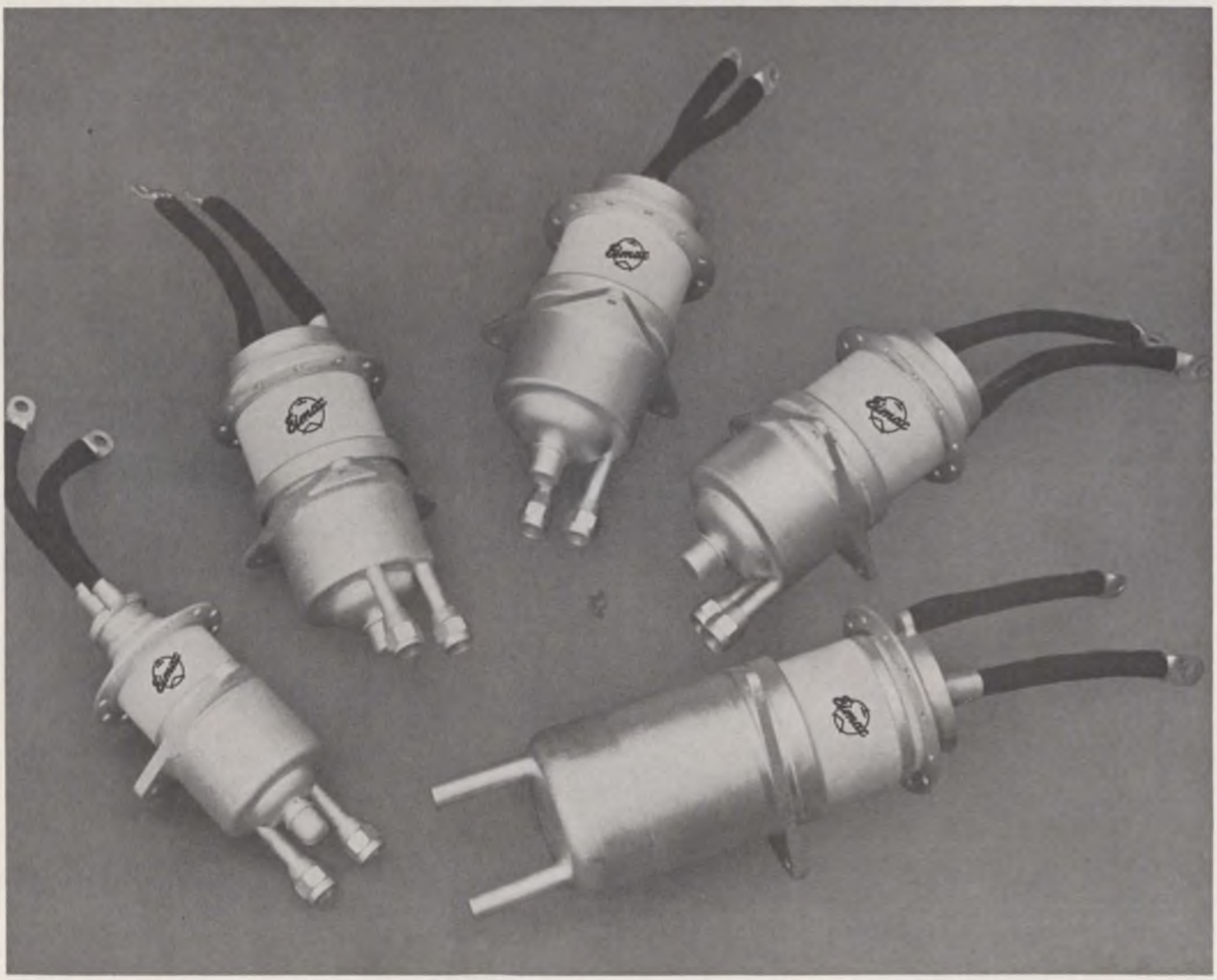
EIMAC introduces new family of rugged triodes for industrial heating

From Eimac comes a new family of water-cooled triodes designed especially for induction and dielectric industrial heating service. The tubes feature a new cast silicon-bronze cooler design with constant cross-section spiral water channels. This design insures uniform anode cooling with minimum water flow and back pressure. For example, the 3CW20,000H3 requires only 4 GPM water flow at 3.5 psi for 20 kW plate dissipation. The new tubes feature filament connecting leads—no sockets are required—and have grid flanges for low inductance connection to the grid. This new industrial family is rated at full power to 90 Mc, with reduced ratings to 140 Mc. All include anode tabs for ease of mounting into industrial machinery plus rugged, high-dissipation grids for industrial oscillator service. Write Power Grid Product Manager for additional technical information, or contact your nearest Eimac distributor.

CHARACTERISTICS

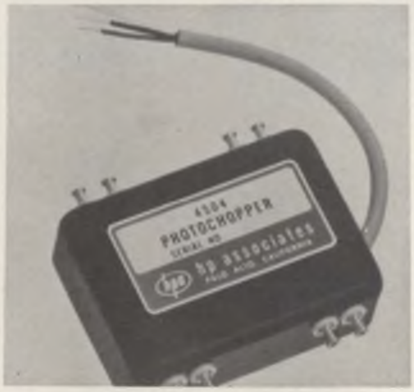
	Plate Dissipation (kW)	Filament Voltage (Volts)	Input Power (kW)	Useful Output (kW)
3CW5,000H3	5.0	7.5	30	15.5 to 22.5
3CW10,000H3	10.0	7.5	40	25.0 to 30.0
3CW20,000H3	20.0	6.3	60	42.0 to 45.0
3CW30,000H3	30.0	10.0	80	55.0 to 60.0
3CW40,000H3	40.0	13.0	120	75.0 to 90.0

EIMAC
San Carlos, California 94070
A Division of Varian Associates



ON READER-SERVICE CARD CIRCLE 67

Photo choppers

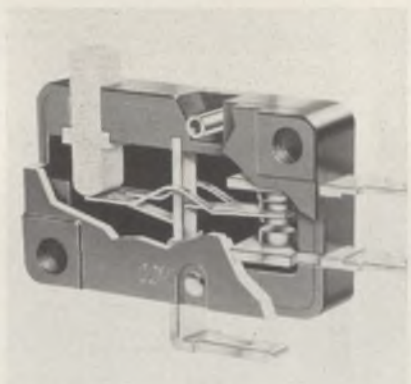


The models 4503 and 4504 are dpdt externally driven photochoppers capable of operating at frequencies to 1 kHz and modulating dc signals below the microvolt level. The two units are identical except that 4503 is a high-impedance type and 4504 is low impedance.

Price: $37.50-$26.50. hp associates, 620 Page Mill Rd., Palo Alto, Calif. Phone: (415) 321-8510.

Circle No. 752

Snap-action switches



A series of 15-amp miniature switches are packaged in a case measuring 1-3/32 x 5/8 x 13/32-in. Called the 4600 series, the switches feature beryllium copper springs, 3/16-in. fine silver contacts and overlap case construction.

Electrical ratings are 15 A at 125-250 Vac, 1/2 hp at 125-250 Vac, 1/2 A at 125 Vdc and 1/4 A at 250 Vdc.

McGill Mfg. Co., Electrical Div., Valparaiso, Ind. Phone: (219) 462-2161.

Circle No. 298

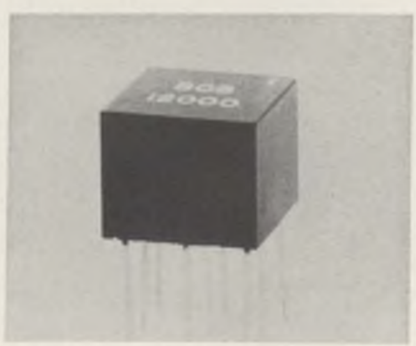
Axial lead chokes

The Series 3201 axial lead shielded chokes offer inductances from 0.1 μH to 100 mH in 20% increments. The units are built to meet the requirements of MS-90537. Body diameter is 0.157 x 0.395-in. length.

P&A: $0.45 to $150 in quantity; stock. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. Phone: (617) 876-2800.

Circle No. 299

Solid-state switches

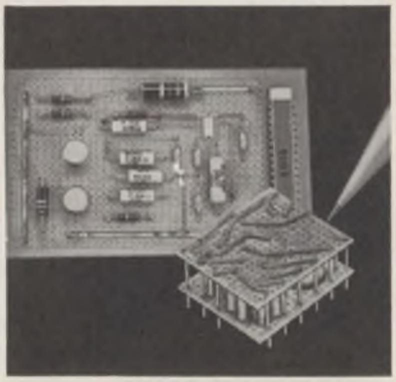


The 202 Series switches feature field-effect operation and are capable of continuous duty in either ON or OFF condition. Each two-pole unit is encapsulated in a 0.632 x 0.632 x 0.5-in. package with a nine-lead inter-connection configuration.

P&A: $50; stock to four weeks. Scientific Control Systems, Inc., 14008 Distribution Way, Dallas 34, Tex. Phone: (214) 241-2111.

Circle No. 351

Look what's new in electronic hardware

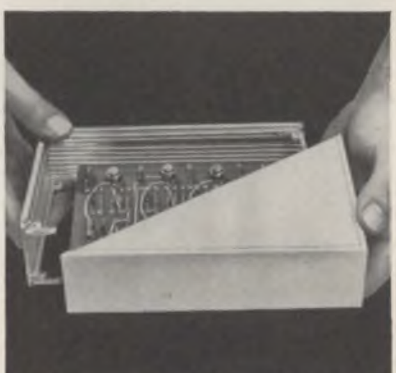


New Micro-Miniature Pre-Punched Insulating Board and Terminals — New Micro-Vectorbord is perfect as a holding matrix for making cordwood modules, and for mounting integrated circuits and discrete components. Dense small hole grid patterns and micro-miniature Push-In terminals, connectors, etc., permit high component densities. Made of epoxy glass in 4 grid patterns: 1/64" to 1/32" thick. Copper clading if required. Frames for stiffening and mounting in card guides. Plugbords with edge mounted Miniature Elco Varicons available 9-52 contacts spaced .05 centers.

Patented

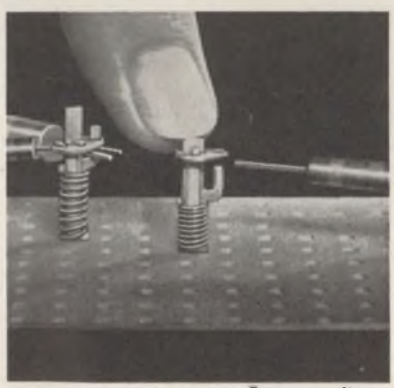
Copper Covered Sheets of Holes — COPPCO Vectorbord utilizes unpunched sheets of 2 oz. copper bonded to pre-punched insulating board with an adhesive liner of thin unpunched epoxy glass. The result is a sheet of holes with an unperforated copper surface. The inherent utility of pre-punched holes is immediately available for terminals or component leads below the unpunched copper and glass liner layers. Yet holes never interfere with etching conductor paths or areas wherever required. Available off-the-shelf on one or two sides of epoxy glass Vectorbord.

New Do-It-Yourself Resist Patterns for Etching Prototype Circuits in Minutes — New pattern sheets of Vector's Rub-On-Resist have lines from 1/64" to 1/8" and transistor pads for .05" and .1" center-to-center layouts. Easy-to-Use Vectoresist eliminates sticky tapes and photographic techniques for making prototype etched circuit layouts. Junctions do not undercut in etching because application pressure fuses joining pieces. Kit 27XA ($5.95) has 1 all-purpose Vectoresist sheet and everything else except hot water for making 2 etched circuit boards in minutes.



Patent pending

New Expandable Cases — New extruded aluminum Frame-Loc Rails are now available in wide size range to make sleek handsome circuit cases (or chassis) virtually any size or shape. Longitudinal grooves accommodate circuit boards on various center spacings. Circuits on etched cards requiring RFI shielding, or those employing bulkier components can be readily packaged. Complete "RF tight" cases with or without mounted shielded connectors, or case parts only are available with all hardware for plug-in rack, or chassis mounting.



Patent pending

Solderless Side Entry U-Clip Terminal — New Solderless U-CLIPS with less than .002 ohms resistance for instant "Push-In" use in 1/16" or 3/32" holes for testing or breadboarding circuits and components. A unique "side entry" slot for component wires is uncovered by finger pressure on a plunger permitting leads to be conveniently "laid in" rather than threaded through the terminal. Contact reliability is achieved by the possibility to criss-cross leads over a 270° range. Terminals may be used again and again.

Vectorize your breadboarding and profit 3 ways!

SPEED — With Vector hardware experimental circuits are assembled in minutes . . . without soldering.

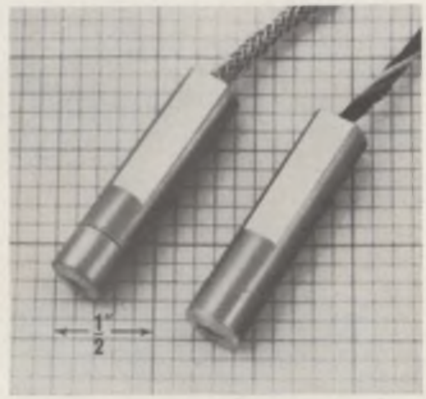
DELIVERABILITY — Prototypes made with Vector hardware are handsome enough to deliver for customer approval.

SAVINGS — Experimental circuits made with Vector hardware can be quickly disassembled and the low cost components used over and over without clean-up.

Vector

ELECTRONIC CO., INC.
1100 Flower Street, Glendale, California

ON READER-SERVICE CARD CIRCLE 69



Magnetic drum head

A new miniature magnetic read/record head, Model 4047D, was developed for use with non-contacting magnetic memory or storage drums in computer and data acquisition systems. The head will withstand continuous application of 120 ma dc without damage. Standard inductance of the 4047D is 67 μh for each leg, at 100 Kc, with a gap of 0.001-in. Other combinations of inductance and gap width can be provided for specific requirements.

Pickering & Co. Inc., Sunnyside Blvd., Plainview, N. Y. Phone: (516) 681-0200

Circle No. 352

Operational amplifier

Featuring a field effect chopper for stability, the epoxy encapsulated Model 1538 offers an output power of 10 V at 20 ma. The module is 0.6-in. x 2.4-in. Other featured specifications include a voltage gain of 160 dB, voltage drift at ±0.5 μV/°C, and current drift at ±2.5 pa/°C within an operating temperature range of −40 to +85°C.

P&A: $165; stock. Burr-Brown Research Corp., P. O. Box 11400, Tucson, Ariz. Phone: (602) 294-1431. TWX: (910) 952-1111.

Circle No. 353

There's a big new addition to the DIEHL line of servo components, motors and packages . . .

ALL NEW

SERVO AMPLIFIERS

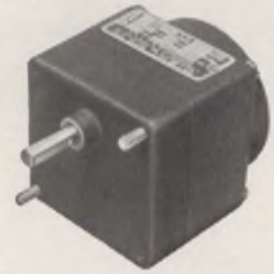
VORTEX BLOWER

MOTOR-TACHOMETER-GEAR TRAINS

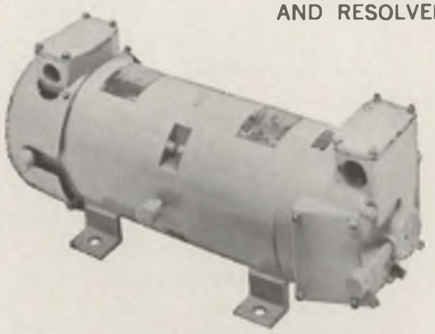
STEP-SERVOMOTORS

PHASE SHIFTERS AND RESOLVERS

POWER SERVOMOTORS



COMMERCIAL INSTRUMENT MOTORS (with and without gear reduction)



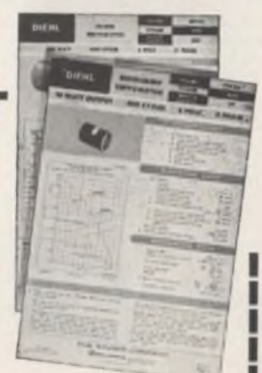
MOTOR-GENERATOR SETS

MULTI-STAGE BLOWERS

D-C MOTORS

INSTRUMENT SERVOMOTORS

Send for detailed spec sheets



THE SINGER COMPANY

* DIEHL DIVISION

Finderne Plant, Somerville, N. J.

Please send specification sheets on

- ☐ Servo Amplifiers
- ☐ Instrument Servomotors
- ☐ Motor-Tachometer-Gear Trains
- ☐ Step-Servomotors
- ☐ Phase Shifters and Resolvers
- ☐ Power Servomotors
- ☐ Commercial Instrument Motors
- ☐ Motor-Generator Sets
- ☐ Multi-Stage Blowers
- ☐ D-C Motors
- ☐ Vortex Blower

Name . . . . Title . . . .

Company . . . .

Street . . . .

City . . . . State . . . . Zip . . . .

* A TRADEMARK OF THE SINGER COMPANY • DI-107

See us at Booth No. 2B39-2B43 at IEEE

ON READER-SERVICE CARD CIRCLE 71

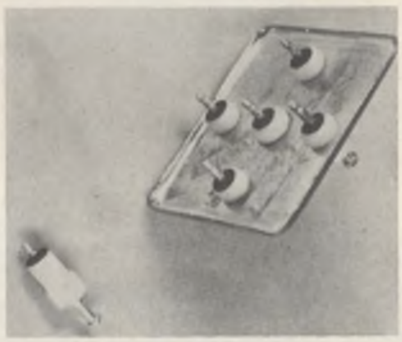
Aluminum heatsinks

The 8039 heatsink measures 3/4-in. in diameter by 11/32-in. high, fitting TO-5 or TO-9 transistor cases. The units are available in either black anodized or hardcoat anodize to withstand over 500 VRMS.

Vemaline Products Co., Franklin Lakes, N. J. Phone: (201) 337-6200.

Circle No. 354

Teflon feed-thru



A new Teflon feed-through terminal is designed to serve as either a conventional panel feed through or as a moisture-proof terminal for component housings. Tests indicate that the terminal will meet the requirements of MIL-T-27A.

Lundey Associates, Inc., 694 Main St., Waltham, Mass. Phone: (617) 893-6064.

Circle No. 355

Transducer-actuator

For computer peripherals and aerospace applications, a high-speed solenoid provides precise rotary motion.

The motion is produced directly and electromagnetically without using cams or linear-to-rotary translating mechanisms. This permits speeds up to 4 milliseconds. Life tests have exceeded 10^8 cycles.

P&A: $45.00; stock. IMC Magnetic Corp., 570 Main St., Westbury, N. Y. Phone: (516) 334-7070. TWX: (516) 333-3319.

Circle No. 291

RF preamplifier

The SRA-821C transistorized rf preamplifier is a weatherproof, solid-state unit designed for mounting at the antenna feed.

Typical noise figures of the SRA-821C range from 1.6 dB for 400 Mc units to 2 dB for 500 Mc units. Preamplifier gain over the entire frequency range is typically 30 dB with a nominal bandwidth of 5%.

P&A: $395.00; 6 weeks. Smyth Research Associates, 3555 Aero Ct., San Diego, Calif. Phone: (714) 277-0543.

Circle No. 292

Wide-band amplifier

An addition to the Min-Econ series, the Model 3596 wide-band amplifier is housed in a 1-1/4- x 2-1/4- x 3-1/4in. package. This unit covers the frequency range of 10 Mc to 175 Mc, with 18 dB gain, and an output capability of 1 p-p into 50 ohms.

P&A: $200; 3 weeks. C-Cor Electronics, Inc., P. O. Box 824, State College, Pa. Phone: (814) 238-2461.

Circle No. 356

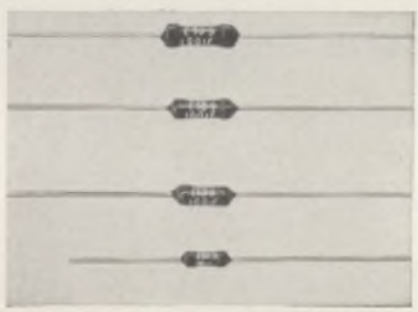
Oblong meters

Called the Imperial Line, oblong meters in eight sizes range from 1-1/2-in. to 7-in. These analog meters are offered in all standard dc types and ac rectifier types. The case material is thermoplastic.

Ideal Precision Meter Co., Inc., 214 Franklin St., Brooklyn, N. Y. Phone: (212) 383-6904.

Circle No. 357

Metal-film resistors

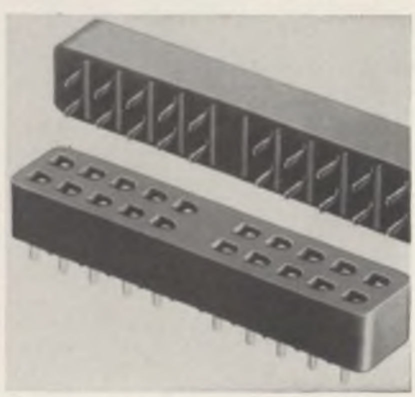


Power ratings from 1/20-watt to 1/8-watt are offered in the capped and conformally coated C Series resistors. The components cover a resistance range of 24.9 ohms to 500k in tolerances down to ±0.1%. Stability and mechanical strength are well above the requirements of MIL R-10509.

P&A: from $0.30 to $2.00; stock to 4 weeks. Angstrohm Precision, 7811 Lemona Ave., Van Nuys, Calif. Phone: (213) 989-3061.

Circle No. 289

Crystal holder



A strip-type crystal holder assembly is designed to replace individual crystal sockets, saving production time and space.

The multiple crystal holder socket, which mounts on printed circuit boards, uses beryllium copper contacts silver plated. It has low-loss polyamide insulation per MIL-P-170-91. Various configurations are available.

E. F. Johnson Co., Waseca, Minn. Phone: (507) 835-2050.

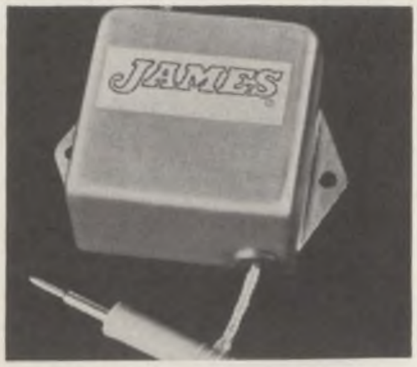
Circle No. 290

TO-60 PC socket

A transistor socket for the new TO-60 case size solders directly to PC boards. Mounted height above the board is 3/32-in. Beryllium copper contacts with silver/hard gold finish are individually stacked into the glass epoxy laminate insulation.

Nugent Inc., 802 E. Eight St., New Albany, Ind. 47150. Phone: (812) 945-0211.

Circle No. 358

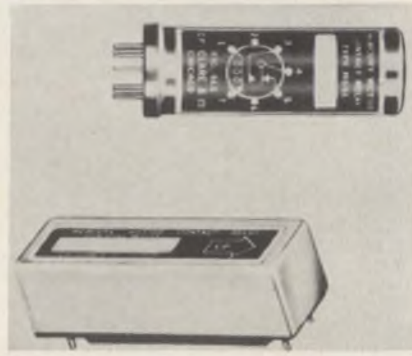


Shielded hf transformers

A series of three hf signal information transformers covers a frequency response range of 500 Hz to 50 MHz. They have complete primary and secondary box shielding. At 50 kHz common-mode rejection of interference is 85 dB. Called Data-Guard, the series is aimed at applications in control, multiplexing, storage and telemetry systems.

P&A: $19.95-$32.40; 2-6 weeks. James Electronics, Inc., 4050 North Rockwell St., Chicago, Ill. 60618. Phone: (312) 463-6500.

Circle No. 359



Mercury-wetted relays

Two sensitivity ratings, 40 mW single-side stable and 20 mW bi-stable, are provided by the HGSL and HGSM mercury-wetted relays. Type HGSL mates with wired assemblies while HGSM is a PC version. Either Form D (bridging) or Form C (non-bridging) contacts are available with power switching ratings up to 100 VA. Low level contact ratings are 0 to 300 mV, 0 to 100 mA.

C. P. Clare & Co., 3101 Pratt Blvd., Chicago, Ill. 60645. Phone: (312) 262-7700.

Circle No. 360

Series 53M Potentiometer for quieter performance, long life, zero backlash!

100% CARBON-TO-CARBON wiper-element contact construction completely eliminates metal-carried carbon wiper and results in an extremely long, noise and backlash free, life. One piece molded construction is the Clarostat secret . . . and for even greater reliability and stability, each unit is completely sealed against moisture, dust and other environmental hazards.

BRIEF SPECIFICATIONS

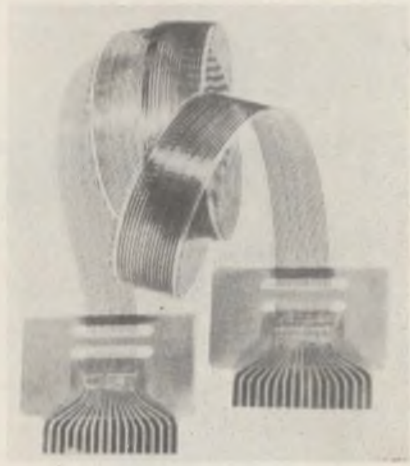
■ Power Rating — 2 Watts ■ Working Voltage—500VDC ■ Resistance Range — 50 ohms to 10 megohms linear, 250 ohms to 5 megohms tapered ■ Available with shaft seals, mounting seals, switches, high torque, ganging, nonmetallic shafts, L & T Pads, concentric shafts, high-voltage standoffs, backlash assemblies, and locking bushings. ■ Meets specifications per MIL-R-94 — Style RV-4.

WRITE FOR COMPLETE SPECIFICATIONS

CLAROSTAT

CLAROSTAT MFG. CO., INC. DOVER, NEW HAMPSHIRE

ON READER-SERVICE CARD CIRCLE 77



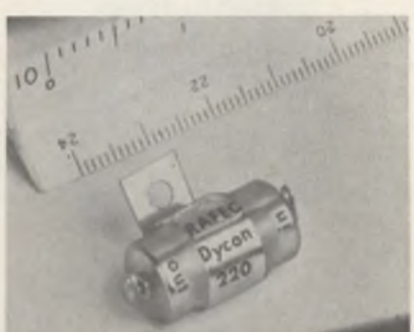
Flat cable in Kapton

Flat flexible cable is now available using DuPont's Kapton. The cables are available with or without shielding in a variety of configurations.

In a test for dimensional stability and shrinkage, the Kapton cable is said to show a variance of only 0.2 to 0.3% at 200 to 250°C. In the same test Mylar showed 3.5% variance at 200°C and melted at 250°C. Kapton is also said to be superior to Mylar in dielectric constant, dissipation factor and tensile strength.

Methode Electronics, 7447 W. Wilson Ave., Chicago, Ill. Phone: (312) 867-9600. TWX: (312) 265-1417.

Circle No. 361



RFI attenuator

The Model 220 attenuator is designed to prevent the accidental actuation of squibs, primers and detonators in the presence of high-intensity EMI. It attenuates frequencies from 50 kHz to radar levels by over 60 dB.

RAFEC Electronics, P.O. Box 566, Temple City, Calif. Phone: (213) 285-4078.

Circle No. 362


$1695
ZH·5400 Z
65

Stock phase analyzer accurate to ±0.004°

Featuring an accuracy of ±0.004 degree of full scale at any range from 50 Hz to 20 kHz, the off-the-shelf Type 203 Vectorlyzer is described by its manufacturer as the most accurate phase measuring instrument commercially available at a moderate price. In addition, it has a full scale range of 0.1 degree.

The instrument, developed and built by Ad-Yu Electronics, Inc., operates on the principle of measuring vector difference of two input voltages. This permits high speed and accuracy for measuring vector relations of alternating voltages.

One of the Type 203 Vectrolyzer's specific design function is to measure very small phase angles from 50 Hz to 20 kHz. It provides full scale deflection of 0.1, 0.2, 1, 2, 10, 20, and 180 degrees. The scale of these phase ranges is 4-1/2 inches long with a total of 100 divisions. According to the manufacturer, phase detection as small as 0.001 degree will produce movement of one-half division on the 1 degree range.

Other uses for the instrument include measuring phase error between a standard and an unknown component, and reading the voltage across two points which are both above ground potential.

The major elements of the instrument are: two step attenuators, two continuously adjustable attenuators, a wide-band phase inverter, an amplitude selector, a degenerative vector difference amplifier, a vector difference detector, a regulated power supply, and a continuously variable tuned filter.

Type 203 specifications

Accuracy: ±0.004 degree of full scale at any range from 50 Hz to 20 kHz

Phase angle ranges: 0-0.1, 0-0.2, 0-1, 0-2, 0-10, 0-20, 0-180 degrees. A 180 degree switch boosts ranges to: 180-180.1, 180-180.2, 180-181, 180-182, 180-190, 180-200 and 180-360 degrees.

Voltage scale tracking accuracy: ±2% from 50 Hz to 20 kHz. Full scale accuracy adjustable for exact reading with variable attenuator up to 100 kHz.

Input impedance: 20 pF shunted by 1 Meg to binding post; 5 pF shunted by 1 Meg with 40 dB attenuator probe.

Stability: Less than 0.5% with constant signals. With built-in filter, center frequency continuously adjustable from 50 Hz to 20 kHz over 30 dB attenuation for harmonics and noise.

Waveform distortion for phase measurement: 0.01% error for each 1% harmonics and noise.

P&A: $998; stock. Ad-Yu Electronics Inc., 249-259 Terhune Ave., Passaic, N. J. Phone: (201) 472-5622.

Circle No. 369

Pulse generator

Speed and flexibility are main features of a new programmable pulse generator (PPG) designed for laboratory and production-line testing of ferrite memory components.

The PPG 2120 is a table-top system offering 4, 8, or 16-step testing programs with operating speeds between 10 kHz and 5 MHz. It provides six output channels fed by high-speed current drives, and has two independent repeat channels.

Digital Equipment Corporation, Maynard, Massachusetts. Phone: (617) TW 7-8822.

Circle No. 370

Phase meter plug-ins

A new precision phase meter makes use of three plug-in modules to enhance usefulness, versatility, and applicability.

The basic meter, model 329-B, reads directly in degrees from 0 to 360, and has twelve 30-degree scales. Useful frequency range is 10 Hz to 300 kHz.

Plug-in "A" is a buffer amplifier; "B" is a high-gain preamplifier, and "C" is a variable input phase shifter. All units are completely solid-state.

Acton Laboratories, Inc, 531 Main Street. Acton, Mass. Phone: (617) 263-7756.

Circle No. 371

Frequency synthesizers cover three ranges

A family of three new solid-state, modularized frequency synthesizers designed for line or battery operation covers the dc to 110 kHz (Model ND 99K), 300 Hz to 1.1 MHz (Model 1M) and 300 Hz to 31 MHz (Model ND 30M) ranges.

All three models have an internal frequency standard provided by a 1 MHz quartz in a temperature-controlled, proportional oven. Stability, is listed at $\pm 5\ (10^{-9})$ /°C from +10°C to +35°C.

Measuring 17-1/2-in. wide x 7-1/4-in. high x 10-5/8-in. deep, and weighing 26-1/2 lbs net, all models are designed for 19-inch rack mounting.

P&A: $3,980 (Model ND 99K)., $4,090 (Model 1M), $5,900 (Model ND 30M); 30 to 60 days. Rohde & Schwarz, 111 Lexington Ave., Passaic, N. J. Phone: (201) 773-8010.

Circle No. 372

RBM CONTROLS NEWS

Serving Major Markets Since 1921

RELAY EDITION: 93

New 3PDT Switching Relays are Most "Versatile" and "Real Cost Savers"!

AC AND DC MINIATURE RELAY users have been presented with new cost-saving opportunities with the introduction of the RBM CONTROLS line of 3 pole double-throw switching relays.

The new Type 93 line includes both open and enclosed types, and is characterized by their rugged construction features, conservative ratings, versatility, and, above all, by several important cost-reducing features.

FRONT WIRING—**All terminals**, both coil and contacts, are out the front of the terminal block surface. This "everything out the front" construction makes it easier to wire, with resulting reductions in assembly costs.

Another cost-reducing feature is the one-screw, single-hole front mounting standard, which cuts both mounting and assembly time.

CONTACT FLEXIBILITY—Both open and enclosed types are available in three terminations — **3/16" quick connects, solder type, or printed circuit.** Continuing with the versatility of the new line, RBM CONTROLS has also provided contact flexibility. Button type power contacts can be provided on the relays with highest quality crossbar heavy duty contacts for reliable circuit operation on multiple switching operations.

MOUNTINGS—Numerous types of mountings are available. For the open type relay they include: (1) 6-32 Stud With Lug, (2) Single Hole With Lug, (3) Front Mounting, (4) Printed Circuit. The enclosed type relay includes: (1) Printed Circuit, (2) 8 & 11 Pin Octal Plug-In, (3) Quick Connect Plug-In, (4) Solder Terminal—Front Mounting, (5) Quick Connect—Front Mounting.

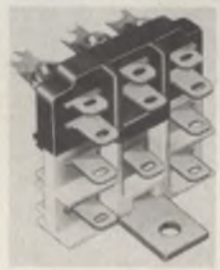
Open and Enclosed Printed Circuit Relays

Open type relays are available with printed circuit terminals for easy, low cost assembly to printed circuit board.

Enclosed type relay plugs into receptacle that is mounted directly to printed circuit board.

Special Construction Offers Many Advantages

MOLDED PLUG
For 3/16" quick connect plug-in enclosed relay provides protection in handling and servicing.



WIRING FLEXIBILITY
Both coil and contact terminals are out front for ease of wiring and low cost assembly.

CONTACT FLEXIBILITY
Button type (a) and crossbar (b) power contacts available on same relay for multiple switching operations.

LOW COST MOUNTING
One screw, single hole standard **front** mounting reduces assembly time.

General Specifications

CONTACTS—To 3PDT, Button—power, Crossbar—low energy loads.

COIL—DC to 110 Volts, AC to 240 Volts.

LIFE—Mechanical—10,000,000 Minimum; Electrical—10,000,000 Dry Circuit.

UL & CSA—Recognized under U/L Component Recognition Program and CSA with variety of contact ratings, coil voltages, and terminations.

Standard controls available from your authorized distributor.

For complete technical data, please write to RBM CONTROLS, Division Essex Wire Corporation, Department 93; Logansport, Indiana.

TEST EQUIPMENT

Transistor tester

A new tester measures small signal parameters of transistors (including FETs) and junction leakage currents down to 1 namp. Gain measurements are made in a 1000 Hz bridge and leakage is tested through a MOS FET operation amplifier input.

Applied Electronics Corp., P.O. Box 43, Metuchen, N. J. Phone: (201) 549-9200.

Circle No. 363

Leakage test set

Semiconductor test module 10CD permits full-scale leakage measurements as low as 100 picoamperes. Breakdown measurements with full-scale currents as low as 1 amp can be made with test potentials to 1 Kv, through the use of two plug-in adaptors which are furnished with the module. The new module is designed for use with the manufacturer's Model 70 semiconductor tester.

P&A: $725; stock. Birtcher Corp., 745 S. Monterey Pass, Monterey Park, Calif. Phone: (213) 268-8584. TWX: (213) 266-6814.

Circle No. 364

Sweep generator head

The model P-855 sweep and cw generator plug-in head is designed to cover the 2 to 32 MHz band in applications such as steep-skirt filter testing. The instrument is a manually swept fundamental oscillator with an output of 1 volt into 50 ohms with agc. Stability is ±35 Hz below 20 MHz and ±70 Hz above 20 MHz.

Kay Electric Co., Pine Brook, N. J. Phone: (201) 746-8080.

Circle No. 365

General purpose scope

Stable triggering up to 30 MHz and a bandwidth of 15 MHz are the leading features of the solid-state oscilloscope 101. Maximum sensitivity is 50 mv/cm. The 17-lb instrument includes a specially designed 3-in. CRT and it can be powered by either a 12-volt battery or ac line.

Price: about $460. EMI Electronics Ltd., Hayes, Middlesex, England. Phone: HAYes 3888.

Circle No. 366

VLF spectrum analyzer

A solid-state spectrum analyzer is specifically designed for examination of the low-frequency, fine structure of phase and loss characteristics of microwave devices. It is also useful in other areas where low-frequency information can be converted to electrical form.

Frequency is dc to 70 cps nominal and filter bandwidth is 1.0 cps at −1.0 dB nominal or 4.0 cps at 20 dB nominal. Input signal level is 5 mV to 5 v rms with input impedance at 50 K nominal.

Rantec Corp., Calabasas, Calif. Phone: (213) 347-5446. TWX: (213) 348-2566.

Circle No. 280

Deviation bridge

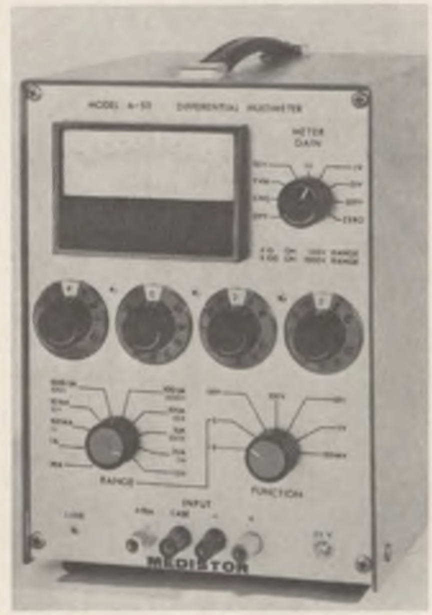
A self-balancing bridge calculates and digitally displays the percent deviation of one resistance from its nominal value, or from another resistance.

The nominal value and permissible deviation limits are set into the instrument by the operator. On command, the Model 220 bridge displays percent deviation with plus or minus indication. If deviation limit is exceeded, a red background and the words OFF LIMIT also appear.

Resistance range is 10 ohms to 10.99 Meg and deviation limits are selectable from 0 to ±19.9% in 0.1% steps. Accuracy is ±0.1%.

Price: $800. Anaheim Instrument Co., 1732 S. Zeyn, Anaheim, Calif. Phone: (714) 635-2600.

Circle No. 281



Low-cost multimeter

This instrument measures differentially both dc voltage and current. A special Wheatstone Bridge circuit allows a wide range of resistors to be measured as well. The limits of error are ±0.05% of reading + 10 μV for all dc voltages from 1 mV to 1 kV. The current ranges extend from 0.1μA to 11 amps and limit of error of ±0.1% of reading or 0.3 nA for all ranges except the 1.1 and 11 amp ranges where the error increases to ±0.25%. The resistance ranges are from 1.1 ohm to 11 Meg full scale. The maximum limit of error on this function is ±0.1% of reading or 1 milliohm.

P&A: $550; 30 days. Medistor Instrument Co., 1443 N. Northlake Way, Seattle, Washington. Phone: (206) 633-5145.

Circle No. 367

Accuracy is our policy

A typographical error appeared in the table of specifications pertaining to Hewlett Packard's Model 3406A sampling voltmeter, p 58 of the December 6 issue.

Full-scale accuracy of the instrument should read as stated in the text: ±3% from 10 kHz to 100 MHz, ±5% from 100 MHz to 700 MHz, and ±8% from 700 MHz to 1 GHz.

Circle No. 368

Swr meter; 4 db noise

The Model 415E swr meter measures standing wave ratio, attenuation, gain, or any other parameter determined by the difference between two signal levels.

Like other meters of its type, Model 415E is a tuned amplifier-voltmeter calibrated in db and swr for use with square-law detectors. Low noise is said to be insured by recent detector advances.

An expand-offset feature allows any 2 db portion of the instrument's 70 db range to be expanded to full scale for maximum resolution, at a specified linearity of ± 0.02 db.

P&A: $350; 4 weeks. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000.

Circle No. 760

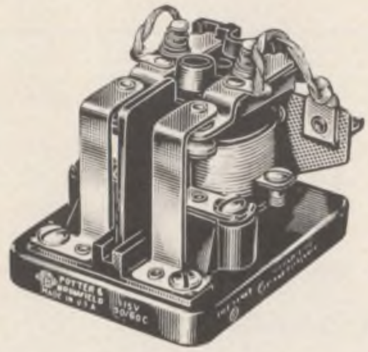
Frequency divider

The model TSA-850 all solid-state frequency divider accepts sine and square waves as well as pulses. Using bistable dividers, the instrument accuracy is solely determined by the counter's crystal. With a dividing factor of either 10 or 100 the unit can be used with most counters within the 500 kHz to 50 MHz range.

Input sensitivity range is 100 mV to 10 V. Impedance is switchable from 2-1/2 k shunted by 15 pF to 75 ohms.

P&A: $685; stock. Amark Corp., 31 Commercial St., Plainfield, N. Y. Phone: (516) 938-3322.

Circle No. 761



Here's why engineers have specified this heavy duty 25 amp relay by P&B for over 30 years

This is the granddaddy of all P&B relays. Our very first design. Many millions are in use throughout the world . . . starting motors, controlling elevators, switching high current and voltage loads, doing a multitude of heavy duty jobs, reliably. Year after year, the PR Series remains high on our best-seller list. Here are some reasons why.

EXCELLENT CONTACT WIPE ACHIEVED WITH FLOATING CONTACT CARRIER

PR relays are designed with a full floating carrier for the movable contacts. Beside providing sufficient contact pressures, the floating carrier builds-in an abundance of wipe to keep the contacts scrubbed on every operation. Large, 5/16" diameter contacts switch 25 ampere non-inductive loads or 1 HP at 115/230 VAC, single phase. A phenolic barrier between the contacts of multipole relays prevent flash-over between contacts.

SELECT FROM A VARIETY OF CONTACT ARRANGEMENTS

PR reliability is available in relays having the following contact arrangements: SPST-NO, SPST-NC, SPST-NO-DB, SPST-NC-DB, SPDT, DPST-NO, DPST-NC, and DPDT. Coil voltages range from 6 to 440 volts A.C., and 6 to 110 volts D.C. A vast number of special variations of these standard parameters have been engineered over the years.

AUXILIARY CONTACTS ADD TO VERSATILITY OF PR RELAYS

A single set of auxiliary contacts (Form A, B or C) can be supplied when the application demands. They are rated at 5 amperes at 115 VAC, 60 cycle resistive. Standard models of PR relays with auxiliary contacts are available from leading electronic parts distributors.

MANY STANDARD RELAYS ARE LISTED BY U/L AND CSA

A wide range of standard PR relays is listed by Underwriters' Laboratories (File E22575) and Canadian Standards Association (File 15734). CSA listing covers AC relays only. These listings can often save you time and extra expense when obtaining UL or CSA qualification for your products.

MAGNETIC ARC-QUENCHERS FURNISHED ON SOME MODELS

For DC loads over 28 VDC, PR relays with normally open contacts can be furnished with permanent magnets to quench arcs. These magnets increase the DC voltage rating to 220 volts resistive . . . and often increase the life of contacts handling DC inductive loads.

PR SERIES SPECIFICATIONS

GENERAL:

Mechanical Life: Single-pole, 1,000,000 (cycles); double-pole 10,000,000 (cycles).

Contacts: 100,000 cycles at rated load. Contact life increases at smaller loads or with appropriate arc suppression.

Breakdown Voltage: 1,500 volts rms minimum between all elements and ground.

Ambient Temperature Range:
DC: −55 to +80° C.
AC: −55 to +45° C.

Weight: Approximately 10 ozs.

Pull-In
DC: 75% of nominal voltage (approx.)
AC: 78% of nominal voltage (approx.)

Terminals: Heavy-duty screw type terminals are standard for coil and contacts. Available with printed circuit, plug-in, 1/4" quick connect and terminals for rear panel wiring.

Enclosure: PR dust cover.

CONTACTS:

Arrangements: Up to 2 Form C (DPDT.)

Material: 5/16" dia. silver standard. Other materials available for special applications.

Load: 25 amps non-inductive or 1 HP @ 115/230 volts AC, single phase. Special version—30 amp. non-inductive at 115/230 VAC; single phase available. (Consult factory)

COIL:

Voltage: AC: 6 to 440 volts.
DC: 6 to 110 volts.

Power: DC: 2.0 watts nominal.
AC: 9.8 volt-amps.

Resistance: 63,800 ohms maximum.

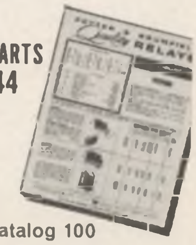
Duty: Continuous, AC or DC (DC coils will withstand 8 watts @ +25° C.

Mounting: Two 5/16" diameter holes on 1 7/8" centers.

LEADING ELECTRONIC PARTS DISTRIBUTORS STOCK 44 DIFFERENT PR RELAYS

Immediate delivery at factory prices.

Ask your distributor for a copy of Stock Catalog 100



POTTER & BRUMFIELD

Division of American Machine & Foundry Company, Princeton, Indiana
Export: AMF International, 261 Madison Avenue, New York, N.Y.

Speed Inquiry to Advertiser via Collect Night Letter ON READER-SERVICE CARD CIRCLE 87

Instant C/L meter to 1 Mc

Direct readings of three-terminal capacitance and two-terminal inductance are provided by the Model 71A meter. The instrument operates at 1 Mc and provides an accurate dc analog output of the measured value.

Capacitance range is 0 to 1000 pf and inductance range is 0 to 1000 μh, each in seven ranges. The resolution of the meter reading is 0.1 unit with a basic accuracy of 1% full-scale.

The instrument is said to be particularly well suited to measurements of semiconductors. It operates with a 15 mv, 1 Mc test signal and includes provisions for dc bias up to ±200v.

P&A: $375; stock. Boonton Electronics Corp., Rt. 287 at Smith Rd., Parsippany, N. J. Phone: (201) 887-5110. TWX: (201) 235-6747.

Circle No. 375

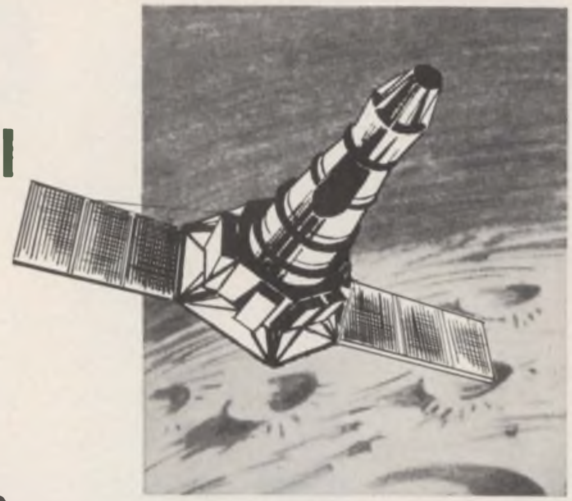
Guard protects meters

Designed for quick bench installation, the Simpson Meter Safe/Guard will protect meters from electrical damage, regardless of polarity. Used with any ac or dc volt-ohm meter with a 20,000 ohm per volt rating, the device prevents overheated springs, coil burnout, and bent pointers.

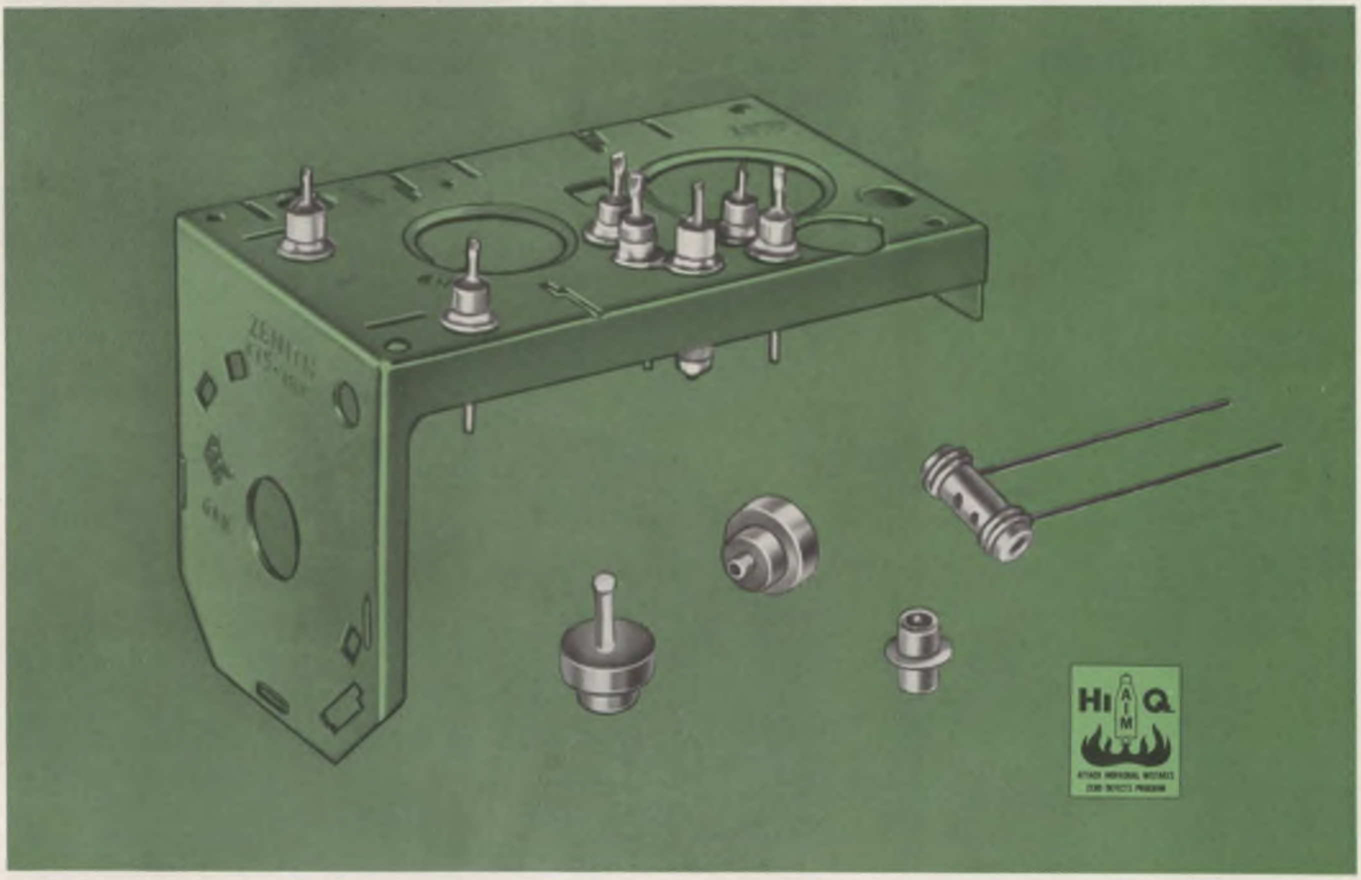
P&A: $1.95; stock. Simpson Electric Co., 400 West Madison St., Chicago, Illinois. Phone: (312) ES 9-1121.

Circle No. 376

HI-Q capacitors for critical lunar shots



and TV tuner trouble spots



We once received a letter that said, in part, "... Ranger 6 ... slammed into the moon on one of the most phenomenally accurate shots ever achieved ... your company has helped to achieve an enviable record in space activities. Even greater challenges await us in space ... your company will help meet (them) with the same enthusiasm and dedication to quality and reliability you have exhibited in the past." But it didn't change our ideas one bit about the importance of quality in "ordinary" capacitors for TV tuners too. That's why Hi-Q capacitors are selected and specified most often for any kind of application—moon shot or mundane.

Of course, our greatest challenges are usually generated in the more exotic developments of electronics for space. But the things we learn in meeting these requirements are also reflected in the increasing performance and reliability of our "everyday" capacitors for less demanding uses.

So whatever your capacitor needs, check with a Hi-Q catalog ... or check with a Hi-Q engineer. You'll find an answer with one or the other.

HI-Q® DIVISION

AEROVOX
CORPORATION
MYRTLE BEACH
SOUTH CAROLINA

SELECTED COMMERCIAL and MILITARY HI-Q PRODUCTS ARE AVAILABLE OFF-THE-SHELF FROM AUTHORIZED AEROVOX DISTRIBUTORS

ON READER-SERVICE CARD CIRCLE 89

Electronic Design's

"TOP TEN" CONTEST

FIRST PRIZE

win 2 round-trip tickets between New York and PARIS

VIA AIR FRANCE

- **Select the "TOP TEN" ads in this issue.**
- **All Electronic Design readers are eligible.**
- **Over 100 other valuable prizes!**

2nd PRIZE

HOFFMAN COLOR TV CONSOLE

Hoffman 23" console, featuring 26,000 volts of picture tube power . . . 4"x6" front-firing speaker. 32"x29"x19⅛" cabinet. (Retail value: $600.00.)

3rd–8th PRIZES

BULOVA ACCUTRON® ELECTRONIC TIMEPIECES

The "Spaceview" is an ideal timepiece for electronic engineers. Its clear-view dial reveals transistorized electronic circuit and tuning fork assembly. (Retail value: $150.00.)

PLUS 100 ADDITIONAL PRIZES

400 IDEAS FOR DESIGN—innovations, techniques, guidelines of design. This attractively bound, hardcover edition will be given to 100 winners. (Retail value: $8.50.)

CONTEST FOR ADVERTISERS, TOO

There is a separate contest for manufacturers and their advertising agencies. See second side of contest insert at right.

here's all you have to do to enter:

Rate the ads appearing in this issue of *Electronic Design*. Select the *top ten*—the ads that, in your opinion, will be best remembered by readers. Your choices will be measured against the 10 ads ranking highest in the "Recall-Seen" category of "Reader Recall"—*Electronic Design's* scientific method of measuring readership. In making your predictions, be sure to consider your 53,000 fellow engineers' interest in the subject matter of the ads, their effectiveness, impact, and attention-getting values.

Entry blanks and complete contest rules appear at right. Don't miss this opportunity to win one of the many valuable prizes. The first prize winner will receive round-trip tickets for two, between New York and Paris, via Air France!

Signal generator

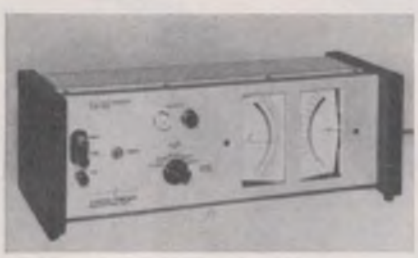
A new sinewave generator, type 191, gives constant peak-to-peak amplitude readings over its entire frequency range.

Total range of the type 191 is continuously variable from 0.35 Mc to 100 Mc in 7 ranges. A 50 Kc reference output is also available. When the output is terminated in 50 ohms, the selected frequency is within ±2% of the indicated reading on a 170° arc scale. Harmonic content is typically less than 5%.

Continuous peak-to-peak voltage sampling holds the output amplitude into 50 ohms constant within ±3% throughout the frequency range at most amplitude settings. The source impedance is 50 ohms for all control settings.

P&A: $400; early 1966. Tekrtonix Inc., P. O. Box 500, Beaverton, Oregon. Phone: (503) 644-0161.

Circle No. 377



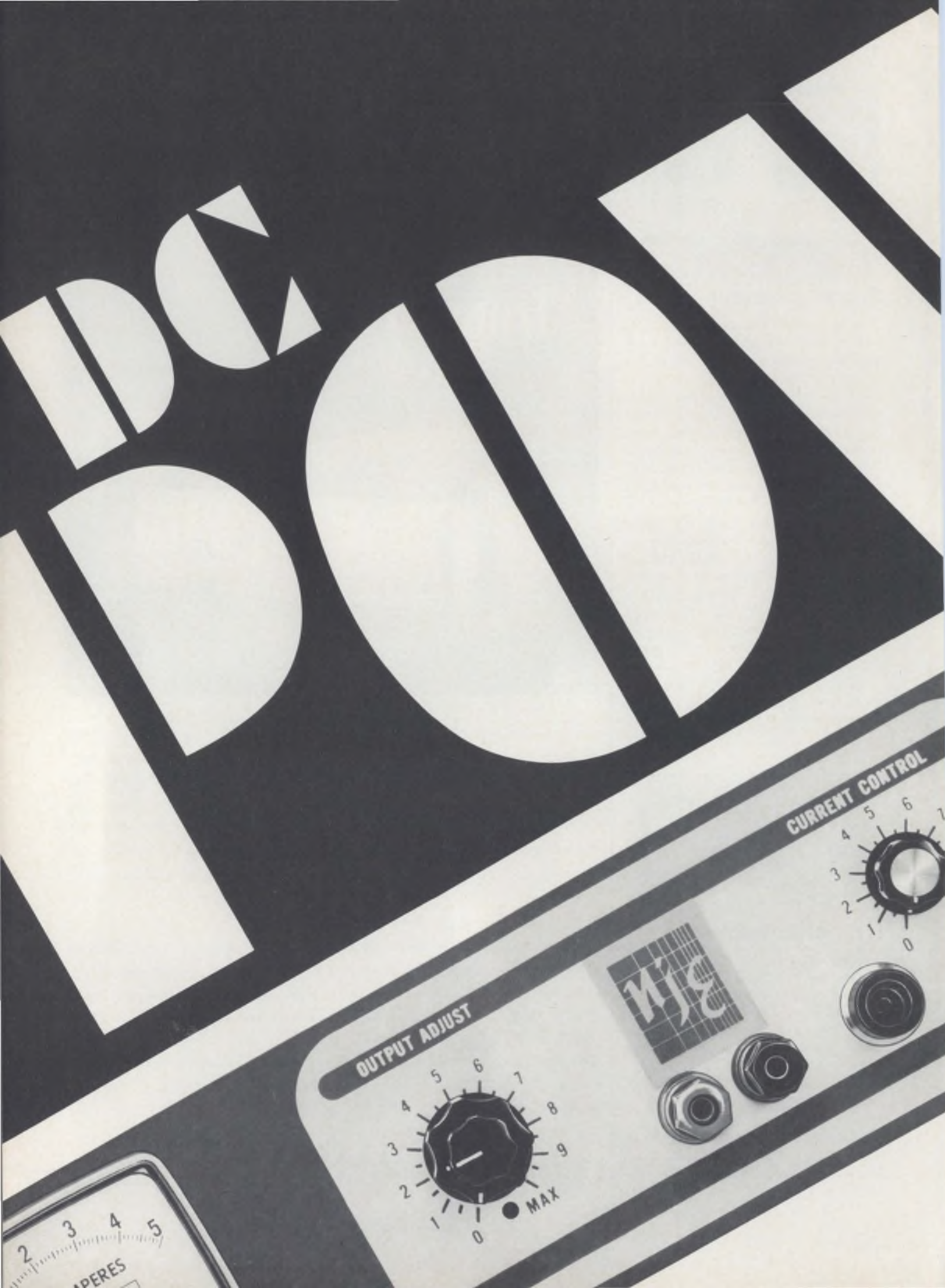
Hybrid dc voltmeter

Combining digital and analog circuitry, the Type 21BV volt-meter is capable of measuring voltages over a broad range, from the low millivolts region to 3.200 volts. After initial range selection operation is fully automatic.

About 90% of an input value is presented in true digital form, the remainder as analog vernier.

P&A: $650.00; 2 to 3 weeks. J-Omega Company, 2278 Mora Drive, Mountain View, California. Phone: (415) 961-2000.

Circle No. 378


CURRENT CONTROL
OUTPUT ADJUST
MAX

NJE is *the* powerhouse source for all **DC power supplies.** Years of intensive specialization, engineering creativity and skillful production give you these great advantages: uncompromising quality, fastest delivery, lowest possible cost consistent with top specs. The result: scores of major companies make NJE their exclusive power consultants. Here is one prime example why:

One supply for constant current or voltage

Premium performance, flexibility, economy—all from one DC power supply: the NJE RVC-36-5-M (shown at left). It can be used as a voltage regulated power supply or current regulated power supply. Load and line regulation for the constant voltage unit is 0.005% or 0.5mv load and 0.01% or 1.0mv line. Load and line regulation for the constant current unit is 1ma/v load change in output and 1ma line. Output is 0 to 36 volts and 0 to 5 amps. Ripple is one millivolt RMS, maximum. Built-in versatility makes it worth much more than its low price of $345.

Free in-plant demonstration

We will demonstrate the above or any other RVC type Power Supply in your plant—no cost or obligation. This will be handled by our factory-trained representative, qualified to demonstrate and answer all questions. For a demonstration, write on your company letterhead today. Or circle our Reader Service number for complete specs and prices on the entire line.

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Electronic Development and Manufacture

ON READER-SERVICE CARD CIRCLE 213

a pot is a pot is a pot...

No it's not!

It's not true that everyone's precision pots are the same... not even when the specs and the prices look alike. A Spectrol precision pot stands apart.

We give you a potentiometer with: (1) the best possible accuracies for linear and non-linear functions that only our own in-house designed winding equipment is capable of providing, (2) high reliability built-in to meet the most demanding environmental conditions, and (3) standard designs that assure positive contact under the most severe shock and vibration.

In addition, we continue to offer exceptional responsiveness to customer requirements for special designs, a service which has firmly established our reputation as a quality custom house.

Therefore, a pot is a pot is a pot—unless it's a Spectrol precision pot. Its superior quality sets it apart. If you don't agree, you probably haven't tried one. If you would like to, contact us. We'll make it easy for you. Ask for our new eight-page short form catalog.

Spectrol Electronics Corporation
17070 East Gale Avenue
City of Industry, Calif. 91745

spectrol

ON READER-SERIVCE CARD CIRCLE 147

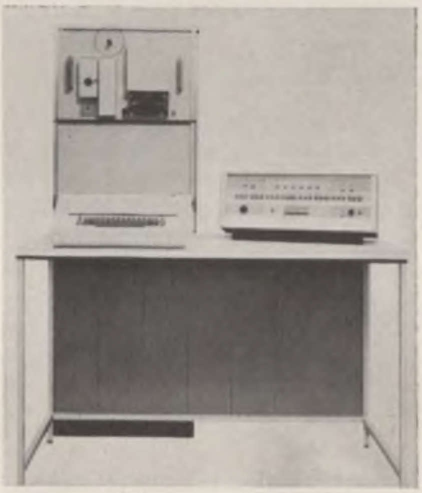
Flotation system

An electronic system is capable of suspending oceanographic instruments at predetermined depths. Designed to be launched from aircraft, surface vessels or submarines, the system automatically seeks a required depth and hovers during an experiment, returning to the surface on completion of its task. It also can be programed to change depths.

Buoyancy of the system is maintained by a piston valve which automatically expels or adds sea water ballast.

Sylvania Electric Products Inc., 730 Third Ave., New York, N. Y. Phone: (212) 551-1000.

Circle No. 379



Microcircuit computer

The DDP-124, a new 24-bit word computer, is constructed with monolithic integrated circuits. It can be applied to a variety of on-line, real-time systems uses, as well as general purpose open shop computation. It is capable of 285,000 computations per second, has a basic memory cycle of 1.75 μs with 0.8 μs access time, and multiples in 14 μs. It includes 4,096 words of core memory optionally expandable to 32,768 words and is program compatible with DDP-24 and DDP-224 general purpose computers.

Price: $65,000. Computer Control Company Inc., Old Connecticut Path, Framingham, Mass. Phone: (617) 879-2600.

Circle No. 380

Care to comment on Electronic Design's new format? Fill in the RFADER-REACTION CARD behind the front cover.

Digital transport

The Model ATM-13 is designed for airborne, shipboard and land-mobile use in such applications as reconnaissance and geophysical work. It is said to be the first recorder of its type to generate data that is computer-compatible. Blocks of data recorded by the ATM-13 are spaced only three-quarters of an inch apart on the tape.

Models include airborne, land-mobile and shipboard designs, seven-track or nine-track, either as a basic transport or with full data electronics.

The ruggedized transport is able to withstand shocks of up to 15 times the force of gravity and operates reliably at altitudes of up to 70,000 feet. Maximum tape speed is 75 ips in read/write, start/stop mode, and more than 100 ips in continuous read and/or write (gapless) mode. In either mode, the ATM-13 can pack up to 800 characters on an inch of magnetic tape.

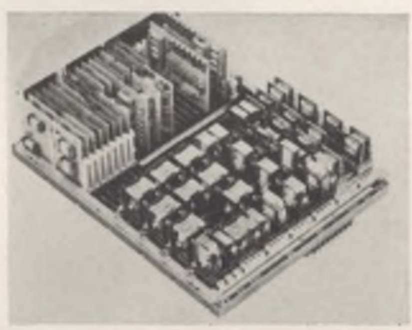
Price: $14,000 to $20,000. Ampex Corp., 401 Broadway, Redwood City, Calif. Phone: (415) 367-4151.

Circle No. 381

Circuit packaging

A flexible circuit packaging system allows manufacturers to intermix solid state and relay circuitry with a compact method for mounting and connecting printed circuit cards.

Two rectangular mounting frames are available. The module I frame can accommodate six rows of single printed circuit cards, with 26 positions per row for a total of 156 card positions. Module I can also be used to mount eight rows of wire contact or permissive make relays (separately or intermixed) for a maximum of 152 relays. Reed relays can also be accommodated in the system.



A slightly larger Module II frame can be used to mount 10 rows of printed circuit cards, with each row containing 28 single card positions for a total of 280 printed circuit cards.

Availability: 30 days. IBM, 1000 Westchester Ave., White Plains, N. Y. Phone: (914) 696-7409.

Circle No. 382

Counting modules

Three new modular instruments, all direct-coupled, mate with the manufacturer's M100, 100 Mc counting system. They are the AN106 dual amplifier, the LG101 linear gate and the AN105 stretcher amplifier.

The AN106 is a bi-polar broadband dual amplifier featuring low noise and fast recovery. Linear output range extends from +0.7 volt to −0.7 volt. Fixed gain is 4.

The LG101 linear gate features buffered inputs and the elimination of signal breakthrough. Limiter input is fully protected, operating range is ±1 volt, and gate opening and closing time is 2.5 nsec.

The AN105 is a general purpose, integrating stretcher amplifier of low impedence outputs. It is designed for negative inputs but is not damaged by large positive or negative transients. Another feature is decay times from 100 nsec to 1 msec.

EG&G Inc., 35 Congress St., Salem, Mass. Phone: (617) 267-9700. TWX: (617) 262-9317.

Circle No. 383

More for your money at MIL-R-27208A levels!

CHECK WITH DALE – In a rigid value analysis program we've lowered prices and – in all cases – raised performance levels. The thoroughly reliable design you see here will do a wide range of Mil-level jobs – for less. Here are its components:

■ **HOUSING** of high temperature diallyl phthalate meets Mil Standard 202 and MIL-R-27208A.

■ **RESISTANCE ELEMENT** has maximum length and diameter to provide highest resolution values available. Unique winding process improves linearity and resolution by absolute captivation of individual turns of wire. Thermo-conductive mandrel forms high mass heat sink eliminating "hot spots." Special Dale "Captive-Weld" process forms strong, low-resistance termination.

■ **WIPER AND SCREW ASSEMBLY** provides positive settings under all environmental conditions. Stainless steel adjustment screw has clutching provision to prevent overtravel damage. Precious metal contacts maintain unvarying pressure and high temperature silicone rubber "O" ring provides excellent environmental insulation.

WRITE FOR NEWLY EXPANDED CATALOG B – containing complete specifications on 57 Dale T-Pots, including many special models – or call us if you want information today!

SPECIFICATIONS MIL-R-27208A MODELS

Equiv. Mil Model	RT-10	RT-11	RT-12	RT-22
Dale P.C. Pin Model	691	1287	1680	5091
Dale Flex. Leads Model	697	1288	1697	5050†
Height	.18	.28	.19	.22 – .19†
Width	.32	.31	.32	.500
Length	1.00	1.25	1.25	.500
Power Rating	1 watt at 70°C, derated to 0 at 175°C			
Oper. Temp. Range	–65°C to +175°C			
Adjustment Turns	15±2	25±2	22±3	23±2
Mounting Centers	.750	1.000	1.000	.520
Standard Tolerance	±5%	±5%	±5%	±5%
Standard Resistance Values	10 ohms 20 ohms 50 ohms 100 ohms 500 ohms 1K ohms	2K ohms 5K ohms 10K ohms 15K ohms 20K ohms		25K ohms 30K ohms 50K ohms (Max. Models 691, 697, 5091 & 5050) 100K ohms

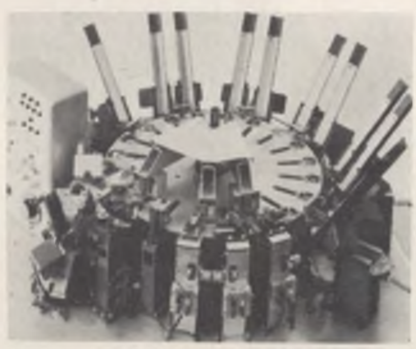
DALE ELECTRONICS, INC.
1328 28th Avenue, Columbus, Nebraska
Also Sold by Dale Electronics Canada, Ltd., Toronto, Ontario, Canada
Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 31

Wire holder

A combination of the 344-3 wire holder and flx-arm vise holds a connector, and supports the lead wires that are being attached. This double action is said to speed production wiring of multiple-lead connectors.

Flotron Industries Inc., 1201 East Grand Ave., El Segundo, Calif. Phone: (213) 678-8164. TWX: (213) 332-5805.

Circle No. 384



Wafer measuring/sorting

"Amecos" is a mechanical and electrical machine that measures and sorts silicon wafers by thickness or resistivity. Maximum speed is 1800 slices per hour. A wide range of thickness, diameter, flat size, and resistivity can be accommodated. The slices are never dropped and are never slid over each other. The process is fully automated from preliminary inspection to final sorting.

Numerical Control Corp., 3033 Jefferson St., San Diego, Calif. Phone: (714) 297-4977.

Circle No. 385

this tiny ENDEVCO device could change your career.

Pixie already is revolutionizing the audio engineer's world, and it's beginning to transform other fields, as well. Pixie is a tiny, semiconductor transducer. It changes its resistive characteristics with force—linearly. A 10-gram force produces a 15% change in resistance. Frequency response is from DC to 50,000 cps. It is powerful enough to drive meters and other readout devices *without additional electronics.* It is an ideal source of proportional feedback. And its price tag—lower than most transistors—makes it ideal for large-volume and expendable applications.

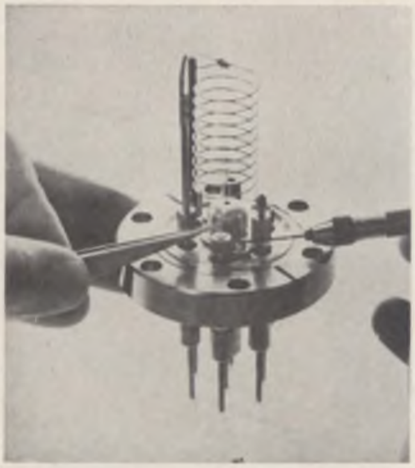
Pixie is looking for new fields to conquer. It is being tested now for such applications as vibration, shock, pressure and motion sensing.

Will you be the man to start the revolution in your field? If you will describe your potential application on your company letterhead, we'll be glad to send you two free Pixies for your experimentation. Write: Mr. B. C. Shoor, Product Manager.

ENDEVCO CORPORATION Σ

801 S. Arroyo Parkway, Pasadena, California 91109
Branch Offices in Palo Alto, Calif.; Chicago, Ill.; Akron, Ohio; Boston, Mass.; Haddenfield, N.J.; Annapolis, Md.; Huntsville, Ala.; Lake Park, Fla.; San Juan, Puerto Rico.

Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 95

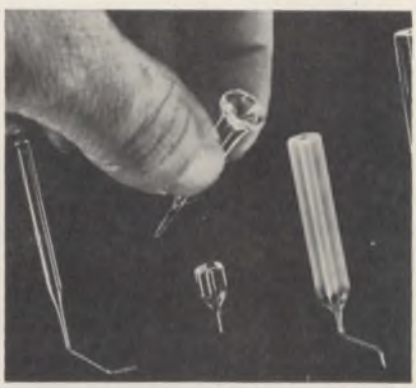


Ionization tube

A bakeable, exposed ionization tube is equipped with filaments, grid and collector that can be replaced by the user. Without the glass envelope, the elements are exposed directly to the vacuum, and the glass gettering surface is eliminated, improving reliability. The tube can be used in vacuum systems down to 2 x 10^{-10} torr (the x-ray limit). Designated the GIC-018, it comes in three separate flange-mounted styles to mount on any diffusion or ion-pumped systems.

Price: $175-220. Consolidated Vacuum Corp., 1775 Mt. Read Blvd., Rochester, N. Y. Phone: (716) 458-2550.

Circle No. 386

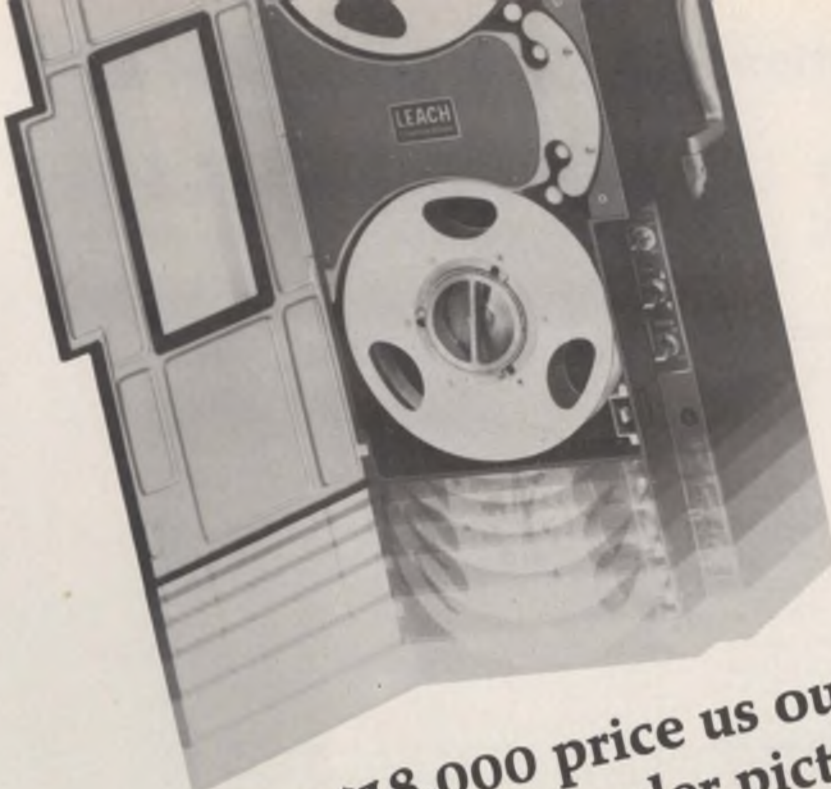


Glass capillaries

Glass capillaries are available accurate to ±0.00005-in. and with holes as small as 0.0005-in. in diameter. Tip OD's are held to ±0.0005-in. and bores are held to ±0.0001-in. consistently. All bores are smooth and "stepless."

Specialty Glass Products, Inc., 2551 Wyandotte Rd., Willow Grove, Pa. Phone: (215) 659-8400.

Circle No. 387


LEACH

Percussive/arc welder

Designated Model 220, a new percussive/arc welder has a dual energy capacitive-discharge power supply, and has separate circuits and controls for the stored energy to the actuator and weld circuits. A RF pulse initiates the weld current, and the RF timing control circuit allows the actuator to attain very high velocities and provides accurate firing at predetermined gap settings.

ITT Cannon Electric, 3208 Humboldt St., Los Angeles, Calif. Phone: (213) 225-1251.

Circle No. 388

Circuit board

A "dry process" technique stamps only a desired circuit pattern onto base material. No etchants or acids are used. Circuit boards are available in 1 oz. copper on a variety of base materials ranging from hard board paper through XXXP phenolics.

Cir-Cut Board Inc., 5616 4th Ave. South, Seattle, Washington. Phone: (206) 723-3320.

Circle No. 745

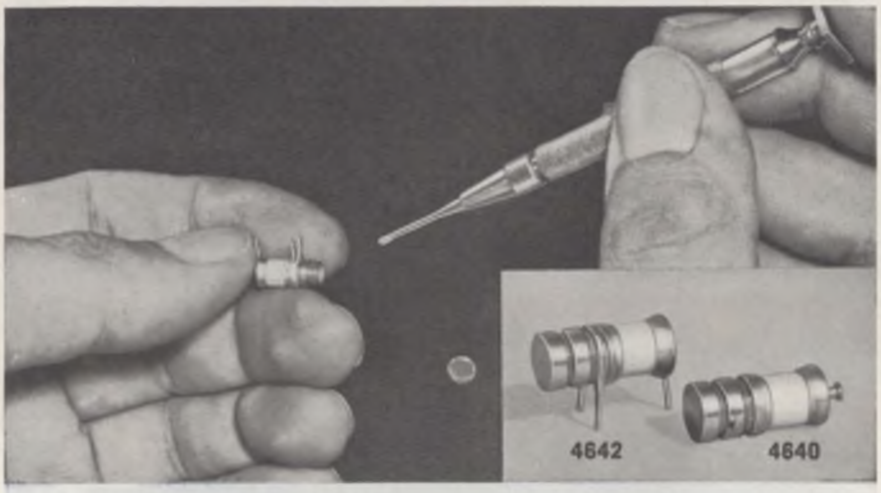
For or against Electronic Design's new look? Cast your vote using the READER-REACTION CARD behind the front cover.

Thermometer pistol

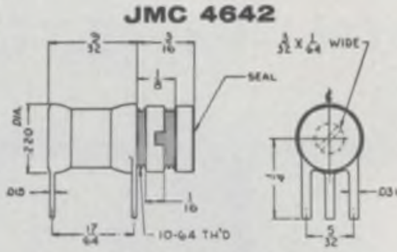
A new, low-cost infrared thermometer measures temperatures from 150° to 3000°F. The Rayner is a self-contained, light-weight pistol which is battery operated. When aimed at a surface, temperature is indicated on the calibrated meter housed in the rear of the instrument.

P&A: $395; stock. Raytek, Inc., 1277 Terra Bella Ave., Mountain View, Calif. Phone: (415) 961-1650.

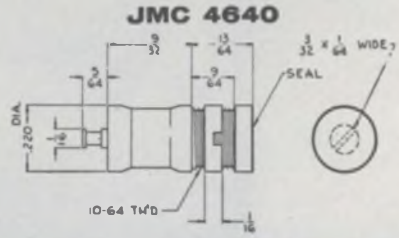
Circle No. 389



JMC 4642



JMC 4640



Poly-pattern generator

Called the poly-pattern generator, an electron beam controller permits generation of various welding patterns such as circles, triangles, squares, rectangles, hexagons, and optional special patterns. These range in size from a dot to the limitation of the electron beam welder.

The welding beam is positioned and driven electronically by controlling the X and Y deflection coils of the welder. Since only the beam is moved, inertia and backlash are essentially zero.

Another special feature of the generator is "modulated puddling," which is accomplished by spinning the welding beam in a dilating and contracting circle. This has promise of being useful in reducing weld porosity in difficult-to-weld materials such as inconel or titanium.

General Electric Co., P.O. Box 15202, Cincinnati, Ohio. Phone: (513) 243-5629.

Circle No. 390

Solder coating systems

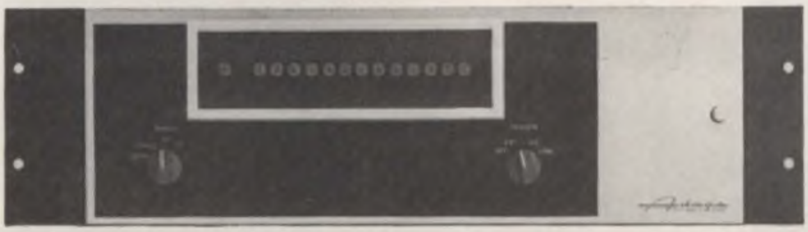
A new solder coating system uses centrifugal force coat printed circuit boards.

The new Model 562 is fully automatic. Up to 100 individual boards can be coated per hour with MSFC 154 quality. Single board capacity is 12-in. x 12-in. or multiple smaller boards. Dip and spin time can be varied from 0 to 15 seconds.

Gyrex Corp., 3003 Pennsylvania Ave., Santa Monica, Calif. Phone: (213) 393-0462.

Circle No. 391

NEED 14-BIT A-TO-D CONVERSION AT 200 KC? OR 8-BIT AT 1 MC? ADAGE HAS IT!



The high-speed, high-resolution VT13-AB and ultra high-speed VT7-AB are the latest additions to the Adage VOLDICON™ line of voltage digitizers. Based on a novel design combining techniques of successive approximation and parallel threshold decoding, the VT13-AB accomplishes a 14-bit analog-to-digital conversion in less than 4 microseconds. The 8-bit VT7-AB performs a complete conversion in under 800 nanoseconds.

Other Voldicon models include:

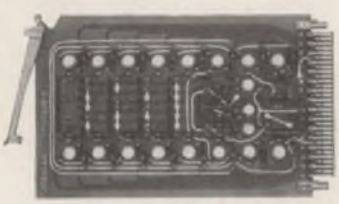
VS Series A-to-D Converters
2 μsec. per bit conversion time
14-bit binary or 16-bit BCD
±.01% accuracy

D-to-A Converters
±150v output
±.01% accuracy
14-bit resolution

And look at these other Adage data systems components!

Series VMX™ Multiplexers
100,000 samples per second
±.002% offset spread; .01% gain spread — no adjustments required
Systems-organized flexible programming

Sample-and-Hold Amplifier, Model SA3
Tracks within .01% in 10 μsec. for FS input step change
100 nanosec. aperture
100 μsec. recovery from 10X FS overloads



Operational Amplifier, Model OP3
Over 5 MC gain-bandwidth product
Approximately 100 pico-amps leakage current
Less than 30 μv offset drift

HZA™ Isolation Amplifiers
100,000 megohms input impedance
±150v input voltage range
1 part in 1,000,000 gain accuracy
Single-ended and differential with 120 db common mode rejection

Digital Logic
Designed for analog/digital system requirements
Compatible modules for digital control, decoding, formatting and interfacing

AC Signal Conditioners
.01% of final value achieved within 15 cycles of lowest frequency
±.05% accuracy

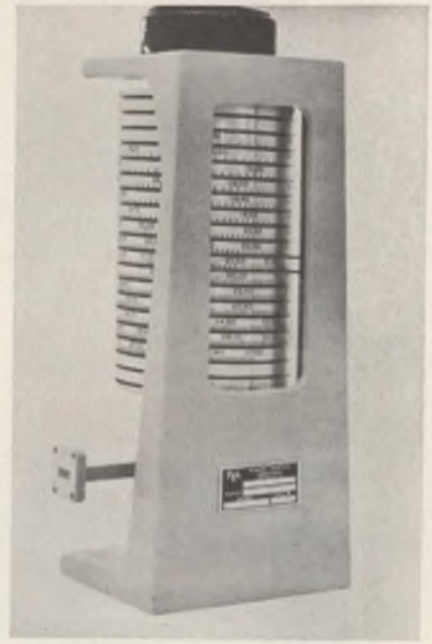
Next time, get a quote from Adage — for components or complete systems. We think you'll like our prices, too. Call or write I. R. Schwartz, Vice President, 617 ST 3-1100.

Adage INC
1079 Commonwealth Avenue
Boston, Massachusetts 02215

Adage, Inc. welcomes employment inquiries from professional engineers.

ON READER-SERVICE CARD CIRCLE 103

MICROWAVE

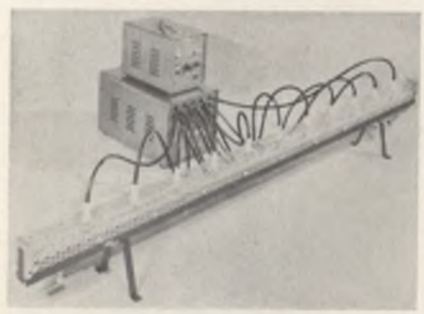


±0.05% wavemeters

Two new precision wavemeters tune from 18 to 26 Gc and 26 to 40 Gc respectively, with an absolute accuracy of ±0.05%. Spurious signals are a minimum of 20 dB down from the main response and absorption dip is 1.5 ±1 dB. Loaded Q is 3500 and power capacity is 20 watts. Temperature range is 22°C ±10°C.

P&A: $500; 30 days. Frequency Engineering Labs., Farmingdale, N. J. Phone: (201) 938-9221. TWX: (201) 938-2456.

Circle No. 392



Uv gas laser

A 50-kilowatt, ultraviolet, pulsed gas laser uses commercial-grade nitrogen to produce self-terminating pulses lasting 10 to 20 ns, with a variable repetition rate of one to 10 pulses per second. Output wavelength is 3371 Å; output bandwidth is less than one Å.

Avco-Everett Research Lab., 2385 Revere Beach Pkwy., Everett, Mass. Phone: (617) 389-3000.

Circle No. 393

TWT power supply

Operating from normal mains supplies to unattended translator stations, a series of solid-state TWT supplies will function under fluctuations of ac supply voltage to provide 3.2kV dc at 0.75 amps to the TWT's with a stability of ±0.5%.

These are closed loop systems for including sub-assemblies of thyristor control stacks, silicon avalanche rectifiers and 3-phase thyristor trigger units.

Standard Telephones & Cables Ltd., Edinburgh Way, Harlow, Essex. Phone: Harlow 26811.

Circle No. 394

High-current transformer

A series of transformers and chokes are designed for current loads of 500 to 1400 A. Copper strip windings are used to reduce size and weight of these units. At these current levels, strips as wide as the coil can be used.

Signal Transformer, Inc., 1661 McDonald Ave., Brooklyn, N. Y. Phone: (212) 376-0615.

Circle No. 396

Spark gap

A triggered spark gap, type TG-182, has an externally adjustable main gap spacing and replaceable electrodes. This unit can be adjusted by loosening a locknut and adjusting the electrode by hand for a main gap breakdown range of 0 to 25 kV. It can be used over an applied voltage range of 1 to 20 kV and its energy handling capability is 6000 joules.

Signalite Inc., 1933 Heck Ave., Neptune, N. J. Phone: (201) 775-2490. TWX: (201) 775-2255.

Circle No. 395

Conductive coatings

Five new conductive metal coatings bond to ceramics (such as alumina or steatite), glass and epoxy base components. They include three fired-on conductive silver compositions with a range of 90 to 96% silver, an ohmic resistance of less than 0.003 ohms/sq. per mil coating thickness; and firing ranges from 925 to 1250°F, 1250 to 1650°F, and 1400 to 1900°F respectively.

Also available is a platinum-gold coating for depositing high reliability conductive films onto ceramics.

Electro Materials Corp. of America, 605 Center Ave., Mamaroneck, N. Y. Phone: (914) 698-8434.

Circle No. 397

Moisture sealant

A thick, semi-flexible epoxy withstands water pressure of over 100 pounds per square inch.

Called Epoxy Sealer, this material adheres to concrete, metal, wood, ceramics, and other surfaces; resists abrasion and wear; and is unaffected by water, oil, gasoline and most solvents and chemicals.

Epoxy Sealer is a two-component epoxy applied by brush, spray, or roller.

Devcon Corp., Danvers, Mass. Phone: (617) 774-1990.

Circle No. 398

Low-density epoxy

The low-density epoxy casting compound HYsol C8-5388 is a pourable system for use where weight is the prime concern. It can be used with a variety of hardeners to produce various characteristics.

Specific gravity at 25°C is as low as 0.60 to 0.70. Density is 0.027 pounds per cubic inch and it does not change with storage. Viscosity is 12,000 at 60°C.

The compound meets the requirements of mil-specs such as BUWEP OS-11891C.

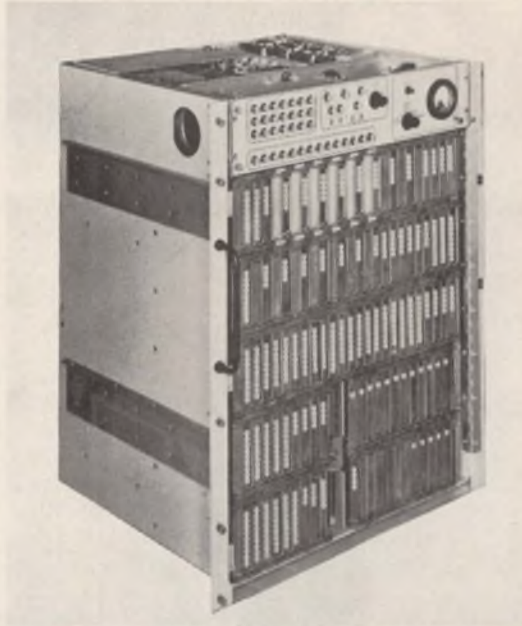
HYSOL Corp., 1100 Seneca Ave., Olean, N. Y. Phone: (716) 372-6300. TWX: (510) 245-2800.

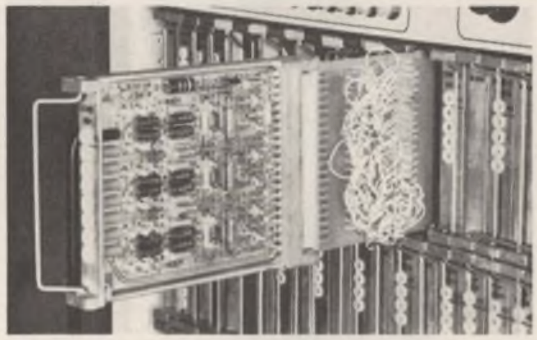
Circle No. 399

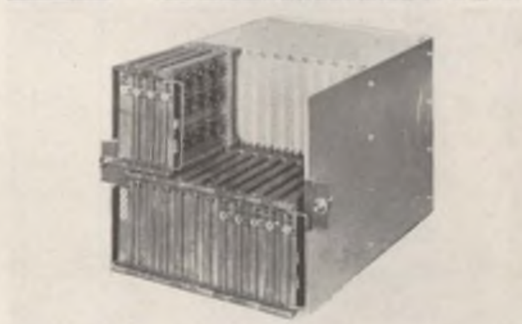
Can you spare a few moments to fill out the READER-REACTION CARD behind the front cover?

Meet the "MR"

A 2-usec, all-silicon memory system that meets rugged environmental specifications







The Fabri-Tek Series MR memory system offers systems designers the well-known Fabri-Tek Memory technology in a new, ruggedized version using components meeting the requirements of MIL-Std 242D. Capacities from 32 to 32,000 words of any bit length are available. Full cycle time is 2 microseconds. (A 8192 X 21-bit system is illustrated here with the front door removed.)

The Series MR meets these environmental specifications:

- Operating temperature . . . −40° C to +71° C
- Humidity . . . meets humidity test procedure 1, Para. 4.4 of Mil-E-5272
- Shock . . . unit operates satisfactorily after being subjected to 15g of acceleration having a duration of 11 msec in each direction of the 3 mutually perpendicular axes.
- Vibration . . . unit operates satisfactorily after being subjected to vibration of from 10 to 300 cps along each of the 3 mutually perpendicular axes as follows: ± 2.5g acceleration from 10 to 36 cps, 0.036" double amplitude from 36 to 46 cps, ± 4g acceleration from 46 to 300 cps.

Ruggedized, die-cast aluminum frames support circuit cards. One card supports the adjacent card to resist severe shock and vibration environments. Easily accessible test points are brought out through the frame.

The memory stack assembly is removable. Lithium-ferrite memory cores meet extreme temperature requirements so it is not necessary to thermally compensate this stack for the maximum temperature limit.

The compact power supply is easily accessible. All voltages used can be adjusted in this section. Power supply transistors are "wind tunnel" cooled.

Instead of conventional printed-circuit board connectors, a single parent board is used and the PC connectors form an integral part of the parent board. System interwiring is all "Wire-Wrap"*.

*T.M. Gardner-Denver Company

If your memory requirement calls for environmental ruggedizing, the Series MR may be just what you've been looking for. Call, wire, or write Fabri-Tek Incorporated, Amery, Wisconsin. Phone: COngress 8-7155 (Area 715). TWX: 510-376-1710.

FABRI-TEK
INCORPORATED

ON READER-SERVICE CARD CIRCLE 107

Application Notes

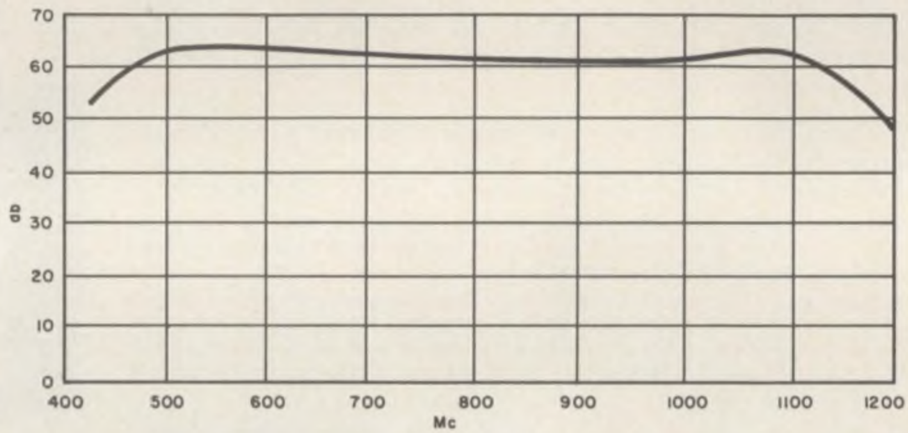
Wideband amplifier design

Starting virtually from scratch, J. K. Lauchner, Motorola Military Electronics senior engineer, outlines the design of wideband amplifiers for L- and S-band operation. In a paper presented at NAECON, Lauchner begins with a description of the newer small signal transistors their parameters and parameter interelationship. Noise, a major limitation at these frequency levels, is given detailed consideration.

The design example, operating from 0.5 to 1.1 Gc, provided the response curve shown above. It uses three germanium 2N2999's in a common-emitter configuration to attain the required stability.

A list of references for further information on this subject is also included in the paper. Motorola Military Products.

Circle No. 700



Loading data

A comprehensive treatment details the effects of loading on several different circuits using potentiometers. Designated technical data bulletin TD-113, the 8-page booklet discusses the theoretical and practical aspects of the output voltage ratio of linear and non-linear potentiometers and of varying or unexpected loads that cause circuit performance problems. Formulas are developed to permit a circuit or system designer to compute the output errors in voltage divider circuits. Markite Corp.

Circle No. 701

Voltage regulator

The theory, design and operation of the manufacturer's line-voltage regulator are fully covered in a 12-page technical manual. Fully illustrated with photographs, charts, tables and wiring diagrams, the two-color booklet is divided into two sections. The first deals with the power circuit of the line-voltage regulator, and the second explains its sensing and control circuit. Sola Electric Co.

Circle No. 702

Hybrid printing

A 12-page booklet provides a source of information on screen printed hybrid integrated microcircuitry. The booklet provides an explanation of how to convert resistor and conductor compositions into reliable low-cost microcircuits using the screen printing process. E. I. DuPont DeNemours & Co., Inc.

Circle No. 703

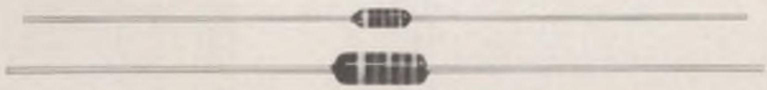
Digital computer

Finger-tip solutions to a wide range of practical, everyday engineering problems—from calibrating a Venturi flow meter to non-linear circuit analysis—are described in application notes on the PDS 1020 digital computer.

The application notes analyze a series of familiar—but time-consuming—problems frequently encountered by the engineer: solving a least square curves fit, for example, or finding and typing points on a parabolic curve. In step-by-step, flow-chart format, the notes show how the 1020 solves each problem. Pacific Data Systems.

Circle No. 704

New CORNING® C Style Resistors give you precision stability, reliability, 1, 2 and 5% tolerances, 100 ppm T.C.



All of which boils down to this. Only one component to specify, buy and stock. One component you can use for general-purpose, semi-precision and precision use alike. One component that satisfies two military specs, as a look at the table quickly reveals. And you still get all the performance advantages of CORNING Glass-Tin-Oxide film resistor construction. Now for your tests. At our expense. Return coupon for samples.

PERFORMANCE CHARACTERISTICS

Characteristics	New CORNING C-Style Resistors			Mil-R-22684B	Mil-R-10509E Characteristic D*
Temperature Rating	70°C	70°C	125°C	70°C	70°C
Wattage C 4 (RL07S) Resistors, 51 ohms to 150K	¼	⅛	1/10	¼	⅛
Wattage C 5 (RL20S) Resistors, 10 ohms to 499K	½	¼	⅛	½	¼
Load Life △ R	1.0%	0.5%	0.5%	2%	1%
Design Tolerance △ R	−2 to +4%	−1 to +2.5%	−1.5 to +3%		
Temperature Coefficient from −55°C to +175°C	±100 ppm			±200 ppm	+200 −500 ppm
Dielectric Withstanding Voltage △ R	±0.10%			±0.50%	±0.5%
Moisture Resistance △ R	±0.50%			±1.50%	±1.5%
Short Time Overload △ R	±0.25%			±0.50%	±0.5%
Temperature Cycling △ R	±0.25%			±1.00%	±0.5%
Effect of Soldering △ R	±0.10%			±0.50%	±0.5%
Low Temperature Operation △ R	±0.50%			±0.50%	±0.5%
Shock △ R	±0.10%			±0.50%	±0.5%
Vibration △ R	±0.10%			±0.50%	±0.5%
Terminal Strength △ R	±0.10%			0.50%	
Voltage Coefficient	±0.001%/Volt				
Shelf Life △ R	+0.10%/Year				±1.0%

*For Type-marked, military lead Mil-R-10509 E Characteristic D Resistors, specify CORNING NA Style Resistors

CORNING GLASS WORKS, Electronics Dr., Raleigh, N. C. 27604.
Send complete data, test samples of new CORNING® C Style Resistors.

Name__________
Title__________
Company__________
Address__________
City__________ State__________ ZIP__________

CORNING ELECTRONICS

Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 109

APPLICATION NOTES

Analog simulation

A special report on the use of analog simulation in the field of scientific education is now available. The report has been prepared to answer the question, "How are educators using analog computers to meet the challenge of teaching science and engineering students?" It describes the advantages of the analog computer as a teaching tool, as well as specific areas of application in different engineering disciplines. Electronic Associates, Inc.

Circle No. 705

Pressure sensor

Application notes show how the ultra-low pressure sensor PSF100 applies to the control of moving webs, films wire, and related flow type industries as well as precision gaging, conveyor systems pneumatic tube systems, etc. The series of eight application notes cover: cooling blower interlock, parts feed control, automatic frost detection, moving webs, wire, film controls, precision sensing and gaging, and precision level control. Fairchild Controls.

Circle No. 706

Photocell uses

The second issue of "Photocell Forum" deals with the way photocells have allowed redesign of the refractometer. The article, by L. E. Maley, vice president of Waters Associates, Framingham, Mass., points out the advantages of a new, dual element photocell by Clariex that permits a small, easily installed instrumentation system to be made. Clairex Corp.

Circle No. 707

Amplifier tests

A 7-page application note describes how to measure open loop operational amplifier characteristics. The information is applicable to a wide range of solid-state operational amplifiers.

Procedures and test circuits are given for measuring open loop gain, dynamic range, input offset voltage and drift, input current offset and drift, supply voltage drift coefficient, input noise, input current tracking, small signal and full output frequency response and common mode input impedance. Analog Devices.

Circle No. 708

New A/D conversion

A new method of analog-to-digital conversion is described in a 10-page brochure. The catalog covers theory, application and full specifications for a precise servo-mechanism which transforms an incoming electrical signal into an illuminated digital display plus digitally coded (BCD) output. The technique is described as inherently less expensive than methods in current use. Theta Instrument Corp.

Circle No. 709

Test chamber

A two-page bulletin pictures and describes one use of a counter-flow constant temperature and humidity chamber. The unit is used for accelerated aging of rigid urethane foam, and the data serves as a basis for chemical production. Blue M Electric Co.

Circle No. 710

Forming thermoplastic

A 12-page manual describes thermoforming techniques for Merlon polycarbonate sheet material. In addition to a description of the properties of this thermoplastic, the manual concisely describes and illustrates a dozen varieties of modern thermo-forming methods and equipment. Mobay Chemical Co.

Circle No. 711

Laminated bus bars

Technical bulletin B-2 provides a detailed coverage of the application of laminated bus bars for power distribution. The illustrated 15-page booklet gives conversion factors for AWG size to flat-stock and formulas for computing variables such as inductance, capacitance and voltage drop. Eldre Components.

Circle No. 712

Microphotography

Microphotography for low-cost, in-house production of microelectronic photomasks and similar photographic applications is described in new 6-page, 2-color technical bulletin. The new bulletin discusses advantages of in-house circuit production, lists camera features, and provides a detailed description of the equipment and its operation. HLC Engineering Co.

Circle No. 713

Retrofitting

The conversion of existing machinery to numerical control is described in a new two-color brochure. The brochure explains how two contouring controls, the 3100 and 3000, can be tailored to particular retrofit applications.

Cost reduction and problem-solving advantages of retrofitting machinery are described in detail for tooling, set up and consistent quality results. Also discussed is the practicality of retrofitting as applied to type of work to be done and the type of the machinery. Successful retrofit case-histories are included. Bunker-Ramo Corp.

Circle No. 714

Deviation measurements

The use of the manufacturer's frequency meters for deviation measurements is described in a four-page bulletin. The required equipment and procedures are fully described and illustrated. Singer Metrics.

Circle No. 715

Polyester Fiberglass

An 8-page technical bulletin gives design and engineering data on five grades of molded polyester fiberglass materials.

Entitled "NVF Molded Polyester Fiberglass Materials," the new bulletin is intended primarily for OEM design and engineering of molded or fabricated parts. It cites 14 specific design advantages of polyester fiberglass materials and it offers complete tables of mechanical, electrical, and physical test values. National Fibre Co.

Circle No. 716

Reed electrometer

A four-page brochure describes the use of the Cary vibrating reed electrometer in measurements of charge and current. It provides procedures and formulas for both rate-of-charge and high-resistance-lead methods of measurements and outlines the parameters common to both techniques. Applied Physics Corp.

Circle No. 717

Commutation and diodes

A practical manner to present the commutation characteristics of a rectifier diode is presented in a technical paper by E. E. VonZastrow and J. H. Galloway of General Electric Co.

The paper gives quantitative recovery data for two popular types of diffused 250 A rectifier diodes in terms of circuit parameters. Using the recovered charge of the diode under the prevailing circuit conditions, quantative data are given for the selection of appropriate protective circuitry. General Electric Co.

Circle No. 718

Frequency compensation

Detailed coverage of frequency coverage through negative feedback in a high-gain integrated operational amplifier is provided in an article by James N. Giles of Fairchild Semiconductor. The article, complete with diagrams and design procedures, is available in an eight-page, binder-punched booklet.

Coverage includes lag compensation, input lag compensation and lead compensation as well as the applicability of the concept to other circuits. Fairchild Semiconductor.

Circle No. 719

Q meter theory/use

Both the theory and use of Q meters are covered in a 40-page book. Compiled partly as a maintenance and operation manual, most of the material will apply to any Q meter. Marconi Instruments Ltd.

Circle No. 720

Grid-controlled phototube

A high transconductance grid mounted close to the photocathode surface of a multiplier phototube permits external electrical control of the emitted photoelectrons. The advantages of this capability are covered in the five-page application note #E9. Complete specifications on the tube and a graph of its control characteristics are also included. ITT Industrial Labs.

Circle No. 721

What do you think of the new Electronic Design? See READER-REACTION CARD behind the front cover.

New Literature

Connector assembly

Descriptions of 43 major series of electronic and electrical connectors are contained in an illustrated short form catalog. The catalog, SF No. 127G, covers ultraminiature, subminiature, miniature and power types, with and without shields or shells. Included also are assemblies featuring floating body isolation types and printed card receptacles and connectors. Among the connectors included are those meeting MIL-C-8384B, MIL-C-21097B, MIL-C-22857C, MIL-C-23216, MIL-C-23353A, MIL-C-25955 and NAS 713, 714 and 715. U.S. Components.

Circle No. 722

Semi-conductor outlines

Supplement No. 1 to JEDEC (Joint Electron Device Engineering Council) Publication 12E contains all officially registered outlines for semiconductor devices. *The supplement to 12E is available at $2.00 per copy from NEMA, 155 E. 44th St., New York, N. Y. 10017.*

High temp connectors

A 20-page catalog, HT-1, describes and illustrates six series of connectors designed specifically for operation in elevated temperatures ranging from 257°F to as high as 1300°F. In addition, some of the connectors also have moisture resistant and nuclear radiation resistant capabilities. ITT Cannon Electric.

Circle No. 723

Industrial instruments

Automatic test equipment, insulation test equipment, test and measuring instruments designed for wide application in test, measuring and control applications are covered in a new 42-page catalog. Catalog 29 provides complete technical data on such items as voltage breakdown testers, a tracking and erosion resistance test set, megohmmeters, decade boxes, impedance bridges and cable fault finders.

A special section is devoted to automatic test equipment such as capacitor sorter-leakage testers, resistor sorters, helixing lathes and disk capacitor testers, Industrial Instruments Inc.

Circle No. 724

Semiconductor devices

Key specifications for more than 500 silicon semiconductors are listed in a new condensed catalog. Included are descriptions of integrated circuits, field effect transistors, silicon planar and Planex transistors (npn and pnp), dual and Darlington amplifiers, diodes and rectifiers. Raytheon Company.

Circle No. 725

Precision potentiometer

The new six-page brochure gives specifications and prices on a 25-type precision potentiometer line. Called short-form catalog #3, the brochure includes bushing mount, servo mount, in Knobpot and Labpot potentiometer styles. Bourns Inc.

Circle No. 726

RF connectors

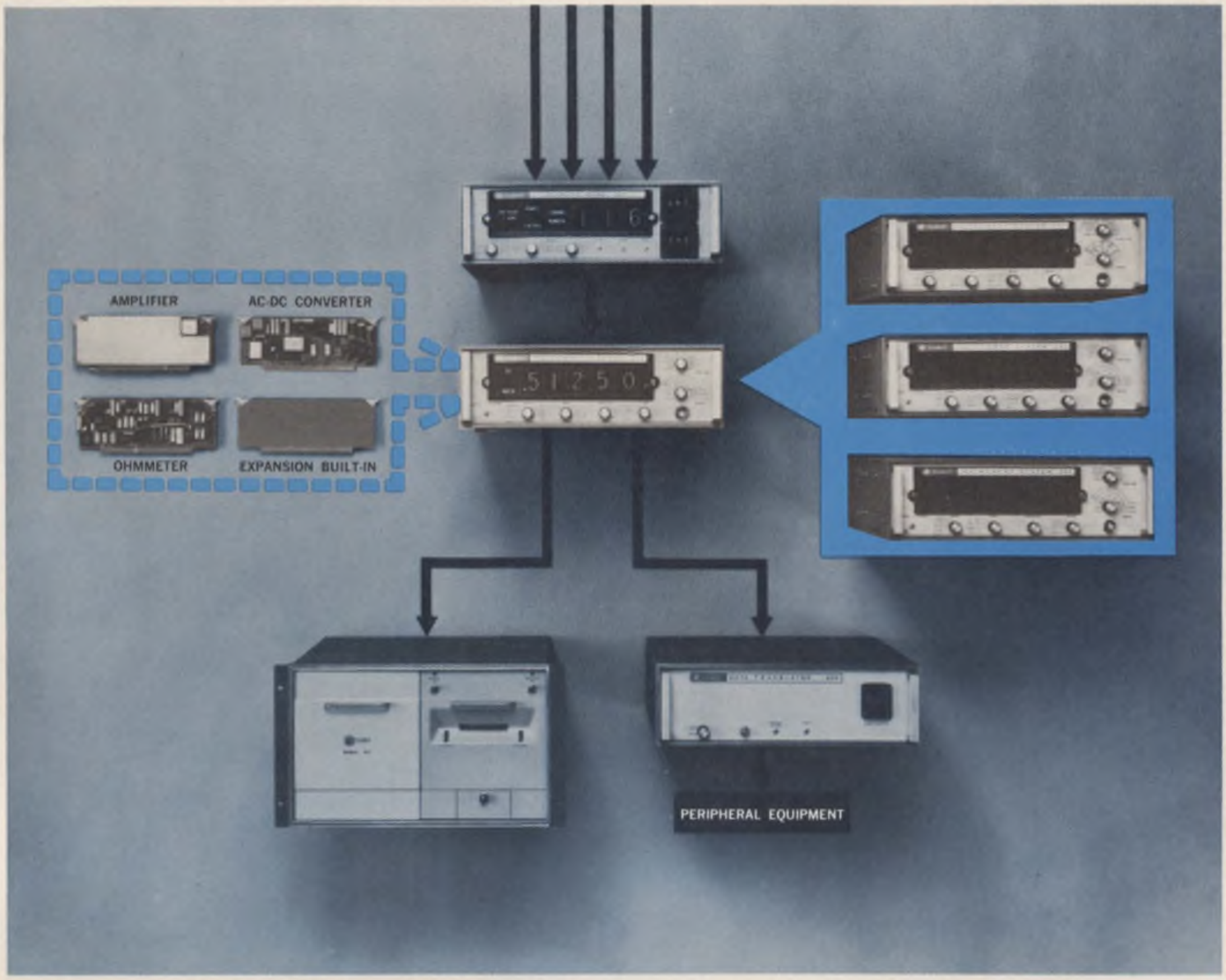
A 4-page bulletin describes a new line of miniature threaded RF connectors. Twenty-one basic configurations are shown together with envelope dimensions and material specifications. Star-tronics, Inc.

Circle No. 727

Electroluminescence

Electroluminescence display devices designed for aircraft, submarine and a variety of military applications are described in a new brochure. The pamphlet includes alpha-numeric, bar graph, bi-stable and crossed-grid displays. Sylvania Electric Products Inc.

Circle No. 728



This Cubic Instrument System can measure anything!

Pure flexibility! Plug-in modules expand your basic DVM system to measure 5 or more functions. Accessories scan, print out or translate

A big claim? Yes, but not too big for Cubic. If it can be measured in terms of DC volts, bipolar DC ratio, AC volts, ohms or low-level DC—and that covers just about anything—it can be handled with one Cubic system. Thanks to Cubic Corporation's systems approach to digital measurement, you can in effect customize the system to your needs.

For instance, start with the voltmeter/ratiometer capabilities of Instrument System 250, shown at the center above. Then . . . either singly or all at the same time . . . plug in a preamp, AC-DC converter, ohms-to-volts converter, or an auxiliary module built to specific requirements. No need to change the modules. Cubic plans the basic system so they stay in place.

You simply select the function on the front panel. And all controls and functions can be remotely programmed. With a few minor changes in connectors, capabilities can be expanded even more. Such adjustments are so simple they can be done in the field. You adapt the system to changing needs by adding input modules and peripheral equipment.

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Instrument System 350: 5-digit, with fast solid-state switching.

Instrument System 250: 5-digit, current summing, reliable reed relays.

Instrument System 150: 5-digit, stepping switch, for industrial use.

Instrument System 240: 4-digit, low-cost unit with reed relays.

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Filter

A new 18-page catalog entitled "Lossyline EMI absorptive filters" gives detailed specifications such as weight, attentuation characteristics and electrical ratings on a line of high frequency nose suppression filters. These filters were specially developed for aerospace and ground applications requiring above 100 dB attentuation from 25 MHz to 45 GHz. Lundy Electronics & Systems, Inc.

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Circle No. 730

Optical benches

A 24-page catalog describes optical and instrument benches for accurate testing of lenses and lens systems. It describes the single rod, double rod and precision lathe-bed type optical benches. Gaertner Scientific Corp.

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Noise generators

A one-page, short form catalog summarizes specifications for six Gaussian noise generators both solid state and tube type. These instruments cover various frequency ranges between dc and 5 MHz. Included are those specifically designed for analog computer and simulation applications. Elgenco Inc.

Circle No. 732

Patent ABCs

A pocket-sized booklet from the Commerce Department provides very readable rundown on what a patent is, what can and cannot be patented, and describes the steps necessary between invention and the granting of a patent. *Copies of this 48-page booklet are available for $0.25 from the U. S. Printing Office, Superintendent of Documents, Washington, D. C.*

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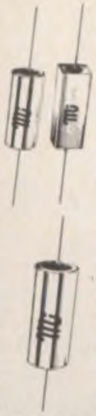

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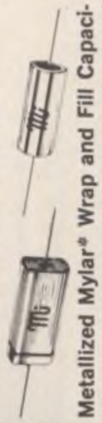

Metallized Mylar* Wrap and Fill Capacitors — shaped under controlled heat and pressure, encased in tight Mylar jacket with epoxy end-fill; fabricated to commercial specifications in .001 to 2.0 mfd. capacitance, 100 & 200 VDC; available in standard ± 20% tolerance, as well as ± 5% and ± 10%. Ask about Series J.

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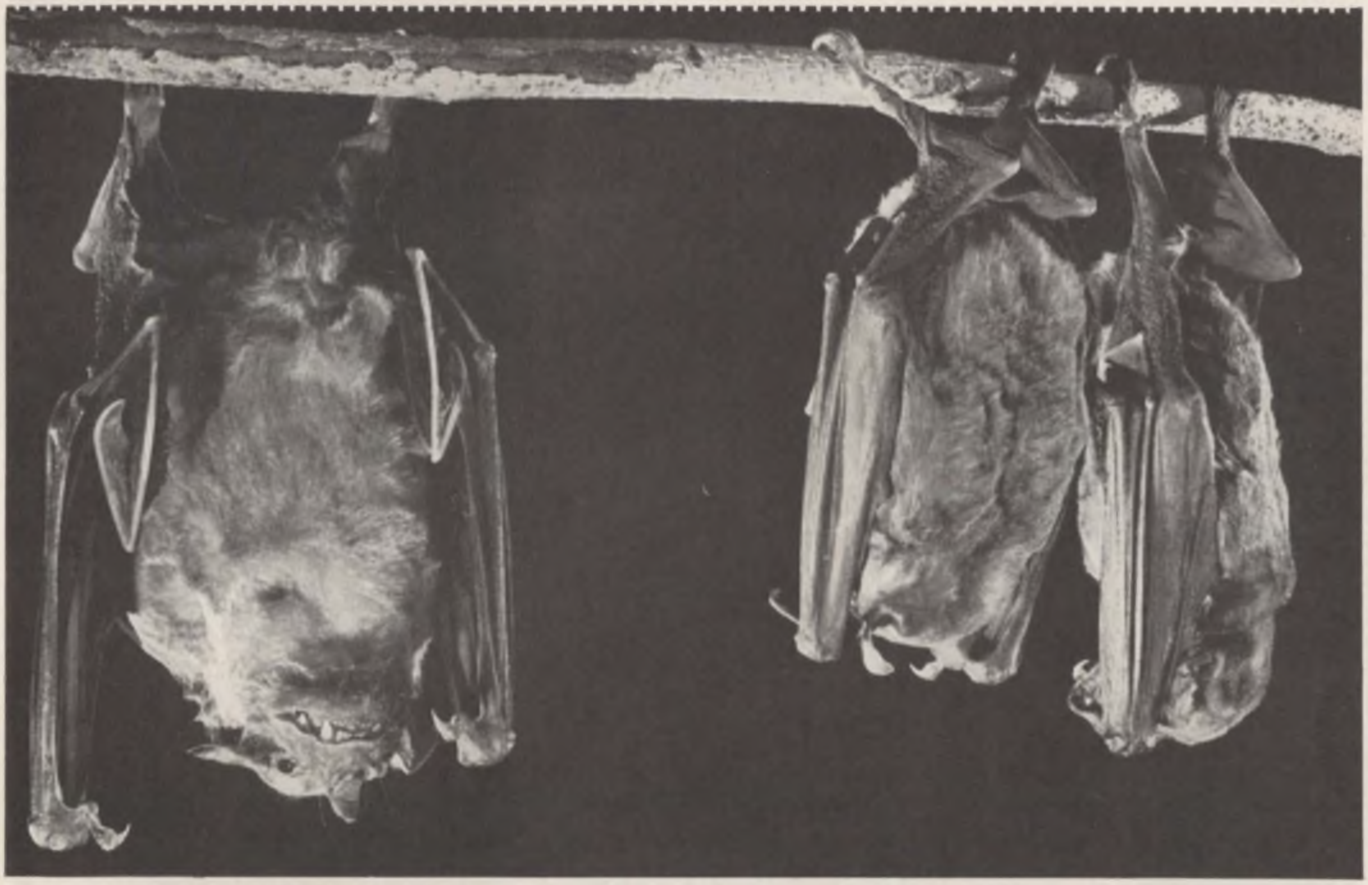

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Solenoid drivers

A new two-page bulletin discusses the problem of inductive overshoot caused by long leads between driver modules and the relays or solenoids they are controlling in memory core testing situations. This overshoot can destroy the driving transistors. The solution suggested in the new bulletin is the use of a zener diode to ground inductive transients. Digital Equipment Corp.

Circle No. 733

Coaxial switches

A wide variety of coax switches are covered in a new, sixteen-page short form catalog. The illustrated catalog #C5-5 contains mechanical and electrical information on 23 different series of switches. A special feature is the section on the Dynaform series, a new modular concept in coaxial switch construction that offers users prompt delivery on a variety of high-performance units. Amphenol.

Circle No. 734

Circuit breakers

A new short form catalog describes thermal series trip circuit breakers and magnetic Trip-Free series trip toggle type circuit breakers. Performance characteristics, size, weight and approved military ratings (where applicable) are summarized for a wide variety of single-pole, two-pole and three-pole circuit breakers. Wood Electric Corp.

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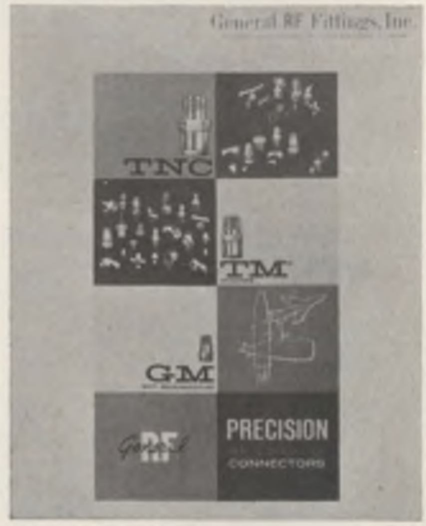

Coaxial connectors

A new 24-page catalog provides complete technical descriptions and specifications for a wide range of plugs, jacks, receptacles, adapters, etc. Also, the new catalog contains complete cable assembly instructions, mounting data, and other useful information. For convenient use and fast reference, it features die-cut pages for easy access to the TNC, TM and GM categories, cross reference, assembly instructions and mounting data. General RF Fittings, Inc.

Circle No. 736

Instrument catalog

A 4-page condensed catalog describes a variety of instruments and related products. Instruments illustrated and described include the 0.5 ppm volt/ratio divider, 4 ppm lead resistance compensator and volt/ratio divider combination. Other instruments shown are the dial-a-source, resist-o-stat and the dial-a-volt.

Three categories of precision wire wound resistors are described, and a new series of modular ladder networks are briefly noted. General Resistance, Inc.

Circle No. 737

Transistor guide

A complete transistor guide covers the commercial, industrial and entertainment segment of the electronics industry. It lists Fairchild epoxy semiconductors, and contains a complete price list. Prices start as low as 19¢ each. Schweber Electronics.

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Rowe Industries Inc.
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174

Test Equipment Reference Data

ELECTRONIC DESIGN'S Test Equipment Reference Issue covers 12 important classes of test instruments. Included are complete up-to-date specifications for approximately 2500 off-the-shelf test instruments, arranged for quick and easy reference and comparison, and cross indexed by product category and manufacturer's name. Technical data prepared from the Directory of Technical Specification/Electronic Test Instruments, by Technical Information Corporation. Twelve application-oriented articles by industry experts complete the package. Price $5; check or money order must accompany order.

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JANUARY						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

FEBRUARY						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

Jan. 5-8

National Society of Professional Engineers Winter Meeting (Bal Harbour, Fla.) Sponsor: NSPE; Paul Robbins, National Society of Professional Engineers, 2029 K St. N. W., Washington, D. C.

Jan. 13-14

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Jan. 25-27

Annual Reliability Symposium (San Francisco) Sponsor: IEEE, ASQC; J. W. Thomas, Jr., Vitro Labs, 14000 Georgia Ave., Silver Spring, Md.

Jan. 30-Feb. 4

IEEE Winter Power Meeting (New York) Sponsor: IEEE; Edward Day, IEEE, 345 E. 47th St., New York, N. Y.

Jan. 31-Feb. 2

International Symposium on Information Theory (Los Angeles) Sponsor: IEEE; A. V. Balakrishnan, Department of Engineering, University of California, Los Angeles.

Feb. 3-8

International Exhibition of Electronic Components (Paris, France) Sponsor: F.N.I.E. (Electronic Industries Assn. of France); General Commissioner: Robert Foucault, 16 Rue de Presles, Paris 15, France.

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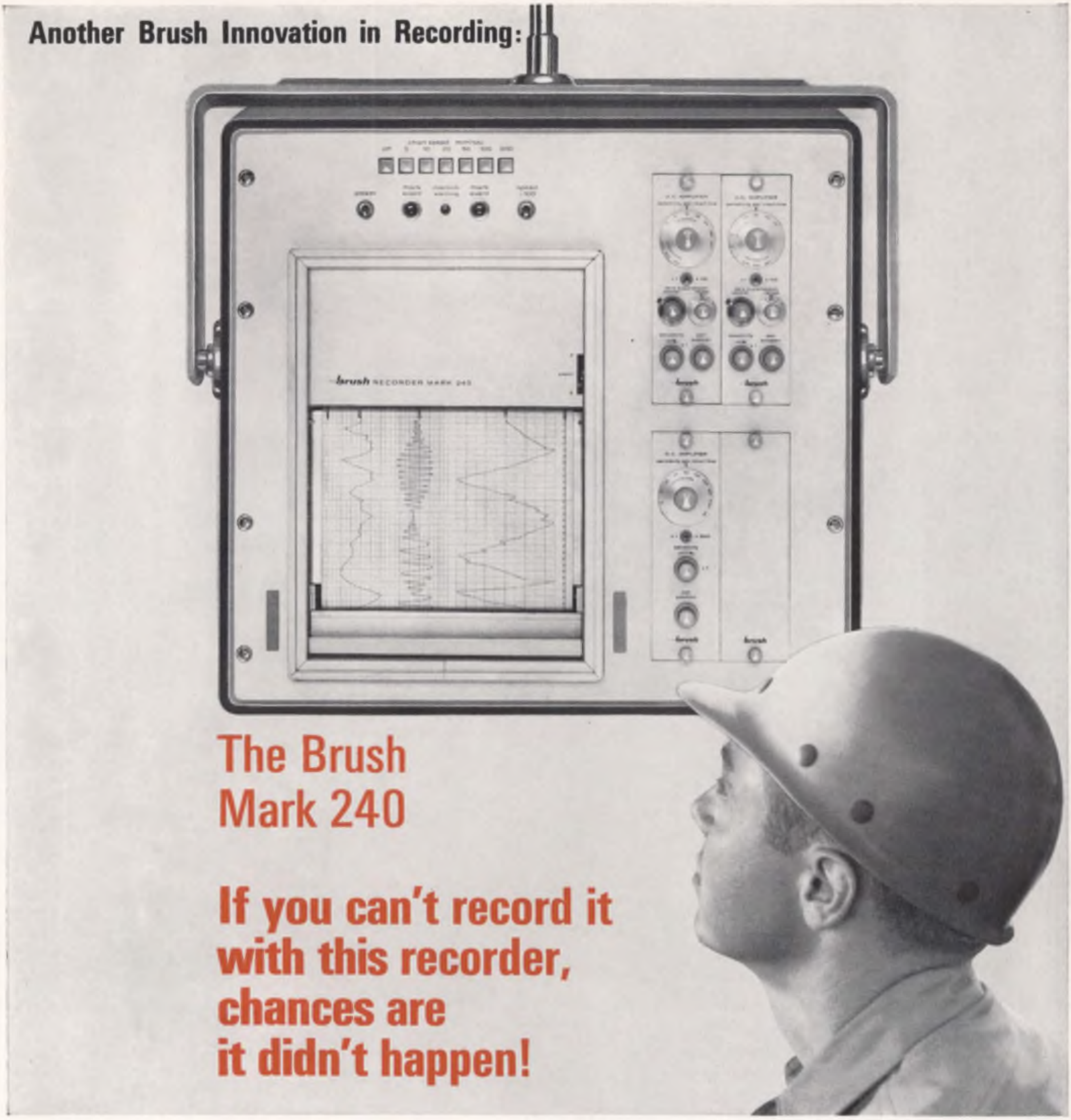

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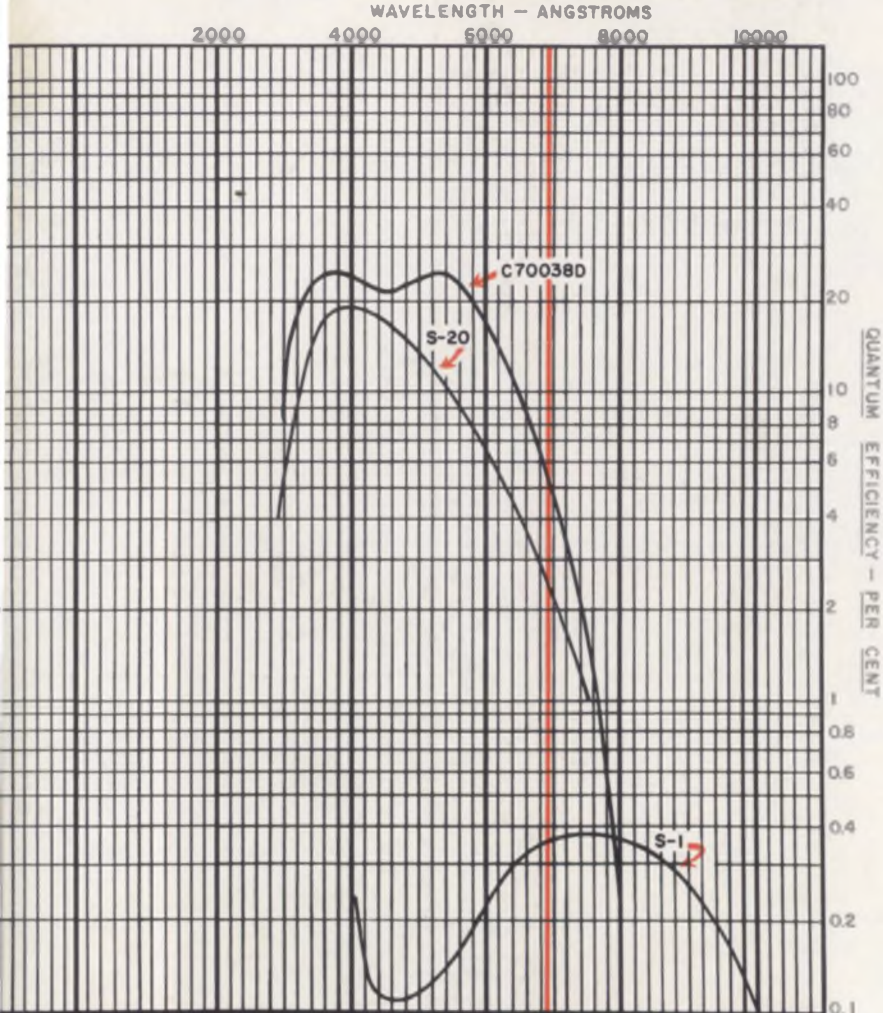

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