DECEMBER 6, 1963

electronics®

A McGRAW-HILL WEEKLY 75 CENTS

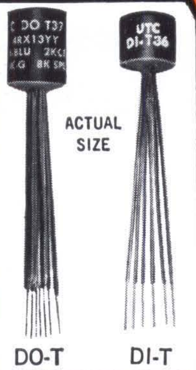
SPECIAL REPORT

TODAY'S SEMICONDUCTORS

AUDIO TRANSFORMERS

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

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



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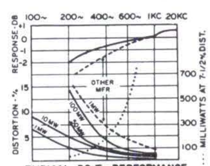
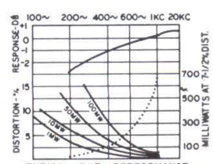


TYPICAL DO-T PERFORMANCE
SOURCE: RATED PRI. IMP. AND D.C.
LOAD: RATED SEC. IMP.



TYPICAL DI-T PERFORMANCE
SOURCE: RATED PRI. IMP. AND D.C.
LOAD: RATED SEC. IMP.

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.)

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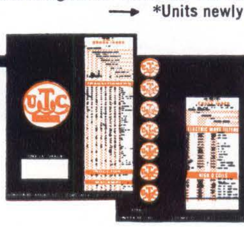

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DECEMBER 6, 1963

electronics

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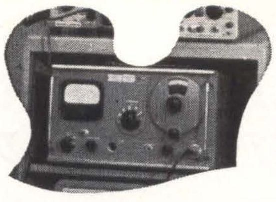
DEPARTMENTS



The Piece that Fits

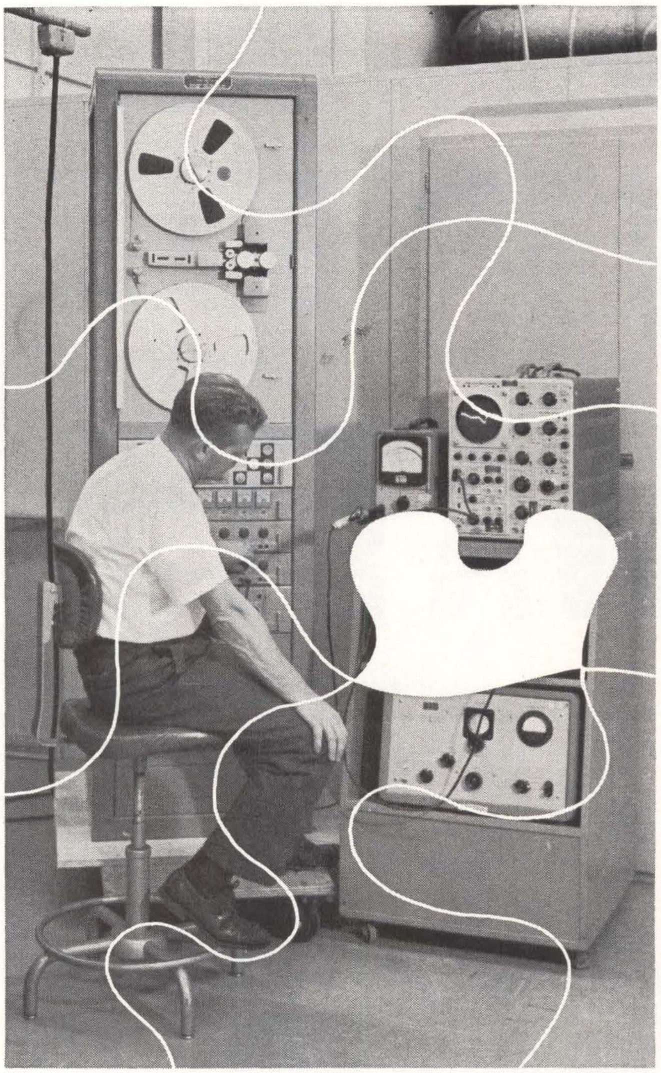


Photo courtesy of Ampex Corporation

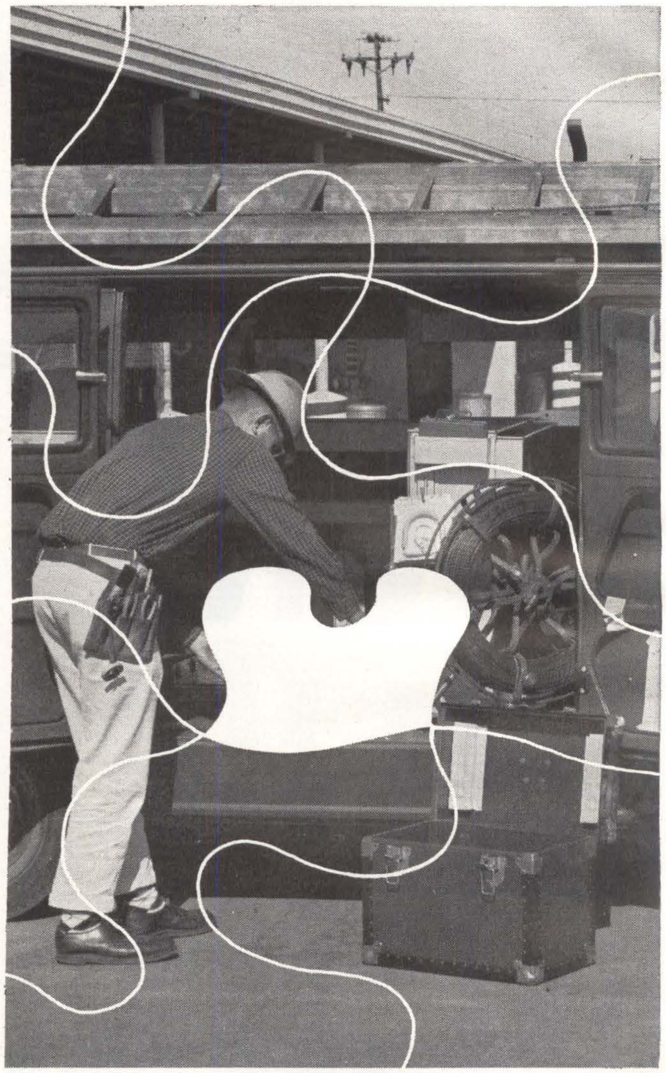


Photo courtesy of Pacific Telephone Company

In the Laboratory

Down in the Systems Evaluation Lab, Ampex engineers systematically probe the performance of complex tape recording systems. One prime source of reliable test data is a Sierra H. F. Wave Analyzer.

Covering a range of 500 kc to 10 mc, Model 158A can measure both the fundamental and harmonic levels of a frequency. It seems custom-built to fit the Ampex picture. The instrument is easy to use. It's precise. Its selectivity permits specific narrowband signal-to-noise determinations.

More reasons why Model 158A fits the laboratory scene?

- The 1-megohm impedance of its input probe limits loading down the circuit under test.
- Two input-level attenuators extend its fine tuning control over signals from −80 dbm to +42 dbm at 600Ω.

Sierra's Model 158A clearly belongs in the most sophisticated professional laboratories. Ampex uses it to perform a number of important specific functions. Price, $1,650.

In the Field

This Sierra 158A has just arrived at a problem site in a Pacific Telephone Company truck. Riding securely in its carrying case, it hasn't been fazed in the slightest by rough back-country roads. Now it's ready to measure for Pacific Telephone's maintenance men with its best laboratory-type precision.

Like all good field workers, the Sierra Wave Analyzer is self sufficient. It doesn't need propping up with a truck-load of equipment to do its job. And it reads the action in dbm to obviate time-consuming calculations.

For the full story on how a Model 158A H. F. Wave Analyzer can fit your field picture, send for the new technical bulletin. Or contact your nearest Sierra sales representative for a demonstration.

SIERRA ELECTRONIC DIV.
OF
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Sierra Electronic Division/3875 Bohannon Drive/Menlo Park, California

Crossroads for Atomic Power

THE 1960's are a time of trial and decision for atomic power.

The quest for low-cost atomic power is almost over, technically. It can, indeed, be competitive. But atomic power now faces another test — public opposition roused by fears that each atomic reactor is a potential atomic bomb.

Despite the fact that safety is the first and paramount consideration in any reactor design, despite the fact that atomic power is probably among the least dangerous industries in the United States today, people living around proposed power reactor sites are being roused into opposition by questions that sound suspiciously rabble rousing.

It is in the electronics industry's interest, we believe, to help our sister science, nucleonics, combat this type of emotional appeal and help atomic power get a fair hearing in the court of public opinion.

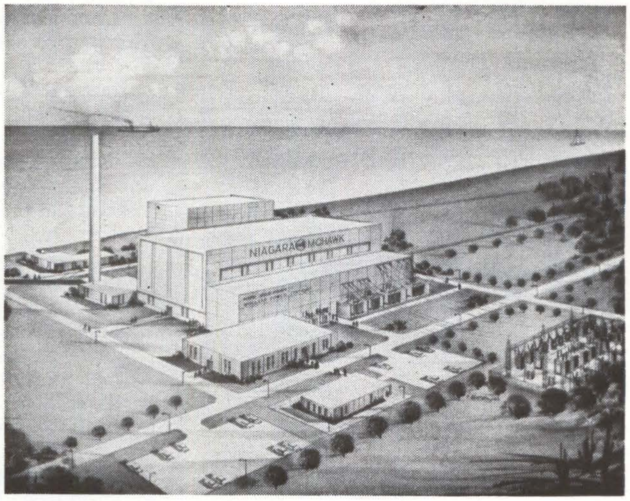
There are two reasons why we in the electronics industry should do our best to see that the facts—pro and con — of reactor safety reach the public. One reason is that electronics has made a substantial technical and financial investment in atomic power. The industry has invested in control components and systems development in hope that a strong and profitable civilian market will materialize. This, however, is not the most important reason. The second reason is more important. The "atom bomb" question is kin to questions like "Do you want to lose your job to a computer?" Such questions demand answers from the technical community as a whole if progress is not to be stifled.

It is important that the public safety question be answered now. For the first time large groups of people are being asked to allow the construction of atomic reactors in their neighborhood. Their favorable answer is vital to continuance of the atomic power program.

For the next few critical years, atomic power needs the support of government, public utilities and the people. Industry cannot go it alone.

Nuclear engineers say they can prove atomic power is competitive. But to prove it conclusively they need experience with big reactors being built to serve metropolitan areas, where the biggest conventional plants are.

Public utilities are willing to pay for such plants. They would like to build them where they are most economic, in the midst of their customers, not in a rural area at the end of a long and expensive transmission line.



NEXT GENERATION atomic power plant. This proposed 500-megawatt station would cost 100 million, go into operation five years from now

The "atom bomb" question attacks this chance for atomic power to become self-sufficient. It provides opponents of atomic power with a lever against the atomic power program, since a large group of people in a small area are a potent political weapon, once roused to opposition.

Before that opposition becomes adamant enough to cripple the program, we—as individuals, and as an industry—can insist in all the forums available to us that the public safety question be considered dispassionately.

Coming In Our December 13 Issue

MORE ON LASERS. This week's state-of-the-art report on injection lasers (p 61) will be followed up in the December 13 issue with a second article. The author, C. M. Johnson, of IBM, will report on application of injection lasers to communications and tracking.

Other feature articles next week will include:

- Simulator that uses both digital and analog techniques to realistically represent the total tactical environment of radar and sonar equipment.
- H-f multicoupler that enables one antenna to handle five point-to-point or broadcast transmitters. Design includes L-C networks that handle 600-w transmitters over a decade bandwidth.
- Integrated-circuit oscillator that may find f-m applications. It can oscillate at around 1 Mc with 1-v output.

COMMENT

MYSTERIOUS SIGNALS

While I wish to express my admiration for your fine journal, I would like to point out two minor errors in, and comment on, 'Mysterious Signals' in your *Comment* column of Nov. 29 (p 6). The first is a misspelling of the doctor's name: it should read Velikovsky, no N. The second is the date of his Princeton lecture: it should be 1953. (Humorously: is this part of the anti-Velikovsky plot?) Immanuel Velikovsky has indeed, as noted in your column, received little credit, but much abuse. His theory of Cosmic Catastrophism answers many questions unanswered for centuries, and, until disproven, is as good as or better, based on logic and available sources, than those now prevalent. As you probably realize, it will be the accelerating discipline of electronics which will bear the load of proving or disproving Dr. Velikovsky. Much has already happened: The Air Force's radar-bounce off Venus (showing slow counter-rotation); the Mariner fly-by (surface temperature of 800 degrees C, which is considered hot); the Stratoscope 2 balloon flight of last March (infrared verification of minute traces of water in the atmosphere of Mars); carbon-14 tests (revising many historical dates); and, the recently announced, U. S. Air Force sponsored, General Electric developed, (Fisher and Price) uranium dating system (giant meteor showers bombarding moon and earth even before recorded time). All have thus far enforced Velikovsky's arguments. Both of his books (Worlds In Collision; Ages In Chaos) establish a sound scientific platform which, as has already been shown, will probably be further proven after the data is made known from the upcoming NASA series of Mariner and Voyager space probes and un-manned landings to, again, Venus, and Mars. It will be extremely interesting to see if electronics, the one discipline crossing many scientific boundaries, will prove the interdisciplinary genius of Immanuel Velikovsky.

L. B. Scott-Duncan

Fords, N. J.

DISGUISED ELECTRONICS

Some of the consumer electronics items that have come out recently are bothering me. I refer to a transistor radio that looks like a bottle of scotch, and a small bar built into a case camouflaged to look like a transistor radio. There's also a radio built into what looks just like a baseball.

If it hasn't already happened, I can see what might occur in the office or home of a gadgeteer who has the bottle radio. A thirsty friend drops in while the occupant is elsewhere, and friend then "uncorks" the bottle for a little snort, ruining fifty bucks worth of electronics. Or an unsuspecting sports-loving friend picks up your baseball radio, slams it into his palm a few times, and then bounces it off the wall.

Now that the time has come when you can listen to a bottle and drink from a radio, it shouldn't be long before this trend gets to the field of laboratory instruments, so that we'll have oscilloscopes that look like wastebaskets, and vice versa.

G. Barbara

Palo Alto, California

REVERSED DIODE

As a subscriber to your publication, I always enjoy the "extras" that your staff occasionally includes in various issues. The electronic color code chart is one of the useful items. With the Industry undergoing changes from day to day, every device must be employed to keep the electronic worker up to date.

Looking over the chart, I find that the nomenclature for diode and cathode end has been reversed. Or, to put it another way, the schematic and the pictorial drawing do not agree as to what end is the cathode (p 37, Nov. 15).

This reversal in the polarity of a diode from schematic to pictorial has been a problem that has plagued the industry for many years. It became particularly important to me when I began working in the design and installation of large-scale computer systems which often contained upwards of several thousand diodes with a tolerance of reversed polarity of zero. Because of this, we used the vacuum-tube symbol for a diode, and investigation showed that the number of accidental reversals dropped drastically.

Keep up the good work in your state-of-the-art articles, and in closing I would like to say that I especially enjoyed those about lasers and their applications.

Frank J. Lutz, Jr.

Patrick A. F. Base, Florida

• The diode symbol at the top of the section on diodes should be reversed.

INTROD

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The portable unit can be used to record and reproduce in the field. If desired, a 100 kc control tone, derived from an internal signal generator, is recorded with the data on the tape. This tape may then be reproduced on the Winston L-4000 Laboratory Recorder/Reproducer allowing the 100kc control tone to drive the fast response, precision, ISO-DYNAMIC® capstan servo system. The ISO-DYNAMIC® system reduces absolute time displacement errors to ±0.2 microsecond, referenced to the control tone. Wow and flutter is also greatly reduced. Other specifications of this new system are equally outstanding. Send for complete details.

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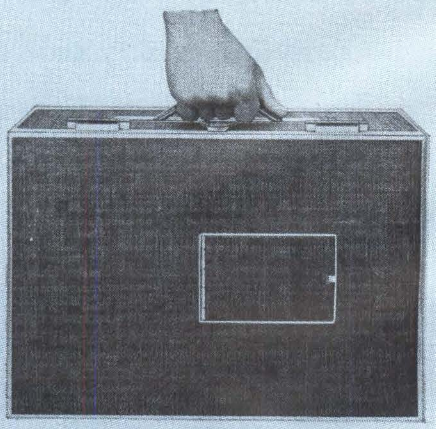

model P-4000

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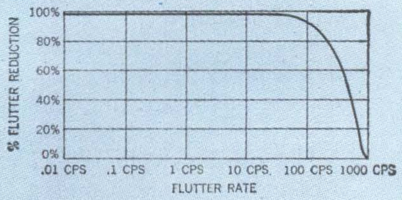


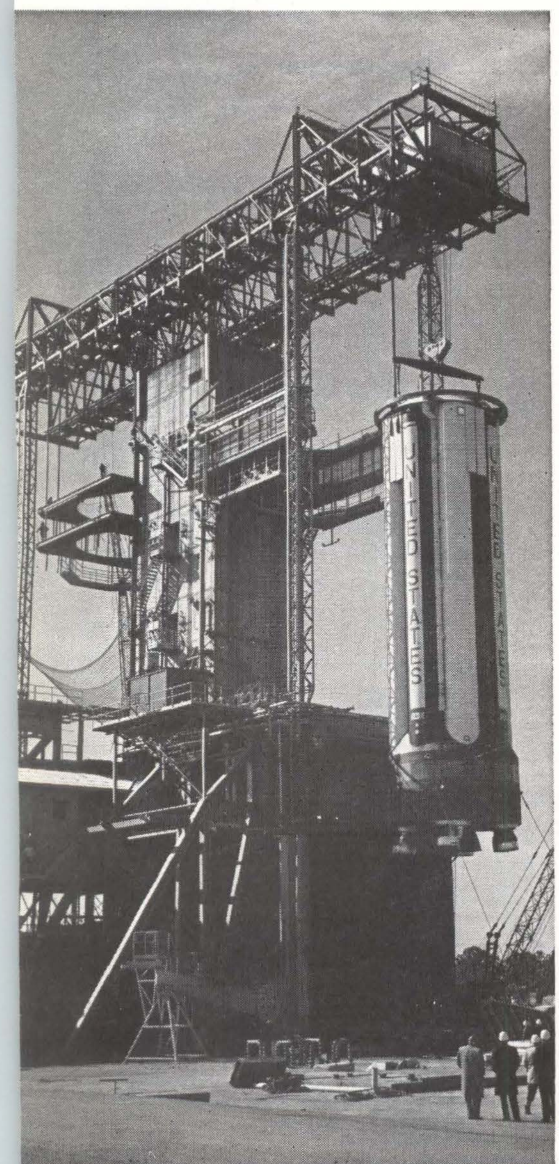
CIRCLE 9 ON READER SERVICE CARD

Saturn Launch Will Trigger Biggest

All tracking nets will follow orbital flight of world's biggest rocket

By **JOEL A. STRASSER**
Assistant Editor

SATURN SA-5 is hoisted onto 175-foot-high tower for static firing test at Huntsville, Ala. Now at Cape Kennedy, it will lift 38,000 pounds into orbit



THIS MONTH, the U. S. may take a commanding lead in spacecraft launch capability. A date around December 18 has tentatively been set for the first orbital flight of the world's most powerful booster. The giant Saturn I (SA-5) will carry into orbit a 38,000-lb dummy payload, from Cape Kennedy (formerly Cape Canaveral).

The biggest payload ever orbited by the USSR was the 14,292-lb Sputnik VII, launched Feb. 4, 1961. SA-5 has a thrust of 1½ million lbs compared to 900,000 for the Russian booster.

The launch will also signal the start of the most massive and complex tracking operation ever undertaken by the U. S. This flight will involve not only NASA's manned space flight network, but also the Satellite Tracking and Data Acquisition Network (Stadan, formerly Minitrack), elements of the Department of Defense's National Ranges, and the network of the Smithsonian Astrophysical Observatory (SAO).

Participating stations include Cape Kennedy; Bermuda; Muchea, Australia; Point Arguelo, Calif.; Kuaia, Hawaii; White Sands, N.M.; Corpus Christi, Texas, and all NASA and DOD C-band radar stations. Space Operations Control Center at Goddard Space Flight Center, Greenbelt, Md., will direct tracking.

A prelude to later Apollo flight, the launch will place SA-5 and its payload into an earth orbit with an apogee of 400 miles and a perigee of 160 miles for 145 days.

Tracking and Telemetry—Precount, countdown and the first two orbits will be handled like the Mercury-Atlas missions. Tests will consist of telemetry recording for two orbits, then skin tracking with C-band radar.

The orbiting vehicle will carry a C-band transponder and a Stadan beacon. The C-band beacon will transmit for 20 minutes and is designed for launch tracking only. C-band radar sites will attempt to skin track when the C-band beacon signal is turned off. The Stadan network will track for about 45 days until the beacon battery is exhausted.

Air-to-ground voice, S-band radar and command subsystems will not be required during this flight. With these exceptions, the operation will be that planned for tracking a manned Apollo spacecraft. Radar will be transmitted to Goddard in real-time and the regular voice communications network will be employed.

Because reentry will result from orbit decay, not retrorockets, and because the payload is so heavy, NASA wants to find out exactly when and where the vehicle reenters the atmosphere. Stations that will help determine this are the SAO Baker-Nunn camera sites, and all NASA and DOD C-band radar in-

Tinyvision

Small-screen tv sales growing; looks like market is here to stay

By **DAN SMITH**
Assistant Editor

SMALL-SCREEN television sets are here to stay, and in a big way, many industry observers feel. Their optimism marks a rapid about-face in marketing opinion.

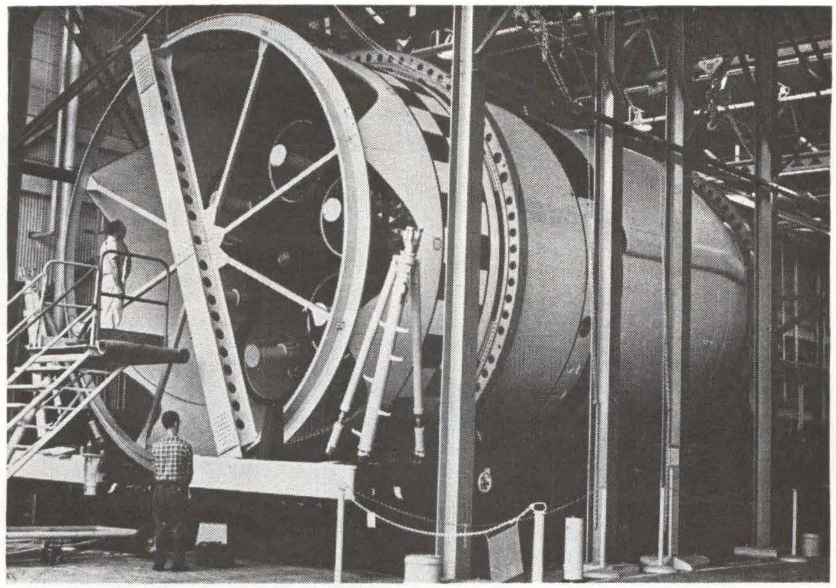
Six months ago, when GE introduced its 11-inch set, such rosy talk would have been greeted with derision. Today most manufacturers are "thinking small." Admiral has entered the field and another firm,

Tracking Test

stallations that will skin-track. Radars include operational FPS-16's and the new FPQ-6's at Carnarvon, Australia, and Patrick AFB.

Data Handling—When the telemetry beacon ceases transmitting after two orbits, look/angle data will be computed at Goddard and updated daily for each tracking station. The Stadan stations will track for 45 days using the Stadan beacon, to supply computers with additional data for revising the look/angle.

Cape Kennedy will feed launch trajectory data to computers at Goddard. Goddard's real-time computers will transmit data to Marshall Space Flight Center, Huntsville, Ala. using a 100-wpm teletype circuit. During launch, time, velocity, altitude, flight-path angle, down-range distance, latitude and longitude will be transmitted at six-second intervals.



INSTRUMENTATION unit will be carried in this second stage, which also provides additional thrust needed to orbit the payload

As the vehicle goes into orbit, data will be received at Goddard by teletype from the many sites around the world. Since many of the radars will have overlapping coverage, NASA has had to work out elaborate data transmission schedules for each site. Data arriving from the Pretoria and Ascension Island stations, for example, will be received by an IBM 7094 at Cape Kennedy and reformatted. The data processor will then transmit the information to the communications center where a paper tape will be cut, held and data transmitted to Goddard later via the real-time computer system.

Market BIG

Curtis Mathes introduced an 11-inch line this week. Prices start at $89.95. Some marketing experts believe that by next spring or summer many others will have brought out small sets of their own.

Sales a Surprise—People in the industry say GE's success has been a surprise. Most companies had written off the midgets a half dozen years ago when GE, RCA and Emerson failed to find a large market for 8-inch sets. "RCA sold a flock of them at $125," an RCA spokesman said. "We brought out another model for $99 and it was years before we could get rid of them. It seemed the market was 10,000 or 15,000 and that was that."

No one knows how large the market is now, but it is considerable. GE says its sales are "very good," but it has not made public any figures. Admiral says it is too early to comment on sales because its sets are just now reaching retail outlets in number. Outside sources say both firms are back-ordered on this item.

Importers Pleased—The reaction of Japanese tv manufacturers, who had this field to themselves for a long time, is perhaps the best indication of the market's strength. According to a spokesman, they feel promotion efforts by U. S. companies are helping their sales. Best estimates of Japanese sales for this year put their total around 100,000 transistor sets, plus a smaller number of vacuum-tube types. Last year the Japanese sold about 30,000 transistor sets in this country.

Realtone has just started production of a 6-inch transistor set with built-in all-channel tuner. The set was designed for the American market and will probably appear here before the end of the year. Persistent reports in the industry say a large merchandising and mail-order house will soon market a 10-inch vacuum-tube set built by Toshiba. List price will reportedly be $84.95. Another report says a U. S. appliance manufacturer will introduce a 12-inch Japanese-made set.

The sudden popularity of the small-screen sets is hard to explain. They are usually thought of as second sets for the bedroom or kitchen, but even this is not beyond dispute. "Maybe some people just want a more 'personal' set—no one really knows," one well-placed observer said. Another, a marketing man, said: "Frankly, I think 11 inches is just the right size. Preliminary surveys showed people want small sets, but they don't want to squint at 4 or 5-inch screens."

TI reports progress on

Today, SOLID CIRCUIT® semiconductor networks are making major contributions in improved reliability, size and weight reductions to more than 50 military equipment programs.

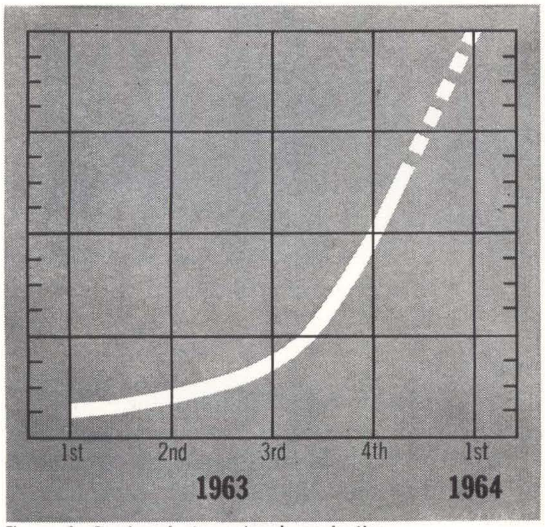


Figure 1. Semiconductor network production

DIGITAL SEMICONDUCTOR NETWORKS	
FLIP-FLOP/SHIFT REGISTER	6
GATES	12
HALF ADDERS	1
INVERTER/DRIVER	3
ONE-SHOT MULTIVIBRATOR	2
LEVEL RESTORER	1
INPUT/OUTPUT	2
MEMORY CIRCUITS	5
LINEAR SEMICONDUCTOR NETWORKS	
DIFFERENTIAL AMPLIFIER	9
DEMODULATOR CHOPPER	1
DRIVER SWITCH	2

Figure 2. Circuit types

Figure 3. Catalog circuit types

SN 521 OPERATIONAL AMPLIFIER	SN 522 OPERATIONAL AMPLIFIER	SPECIFICATIONS	
		Open-loop voltage gain	62 db
		Common-mode rejection	60 db
		d-c offset referred to input	–0.5 mv
		Frequency response	dc to 50 kc
		Input impedance	12 k ohms
		Output impedance	10 k ohms & 160 ohms
		d-c drift referred to input	8 μv/°C

T_A = –55°C to +125°C		SN 510	SN 511	SN 512	SN 513	SN 514	SN 515
		FLIP FLOP	FLIP FLOP	NOR/NAND	NOR/NAND	DUAL NOR/NAND	EXCLUSIVE OR
TYPICAL POWER DRAIN T_A = 25°C	$+3V_{CC}$	2 mw	2 mw	2 mw	2 mw	2 mw ea	3 mw
	$+6V_{CC}$	7 mw	7 mw	7 mw	7 mw	7 mw ea	11 mw
FAN-OUT		4	4 & 20	5	5 & 25	5 ea	4 & 5
TYPICAL SYSTEM CLOCK SPEED	$+3V_{CC}$	300 kc THROUGH 4 LEVELS OF LOGIC AT T_A = 85°C.					
	$+6V_{CC}$	500 kc THROUGH 4 LEVELS OF LOGIC AT T_A = 85°C.					

Production Volume — An eight-fold increase in production rates has been achieved by Texas Instruments since the beginning of the year (Figure 1). During the fourth quarter of 1963, for example, TI will produce and ship more integrated circuits than the entire industry produced in the second quarter.

As a result of TI's unparalleled production experience, you can plan now to incorporate *SOLID CIRCUIT* semiconductor networks in your equipments with full confidence that your production requirements will be met. This ability to produce large quantities of semiconductor networks is the direct result of process controls and expanded manufacturing facilities proven in actual volume production of a variety of network types.

Circuit Functions — TI is currently delivering volume quantities of 44 different digital and linear circuit types, as compared to only 10 a year ago. This production-based variety (shown in Figure 2) means that more of your circuit functions can be performed by semiconductor networks to obtain greatest system benefits. In addition to the 44 current network types, more than 100 other circuit variations have been produced to individual customer requirements during the past two years.

Among the 12 logic gates listed, for example, some have propagation delay times as low as 8 nanoseconds. Others perform logic functions at power drain as low as 2 mw. In the linear units, networks are amplifying at frequencies from DC to 5 mc.

TI semiconductor networks are often designed to provide three to five circuit stages within a single unit. These multi-stage networks mean fewer units are required for your system — reducing connections, size, weight, and cost.

For your applications, two catalog lines are available (see Figure 3). Series 52 linear networks are differential and operational amplifiers designed for control systems. The Series 51 digital networks are particularly designed for aerospace applications where low power drain is important. Both Series 51 and 52 are designed for "master slice" applications to provide circuit variations within the general parameters shown.

A new catalog series of high-speed digital networks is now in production and will be announced soon.

Advanced Process Technology — All TI semiconductor networks are formed in a single silicon substrate. Depending on circuit requirements, epitaxial, NPN, PNP, or NPN and PNP structures are used. With process

Semiconductor Networks

and material flexibility, it is possible to economically produce wide variations of single and multi-stage circuit functions to satisfy systems requirements.

Reliability — Third quarter 1963 reliability data indicates failure rates for a complete circuit below 0.1 percent per 1000 hours at 85° C (Figure 4). TI's weekly-add-to test and accelerated life test program gives a quick indication of both product reliability and process control.

As a result of TI's extensive and continuing reliability program, test results of more than 4000 semiconductor networks have established specific data that design engineers can use in systems reliability projections. This information includes "weekly-add-to," accelerated life, environmental, and step-stress test data. This reliability information is available for your use.

New Welded Package — To further improve reliability, all products are being converted to a welded-seal package. This package, (Figures 5 and 6) made from Kovar and hard glass, has been mass-produced for over a year and is rapidly being accepted as a standard for semiconductor networks. Its flat-form factor and 50-mil spacing between leads allow it to be used with a variety of equipment assembly techniques — printed circuit cards, cordwood, and thin film substrates. To further facilitate handling and assembly, lead lengths have been increased from 0.080" to 0.185".

For Systems Manufacturers—Related test and assembly equipment is now available for breadboarding, engineering and production of semiconductor network systems.

TI's new dynamically controlled parallel-gap welder (Figure 7) is the only welder that features feedback control of weld voltage. This enables the welder to adjust itself to a wide range of differences in lead dimensions, plating and surface conditions — without operator adjustment — providing welds of consistent high quality. As many as 40 welds can be made per minute without burn-outs, blow-outs or cold welds.

The TI model 659A integrated circuit tester (Figure 8) performs 36 DC tests on networks in 2 seconds, or two units can be operated in series for a 72-test sequence. Programmed plug-in circuit boards—for bias conditions, tuning, limits, and sorting logic — are obtainable to give go/no-go tests.

To facilitate handling of semiconductor networks, carriers along with associated test sockets and shearing tools have been developed.

This report summarizes the significant advances made by Texas Instruments in technology, production, handling, and assembly of semiconductor networks. This comprehensive program has made available a total capability to support your program requirements. For information, call your nearest TI sales office.

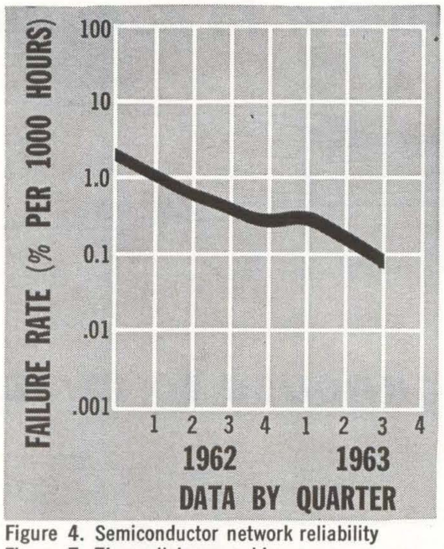
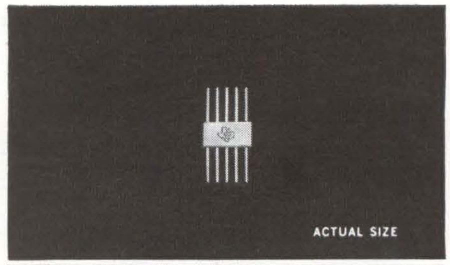
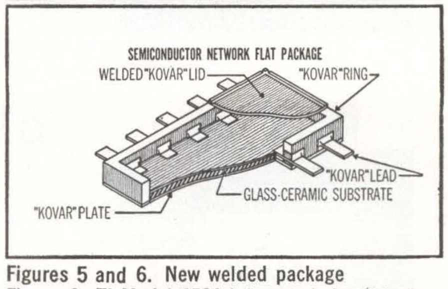


Figure 4. Semiconductor network reliability





Figures 5 and 6. New welded package

Figure 7. TI parallel-gap welder

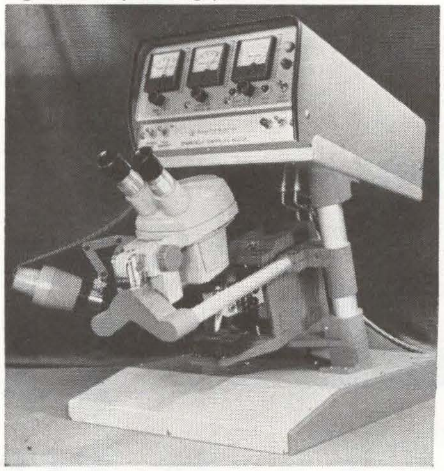
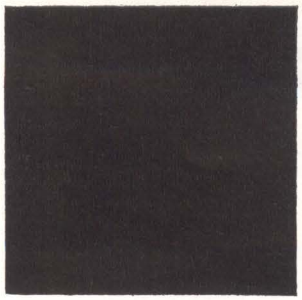
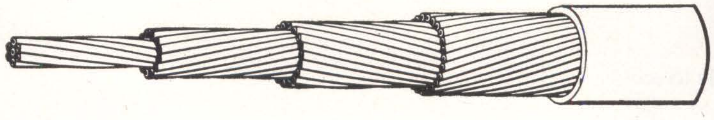
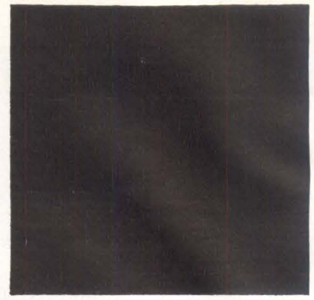


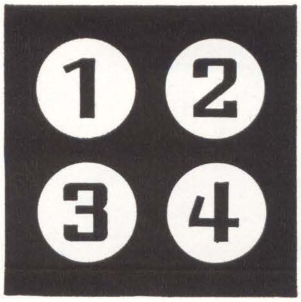
Figure 8. TI Model 659A integrated circuit tester



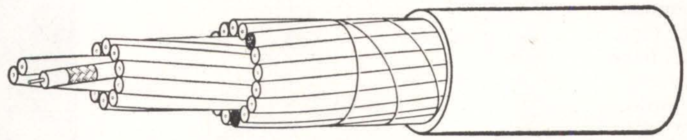
black box to black box...

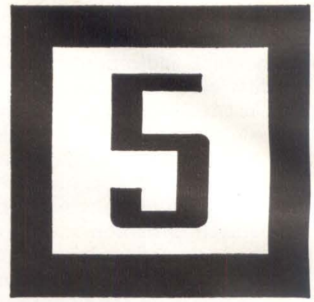


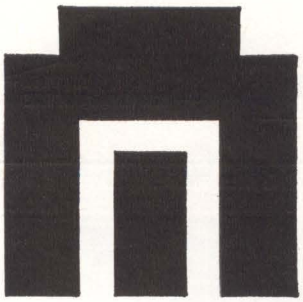




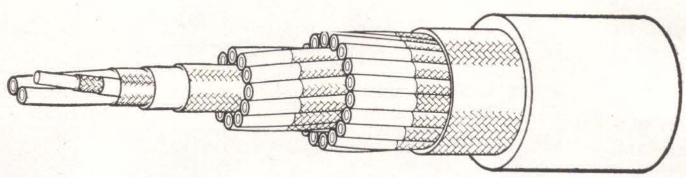
computer to computer...

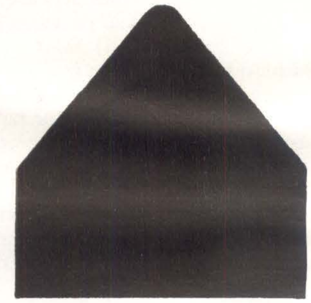




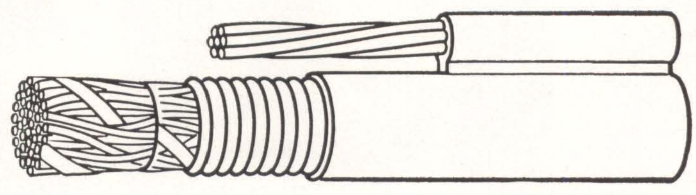


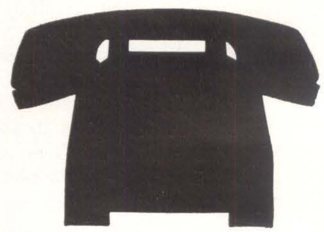
blockhouse to missile...





phone to phone...





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Performance advantages of a better broadband instrumentation tape

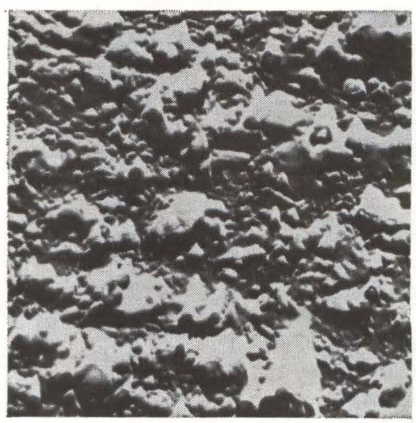
—in pre-detection, pulse code modulation, and other critical high-frequency instrumentation recording applications.

The shortest wavelengths in broadband recording are less than five times those of visible light. To magnetically record and reproduce such wavelengths requires a tape surface smoothness approaching that of an optical surface.

Memorex Type 62 Broadband Tapes look smooth to the eye, but what is more important, they look smooth even to the electron microscope — competitive products do not. They are twice as smooth as the best competitive tape, and this near-perfect surface is produced unerringly over the miles of tape on each roll.

Electron microphotographs of surfaces of Memorex tape and competitive product

MEMOREX TAPE



LEADING COMPETITIVE TAPE

Users of Memorex Type 62 Broadband Tapes receive important performance advantages, including:

as much as 6 db more response at the highest frequency —the result of the ultra-smooth surface;

as much as 3 db greater undistorted output — the result of a coating more densely packed with well-oriented particles of oxide;

more than 3 db higher signal-to-noise ratio — the result of extreme uniformity of distribution of particles within the coating;

no measurable increase in dropouts, even after 100 plays — the result of scrupulous cleanliness and care in manufacturing and the use of a durable, electrically conductive coating which will not shed oxide.

These improvements in performance were measured on a Mincom CM 100. Still greater improvements can be expected when using recorders with more extended bandwidth.

Memorex broadband tapes offer you a wider choice of coating thickness to suit your recording application:

62J (370 μinch coating) — for high output

62K (270 μinch coating) — a new intermediate coating thickness

62L (170 μinch coating) — the thinnest coating offered to date, giving you 25% more playing time per roll.

Digital or pulse recording applications—The smooth, thin coatings of Type 62 Broadband Tapes will provide the higher resolution and greater pulse packing densities required by advanced recording systems.

Memorex manufactures precision magnetic tapes for instrumentation and computer use, including Type 22 Computer Tape (tested and certified at 800 and 556 bpi), Type 33 Instrumentation Tape, Type 42 High Resolution Tape, and Type 62 Broadband Tape. To obtain complete technical data sheets, write to Memorex Corporation:

1182 Shulman Avenue / Santa Clara, Calif.

Important New Report for all Instrumentation Tape Users

MEMOREX Monograph #2, titled *"Head Wear Considerations in Magnetic Tape Recording,"* available free on request. Write MEMOREX at address above.

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PRECISION MAGNETIC TAPE

CIRCLE 15 ON READER SERVICE CARD

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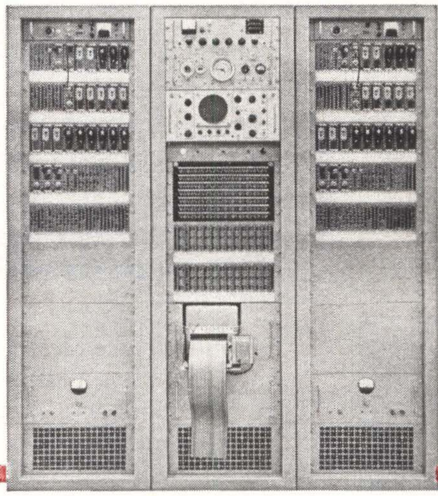
CUSTOM TIMING SYSTEMS FROM STANDARD ASSEMBLIES

You get solid state timing systems tailored to your specific requirements—from sophisticated range timing systems to portable instrumentation—with Astrodata's unique, building-block production technique.

For example, you can select fundamental units from the table below, then designate standard options to obtain exactly the timing functions most suited to your particular requirements. Numerous standard options have been designed and built to provide you with the most versatile—and highly reliable—timing equipment available today.



TIME CODE GENERATING SYSTEMS

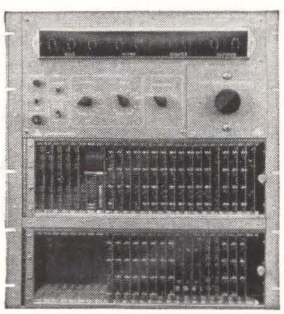
IRIG, NASA, AMR, PMR, White Sands, Eglin and special codes available

Model 6190 Up to 8 serial time codes simultaneously... standard pulse rates... decimal display ... stability to 1 part in 10^8.

Model 6140 Up to 4 serial time-of-day codes simultaneously... standard pulse rates... decimal display ... stability to 1 part in 10^8.

Model 6100 Up to 4 serial time-of-day codes... standard pulse rates... binary display... stability to 1 part in 10^8.

TIME CODE TRANSLATOR SYSTEMS



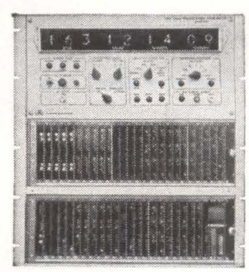
Model 6220 UNIVERSAL... translates all serial time codes to decimal display... parallel BCD output. Tape Search and Control Units (Models 6224, 6225, 6226) available for universal automatic tape search.

Model 6204 translates serial time code... provides parallel output and display consistent with input code format.

Model 6201 translates time-of-day serial code to parallel output and binary display.

Model 6200 converts input serial time codes to time-of-day display.

TERMINATING SYSTEMS



Model 6420 TIME CODE TRANSLATOR/GENERATOR... operates as Translator and/or generator... synchronizes time code generator to input serial time code... no interruption of output on loss of input signal.

Model 6620 Timing terminal unit... provides basic module for standard terminal function assemblies... can be assembled to provide any necessary terminal, signal conditioning or conversion functions... assemblies available: AGC amplifiers, demodulators, neon drivers, high level amplifiers, balanced line drivers, galvo amplifiers, relay drivers.

A new 48-page handbook of the most commonly used time code formats has been compiled as a handy reference for instrumentation engineers. For your free copy write to

For applications assistance when considering your timing system, contact your nearest Astrodata representative or the Timing Instrumentation Group direct.

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10

New Tube Shrinks Color Tv Camera

COLOR-TV CAMERA about one-fourth the size of image-orthicon cameras and requiring about one-third the lighting level needed by color vidicon cameras is reported by Philips of The Netherlands. Called the Plumbicon color camera, it is described as "a major break-through in color television production." Philips says its very low response time is independent of illumination level and that the Plumbicon tube is also highly suited to black-and-white tv.

The camera's advantages are due to a new lead-oxide photosensitive surface in the tube, which has no saturation point, it is reported. As a photo-conductive device, the tube is more nearly related to a vidicon than an orthicon. It has negligible dark current, which eliminates background shading; there is no image lag or "burn-in," it is stable over a wide temperature range and warms up in 5 minutes.

Three Plumbicon tubes, each an inch in diameter and 8 inches long, are used as pickup tubes in the camera, which, without lens, weighs 77 pounds. Frequency response is ± 1 db at 7 Mc; light requirements at f 1.9 are 100 foot-candles.

The Plumbicon camera may eventually be manufactured in the U. S. by North American Philips, which is now importing it. It will be distributed by Theater Network Television, Inc. The closed-circuit Plumbicon camera is part of a new color-tv system, together with the color Eidophor (p 42, Oct. 4).

Aussies Want Sage

AUSTRALIA is in the market for a nation-wide command and control system, presumably a smaller version of our Sage. Although details have not been released, it is known that approximately 15 U. S. companies, and others in Europe, have been invited to make proposals on the system.

EIA's Market Predictions

LOS ANGELES—Electronics industry factory sales are expected to reach $16.3 billion in 1964, according to EIA President Charles F. Horne, who presented the organization's market estimate at this week's EIA Winter Conference here.

	1962	1963 (Millions of Dollars)	1964
Consumer electronics	2,407	2,550	2,650
Industrial electronics	2,450	2,700	3,000
Federal electronics	8,348	9,400	9,900
Components, replacement	620	675	750
Electronics, Total	13,825	15,325	16,300
Television	953	1,010	1,025
Radio	386	375	370
Phonographs	385	460	525
Other	683	705	727
Consumer Electronics, Total	2,407	2,550	2,650
Active components	1,210	1,165	1,145
Passive	897	920	950
Other	1,561	1,705	1,855
Components, Total	3,668	3,790	3,950

Engineer Enrollments Up, Graduates Still on Decline

BACHELOR DEGREES awarded to engineers declined 4.3 percent this year, the fourth year in a row, while September enrollments were up—1.3 percent—for the first time since 1957. To educators it gives some hope that the downtrend has slowed. Doctorates awarded rose 15 percent, setting a record, and master's degrees 8.3 percent.

Small Computer Market Gets a New Entry

NEW YORK—Honeywell this week entered the small computer market with its H-200 system, which rents for a minimum of $3,160 a month. The system includes a central processor with 2,048 characters of memory, printer and card reader-punch. Memory cycle time is 500 mano-seconds. An automatic program conversion package translates the programs of the IBM 1401, 1440 and 1460 to H-200 programs, Honeywell says. The Honeywell 200 will be marketed to new computer users, as a satellite system for large computers, and as a replacement for existing small machines.

Anisotropic Studies Given Another Push

ARMY HAS AWARDED another contract for the study of microwave and millimeter-wave generation with anisotropic materials (p 19, Oct. 25). This one, for $80,420, goes to Microwave Electronics Corp. here. Pyrolytic graphite and bismuth and indium antimonide have been suggested for investigation.

MEC experiments will be based upon theoretical calculations by Pines and Schrieffer of the University of Illinois, which indicated that two electron beams could be made to drift within a solid and the interaction of the two results in a growing space charge wave. There has been much study of this within gaseous plasmas, but oscillation frequency is limited because of relatively low gas plasma density.

Gimbaled Mount Built For Laser Telescope

TRACKING MOUNT, able to point a 3,500-pound laser telescope to an accuracy of about two seconds of arc, has been delivered by Northrop to NASA's Goddard Space Flight Center. The telescope will help devise new electro-optical tracking systems for satellites and space probes. Resting on hydrostatic bearings, the 25-ton mount's gimbal, yoke, and telescope can be moved manually or semi-automatically with fingertip pressure, the firm says, in both equatorial and X-Y modes. It consists of a base, a symmetrical open yoke for the X-axis, and a gimbal supporting the telescope's Y-axis bearings.

R&D Funds Going Up

R&D EXPENDITURES in this country during 1964 should hit $20 billion, predicts Battelle Memorial Institute. Government will spend about $13.9 billion; industry, about $5.6 billion, and academic and nonprofit institutions, about $500 million, Battelle says, calling its estimates conservative. This would be the third consecutive year that more than $1.5 billion has been added to R&D funds. Battelle estimates total R&D expenditures in 1963 at $18.3 billion

Gravity-Gradient Craft —When It Might Fly

WASHINGTON—NASA could put up a gravity-gradient satellite (p 16, Aug. 23; p 19, Oct. 11) within 12 months, once given the go-ahead, although 24 months would be needed to prepare a fully-instrumented spacecraft. ComSat is considering gravity-gradient stabilization to earth-orient a medium-altitude communications satellite.

First type NASA wants to fly would be a three-axis system with tv cameras to monitor thermal bending, provision for changing moments of inertia, and several damping systems for comparison tests. Bell Telephone Labs and GE systems are promising, NASA says, although other versions are being examined.

Universal ComSat Station Planned for Nova Scotia

MONTREAL — Ten-kilowatt communications satellite ground station capable of handling both medium-altitude Relay and Telstar spacecraft as well as high-altitude Advanced Syncom will be built near Halifax, N. S. by RCA Victor, Ltd., under a $5-million contract awarded last week by Canada's Dept. of Transport. The station will have an 85-ft. dish with a multimode, multi-horn feed enclosed in a pressurized radome. Antenna efficiency will measure 56 percent at the output of the horn.

Station frequencies will conform to those announced for communication satellites at the ITU meeting in Geneva (p 14, Nov. 22). Either a traveling-wave-tube or klystron amplifier will be used at the station, which will be able to handle either ssb or f-m. The antenna, on an azimuth-elevation mount, will have a noise temperature of 65 deg K at 7.5 deg elevation angle and pointing accuracies of 0.03-deg maximum under autotrack, 0.06-deg max under programmed steering.

Laser Will Track Range Missiles

C-W GAS LASER will be used to track missiles along the Atlantic Missile Range. The system, which Pan American is developing, will automatically track and range on the radiation bounced off small retroreflectors mounted on the missiles. Called Opdar, for Optical and Ranging System, it is to give the missile's position, velocity and acceleration from 0 to 50,000 feet in altitude.

MEETINGS AHEAD

FALL URSI MEETING, IEEE Seattle Section, URSI, Boeing Scientific Research Laboratories; University of Washington, Seattle, Wash., **Dec. 9-12.**

NON-LINEAR PROCESSES IN THE IONOSPHERE MEETING, NBS; Central Radio Propagation Laboratory, Boulder, Colo., **Dec. 16-17.**

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE MEETING, AAAS; Cleveland, Ohio, **Dec. 26-30.**

RELIABILITY-QUALITY CONTROL NATIONAL SYMPOSIUM, IEEE, ASQC, ASME, EIA; Statler Hilton Hotel, Washington, D. C., **Jan. 7-9.**

INTEGRATED CIRCUITS SEMINAR, IEEE New York Chapter; Stevens Institute of Technology, Hoboken, New Jersey, **Jan. 15.**

ANTENNA RESEARCH APPLICATIONS FORUM, Midwest Electronics Research Center; University of Illinois, Urbana, Ill., **Jan. 27-30.**

INSTRUMENTATION SYMPOSIUM, ISA North Central Area; New Sheraton-Ritz Hotel, Minneapolis, Minn., **Jan. 30-31.**

MILITARY ELECTRONICS WINTER CONVENTION, IEEE-PTGMIL; Ambassador Hotel, Los Angeles, Calif., **Feb. 5-7.**

ELECTRONIC COMPONENTS INTERNATIONAL EXHIBITION, FNIE, SDSA; Paris Exhibition Park, Paris, France, **Feb. 7-12.**

PHYSICAL METALLURGY OF SUPERCONDUCTORS MEETING, AIMMPE Metallurgical Society; Hotel Astor, New York, N. Y., **Feb. 18.**

INTERNATIONAL SOLID STATE CIRCUITS CONFERENCE, IEEE, University of Pennsylvania; Sheraton Hotel and University of Pennsylvania, Philadelphia, Pa., **Feb. 19-21.**

ADVANCE REPORT

ENERGY CONVERSION, CONTROL CONFERENCE, IEEE *Region 3; Clearwater, Fla., May 4-6, 1964; Dec. 15 is deadline for submitting five copies of 300-word abstracts, plus 100-word biography, to Paul G. Hansel, Vice President, Engineering, Electronic Communications Inc., 1501 72nd St. North, St. Petersburg, Fla. Some topics include SNAP systems, nuclear batteries, photoelectric conversion, electroluminescence, lasers, cryogenics, control techniques, plasma applications, converters-conditioners, magnetohydrodynamics,*

Single-Frequency Laser Made

MINIATURE helium-neon gas lasers that operate as single-frequency oscillators have been developed at Bell Telephone Laboratories by E.I. Gordon and A.D. White. Large gas lasers oscillate at many frequencies.

The new lasers have discharge tubes 2 inches long and 0.04 inch in diameter. They can be tuned to any frequency in a 1.5-Gc range centered at 473 Tc (visible red) by moving end mirrors less than 12 microinches with a piezoelectric transducer. The helium 3 isotope is used instead of the normal helium 4 gas.

The lasers operate continuously at room temperature with d-c input and are frequency stable. Since mirror displacement of less than 1 μinch causes a measurable frequency change, the devices can be used in precise measuring instruments.

Vlf Tests Probe Ionosphere Absorption

PALO ALTO, CALIF.—Vlf reception tests in Antarctica may lead to a breakthrough in the causes of absorption in the ionosphere, says Robert A. Helliwell, professor of electrical engineering at Stanford University here. Daily variations of vlf transmissions suggest a connection between electromagnetic wave packets in the whistler mode and charged particles which are thought to cause absorption in the D region when they penetrate to that depth, he told ELECTRONICS. The tests were conducted at Eights Station, Ellsworth Island, Antarctica, by Michael Trimpi.

Aircraft Data Recorder Watches Critical Parts

AIR FORCE has ordered from Lockheed an aircraft maintenance recording system that continually watches critical parts and systems during flight. These findings are recorded on magnetic tape, which upon landing can be played back at 100 times recording speed. The system keeps track of 71 parameters, Lockheed said.

Computer Will Design Other Computers for AF

BEDFORD, MASS.—A major tool for designing complex military command and control systems of the 1960's and 1970's went into operation this week at the Electronic Systems Division, Hanscom Field. The Military Information Systems Design Laboratory (p 28, June 28) is also expected to make major contributions to computer usage in nonmilitary areas.

The SDL permits experimental simulation of C&C systems and rapid exploration of proposed designs. Subsystems can be simulated and tested and hardware can be evaluated before incorporation into a system. Core of the SDL is the 7030 Stretch computer. Mitre Corp. will operate the design lab. One of its major tasks will be the design of command and control components for the National Military Command System (p 28, March 22).

Lensless Photo System Uses Laser Light Source

IMAGE FORMATION without use of lenses is reported by University of Michigan this week in the Journal of the Optical Society of America. The two-step process uses a point light source, such as a laser or mercury arc lamp, to illuminate the subject and record a phase reference on the film, in a camera-like device. The resulting blurred negative (a diffraction pattern) is reconstructed using a projector-like device. A beam of coherent light—from a helium-neon laser in this experiment—is directed through the negative, and mixed with a reference beam to form a normal picture.

IN BRIEF

STAR TELESCOPE that will detect radiation within a steadily revolving field of view from all stars, instead of by locking on one, is being developed by Honeywell. NASA will use it.

PULSE GENERATING system is Holley Carburator's new entry into the field of electronic ignition. The $99.95 unit uses a magnetic cam and an adaptor plate for system changeover without distributor modification.

PEACE CORPS has ordered 1,500, 23-inch Admiral tv sets to help cut illiteracy in Colombia. Colombia is also expected to buy 50,000 citizens' band radios. It has ordered 1,000 from Cadre Electronics.

AIR FORCE has awarded General Precision Inc. a $5.6-million supplemental contract for flight feasibility tests of a stellar-inertial guidance system.

HUGHES Aircraft received $30.2-million more from the Navy for work on the Phoenix missile system. Raytheon got another $30 million from Army for the Hawk missile.

LENKURT has developed a system that transmits 2,400 bits of data per second, via radio. System is based on Lenkurt's Duobinary coding technique (p 61, March 1962).

TIROS 8, first weather satellite to carry an APT camera (p 20, July 26) is to be launched about Dec. 17.

BEACON on the Centaur booster, placed in orbit Nov. 27, is no longer working and the craft is now being tracked by cameras. Autopilot was controlled by a small digital computer built by General Precision.

ITT HAS COMPLETED acquisition of Cannon Electric's assets. Litton Industries has postponed acquisition of Clifton Precision Products because of a labor dispute at Clifton. United Aircraft plans to buy Vector Manufacturing.

HONEYWELL'S British subsidiary has begun building medium and large computers in Scotland.

EXPLORER XVIII, known as IMP (p 40, Nov. 29) and launched Nov. 26, has been relaying "excellent" data to earth, says NASA.

Johnson's Word To Contractors: Cut Down Costs

President Johnson is making a strong bid to establish himself as a frugal president. He has reaffirmed his policy to maintain a strong military position, but he is warning contractors that he intends to get full value for every defense dollar spent.

A first step is a letter sent to 7,500 defense contractors calling on them to save money wherever possible. Johnson told them to "establish an affirmative program of cost reduction in the performance of defense contracts, both those which you now hold and those which you may subsequently receive. If you already have such a program in being, then I call on you to accelerate, expand and intensify this effort."

Backing up cost-saving moves already started by Defense Secretary McNamara, Johnson said his goal is to save up to $1.5 billion of an estimated $56-billion defense spending in fiscal 1964. There are no big departures in Johnson's letter, but it puts extra steam behind the cost-saving drive and is an important sign of Johnson's support of McNamara.

Contractor Squeeze Aimed At Tax Cut

One reason Johnson is putting the squeeze on defense contractors is the hope that this will impress conservative congressmen and will set moving the proposed $11-billion tax cut. There is little hope, however, of Congress approving the tax cut this session. Best guess for its passage is early next year, though a speedup method under consideration is to pass the first phase, $7 billion in cuts, before the end of this year.

Strategic-Force Spending To Fall "Substantially"

Efforts, on a federal level, to ease the economic strain as military programs shrink will continue (ELECTRONICS, p 20, Nov. 8).

Defense Secretary McNamara warned of the coming changes in a speech just before President Kennedy's death. McNamara's remarks are worth repeating now, because insiders say Johnson subscribes to the secretary's thinking in that speech.

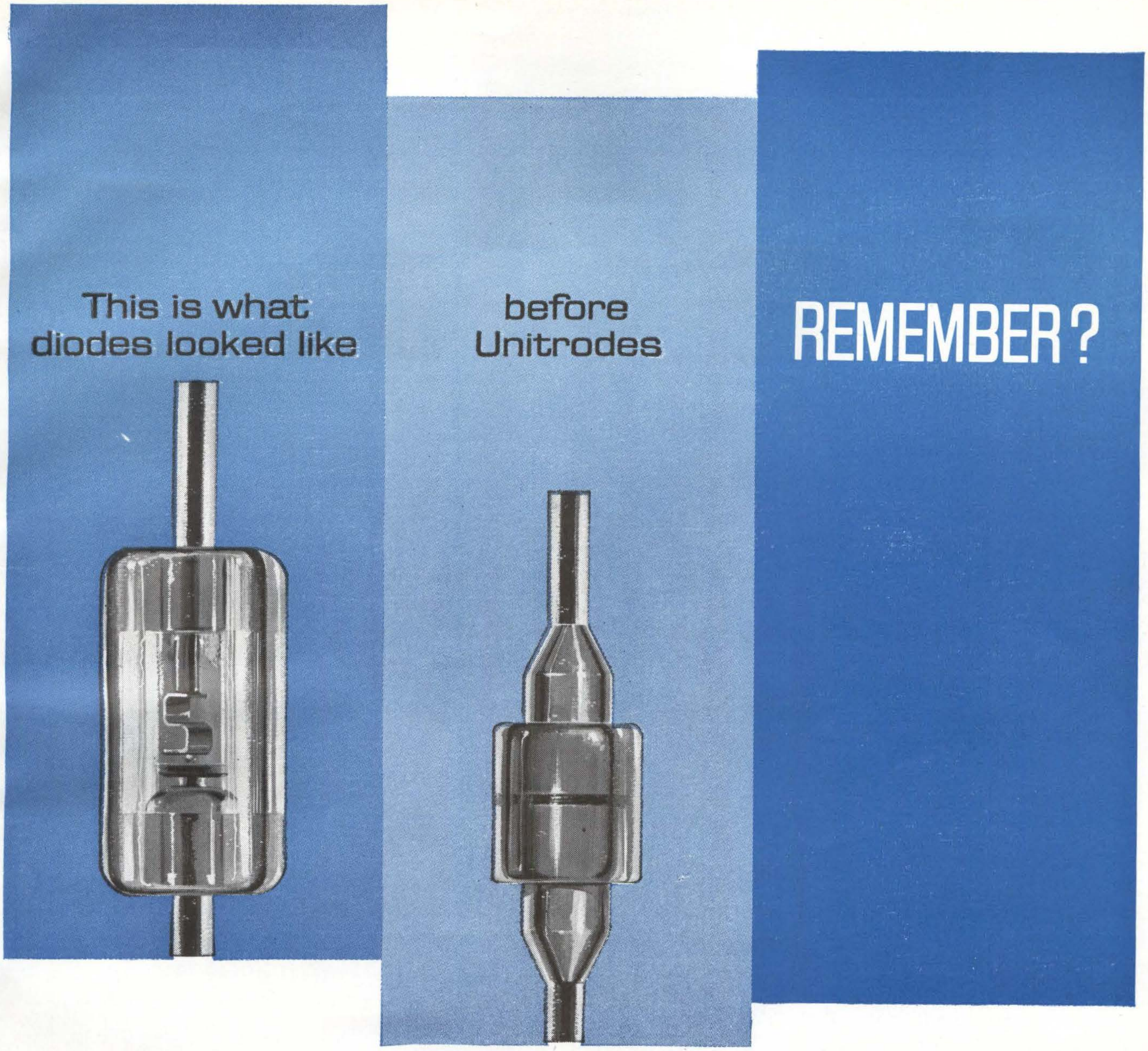
"We can anticipate that the annual expenditure on strategic forces will drop substantially," McNamara said, "and level off well below the present rate of spending." This does not mean that defense spending will be less next year—it won't—but that the trend is apparent.

McNamara said that in the past few years the defense establishment has been built up to levels considered necessary under present world conditions. U. S. nuclear strength, he asserted, is so great that even the most effective Soviet surprise attack would still leave the U. S. able to "destroy the attacker's society," so there is no point in developing "overkill" capabilities.

Perhaps even more important to industry is the shift from big hardware, such as missiles, which call for large numbers of production workers and large supplies of material, to sophisticated electronic systems that use little material and fewer, more skilled men.

13 Electronics Firms in Top 100

Thirteen electronics companies were among the 100 companies receiving the largest dollar volume of military prime contracts in the fiscal year ending last June 30. Electronics also accounted for a substantial portion of the income of 23 missile-space firms, 17 aircraft companies and 5 nonprofit institutions on the "top 100" list. Lockheed Aircraft, with $1.5 billion in contracts, led the list for the second consecutive year, followed by Boeing, North American Aviation and General Dynamics. AT&T, General Tire & Rubber (which includes Space-General Corp.) and RCA were among the top 15 contractors.



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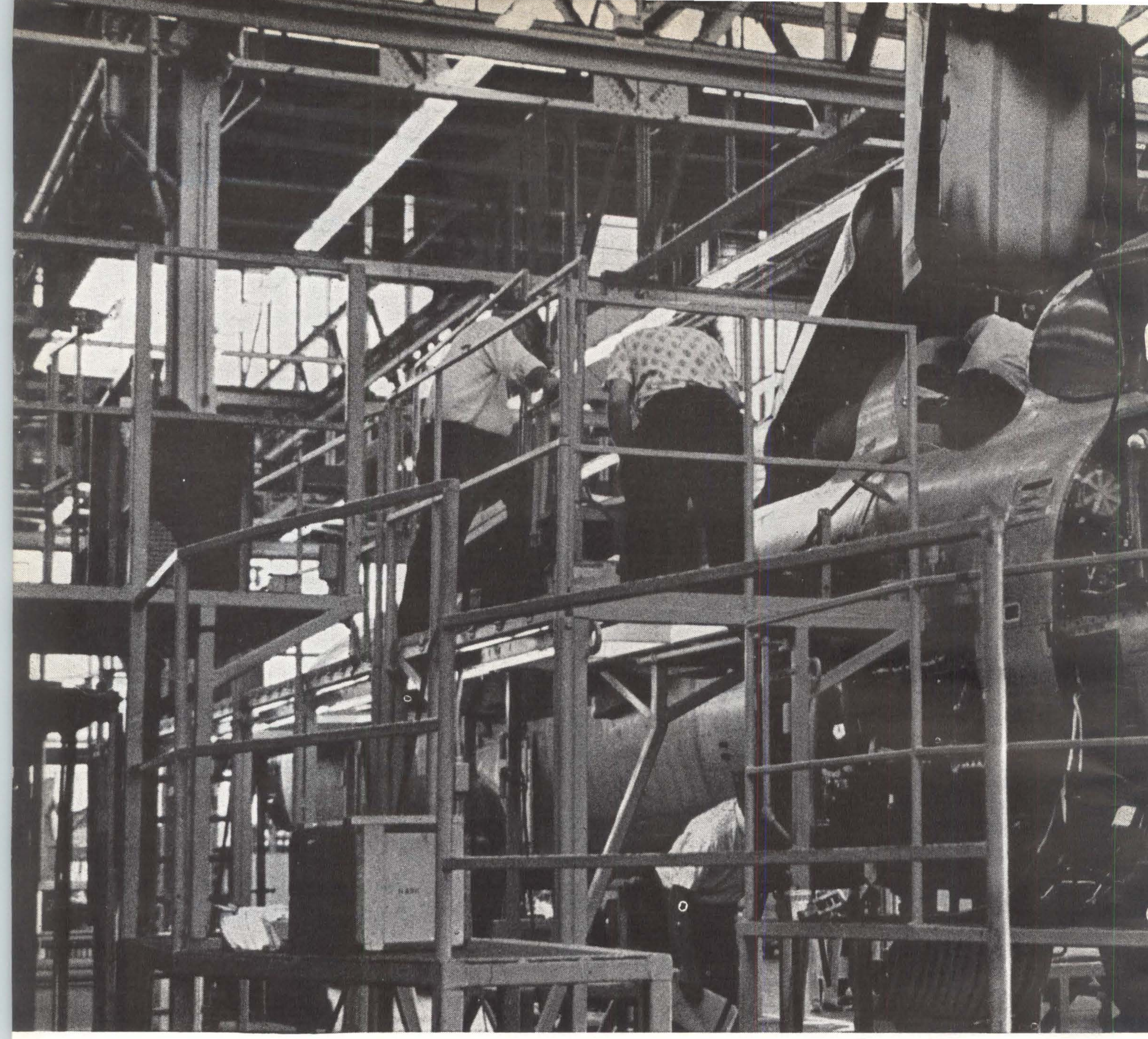

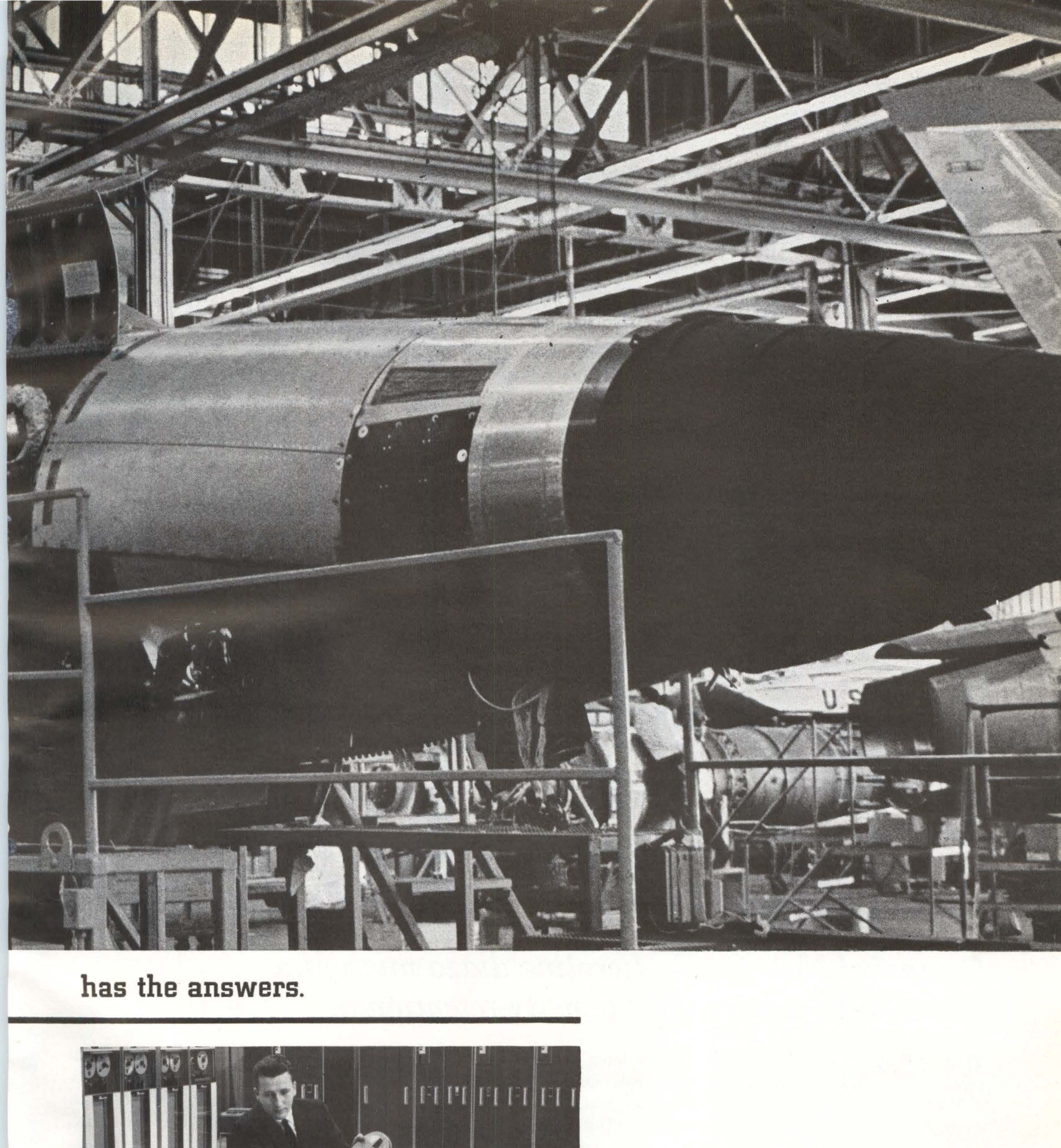

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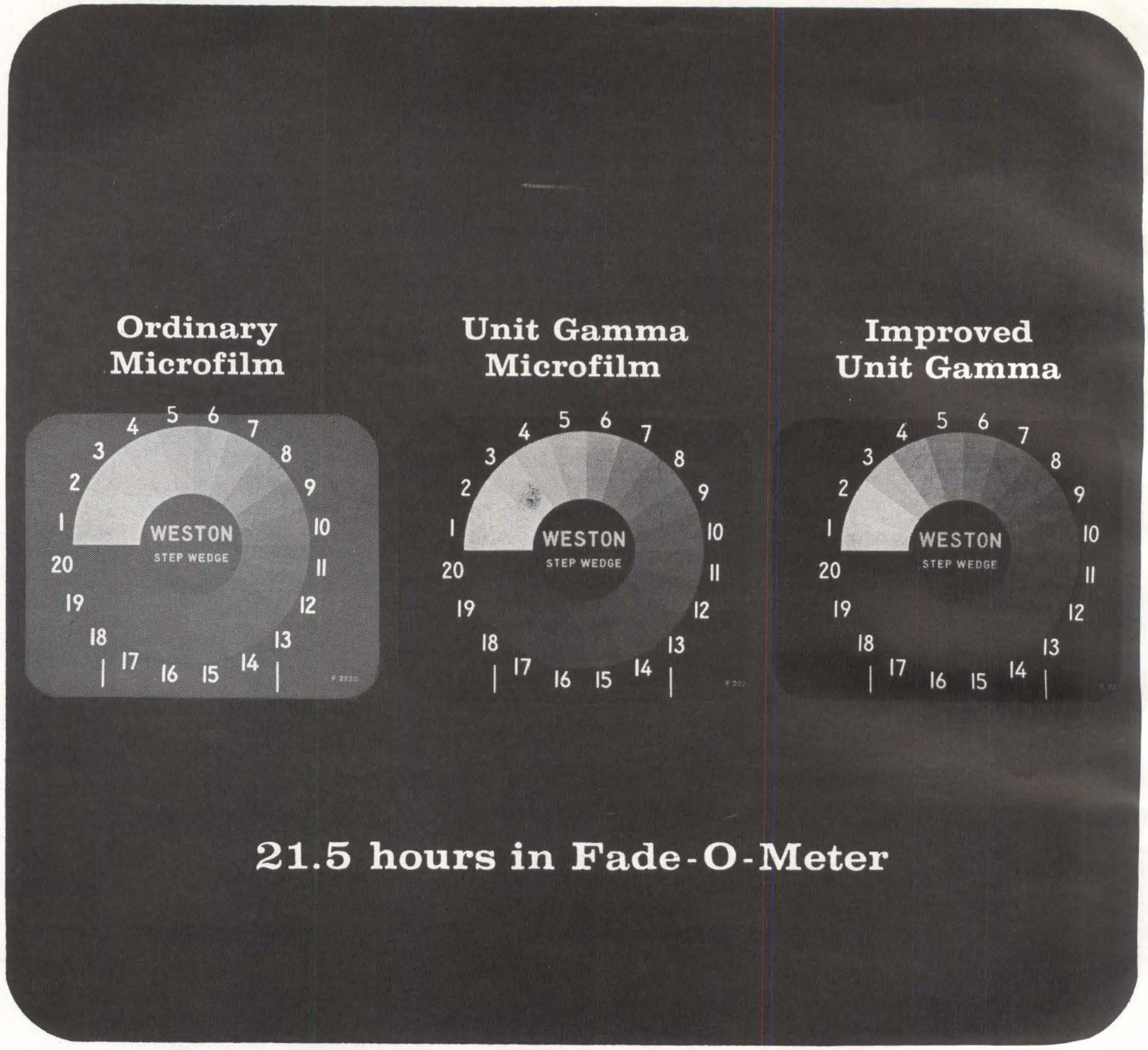

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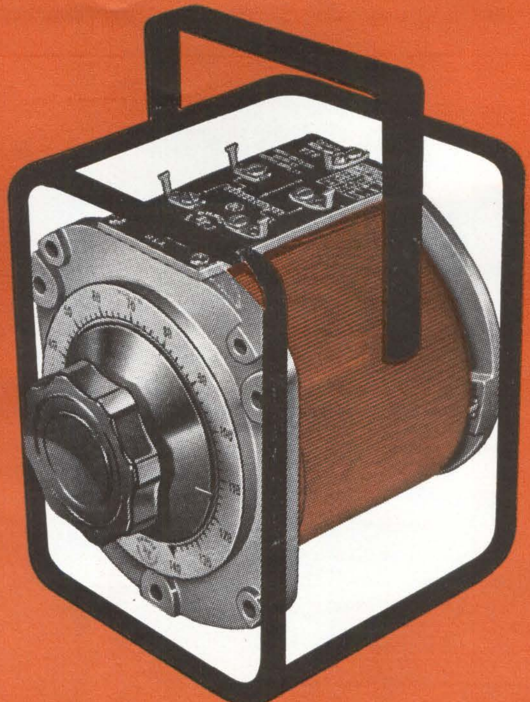

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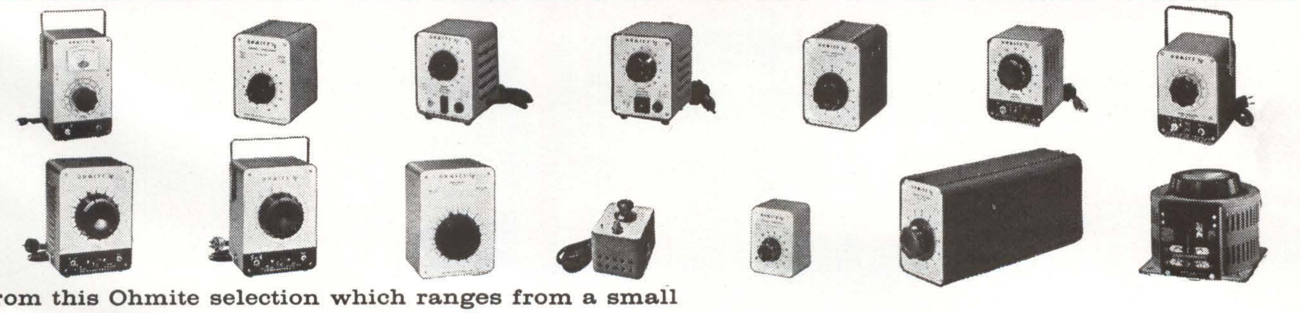
120	1.75	0-132	Portable	**VT2F**
120	1.6	0-120	Fixed Mtg.	**VT2NE**
120	2.0	0-120	Portable	**VT2NF**
120	2.8	0-140	Fixed Mtg.	**VT4E**
120	3.5	0-140	Portable	**VT4F**
120	3.5	0-140	VT4F w/gnd. in. & out.	**VT4FC**
120	3.8	0-120	Fixed Mtg.	**VT4NE**
120	4.75	0-120	Portable	**VT4NF**
120	4.75	0-120	VT4NF w/gnd. in. & out.	**VT4NFC**
120	6.0	0-140	Fixed Mtg.	**VT8E**
120	7.5	0-140	Portable	**VT8F**
120	7.5	0-140	VT8F w/gnd. in. & out.	**VT8FC**
120	6.0	0-120/140	Deluxe Portable	**VT8G**
120	6.0	0-120/140	VT8G w/gnd. in. & out.	**VT8GC**
120	8.0	0-120	Fixed Mtg.	**VT8NE**
120	10.0	0-120	Portable	**VT8NF**
120	10.0	0-120	VT8NF w/gnd. in. & out.	**VT8NFC**
120	20.0	0-120/140	Basic Case	**VT20B**
120	25.0	0-120	Basic Case	**VT20NB**
120	16.0	0-120/140	Fixed Mtg.	**VT20E**
120	20.0	0-140	Portable	**VT20FC**
120	16.0	0-120/140	Portable	**VT20GC**
120	20.0	0-120	Fixed Mtg.	**VT20NE**
120	25.0	0-120	Portable	**VT20NFC**

Input Volts	Maximum Output Amps.	Maximum Output Volts	Feature or Connection	Stock No.
WITH METERS				
120	6.0	0-120/140	w/voltmeter, gnd. conn.	**VT8GCV**
120	6.0	0-120/140	w/volt. & ammtr., gnd. conn.	**VT8GCVA**
120	6.0	0-120/140	w/volt. & wattmtr., gnd. conn.	**VT8GCVW**
120	10.0	0-120	w/voltmeter, gnd. conn.	**VT8NFCV**
120	10.0	0-120	w/volt. & ammtr., gnd. conn.	**VT8NFCVA**
120	10.0	0-120	w/volt. & wattmtr., gnd. conn.	**VT8NFCVW**
120	16.0	0-120/140	w/voltmeter, gnd. conn.	**VT20GCV**
120	16.0	0-120/140	w/volt. & ammtr., gnd. conn.	**VT20GCVA**
120	16.0	0-120/140	w/volt. & wattmtr., gnd. conn.	**VT20GCVW**
120	25.0	0-120	w/voltmeter, gnd. conn.	**VT20NFCV**
120	25.0	0-120	w/volt. & ammtr., gnd. conn.	**VT20NFCVA**
120	25.0	0-120	w/volt. & wattmtr., gnd. conn.	**VT20NFCVW**
TWO-IN-TANDEM ASSEMBLIES				
240	20.0	0-240/280	Series Conn.	**VT20-2B**
240	25.0	0-240	Series Conn.	**VT20N-2B**
120	20.0	0-120/140	Open Delta Conn., 3-Phase	**VT20-2B**
120	25.0	0-120	Open Delta Conn., 3-Phase	**VT20N-2B**
THREE-IN-TANDEM ASSEMBLIES				
240	6.0	0-240/280	"Y" Conn., 3-Phase	**VT8-3E**
240	20.0	0-240/280	"Y" Conn., 3-Phase	**VT20-3B**
240	25.0	0-240	"Y" Conn., 3-Phase	**VT20N-3B**



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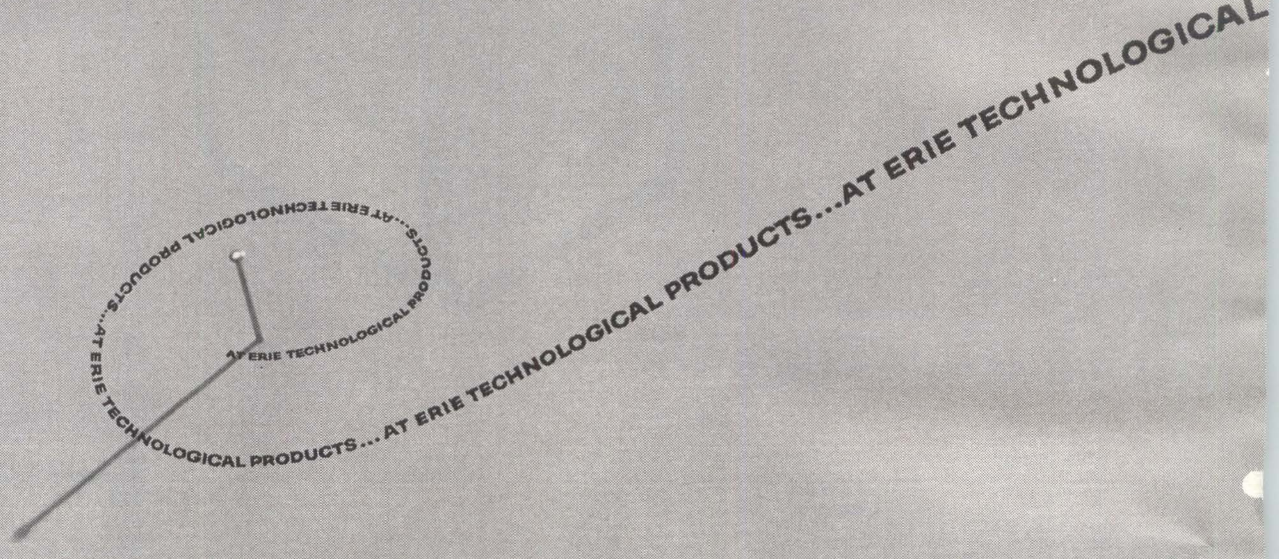
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Array Radar's Problem: Too Many

Designers call for advances to raise power, cut complexity

By **THOMAS MAGUIRE**
Regional Editor, Boston

BOSTON—The push in radar systems toward higher average power and higher resolution in range and angle will impose increasingly stringent requirements on components makers.

In phased-array systems, according to a Raytheon systems manager, the huge number of components imposes a heavy burden of reliability.

"If you have 5,000 duplexers with an mtbf of 5,000 hours," said Max Michelson, "that means one failure per hour." Also because of component volume, low-cost production is likewise at a premium. And, ingenuity of design will be necessary for the distribution network and monitoring equipment (ELECTRONICS, p 29, Nov. 15).

Among needs noted and trends predicted at an EIA-sponsored conference on microwave components last month were these:

- Need for reduction of microwave components to parallel microcircuit development
- Trend to cooled parametric amplifiers for range improvement, to permit lower minimum-discernible signals
- Need for solid state power sources—reliable, compact, low in cost
- Call for exploration of techniques which would preserve benefits of phased arrays but avoid massive componentry.

The table summarizes some of the present and future requirements for components as estimated by systems designers.

Phased-Array Problems—Most systems people agreed that eventually phased arrays will be increasingly used for high resolution, reliability and accuracy. But Frank Klawsnik, of RCA, urged exploration of the possibility of doing the same job with fewer elements—reduce the number of components and still retain the required aperture. There may be a way, he said, of feeding, for example, 100 radiators in groups instead of using separate phase shifters, switches and delay lines. And Wesley Matthews, of Sperry, said the use of interferometric techniques instead of a continuous array of radiation is being explored, employing end-element signals only and processing them to discriminate against ambiguities.

Klawsnik also listed these needs: ferrite phase shifters, in L or S band, that give 360-deg shift, variable continuously or at least in small steps; 1-microsecond switches which feed all elements with phase and time delay; good diodes that cost, not $10 each, but 50 cents, and can switch in different lengths of the line in a corporate feed system.

M. B. Rapport of Hughes Aircraft told the component makers that, in air surveillance systems and other types of radar, demands for higher rates will require faster and faster switching techniques.

How to Handle Power—Robert K. Greenough, of GE, pointed out that, with 50 and 100-kw radar tubes coming (ELECTRONICS, p 27, Nov. 8), the problem that will increasingly present itself is what to do with this kind of power after it gets out of the tube—especially with low-noise receivers nearby.

Normal r-f components need to be re-examined, said Greenough, particularly for vswr and low insertion loss. They need to be shrunk in size, they should be portable, and the packaging and cost need to be reexamined: "A suitcase Mistram might not be a dream if these components were reduced." Mistram is a large, trajectory-measurement system used on the Atlantic tracking range (ELECTRONICS, p 12, June 14).

According to Michelson peak-power handling is about at its maximum for the foreseeable future. Av-

ESTIMATED PRESENT AND FUTURE REQUIREMENTS FOR COMPONENTS

COMPONENT	PRESENT		FUTURE	
	Rotating Array	Fixed Array	Rotating Array	Fixed Array
Antenna				
gain (db)	34	43	43	?
beamwidth (deg.)	~2.5	~1	~1.1	?
sidelobe level (db)	−18	−25	−25	?
Beam Steering Device	F/mech[a]	ϕF[a]	F/mech[a]	$\phi\phi$[a]
power level peak	1 Mw	20 kw/unit	4–7 Mw	10–30 kw/unit
bandwidth	narrow	narrow	narrow	wide
loss (db)	0.6	0.6	0.6	0.6
Rotary Joint				
channels (No.)	3	—	3	—
power level (Mw)	1	—	4–7	—
loss (db)	0.25	—	0.25	—
Receiver (preampl)				
noise figure (db)	6.5	7	3	4
bandwidth (Mc/s)	4.5	0.4	350	400–700
type	paramp	paramp	paramp	tunnel diode
Transmitter				
tube type	klystron(1)	twt(1)	Amplitron(4)	cfa(4)[b]
peak power (Mw)	1	1–3	4–7	1–3
duty cycle	0.004	0.002	0.004	0.05
instantaneous bandwidth	1	1	10	500
Duplexer				
power level (Mw)	1	1–3	4–7	1–3
loss (db)	0.3 rec.	0.3 rec.	0.5 rec.	0.3 rec.
loss (db)	0.7 trans.	0.7 trans.	0.6 trans.	0.6 trans.
vswr	1.25	1.25	1.25	1.25

	PRESENT	FUTURE
Phase Shifters	(ferrite)	
switching time (μs)	800	<1
power level (peak)	50 kw	15 kw
loss (db)	1.9	1.5 max.
R-F Switches	(S-band)	(C-band)
switching time (μs)	500	50
power level (peak)	2 Mw	10 Mw
loss (db)	0.5	0.5
Low-Loss R-F Filters		
loss (db)	0.5–1	0.5–0.25
rejection (db)	40–60	60–100
power level (peak)	1 Mw	1–7 Mw
power level (average)	1 kw	10–30 kw

NOTES

a) These designate techniques for changing azimuth and elevation: F/mech means changing in one dimension, say azimuth, by frequency differences between elements or frequency shifts, and changing elevation by mechanical steering; ϕF means using a combination of phase and frequency differences for azimuthal and vertical steering; $\phi\phi$ means using phase differences between adjacent elements for azimuthal and vertical steering

b) Crossed-field amplifiers

Components

erage power, however, will go up, and components must be able to handle it.

Filters to suppress spurious and harmonic outputs will have stringent requirements. Duplex recovery time will be less important, he said.

The FAA, Lawrence Shoemaker said, is increasing its use of radar beacon systems. For the transponders, 500-watt solid-state sources are needed, also low-cost transducers and digitizers.

Tunnel-Diode Receivers—Matthews said tunnel diodes may soon be used extensively in moderately low-noise receivers; where there is substantial noise ahead of the front end, nothing is gained by use of extremely low-noise receivers.

For present-day radars that have to operate 24 hours a day, Matthews said, better rotary joints and scanners are needed. Also needed are high-power switches to check out standby equipment, or permit frequency diversity with two radars.

Matthews also cited the need for both ferrite and diode phase shifters, probably digital types to match computers, and nanosecond switches, tunable filters, and limiters with 80-db isolation and low insertion loss.

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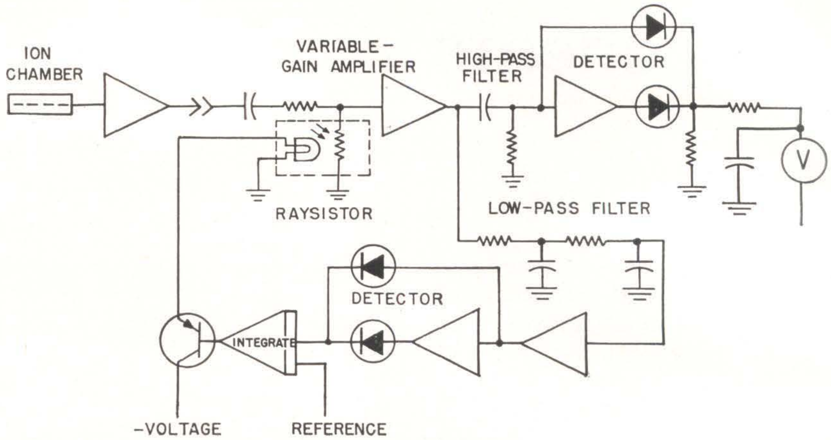

NEUTRON ACTIVITY in reactor pile is read directly on meter

New Monitor for Reactors

Noise analyzer gives direct reading of subcritical reactivity

By **ERIC VALENTINE**
Assistant Editor

NEW INSTRUMENT to measure subcritical reactivity in nuclear piles was to be demonstrated on Tuesday to AEC representatives. The developers say it is the first instrument to give a direct reading of neutron activity in shut-down reactors.

The instrument has been installed at the "cold, clean" (low power and few gamma rays) Westinghouse reactor at Waltz Mills, Pa. Called a shutdown-reactivity meter, it measures the power spectral density in the reactor core, to provide a warning against unexpected criticality.

Monitoring Problem — M. A. Schultz, of Milletron, Inc., who developed the meter with AEC backing, says the technique used can lead to a simple, direct device to assure regulation of commercial atomic power plants during periodic nonoperational phases.

Reactors, he told ELECTRONICS, can't really be shut off. There is always some neutron activity, even below criticality. He attributed the SL-1 reactor accident in Idaho, in which three were killed, to lack of subcriticality measurements.

There are now two ways to measure shutdown reactivity, Schultz says: the pulsed-neutron technique, using an accelerator in the pile to record decay rates of neutron bursts, and neutron counting. The first, he says, is complex, and the second requires interpretation.

Noise Analysis Method—The Milletron technique is based upon noise analysis. Amplitude fluctuations—which Schultz calls noise—created by the difference in time of arrival of fission neutrons at a detector can be measured on a more or less absolute scale. The ratio of the frequency content at a high frequency to the content of a low frequency is a direct measure of reactivity.

By comparing the noise amplitude in various frequency bands, says Schultz, activity in a subcritical pile (when the multiplication factor is below one) can be determined.

Milletron's equipment (see diagram) divides the high-frequency amplitude by the low-frequency amplitude. This is accomplished by holding the amplitude of one signal constant with a servo system. Output is shown on a digital voltmeter.

Subcritical reactivity has been measured in this way down to as low as —8 percent, when the ion chamber was located at the center of the reactor core, Schultz reports.

Power Reactors—Schultz points out that at present the system is suitable only for the 30 or so cold clean reactors in the U. S. For power reactors, a means must be developed to read neutron signals among high gamma concentrations—a discrimination technique considered feasible.

NEWS

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E	60 C	135 C
B	90 C	135 C

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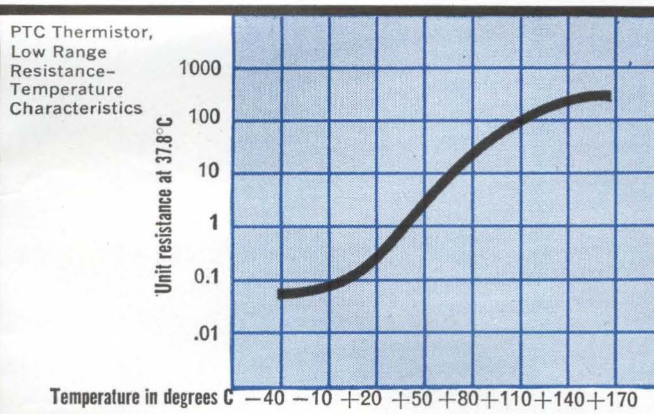
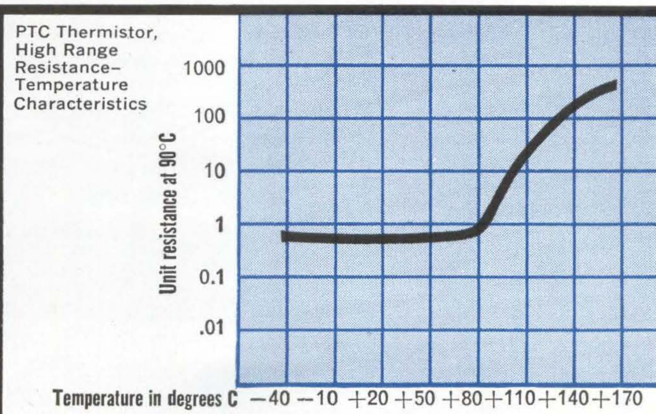


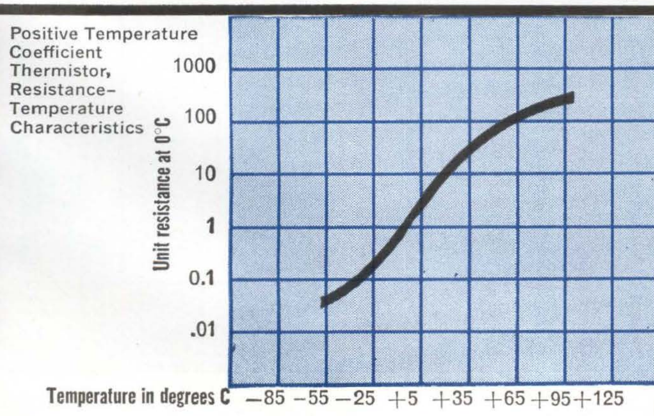
Composition A

Part Number	Finished Body Sizes Diameter	Thickness	Resistance Ohms at 37.8°C
A1406P-1	0.420	0.180	650 ± 20%
A0905P-1	0.295	0.170	1100 ± 20%
A0910P-1	0.295	0.220	2100 ± 20%
A0610P-1	0.220	0.190	5000 ± 20%



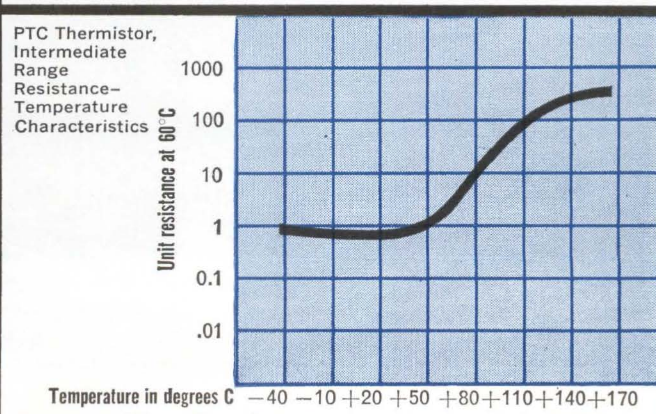
Composition B

Part Number	Finished Body Sizes Diameter	Thickness	Resistance Ohms at 90°C
B1406P-1	0.390	0.160	22 ± 20%
B0906P-1	0.280	0.160	40 ± 20%



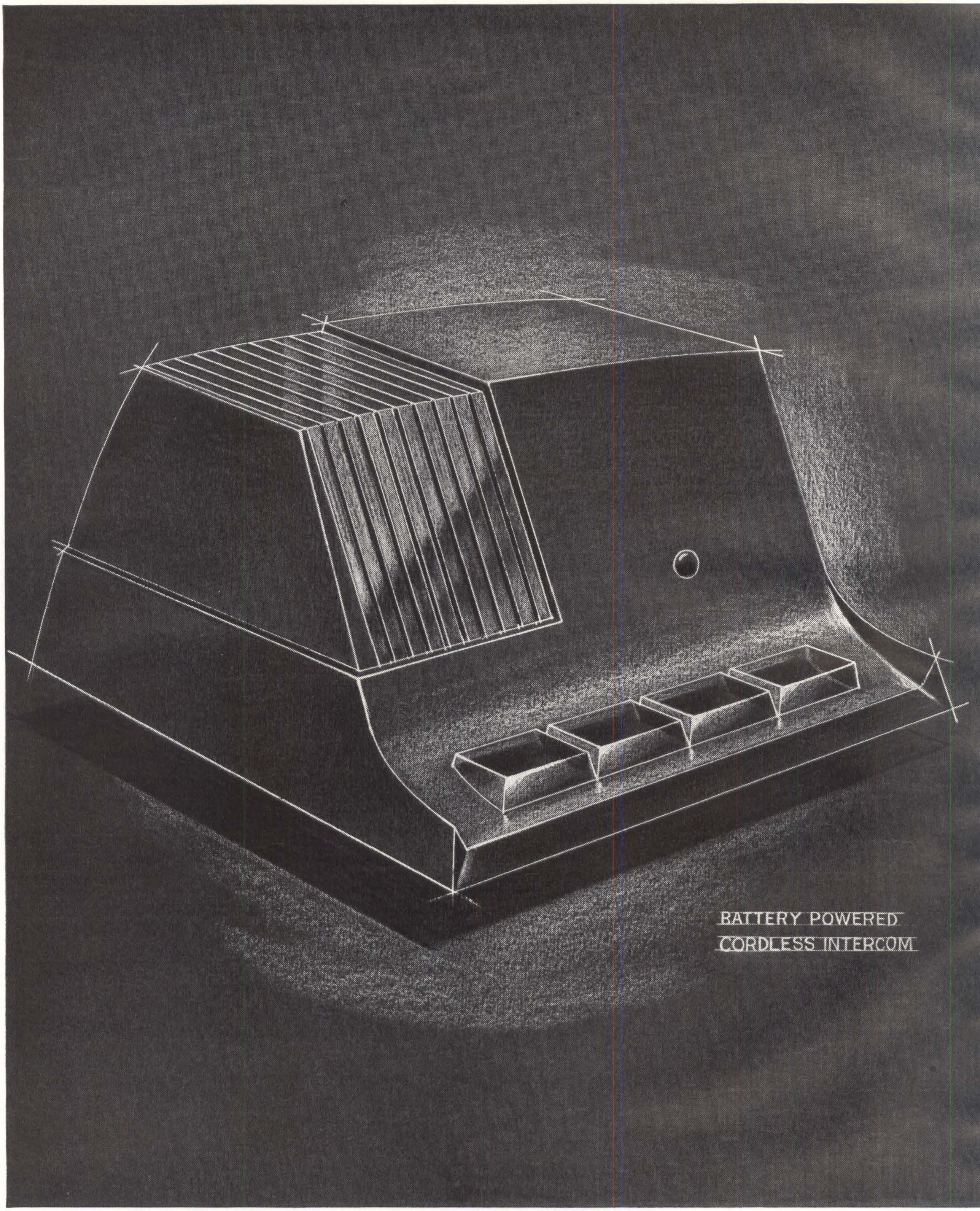
Composition D

Part Number	Finished Body Sizes Diameter	Thickness	Resistance Ohms at 0°C
D0910P-1	0.280	0.220	5000 ± 20%
D0904P-1	0.280	0.150	2400 ± 20%
D1406P-1	0.420	0.180	800 ± 20%



Composition E

Part Number	Finished Body Sizes Diameter	Thickness	Resistance Ohms at 60°C
E1406P-1	0.420	0.180	56 ± 20%
E0606P-1	0.220	0.180	150 ± 20%



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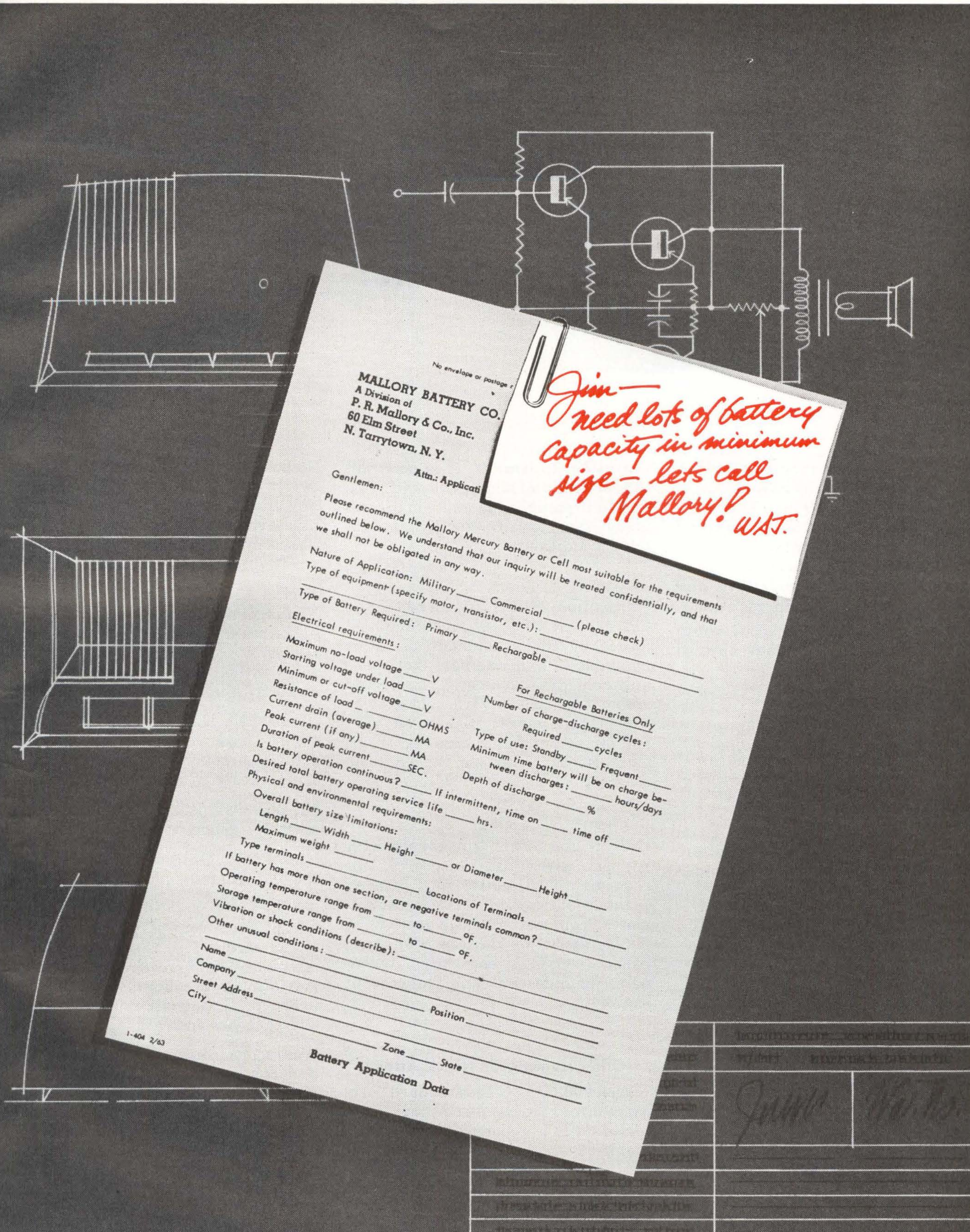

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checking flash X-ray system

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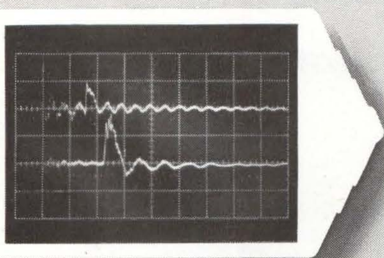

Quality-control test on new flash x-ray system from remote test console. Upper trace displays radiation output of the tube as monitored by an x-ray detector (0.2 μsec/cm, 20 v/cm). Lower trace displays the square-wave tube current (0.2 μsec/cm, 50 v/cm).

photographed at Field Emission Corporation, McMinnville, Ore.

New 600-kv flash x-ray system with pulser and x-ray tube assembly.

Test Engineer at Field Emission Corporation, McMinnville, Oregon, uses a Tektronix Type 555 Oscilloscope and C-12 Camera to monitor and record dual-beam displays of single-shot phenomena on new flash x-ray system.

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In testing this new x-ray system with the Type 555, the engineer uses internal triggering from one channel to achieve direct time-relationship between the simultaneous displays of x-ray output and tube current. With the C-12 Camera, he records critical timing and amplitude pulses up to 600 kilovolts at 1500 amperes, 0.15 microsecond duration.

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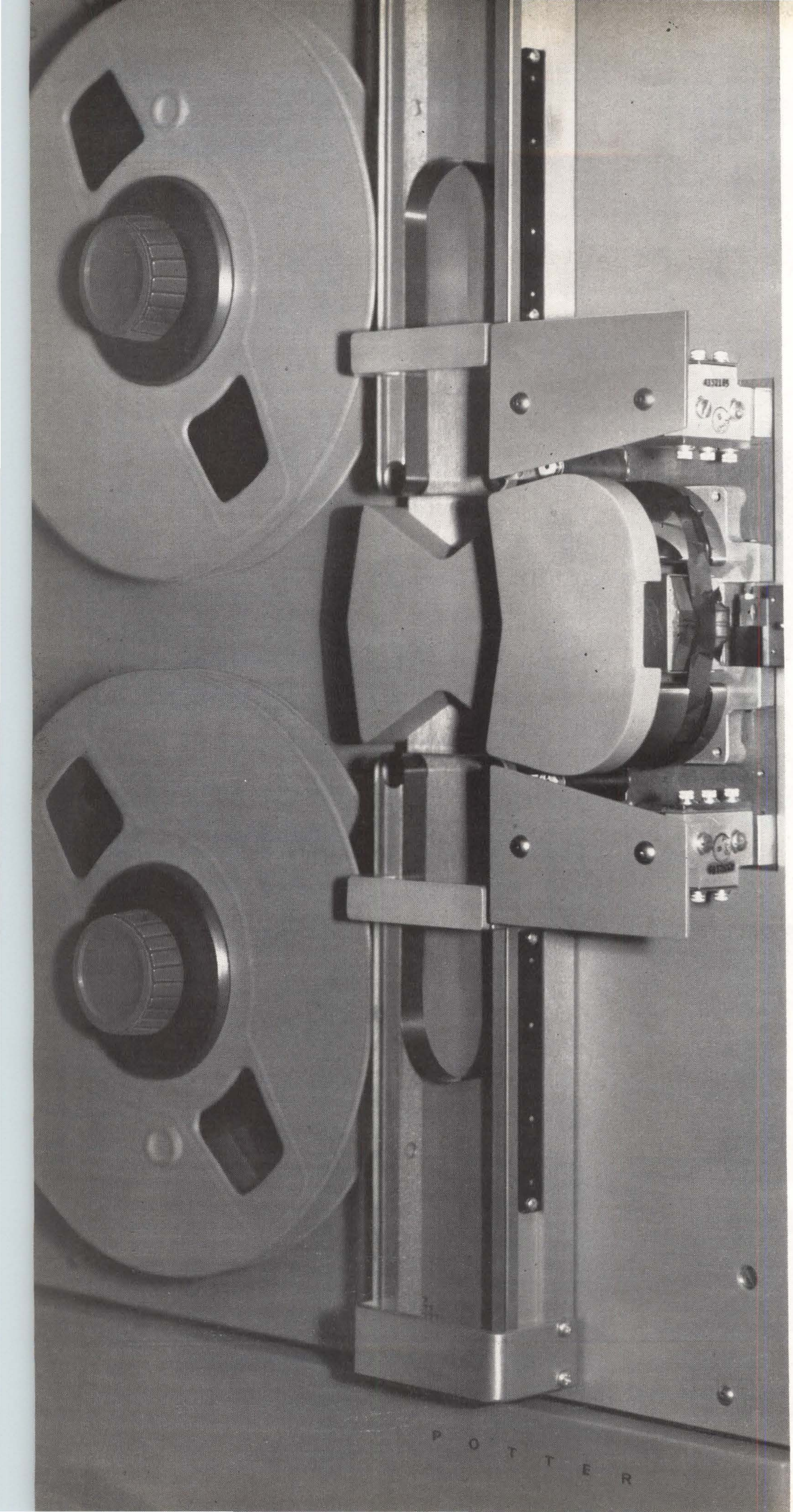

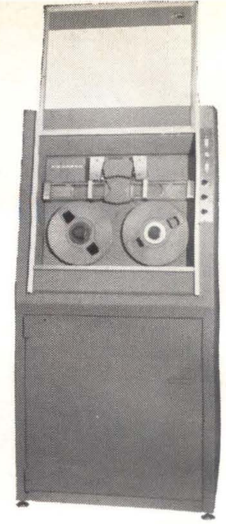

A very big transport in a 2-foot package

This is Potter's MT-24, a new vacuum column, digital magnetic tape transport which is already proving big in the field. Packed into its mere 24″ height (or length if you prefer to mount it sideways) is all the dependability and performance of tape drives costing over twice as much. Here are the facts:

PERFORMANCE — Read/write tape speeds from 3 to 36 ips, data transfer to 28.8 kc, 200 commands per second. (50 ips and 40 kc performance available in the MT-36 companion unit at very little increase in price!)

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TODAY'S SEMICONDUCTORS

Modern semiconductor electronics began with the use of point-contact polycrystalline germanium diodes as radar mixers during World War II. It received a big push, conceptually, with the invention of the point-contact transistor in 1948.

But, practically, the semiconductor field has gained its major impetus from advances in materials technology. Zone refining of germanium; successful commercial production of electrically pure silicon; vapor-phase diffusion of impurities; perfection of planar, or oxide-passivated, silicon devices; and epitaxial layer growth were all milestones in the development of today's semiconductors.

Drawing upon the rich background of materials and device technology, semiconductor manufacturers now offer the circuit engineer a large and often bewildering array of transistors, diodes and special devices.

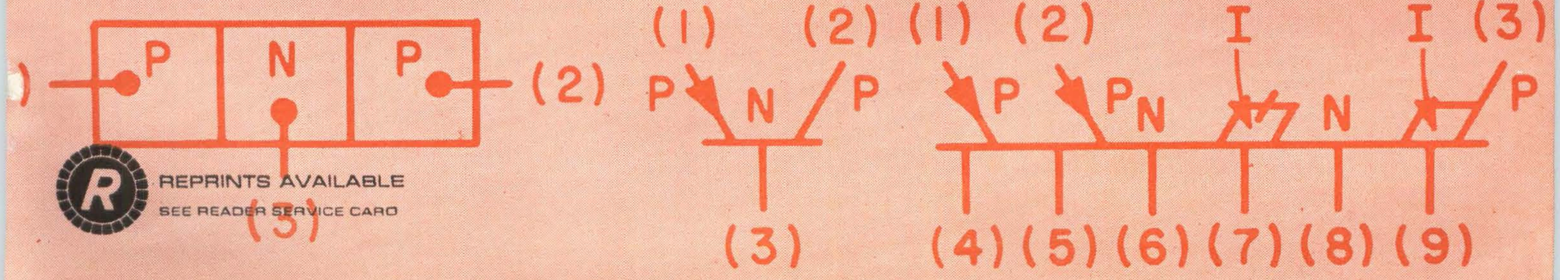
In this report, five specialists in circuit applications of semiconductors discuss some of the newer devices now available to circuit designers. They tell how and where to use them to get the greatest advantage. Applications treated include: logic circuits; small-signal applications, including high-frequency and very-high-frequency circuits; and power and control circuits.

These applications make use of devices such as: high-speed switching transistors, tunnel diodes, *pnp* low-noise silicon transistors, special agc transistors, complementary *pnp-npn* silicon transistors, varactor diodes, *pin* diodes, silicon controlled rectifiers, silicon controlled switches, light-activated switches, bidirectional and unidirectional switching diodes, unijunction transistors and more.

Circuits specifically covered will encompass: NAND-NOR logic in various configurations, low-noise audio amplifiers, vhf frequency multipliers, r-f amplifiers, agc circuits, controlled rectifiers, d-c and frequency converters, motor-speed control and many other applications.

Besides highlighting these new, practical semiconductor-circuit applications, each section includes a comprehensive bibliography.

JOHN M. CARROLL, Managing Editor



TRENDS IN LOGIC CIRCUIT DESIGN

Modern semiconductor components provide the logic designer with a broad spectrum of techniques. Today the question is when to use which one. This section compares several widely used logic circuits: TRL **nor,** TDL **nor,** TDL **nand,** DCTL **nor** and nonsaturating circuits such as current-mode logic, current-inhibit logic and emitter-follower logic; also use of tunnel diodes and integrated circuits

By **ARCHIE LAMBERT,** Applications Engineer, Texas Instruments Incorporated, Dallas, Texas

ARCHIE LAMBERT received his MSEE from the University of Arkansas; his professional experience has been in circuit development. His present speciality is the design of high-speed logic and switching circuits in TI's Semiconductor Research and Development Labs

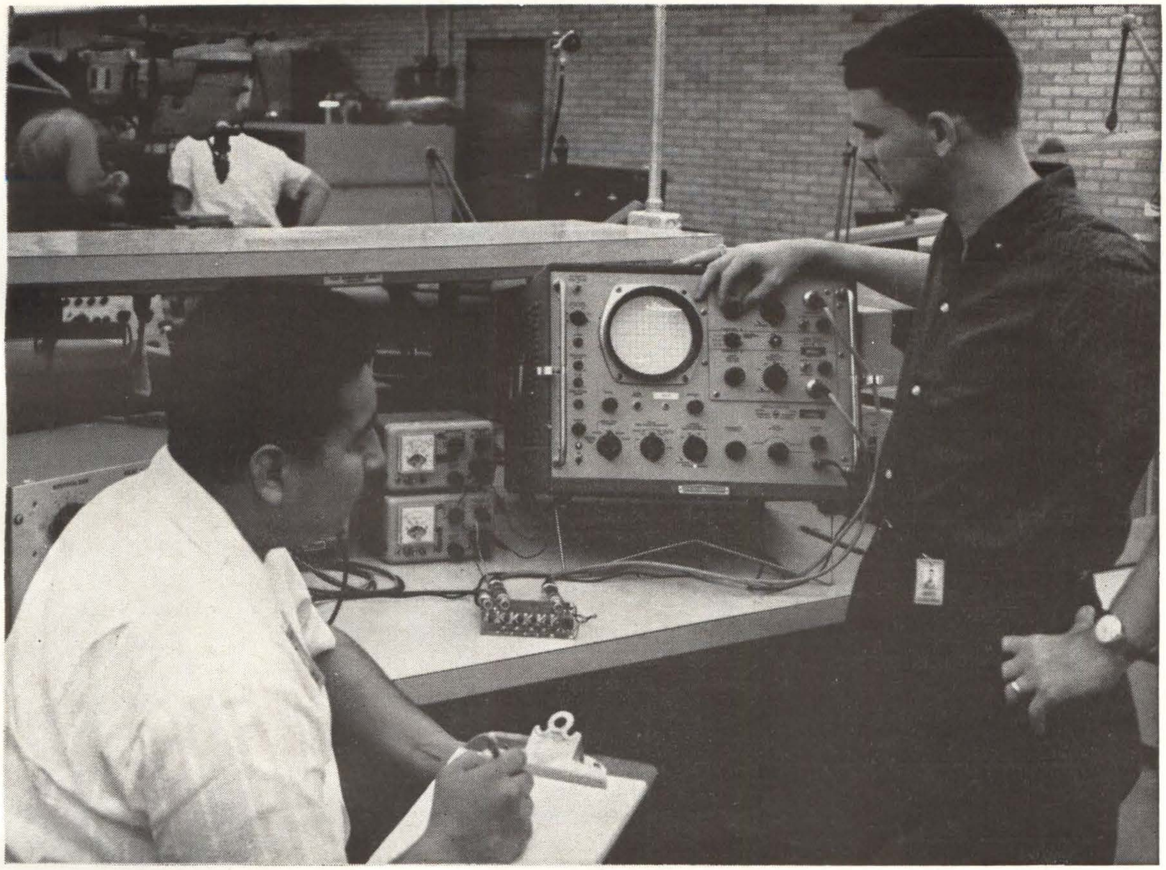
DESIGNERS of logic circuits face perhaps the greatest challenge in the entire electronics field. They are confronted with not only a large number of logic circuit configurations, but also with a wide range of design philosophies. Advantages and disadvantages of various design philosophies will be discussed in this section. Several widely used logic-circuit configurations will be described and the advantages and disadvantages of each listed. The use of relatively new semiconductor devices in logic-circuit designs will be mentioned and for completeness, solid-state networks will be discussed briefly.

DESIGN PHILOSOPHY

Absolute Worst Case—The designer of logic circuits must cope with reliability requirements on one hand and circuit application efficiency on the other. If he chooses to design highly reliable circuits, he may design circuits to operate properly even when every circuit parameter has drifted to its absolute worst-case or end-of-life tolerance limit. The circuits so designed will be highly reliable from an aging standpoint; however, circuits designed to such an extreme may not be practical.

For example, a transistor switching circuit designed to operate under absolute worst-case conditions may have a seriously limited fan-in and fan-out. The switching circuit may not be able to switch a load power much in excess of the drive power input. The use of such a design may be excessively expensive since a large number of circuits will be needed to perform the desired logic. Moreover, the conservative design may, in fact, decrease overall machine reliability because of the quantity of circuits used.

Initial Worst Case—On the other hand, the designer may favor circuit application efficiency and use only initial tolerance limits in the design. But then one or more circuit



APPLICATIONS engineers measure logic circuit propagation time in circuits they have developed

parameters may dominate circuit operation. If these parameters drift beyond initial tolerance limits, the circuit may fail before the majority of components have approached their end of life limiting values. Thus, both the conservative and the liberal approaches have disadvantages.

Statistical Design—A statistical approach is desirable from both the reliability and the application efficiency standpoints. The statistical approach means that circuits are designed so that the chances of circuit malfunction are extremely remote. One disadvantage is the time required to obtain the statistics for a particular design. However, if it can be assumed that all parameters possess normal distributions and that all tolerances are specified at the same relative limits, formulas from statistical literature may be used to determine overall tolerances. For example, if parameters are being added as in Eq. 1, formulas from literature on statistics may be used to obtain the tolerance of a parameter

$$ax = b_1 y_1 + b_2 y_2 + b_3 y_3 \cdots + b_n y_n \quad (1)$$

If b_n = nominal value of nth parameter; a = nominal value of resulting parameter; $x = 1 + T_x$ where T_x is resulting tolerance; and $y = 1 + T_{yn}$ where T_{yn}'s are individual tolerances then

$$T_x = \sqrt{\frac{(b_1 T_{y1})^2 + (b_2 T_{y2})^2 + (b_3 T_{y3})^2 + \cdots (b_n T_{yn})^2}{(b_1 + b_2 + b_3 + \cdots b_n)^2}} \quad (2)$$

Unfortunately, not all expressions are as simple as Eq. 1. When an expression of the form shown in Eq. 3 is too complicated for the application of simple statistical formulas

$$ax = f(b_1 y_1, b_2 y_2, b_3 y_3, \ldots b_n y_n) \quad (3)$$
$$a = f(b_1, b_2, b_3, \ldots b_n)$$

the expression may be expanded in an approximate Taylor series as shown in Eq. 4. All second-order effects have been dropped from the expression since their effect is negligible for practical tolerance limits. Equation 4 is now in the form of Eq. 1 and the resulting tolerance is as shown in Eq. 5

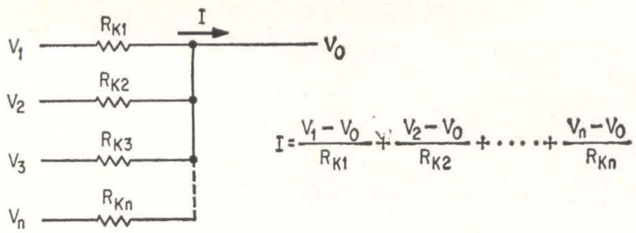
$$x \approx 1 + \frac{\partial x}{\partial y_1}(y_1 - 1) + \frac{\partial x}{\partial y_2}(y_2 - 1) + \frac{\partial x}{\partial y_3}(y_3 - 1) + \cdots \frac{\partial x}{\partial y_n}(y_n - 1) \quad (4)$$

$$T_x = \sqrt{\left(\frac{\partial x}{\partial y_1} T_1\right)^2 + \left(\frac{\partial x}{\partial y_2} T_2\right)^2 + \left(\frac{\partial x}{\partial y_3} T_3\right)^2 + \cdots \left(\frac{\partial x}{\partial y_n} T_n\right)^2} \quad (5)$$

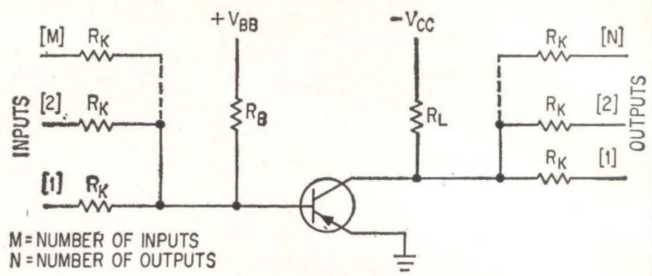
Consider the circuit shown in Fig. 1. The expression for

WHAT PRICE RELIABILITY?

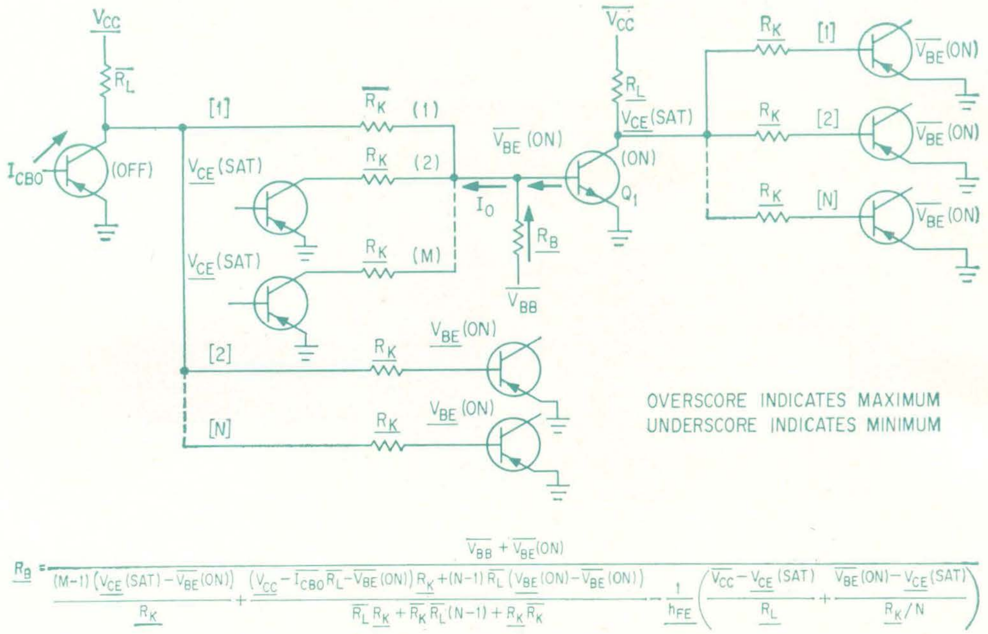
The logic designer today constantly faces the problem of balancing reliability requirements against circuit application efficiency. There are several schools of design philosophy. Absolute worst-case design is based on end-of-life parameters and represents the extreme right wing or conservative approach. Initial worst-case design uses only initial tolerance limits and represents the liberal or left wing. Statistical design techniques take the middle of the road but often require more time and trouble than they are worth. One answer is called quantized probability design. It approaches the middle of the road from the conservative side



CIRCUIT CONFIGURATION frequently encountered in logic circuit design—Fig. 1



BASIC transistor-resistor logic (TRL) circuit—Fig. 2



LIMITING - CONDITION **on** circuit for TRL and the **on** equation—Fig. 3

current I may be written in the form

$$x = 1 + T_1 = \frac{V_1 - V_0}{IR_{K1}} + \frac{V_2 - V_0}{IR_{K2}} + \cdots + \frac{V_n - V_0}{IR_{Kn}} \quad (6)$$

Equation 6 is now in the form of Eq. 3. The following expression shows how the nth term of Eq. 5 may be obtained for this circuit

$$\frac{\partial x}{\partial y_n} = \frac{\partial x}{\partial\,(1+T_{vn})} + \frac{\partial x}{\partial\,(1+T_{Kn})} + \frac{\partial x}{\partial\,(1+T_{V0})}$$

Thus, the tolerance expression for the circuit is

$$T_1^2 \approx \left[\frac{\frac{V_1}{R_{K1}}}{I}\right]^2 (T_{V1})^2 + \left[\frac{\frac{V_2}{R_{K2}}}{I}\right]^2 (T_{V2})^2 + \cdots + \left[\frac{\frac{V_n}{R_{Kn}}}{I}\right]^2 (T_{Vn})^2 + \left[\frac{\frac{V_0}{R}}{I}\right]^2 (T_{V0})^2 + \left[\frac{\frac{V_1 - V_0}{R_{K1}}}{I}\right]^2 (T_{K1})^2 + \left[\frac{\frac{V_2 - V_0}{R_{K2}}}{I}\right]^2 (T_{K2})^2 + \cdots + \left[\frac{\frac{V_n - V_0}{R_{Kn}}}{I}\right]^2 (T_{Kn})^2 \quad (7)$$

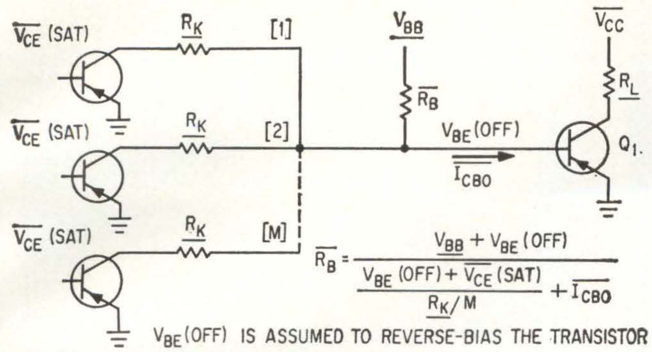
where $R = R_{K1} \,||\, R_{K2} \,||\, \ldots \,||\, R_{Kn}$

Quantitized Probability Design—Often the labor and time required may prohibit the statistical approach. By properly weighting each independent variable according to its effect on the dependent variable and assigning limits accordingly, it is possible to use an approach that will in all cases be more conservative than the statistical approach but less conservative than the end-of-life worst-case approach.

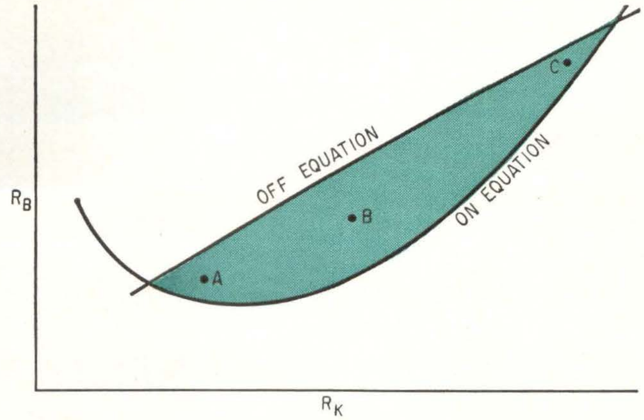
For example, in Eq. 3 parameters which have large partial derivatives would be weighted much heavier than those having small partials. By assigning worst-case end-of-life tolerance limits to parameters that have large partials, initial worst-case tolerance limits to parameters having second-order effects (somewhat smaller partials), and nominal values to parameters having third-order effects (negligible partials) it is possible to approach the statistical design from the conservative side.

SATURATED LOGIC

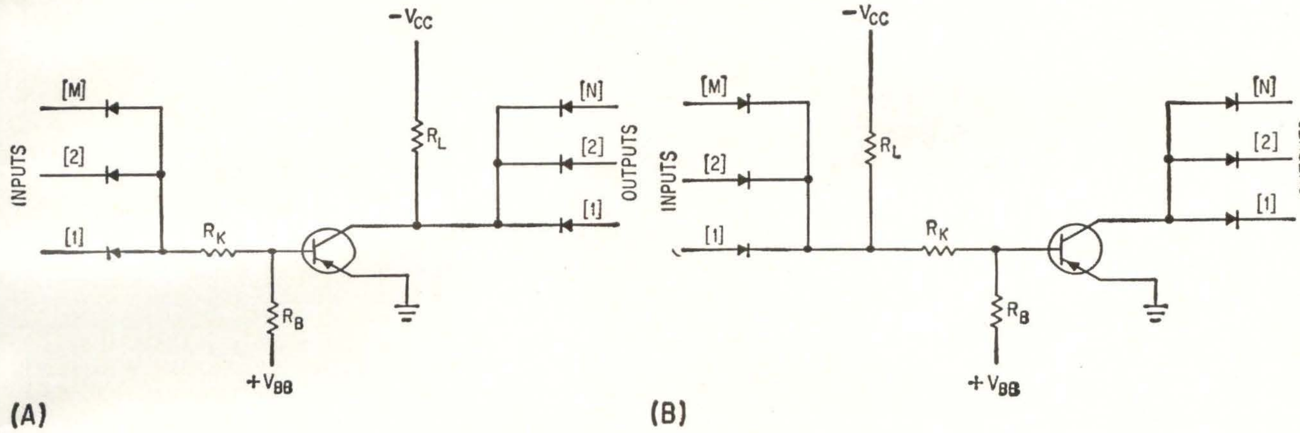
TRL NOR Circuit—Transistor-resistor logic (TRL) circuits use only transistors and resistors to perform logical operations. These circuits are sometimes referred to as NOR logic blocks because of the way in which the output is related to one or more inputs. Figure 2 shows a TRL circuit with M inputs and N outputs. A negative signal (binary 1) to the input resistors will cause the *pnp* transistor to be in saturation



LIMITING-CONDITION off circuit for TRL and the off equation—Fig. 4



SAMPLE CURVE for limiting-case circuit design—Fig. 5



TRANSISTOR-DIODE LOGIC (TDL) nor circuit (A) and TDL nand circuit (B)—Fig. 6

and the collector potential to be driven nearly to ground (binary 0). Because the OR and the NOT functions are performed by the input resistor network and the transistor respectively, the circuit is considered to be a NOR circuit.

A logical expression for this circuit is

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

If the binary expression for negative and ground levels are reversed

$$\text{Output} = \overline{A} + \overline{B} + \overline{C} = \overline{ABC}$$

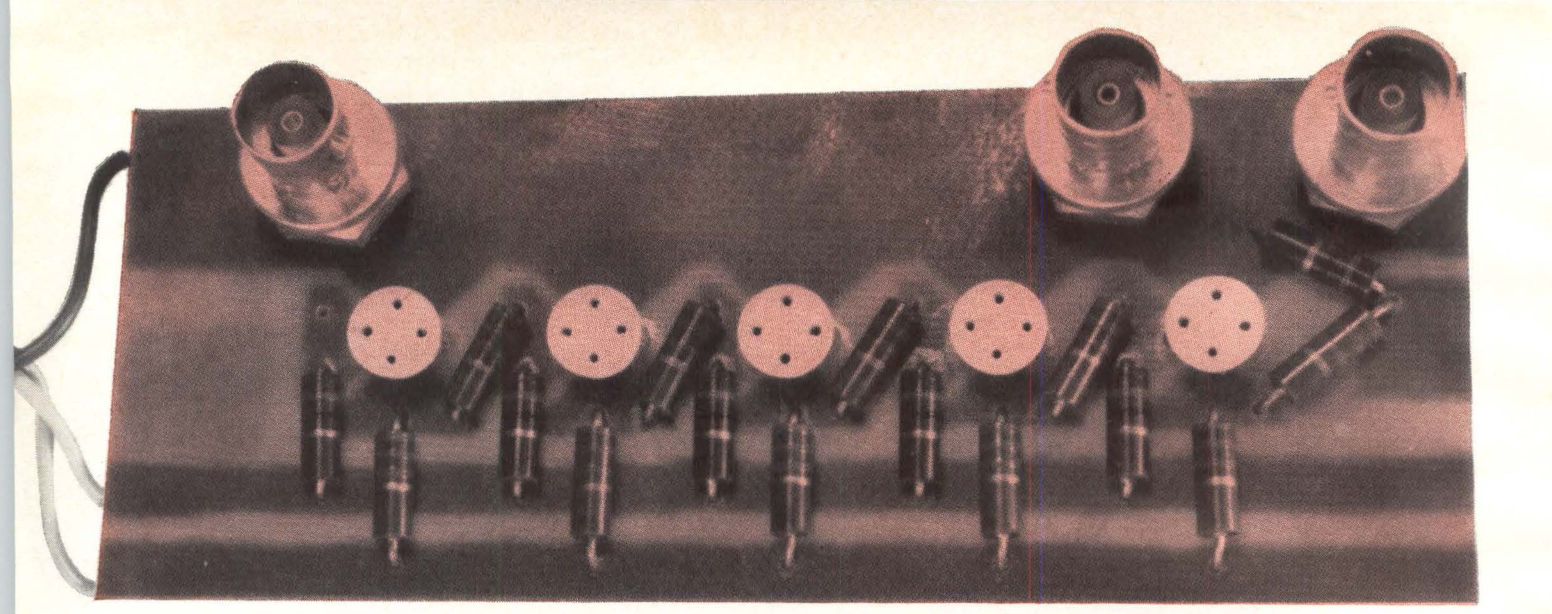
These expressions show that the circuit performs the NOT and the AND function for reversed reference levels. Therefore, the only difference in the NOR and NAND circuit is the assignment of reference levels.

Figure 3 shows a limiting condition for maintaining transistor Q_1 in saturation. All input transistors except one are in saturation and all circuit parameters have gone to the limit which would tend to reduce base drive to Q_1. The equation shown in the figure is an expression for a minimum value of R_B in terms of all other circuit variables.

Figure 4 shows the limiting case for maintaining Q_1 at cutoff. The equation is an expression for the maximum value of R_B which will assure that the transistor remains cutoff. All values on the right hand side of the two equations (except $\overline{R}_K$ and $\underline{R}_K$) are selected on the basis of collector current requirements, expected range of saturation voltages, voltage and resistor tolerances, and desired values of M and N.

By solving the two equations, plots (see Fig. 5) of maximum and minimum R_B versus R_K are obtained. The area between the curves represents a closed set of solutions. Any solution in the enclosed area is valid. However, there are some rules of thumb for selecting a solution. The theory behind the design would allow the selection of any point lying on or between the two curves. However, by moving in from the boundaries, a safety factor is incorporated in the design; reliability increases as the point chosen moves from the boundary toward the center of the set. In general, speed can be increased by moving toward the origin on the set. Power dissipation can be decreased by moving away from the axis on the set. Thus, point A would allow the fastest operation, point B would increase reliability and point C would decrease power drain.

The design equations given for the TRL circuit may be used to favor either the conservative or the liberal approach. The conservative approach may be favored by using absolute worst-case tolerance limits. However, in many cases the result is much too conservative and inefficient. Then the equations may be used with more optimistic tolerance limits to improve circuit efficiency. The assignment of tolerance limits should be based upon engineering judgment and a detailed analysis of the pertinent equations. All partial derivatives should be weighted in assigning tolerance limits.



PROPAGATION test circuit for the TIX895 experimental switching transistor—front view, above; rear view, opposite page

Having obtained a solution, the designer should check by using one or more of these procedures.

- Make Monte Carlo runs on a computer using conservatively estimated parameter distributions.
- Test a large number of circuits under adverse conditions.
- Make an analytical study using Taylor expansion and statistical formulas.

Transistor-Diode NOR Circuit Diodes may be used with transistors to perform the NOR function (see Fig. 6A). The circuit performs the same function as the TRL circuit; however, isolation of inputs and outputs provided by the diodes allows more fan-ins and fan-outs for identical transistors. Limiting condition ON and OFF equations may be developed for this circuit and a design procedure similar to that for TRL may be used.

Transistor-Diode NAND Circuit A second transistor-diode logic block is shown in Fig. 6B. The transistor with the input diodes performs the NOT and AND operation on input signals. A logical expression for the output of this circuit is

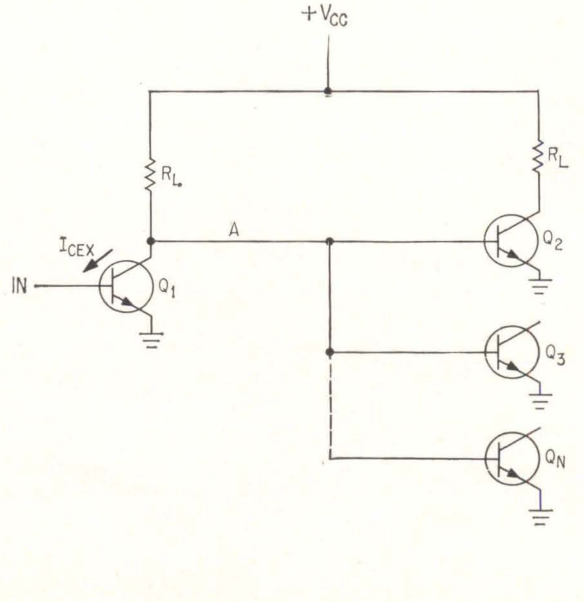
$$\text{Output} = \overline{ABC}$$

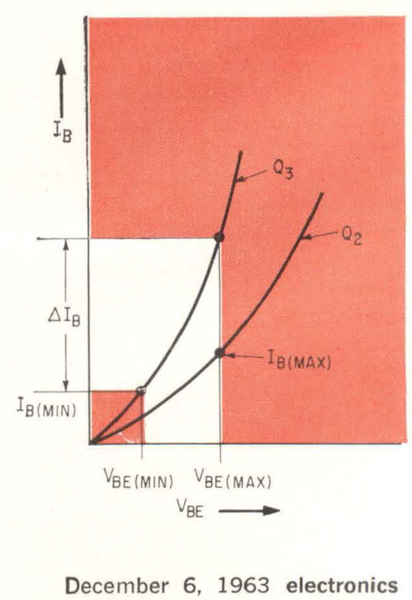
Propagation time in the transistor-diode NAND circuit can be reduced by a factor of 50 percent or more without introducing crosstalk by placing a speed-up capacitor across R_K. The propagation time attributed to storage time can be made negligible by selecting the capacitor on the basis of stored base charge.

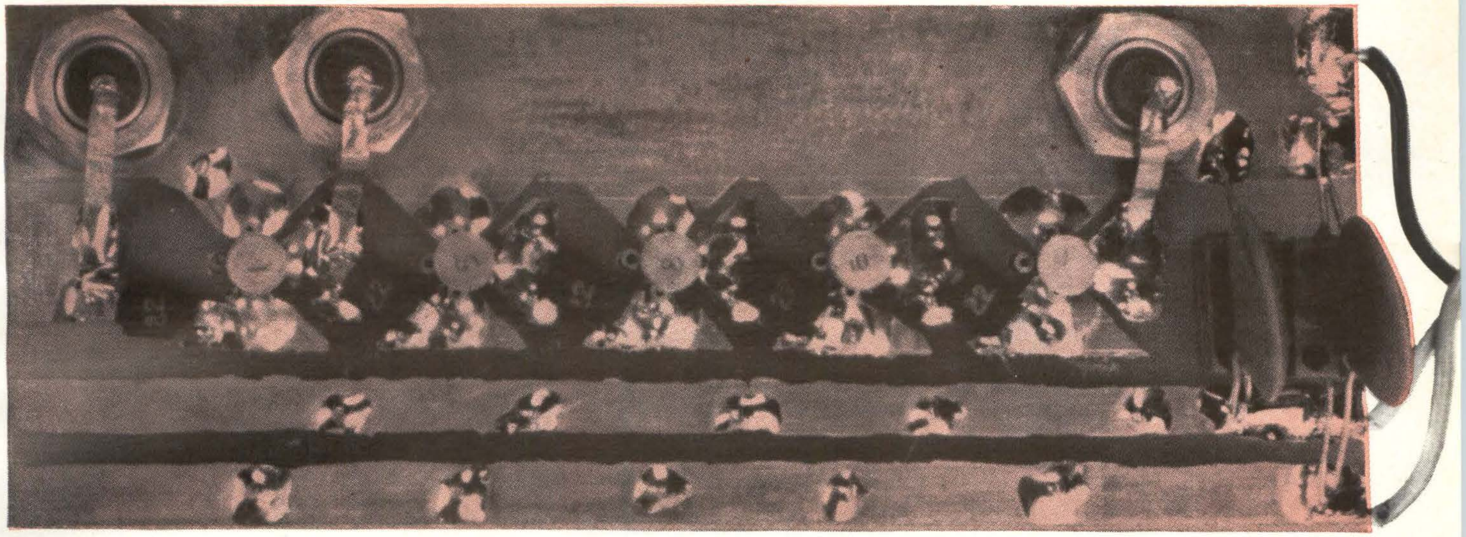
The calculation of capacitance for a required switching time becomes complicated because of the nonlinear input impedance of the transistor. The time constant of the input circuit with a speed-up capacitor is the product of the capacitor and equivalent resistance comprised of R_K, R_B and the input resistance of the transistor. This time constant will determine the speed of charging and discharging the capacitor. For proper operation, the capacitor voltage must reach a large percentage of its final value before the input changes. The value of the capacitor is generally between 10 and 20,000 pf, depending upon Q_{SX} (excess stored base charge) and supply voltages used.

Two criteria must be used in choosing the capacitor. First, charging and discharging currents increase with the size of the capacitor. Secondly, input circuit time constants increase with the size of the capacitor and therefore the time required for the capacitor to reach a static value increases. Thus, the value of the capacitor must be a compromise between improved switching time and the clock rate. The faster the desired switching time, the higher the transient current necessary, and the larger the selected value of the capacitor. The higher the desired clock rate, the smaller the

DIRECT-COUPLED transistor logic (DCTL) nor gate circuit—Fig. 7







input circuit time constant allowable and the smaller the selected value of capacitor.

DIRECT-COUPLED TRANSISTOR LOGIC

Direct-coupled transistor logic (DCTL) does not rely upon diodes, resistors or capacitors for coupling between stages. Coupling between transistor elements is direct. The choice of element interconnections will depend upon the logic function desired. Figure 7 shows a typical DCTL NOR circuit. The transistor to be used in such a design should possess the following d-c characteristics: a low collector saturation voltage, a relatively high minimum base-to-emitter voltage with a narrow spread, a reasonably high current gain, and low collector-to-emitter leakage.

As can be seen from Fig. 7, Q_2 will conduct when Q_1 is OFF. The voltage at point *A* will depend upon the input impedances of Q_2, Q_3 and Q_n. If Q_2 and Q_3 have input characteristics as shown in the inset, Q_2 will require $I_{B(max)}$ and $V_{BE(max)}$ to saturate. Transistor Q_3 requires $V_{BE(min)}$ and $I_{B(min)}$ to saturate. Thus, for proper operation of the circuit, the excess base current to Q_3 will be

$$\frac{V_{BE(max)} - V_{BE(min)}}{R_S} = \frac{\Delta V_{BE}}{R_S} = \Delta I_B$$

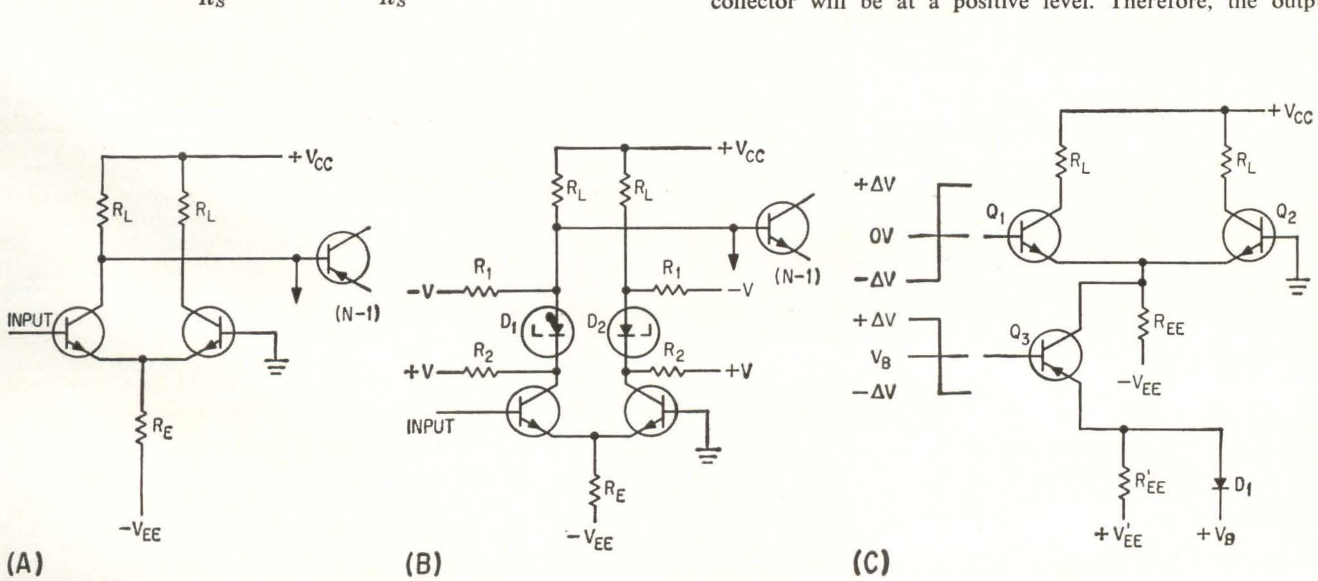
Because of this additional current requirement, the limiting condition for determining fan-out is when one transistor has a V_{BE} characteristic similar to Q_2 and all other transistors have characteristics similar to Q_3. The collector saturation voltage must be less than the minimum ON base-to-emitter voltage encountered to assure that all output transistors are OFF when Q_1 *is* ON.

NONSATURATED LOGIC

The most common forms of nonsaturated logic circuits are current-mode logic, current-inhibit logic, and emitter-follower logic.

Nonsaturated logic is often used when desired operating speeds are higher than those attainable with saturated logic. The most frequently used nonsaturated logic configuration (see Fig. 8) is the current-mode switch. Because the transistor is operating nonsaturated, turn-off storage time is almost negligible. Also, the operating point is optimized for f_T and C_C.

Figure 8A shows a complementary current-mode switch. The collector current is determined by V_{EE}, R_E and h_{FB}. If R_L is small enough, the transistor will not saturate and the collector will be at a positive level. Therefore, the output



NONSATURATING LOGIC showing current-mode switching (A) and a typical current-inhibit circuit (B)—Fig. 8

can be used to drive a complementary transistor. Figure 8B shows how the circuit may be modified to shift the operating point so that the output may be used to drive an identical stage.

Parameters to be considered in the design of current-mode logic circuits are power dissipation, current gain, base-to-emitter voltage, collector leakage, collector cutoff frequency, and collector-to-base capacitance.

A current-inhibit logic circuit is shown in Fig. 8C. If Q_3 is in the ON condition, it will inhibit the emitter current to Q_1 and Q_2. The emitter current from Q_3 may in turn be inhibited by another transistor operating at a higher current. Various combinations of complementary transistors may be arranged to give the desired logic function.

In some cases diodes perform all logic functions while emitter followers placed between cascaded stages restore the current signal level. Speed is not seriously impaired by the addition of the emitter followers since an emitter follower is much faster than an ordinary saturating common-emitter stage. However, there exists the problem of voltage-level restoration after a number of cascaded emitter follower and diode stages. The number of stages between level restorers will depend upon minimum output swing of last voltage amplifier, maximum input swing required of next voltage amplifier, and drift in voltage between inputs and output of the diode gate.

COMPARISON OF LOGIC TYPES

TRL Versus TDL—When speed or maximum fan-in is not of primary importance, TRL circuitry rather than TDL may be used to achieve simplicity, economy and reliability. The speed of a TRL circuit is primarily transistor dependent up to the point where load resistors and junction capacitances impose limiting time constants. Generally there is a good correlation between transistor switching times and TRL circuit propagation time.

TDL NOR Versus TDL NAND—Primary differences between TDL NOR and NAND circuits are speed and fan-out capabilities. By using a speed-up capacitor to obtain approximate voltage drives during switching, the propagation time of a TDL NAND circuit may be reduced to 50 percent of the propagation time of an equivalent TDL NOR stage. However, the NOR circuit offers better fan-out capabilities.

The TDL NAND circuit may be more difficult to design but often the speed gained by adding a speed-up capacitor outweighs this disadvantage. The TDL NAND circuit is the only saturated logic configuration in which propagation time can be decreased significantly with speed-up capacitors without introducing crosstalk. However, if speed is not of primary importance, the higher fan-out of the TDL NOR circuit makes it desirable in some systems. Also, if speed-up capacitors are not used with the TDL NAND configuration, the equivalent NOR circuit is slightly faster. If speed is not of primary concern, TDL NOR will be more economical.

DCTL—Since the DCTL configuration has no passive elements between active devices, severe requirements are placed on the transistors to assure uniform operation throughout the system. The output voltage swings are small and switching performance is much more dependent on transistor parameters than it is with TDL circuits. Propagation time through DCTL circuits is in general faster than through TRL circuits and slower than through TDL circuits. The possibility of heavy saturation of direct-coupled stages causes storage time to be a predominant factor in the propagation time.

In general, the DCTL configuration will require many more active elements to perform a logic function than will TDL and TRL configurations. In some cases the sheer quantity of active elements may present a reliability problem.

Nonsaturated—Since storage time is a significant portion of propagation time, nonsaturated logic is used to eliminate this part of the delay. The price for this faster operation is increased power dissipation, increased number of components and a resulting increase in cost. In the past the speed advantage often outweighed the disadvantages, making nonsaturated logic economically feasible. Today, with the low storage time performance of silicon and germanium epitaxial diffused-base switching transistors, the advantage gained by using nonsaturated logic is not nearly so significant as it was a few years ago.

SPEED CONSIDERATIONS

It can be shown empirically that propagation time for certain saturated logic circuits may be approximated by

$$t_p = \frac{t_{ON}}{4} + \frac{t_{OFF}}{2}$$

Where t_p = propagation time per stage; t_{ON} = total turn-on time of the transistor; and t_{OFF} = total turn-off time of the transistor.

Thus if OFF time is reduced from four times the ON time to one and one-half times the ON time, the propagation can be reduced 56 percent. In the past it was not unusual for switching transistors to have storage times which caused turn-off time to be four or more times as large as turn-on time. However, epitaxial multidiffused switching transistors with turn-off times only slightly greater than turn-on times are common today. For example, the 2N743, 2N744, 2N2368 and 2N2369 silicon switches have typical turn-on times of 10 nanoseconds and typical turn-off times of 15 nanoseconds.

Propagation time in TDL circuits of approximately twenty nanoseconds per stage is easily realized with these transistors. If speed-up capacitors are used, propagation times of 5 to 10 nanoseconds per stage can be obtained. The 2N2411 and 2N2412 transistors (complements of the above) exhibit only slightly longer switching times. In the germanium area, the TIX895 has a total switching time of 5 nanoseconds. Propagation time with speed-up capacitors of one nanosecond per stage has been obtained. A photo shows the test circuit. At present, economics limits the use of this transistor to small volume circuits. However, propagation times equivalent to those of the 2N743 series and 2N2368 series may be obtained using the 2N797 and 2N964 complementary transistors. Pyramiding capabilities of the 2N964 and 2N797 are better than those of the 2N743 and 2N744; however, silicon has the advantage of being able to operate at a much higher temperature.

NEW SEMICONDUCTOR PRODUCTS

Relatively new semiconductor products such as the field-effect transistor, the unijunction transistor, the avalanche switch, and the new low-level *pnpn* device lend themselves to special computer circuits. The field effect's high transconductance and high input impedance make it attractive as a memory sense amplifier. The unijunction's negative-resistance characteristic makes it particularly desirable for use in slow-speed ring counters, low-frequency oscillators, and timer circuits. The avalanche transistor's ability to switch currents up to 10 amperes with rise times of three nanoseconds makes it desirable in discriminator circuits, strobe circuits, core and thin-film driver circuits, level-detector circuits, and pulse-generator circuits. The new low-level silicon-controlled switch has applications in low-level, low-speed, high-voltage ring-counter circuits.

The negative-resistance semiconductor devices mentioned have frequency characteristics which impose severe limitations on clock rates. The tunnel diode, on the other hand, has good high-frequency characteristics making possible logic circuits operating at clock rates between 100 megacycles and 1,000 megacycles. A tunnel-diode balanced-pair logic circuit described by Gibson has a fan power of four and operates reliably on a sinusoidal clock source of 250 megacycles.

The balanced pair or twin circuit is shown in Fig. 9. The supply voltage which can be a sinusoid, is obtained from the secondary of the centertapped transformer. The tunnel diodes are in series and the inputs and outputs are taken between ground and the junction of the tunnel diodes. When the supply goes positive, point *A* positive with respect to point *B*, the diodes conduct in the reverse direction and point *C* remains at ground since the diodes, the supply voltage and the resistors R_S form a balanced bridge. When the supply goes negative, point *B* positive with respect to point *A*, the diodes conduct in the forward direction and point *C* will remain at approximately ground potential until peak current in one or the other diodes is reached. Which diode reaches peak first is dependent on whether the input is negative or positive. If the input is positive, current will flow into point *C* and diode D_2 will switch to its high-voltage state. Therefore, the tunnel-diode balanced-pair circuit gives an output of the same polarity as the majority of the inputs.

Lead inductances and diode capacitances introduce a delay in the transmission path between the two diodes in the twin circuit. This delay and not the finite switching time of the diodes is the principal factor limiting speed of the circuit. State-of-the-art tunnel diodes switch in 27 picoseconds—the time it takes light to travel 0.3 inch. Thus, packaging and not diode speed will limit the speed of future computers.

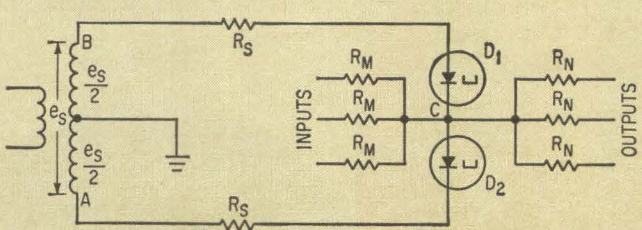
CHOICE OF LOGIC TYPE

The selection of one or more of these logic types will entail a compromise based on reliability, speed, cost, power and size factors. The relative order of importance of each of the factors will naturally vary with different programs. The table, based on a recent marketing survey, shows the relative importance of factors influencing the selection of a type of logic circuit. The ranking of factors influencing military airborne applications is based on the assumption that microminiature circuits will be used during the 1966-1969 period. Note the change from the 1963-1966 period.

Solid-state networks will play an important part in future logic circuit designs. The importance of this role will depend in part upon technological breakthroughs. In the short period since the introduction of the integrated network, major improvements such as reduction of R_{CS} from 100 ohms to 10 ohms, have occurred. Some manufacturers offer fully integrated circuits capable of 20 to 30-megacycle clock rates—a great improvement over speeds initially available with integrated circuits.

In the next 10 years new forms of integrated circuits will arise bearing little resemblance to those presently being produced. The difference in future products and today's solid-state networks will probably be as striking as the differences between grown or alloy-junction transistors and the new epitaxial multidiffused switching transistors. Research areas which may greatly influence logic circuit design include research with new materials, active thin-film-device research, bionics, new fabrication techniques, and optoelectronics.

TUNNEL-DIODE LOGIC showing the balanced pair or twin circuit—Fig. 9



FACTORS INFLUENCING SELECTION OF CIRCUITS-TABLE

MA — Military Airborne Computers
MG — Military Ground Computers
Com — Commercial Computers

	1963-1966			1966-1969		
	MA	MG	Com	MA	MG	Com
RELIABILITY	1*	2	3	1	2	2
SPEED	4	3	2	2	2	1
COST	3	1	1	3	1	1
POWER	3	4	4	4	4	4
SIZE	2	4	4	3	3	3

*Numbers indicate relative importance

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HIGHLIGHTS OF SMALL-SIGNAL CIRCUIT DESIGN

Small-signal semiconductor applications stress low noise combined with high gain in audio applications while on the r-f side the push is still towards combining high-frequency operation with high power-handling capability. This section presents a sampling of recent achievements in device design and circuit application

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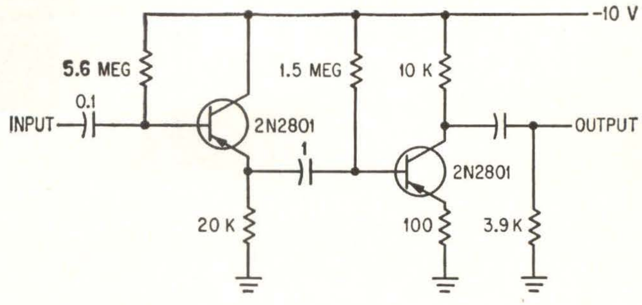
TODAY'S important small signal semiconductor devices were, with few exceptions, conceived in elementary form over a decade ago. Recent advances in technology and manufacturing methods have made possible important improvements in the basic devices, and, perhaps more important, from the standpoint of the user, often made their application feasible economically.

In some cases, the gains parallel specific electron-tube techniques, while in others the improvements could be achieved only with semiconductors. It is the purpose of this section to point out some specific advances in today's semiconductors, to show how these advantages are obtained from the point of view of device structure, and to illustrate areas of application or specific uses. Seven junction devices, both bipolar and unipolar, are considered.



LOW-NOISE audio amplifier uses pnp silicon transistors—Fig. 1

AUDIO DEVICES AND CIRCUITS

Silicon pnp Transistor—A *pnp* silicon transistor can be made to exhibit a lower noise figure and beta (h_{FE}) linearity extending to lower currents than can its *npn* counterpart. In oxide-masked structures, planar *p*-regions typically exhibit higher values of surface recombination than do *n*-type regions, and the severity of the problem increases with decreasing *p*-region doping density. In *npn* transistors, then, the beta fall-off is associated with high recombination at the surface of the moderately doped *p*-type base region near the emitter-base junction. Since the emitter is more heavily doped than the base, and recombination is less a problem in the more heavily doped region, better beta linearity is achieved in *pnp* structures. In addition, for identical impurity concentrations, an *n*-type base region will have lower resistivity; this results in a lower r_b' and better noise figure.

Until recently, however, recombination-generation leakage current in the lightly doped collector region of the *pnp* structure was a problem precluding high values of collector-base breakdown voltage. This difficulty has been overcome by the annular process. The heavy concentration $p+$ ring diffusion surrounding the base limits the spread of the area of high leakage-current generation. By this method, *pnp* transistors with collector-base breakdowns exceeding 100 volts and having leakages comparable with *npn* devices may be produced.

Low-Noise Audio Amplifier—Figure 1 shows a simple audio amplifier, which uses 2N2801 *pnp* silicon transistors. This circuit features high input impedance and low noise, made possible by the low leakage and excellent gain at low collector currents inherent in silicon annular devices.

Low-noise operation requires operation at low d-c collector currents. However, collector current must still be kept high enough for the transistor to provide useful gain. The 2N2801 transistor used in the input stage is operated at a collector current of 100μa. At this current the device has a typical 1-kc noise figure of 2 db and it still has useful gain.

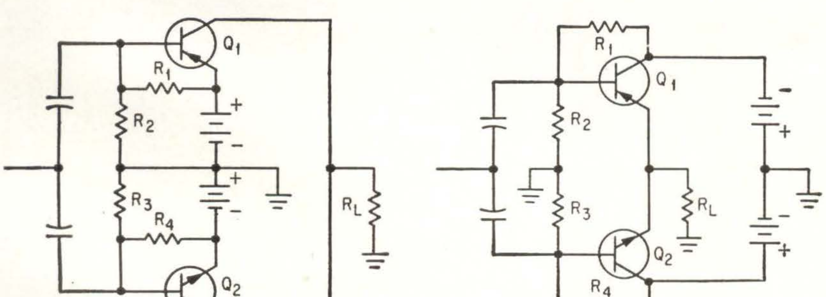
The circuit has an overall power gain of 44 db and an input impedance of 440,000 ohms. With an input power of 0.0049 μwatt (−53 dbm), the circuit delivers 2 volts peak-to-peak output to a 3,900-ohm load with hum and noise 57 db down. The 3-db frequency response is 20 to 100,000 cps.

The input stage is a common-collector or emitter-follower amplifier. This configuration, plus the large base bias resistor, allows a high input impedance to be obtained without feedback. The second stage is a common-emitter amplifier. It must also have a higher input impedance than the normal common-emitter amplifier so that it will not load the input stage. The input impedance of this stage is increased by the combination of emitter resistor degeneration and a large base bias resistor. Collector current in the second stage is 500 μa.

Complementary-Symmetry Audio Output—The circuit usefulness of complementary components has long been recognized. For several years, limitations in technology made *pnp* silicon units inferior to their *npn* counterparts, precluding complementary applications in high quality equipment. With the advent of the annular process described earlier, this limitation no longer applies to silicon transistors. Complementary units with similar characteristics may be fabricated. With identical geometries, collector leakages are nearly equal with similar collector breakdown voltages. Currena gains may be matched over a wide range of collector current. With careful processing, variations between noise performance and current gain at low current of complementary types may be held to a minimum. Thus, the annular technique makes possible highly symmetrical complementary transistors. The design of practical complementary-symmetry push-pull audio output circuits has become a reality with the introduction of identical *npn* and *pnp* silicon annular transistors, such as the 2N2218 *npn* and 2N2904 *pnp*.

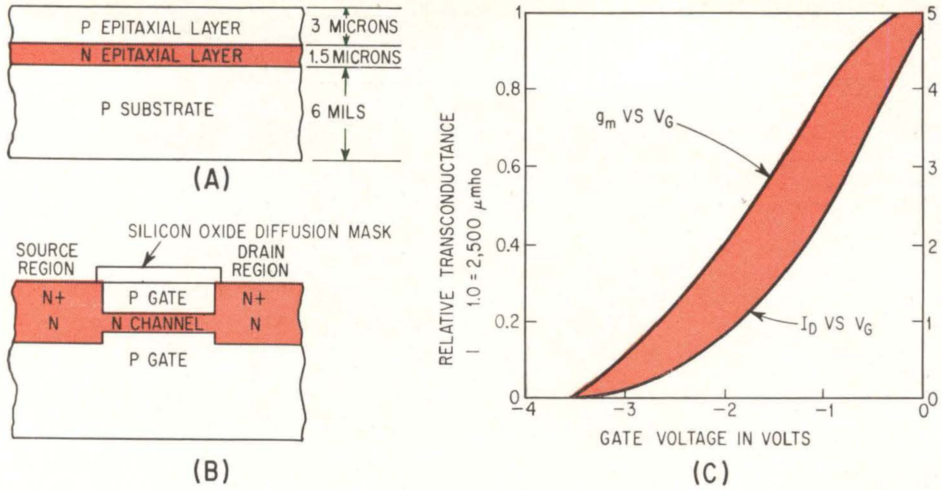
Figure 2A shows a typical common-emitter complementary-symmetry push-pull audio output stage.

Transistor Q_1 is a *pnp* and Q_2 is an *npn*. During the half-cycle, when the signal voltage at the input of Q_1 and Q_2 is negative, Q_1 conducts and current flows from Q_1 down through R_L to ground. During the half-cycle when the signal voltage goes positive, Q_2 conducts and current flows from ground up through R_L and to Q_2. Thus, push-pull action is obtained. A small no-signal forward bias reduces crossover distortion. The d-c current is balanced out in the load by the opposite con-



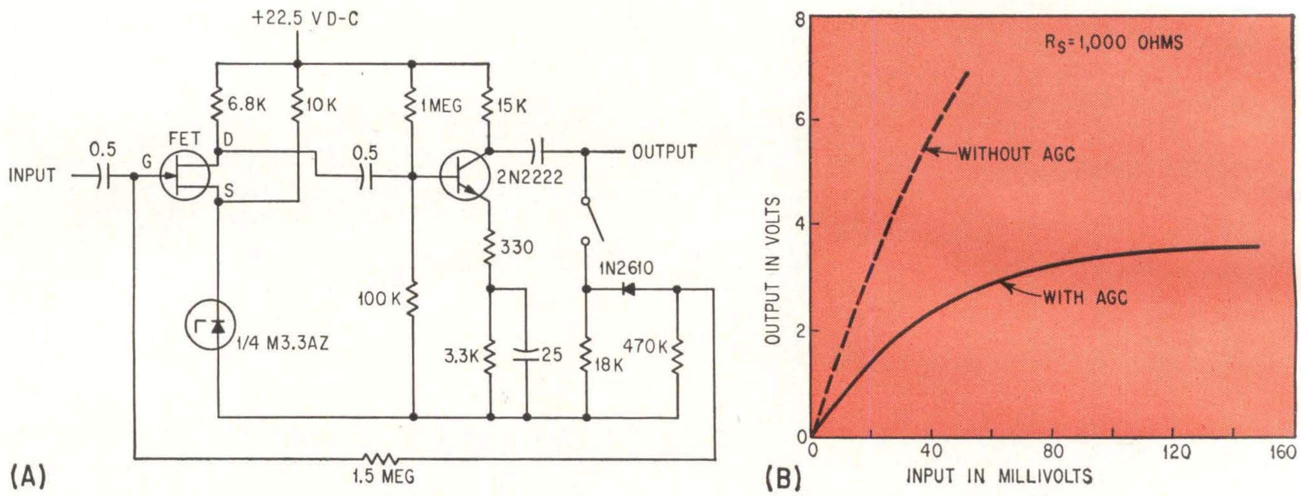
(A) (B)

COMPLEMENTARY-SYMMETRY silicon pnp and npn transistors make possible the emitter-coupled output amplifier (A) and the emitter-follower configuration (B)—Fig. 2



◄ FIELD-EFFECT TRANSISTORS. Epitaxial starting material (A), structure completed by a single diffusion (B) and typical transfer characteristics (C)—Fig. 3

AUDIO AMPLIFIER with agc provided by a field-effect transistor (A) and the circuit's transfer characteristic (B)—Fig. 4 ▼



duction paths of the *pnp* and *npn* transistors. Therefore, R_L can be coupled directly to the load.

The main advantage of the complementary-symmetry circuit is that phase inversion is not needed in the driver circuit and a complete transformerless power amplifier can be designed. One disadvantage of a circuit of this type is that two d-c supply voltages of opposite polarity are required. The supplies also must offer a low internal impedance to the signal current if full output is to be realized.

Figure 2B shows a common-collector or emitter-follower complementary-symmetry circuit. This circuit has less power gain and a considerably higher input impedance than the common-emitter circuit. It can be used where the higher input impedance is desired and the lower power gain and unity voltage gain are not objectionable.

Field-Effect Transistors—Though they were invented over a decade ago, field-effect transistors are only now coming into mass production due to recent advances in silicon epitaxy. In combination with diffusion techniques, epitaxial processing makes possible reliable, low-noise field-effect transistors. One possible fabricational sequence is depicted by Fig. 3. The channel is grown epitaxially on a substrate wafer, which serves as one gate. The top gate is then deposited epitaxially over the channel region. The structure is completed by high-concentration diffusions which make contact to the channel layer, forming the source and drain contacts, and defining the lateral geometry of the structure.

By choosing the impurity concentrations of the top gate the same as the bottom gate on substrate, symmetrical devices with step junctions may be formed. The heavily doped source and drain contacts contribute little parasitic resistance, and, hence, do not add significantly to the thermal noise. Thermal noise is the principle noise source in a field-effect transistor at frequencies where the $1/f$ noise is not important. The $1/f$ contribution is low because of the oxide-passivated gate junctions. Connection may be made to either or both top and bottom gates, allowing flexibility in application.

The field-effect transistor exhibits a transconductance that varies with gate voltage V_G in accordance with

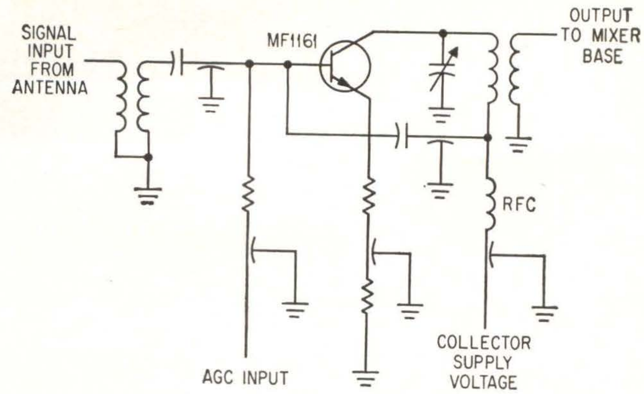
$$\frac{\partial I_D}{\partial V_G} = g_m = g_{m0}\left(1 - \frac{V_G}{V_P}\right)^n$$

where V_P is the pinch-off voltage, I_D is the drain current, and the exponent n is very nearly 2. Variation of both g_m and I_D is shown in Fig. 3C. This transconductance variation is useful in audio circuits where automatic gain control is needed, perhaps to compensate for unequal input levels.

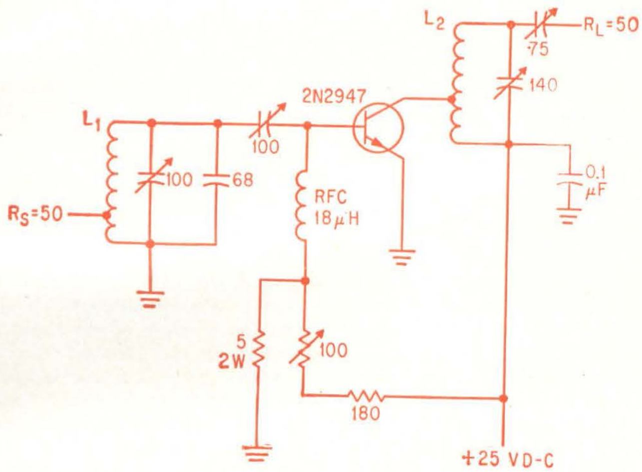
A circuit which achieves this function is shown in Fig. 4A. Two stages are employed to obtain sufficient voltage to control gain of the first stage. The output voltage is rectified and the

A DECADE OF PROGRESS

Semiconductor devices have come a long way in the past ten years and modern manufacturing techniques, especially planar diffusion and epitaxial growth, deserve a large share of the credit. Today semiconductors can do almost every thing a vacuum tube ever did and sometimes do things a vacuum tube never could do. This article highlights the art, coming to grips with such knotty problems as achieving really effective automatic gain control, low noise amplification and operation at high frequencies and significant power levels



SPECIAL AGC TRANSISTOR is used in a vhf transistor television tuner—Fig. 5



L_1 = 3-1/4 T NO. 18 TINNED WIRE, 1/2" DIA, 1/2" LONG, TAPPED 3/4T FROM COLD END

L_2 = 4T 1/8" COPPER TUBING, 3/4" DIA, 1-1/4" LONG, TAPPED 1-1/4" T FROM COLD END

CAPACITANCE VALUES IN PF UNLESS OTHERWISE MARKED

HIGH-FREQUENCY high-power silicon transistor makes possible this 30-Mc linear amplifier for single-sideband communications—Fig. 6

resulting negative voltage fed back to the gate of the field-effect transistor. Transfer characteristics of the circuit are shown in Fig. 4B. The effect of the agc is most noticeable at input levels above 50 mv. Without agc the amplifier dips at input levels of 50 mv, whereas, the agc feedback extends the input level by a factor of three. The negative feedback also extends the frequency response of the circuit.

R-F DEVICES AND CIRCUITS

Silicon AGC Transistor—The frequency response of junction transistors is determined by the transit time of injected minority carriers through the neutral base region and the collector depletion region, together with the charging times associated with emitter and collector depletion capacitances. All these times are a function of operating currents and bias voltages.

As current is increased, in a high-frequency structure, the collector silicon series resistance increases, reducing collector-base bias voltage and increasing base width. If the current density is sufficiently high that the charge of the injected mobile minority carriers passing through the base into the collector is not negligible, the boundaries of the collector base depletion region are altered, and the transit time is affected.

Specifically, the current-gain bandwith frequency f_T is reduced as the current density is increased. If this effect is augmented by the decrease in beta due to reduced injection efficiency as current is increased, significant agc action in the 6-db-per-octave region of the beta characteristic may be achieved in a silicon transistor whose geometry and impurity concentrations are appropriately chosen. Power gains of 20 db with a noise figure of less than 5 db at 200 Mc may be obtained with the same device by utilizing a high base-doping level and an epitaxial collector. Automatic-gain-control action may reduce the gain 20-25 db as the collector current level increases from 2 ma to 20 ma.

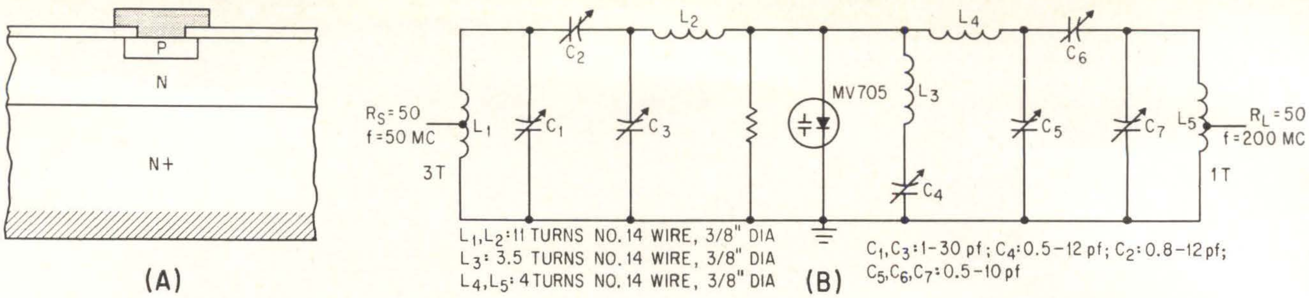
Television Tuner—Figure 5 is a simplified schematic diagram of the r-f stage of a modern all-transistor vhf television tuner. Channel switching and the input circuit balun and filters have been omitted for simplicity.

The circuit uses the MF1161 *npn* silicon transistor. This transistor provides the high amplification, low noise figure, and the excellent automatic gain control (agc) characteristics required for a tv r-f amplifier. Typical 200-Mc performance of the MF1161 is 20 db power gain with 4.9-db noise figure.

Of particular interest in this circuit is the agc system. The purpose of the agc system is to reduce gain with stronger signals to prevent stage overloading and resulting distortion.

The conventional method for obtaining agc operation is to vary the gain of the transistor by changing the d-c operating conditions.

The two common methods for obtaining agc in transistor



VARACTOR DIODE. Its construction as an epitaxial passivated device (A) and application in a vhf frequency multiplier (B) —Fig. 7

circuits are called reverse agc and forward agc. With reverse agc, transistor gain is reduced by decreasing collector current. However, decreasing collector current reduces the signal handling capability of the stage. This is a disadvantage, since it occurs at a time when the signal is increasing. With forward agc, transistor gain is decreased by increasing collector current. Forward agc is more desirable, since the transistor signal-handling capability is increased with increasing signal amplitude.

Forward agc is used in the tuner circuit shown. The agc input point becomes more positive with increasing signal. This causes the transistor collector current to increase. Due to its specially designed agc characteristics, the gain of the MF1161 decreases sharply but smoothly as the collector current increases, thus producing the desired agc action in the circuit.

An additional effect which also aids the agc action is the change in transistor collector-emitter voltage with changing collector current. The d-c power supply voltage is applied to the series combination of the transistor and its emitter resistors. As collector current increases, the voltage drop across the emitter resistors increases, causing collector-emitter voltage to decrease. This decreasing collector-emitter voltage also reduces transistor gain.

High-Frequency Power Transistors—The power gain of a transistor is proportional to $f_T/r_b'C_c$. High-frequency power transistors have been brought about by photolithographic techniques allowing fine geometries and improved diffusion systems which achieve high concentrations with reduced density of defects. Both these advances lower r_b'. Low C_c is obtained by an epitaxially formed collector region. A high f_T results from the narrow base widths necessitated by the low lifetimes obtained in diffused silicon structures. Adequate control of base thicknesses on the order of a micron is obtained.

By utilizing the annular process described earlier, either *npn* or *pnp* units may be fabricated. Collector breakdown of narrow-base diffused units can occur in small isolated areas, which may then be heated excessively by the power dissipated in them, resulting in destruction of the device. Hence, care must be used to avoid exceeding breakdown voltage, even momentarily, and load lines are much more restricted than with low-frequency, wide-base power transistors. With this limitation in mind, today's high frequency power transistors are important devices in switching and in r-f applications from 10 to a few hundred megacycles.

30-Mc Linear Amplifier—Figure 6 shows a 30-Mc single-sideband linear power amplifier capable of delivering an output power of 8 watts PEP (peak envelope power). A single 2N2947 *npn* silicon transistor mounted in a TO-3 diamond package is used in the amplifier. The power gain is 13 db, and all odd-order distortion products are at least 30 db below the desired signal. The amplifier is operated from a 25-volt d-c power supply.

The difference between this amplifier and a similar one designed for class C operation in a c-w, a-m or f-m transmitter lies primarily in the d-c bias circuit. For class C operation, the only d-c bias voltage normally applied is the collector supply voltage. The 18-μh r-f choke and resistive divider in the base circuit would be omitted. The transistor is biased ON by the driving signal on the base. This results in one of the great advantages of a transistor transmitter—if the driving signal is suddenly removed, the power amplifier merely shuts off and sustains no damage.

To obtain linear operation, a small amount of forward bias is applied to the transistor. This is the function of the resistive divider and isolating choke in the base circuit. The d-c bias is adjusted so that a small collector current flows with no driving signal applied. When the driving signal is applied, it then causes the transistor to be biased ON to full operating collector current. The 2N2947 operating collector currents in the circuit shown are 20 ma with no signal and 350 ma with signal.

Varactor Diodes—A varactor is a diode which exhibits a nonlinear relation between voltage and capacitance under reverse bias. Operated in the reverse bias direction, the varactor behaves as a nonlinear capacitance in series with a resistance. This resistance is made up of bulk and contact resistances. These diodes also exhibit nonlinearity when operated in the forward direction near the origin of the *V-I* curve.

When the varactor is operated in the forward direction between 0 and 0.7 volt, charges are injected, swept across the junction and removed when the incoming wave starts on its negative slope, or when the diode is reverse biased. This yields several advantages, one being low noise level. This effect occurs abruptly between 0 and 0.7 volt, provided the lifetime is long enough to keep the carriers from recombining.

This mode of operation gives a large increase in capacitance compared to a diode operated under reverse bias conditions.

The advent of oxide passivation and epitaxial growth has increased the sensitivity, reliability and breakdown voltages of these devices. The use of oxide passivation has decreased the leakage across the *p-n* junction, thus giving more stable reverse characteristics. Epitaxial growth allows construction of a thin *p-n* junction which is mechanically strong. It also provides for low series resistance so that power losses due to the *IR* drop under the base diffusion are minimal. A typical finished unit has the structure shown in fig. 7A.

Frequency Multipliers—The circuit shown in Fig. 7B is a (50-200 Mc) frequency multiplier using the MV705 varactor diode. This circuit, together with a transistor 50-Mc transmitter, delivers 22 watts power output at 200 Mc using semiconductor circuits.

The circuit consists basically of three tuned circuits: an input circuit (L_1C_1, C_2, C_3 and L_2), an output circuit (L_4, C_5, C_6, C_7 and L_5) and an idler circuit (L_3 and C_4). The input and output circuits are double-tuned using capacitive coupling (C_2 and C_6). The idler circuit is a series tuned circuit. This idler circuit is omitted for frequency doubling.

Self-bias is provided by shunting a large resistor across the varactor diode. The optimum value of the resistance depends somewhat on the required frequency multiplication (doubler, tripler, etc), the output frequency and the power output. A typical value of this resistance is 100,000 ohms.

PIN Diodes—A switching diode is characterized by the following parameters: forward current and voltage, reverse voltage and current, junction capacitance, and the speed with which the diode can be switched on and off. A *pin* diode has heavily doped end contact regions and a near-intrinsic central base region of either *n* or *p* type to sustain the reverse voltage.

The *pin* diode is usually formed by starting with a heavily doped *n*-type substrate, adding a lightly doped *n*-type epitaxially grown center region (the same conductivity type as the substrate), and a *p*-type diffused region, heavily doped. The *pin* diodes can also be constructed using *p*-type substrates and epitaxial layers, followed by heavily doped *n*-type diffusions.

The *pin* diode has several advantages over the conventional *p-n* type forward and reverse terminal characteristics. Under forward biasing minority carriers are injected into the lightly doped *n*-region. When injection is sufficiently high, the heavily doped $n+$ region in place of the ohmic contact excludes minority carriers. This exclusion of carriers has the tendency to make carriers pile up in the center region and this accumulation can become sufficiently great to result in increased conductivity modulation which decreases the resistance in the center region. Where high reverse voltages are required and the diffusion length is much less than the base width, the *pin* diode can stand a narrower base width with higher resistivity material to maintain high breakdown. This is possible because avalanche multiplication of minority carriers does not occur immediately when the space charge region reaches the heavily doped *n* region. Among other applications, *pin* diodes have been used to perform the functions of t-r and atr switches in the front ends of some microwave radars and other equipment.

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POWER AND CONTROL CIRCUITS

Semiconductor devices such as the silicon controlled rectifier (SCR), complementary SCR, silicon controlled switch (SCS), light-activated switch (LAS) diode, LAS triode, unilateral and bilateral diode switches, gate-turn-off (GTO) switch, power and unijunction transistors find application in rectification, phase control, inversion and static switching

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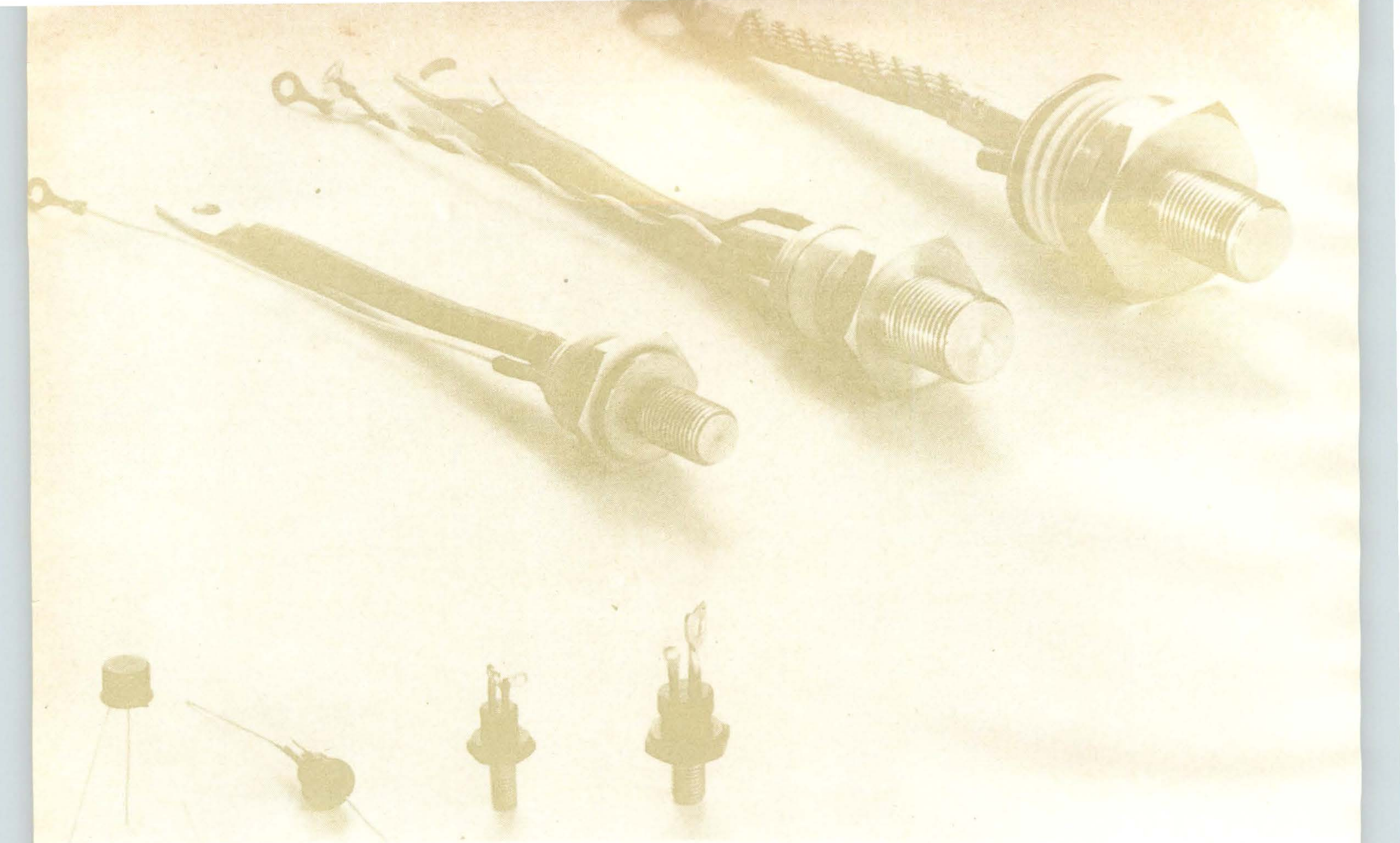
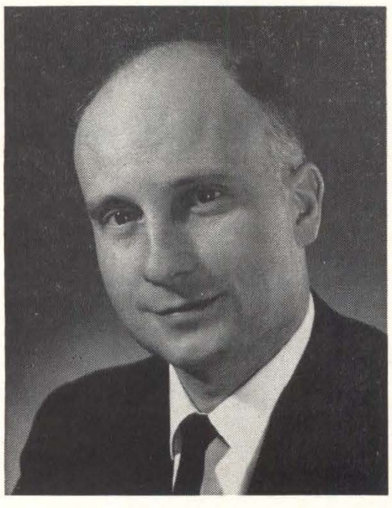
SEMICONDUCTOR electronics is moving into the power control field in a big way. Starting with the availability of large-area silicon rectifier diodes for the components market in the mid 1950's and the commercial silicon controlled rectifier (SCR) in late 1957, silicon power semiconductors are today serving in practically all basic industries. Semiconductor electronics has invaded even the fields of heavy rotating machinery and control. The progress of the controlled silicon power semiconductor is dramatized by SCR's used as the main drive armature power supply for a 12,000-horsepower reversing plate mill now being built for a major steel company. A similar system is being built for a large aluminum company.

Not only can today's power semiconductors do a better job in applications where they replace older devices but they are making applications possible that had been hitherto either not practical or not developed because of the unavailability of



LINE UP of typical silicon controlled rectifiers on the market today. They range from small SCRs in the 1 to 10-ampere applications in portable power tools, lamp dimmers and appliances



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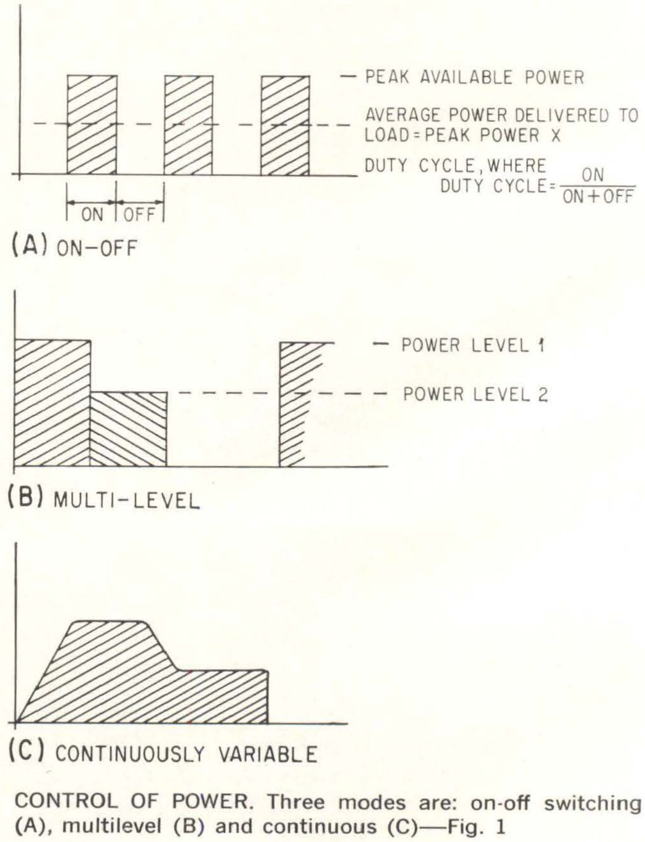
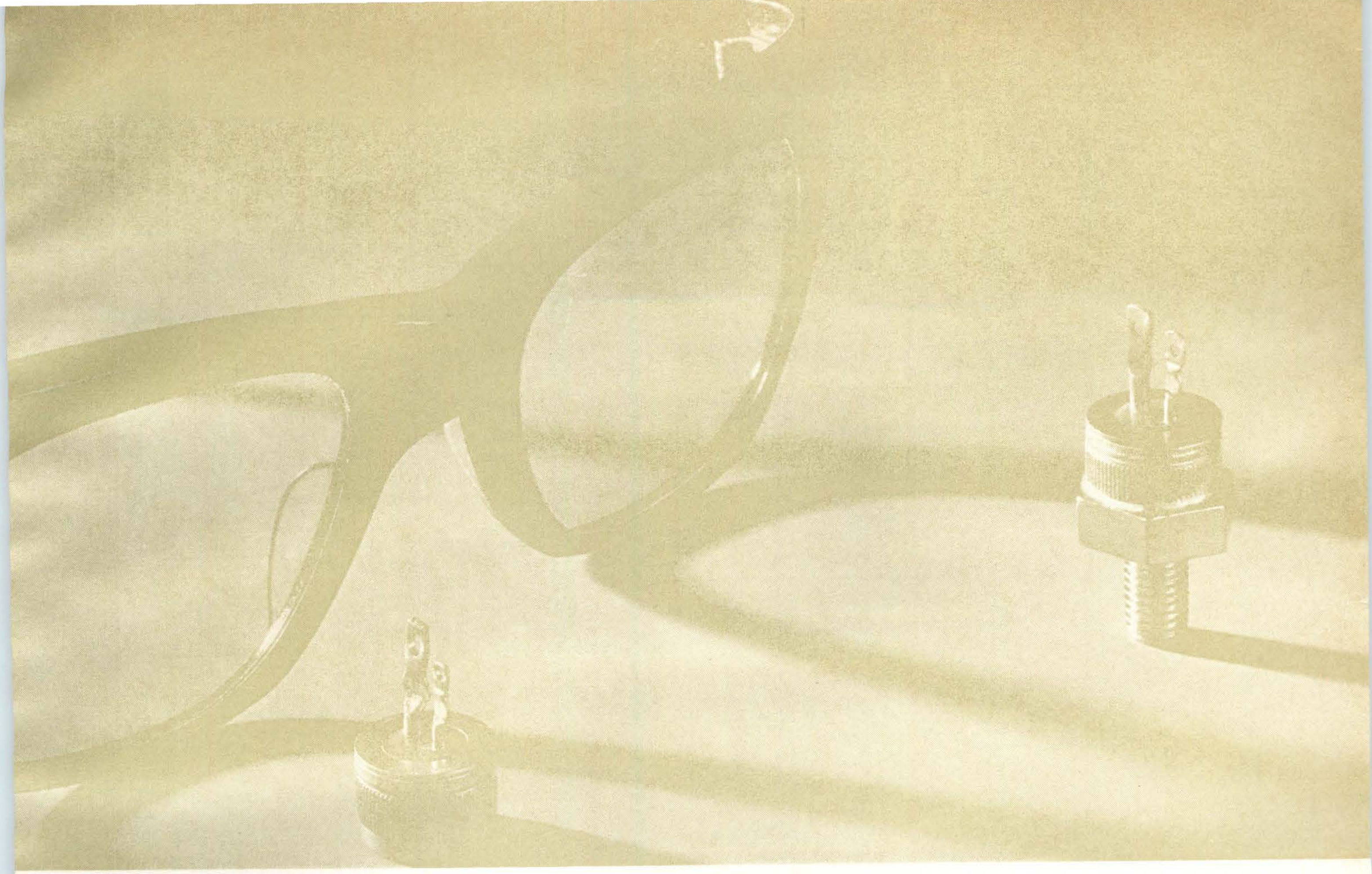


CONTROL OF POWER. Three modes are: on-off switching (A), multilevel (B) and continuous (C)—Fig. 1



class to units for use in power-control applications above a kilowatt. The SCRs at the right are designed for volume consumer

control devices. Converting d-c to a-c power has long been feasible by rotating machinery. However, high-frequency fluorescent lighting becomes practical only with the availability of efficient and easily installed SCR inverter units of sufficiently high output frequency (several kc) and ratings (10 to 50 kva) to supply large commercial installations. A new development is large power inverters such as the 322 kva SCR inverter operated by a utility system in the South West as a part of a civil defense testing program.

BLUE-COLLAR ELECTRONICS

Power and control circuits represent electronics in a blue shirt with its sleeves rolled up. They are the heart and soul of true industrial electronics whether they are helping provide more efficient fluorescent lighting or controlling the drive of a steel-plate reversing mill.

Until recently this field was the domain of the ignitron and mercury-vapor rectifier. And these components were still waging a running battle for acceptance against older techniques embodied in rotating motor-generator sets.

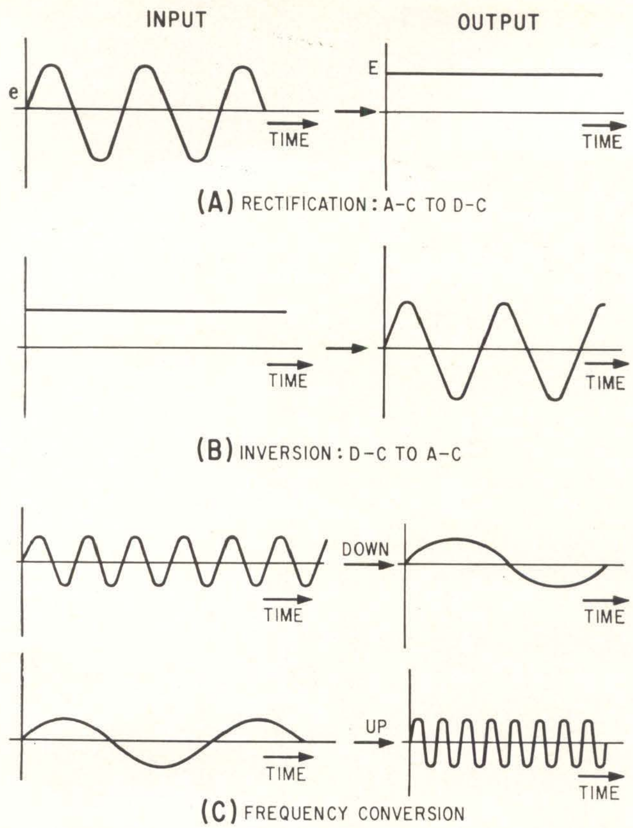
But today semiconductor devices are taking over much of this large and growing field. Most of these devices are based on the **npnp** transistor. However, power men are accustomed to looking at things from the anode side instead of the cathode, also they apparently feel more at home with a rectifier than with a transistor—ergo we have the **pnpn** silicon controlled rectifier or SCR

Attesting to the rapid acceptance of power semiconductors is the growth of the SCR market. From practically nothing in 1958 the market is today estimated at twenty million dollars annually and it is expected to grow 25 percent within the next three years.[1] Notwithstanding the acceptance of power semiconductors in military applications it appears that the greatest growth in the usage of these devices and their control technology is in industrial and consumer applications.

POWER CONTROL AND CONVERSION

One way to classify power control is by the manner in which power is doled out to the load. The full available power may be applied ON-OFF at a predetermined duty cycle as in a thermostatically controlled frying pan, Fig. 1A. The control may apply multistep power levels to the load as in a multispeed motor, Fig. 1B. Or, the control element may be capable of applying continuously variable power into the load, Fig. 1C. In these cases, the average power delivered to the load may be controlled open-loop or closed-loop by a low-power control circuit.

The form of the electrical power supply to the load is important: alternating current at a different voltage or frequency, or direct current at a voltage different from that directly available from the source may be required depending on the load. An adjustable-speed d-c motor operating from an a-c power source may require a variable d-c armature voltage of low ripple content; a telephone office may require well regulated 120 v a-c, 60-cycle emergency power from a battery source in the event of failure of utility power—the changeover from utility power to battery power must be made within a half-cycle of line frequency. Or, parts of an aircraft electrical system may require well regulated 400-cps power from the variable-frequency output of an alternator coupled directly to the variable speed shaft of the aircraft's turbine. It may be



MAJOR POWER device functions are: a-c to d-c rectification (A), d-c to a-c inversion (B) and frequency conversion (C)—Fig. 2

necessary to rectify a-c to d-c (Fig. 2A), invert d-c to a-c (Fig. 2B), or to convert frequency (Fig. 2C).

Rectification—Power-control and conversion circuits are illustrated in Fig. 3. Figure 3A shows a diode supplying a resistive load from an a-c source. The diode conducts as soon as its anode A is positive with respect to its cathode K. It passes all positive half-cycles of the line frequency; it blocks the negative half-cycles. The unidirectional load waveform has an average or d-c value, unlike the input a-c waveform. Therefore, rectification, or power conversion from a-c to d-c, has been effected.

By circuit arrangement, all half-cycles of the a-c supply can be passed on to the load resulting in full-wave rectification (Fig. 3B). The average output voltage is doubled and filtering for a smooth output is much easier due to the lower ripple content of the waveform.

Substituting SCR's for the diodes in the previous two circuits, phase controlled rectification is achieved when the SCR's are driven from a triggering circuit TR. Figures 3C and 3D show this substitution. With no trigger signal, the SCR blocks both input voltage half-cycles and no voltage appears at the load. As conduction is delayed by an angle α, a chopped half-sinusoid is delivered to the load. When $\alpha = 0$ (no delay in conduction), the circuit delivers 100 percent of its possible output. In the bridge circuit (Fig. 3D) only two diodes need be replaced with SCR's to obtain full control over the d-c, or rectified voltage delivered to the load.

Phase Control—This is illustrated with an a-c load in Fig. 3E. Each SCR delivers a half-cycle of the supply to the load. When the triggering delay angle $\alpha = 0$, the load sees the full a-c supply as though there were no power control circuit interposed. When $\alpha = 180$ electrical degrees, the load voltage is zero. For intermediate values of trigger delay angle α, the effective load voltage assumes different values in accordance with a cosine function. The circuit configuration of Fig. 3E is the inverse-parallel, or back-to-back, a-c control circuit used in lighting and heating control applications.

If the load in the rectification circuit of Fig. 3D is sufficiently inductive, the current through it will continue to flow even after the line voltage has reversed and the SCR's are turned off. More specifically, the counter-voltage of the load inductance will be of a polarity to mainatin the load current I_L.

In the circuit of Fig. 3D the two diodes of the bridge circuit provide a low resistance path for the current I_L. The current will free-wheel through these diodes as long as the counter-voltage exceeds two diode drops, or until the other SCR is brought into conduction and supplies load current from the a-c source.

However, if all legs of the bridge circuit contain SCR's, as in Figure 3F, the inductive load current I_L is inhibited from free-wheeling by a forward-blocking SCR. If the load inductance is assumed sufficiently large to cause continuous current in the load for the trigger delay angle α, the current flowing when the supply line voltage reverses at $\omega t = \pi$ will continue to flow through the SCR's against the negative line voltage. Thus the conducting SCR's are applying negative voltage to the load during the time of trigger delay α.

The net load voltage E_{dc} in this operation is the average of the algebraic sum of the shaded areas shown in Fig. 3F. When $\alpha = 90$ electrical degrees, the average output voltage is zero. When triggering is delayed beyond 90 deg., the applied load voltage reverses and the rate at which inductive energy is returned into the a-c supply is increased. Thus highly inductive d-c loads can be forced to zero. This has significance in excitation supplies for generator fields, magnetic chucks and lifting magnets. However, the direction of net power transfer is still from the a-c line to the load; only the reactive power stored in the inductance is returned to the supply line; and the circuit continues to function as a rectifier.

If the polarity of the rectified d-c output voltage is to be reversed, or if net power must be returned to the supply line without the reversal of load voltage, two bridge circuits may be connected antiparallel as shown in Fig. 3G. If a d-c motor load is to be driven in both directions of rotation, one bridge can supply the polarity for forward rotation, while the other bridge supplies power for reverse rotation. To bring the motor to a stop from its forward direction, the energy stored in the rotating inertia of the load may be returned to the supply line by turning on the reverse bridge converter. Thus the motor is decelerated by regenerative braking in contrast to dynamic braking in which a resistor is merely placed across the armature terminals to absorb the stored load energy.

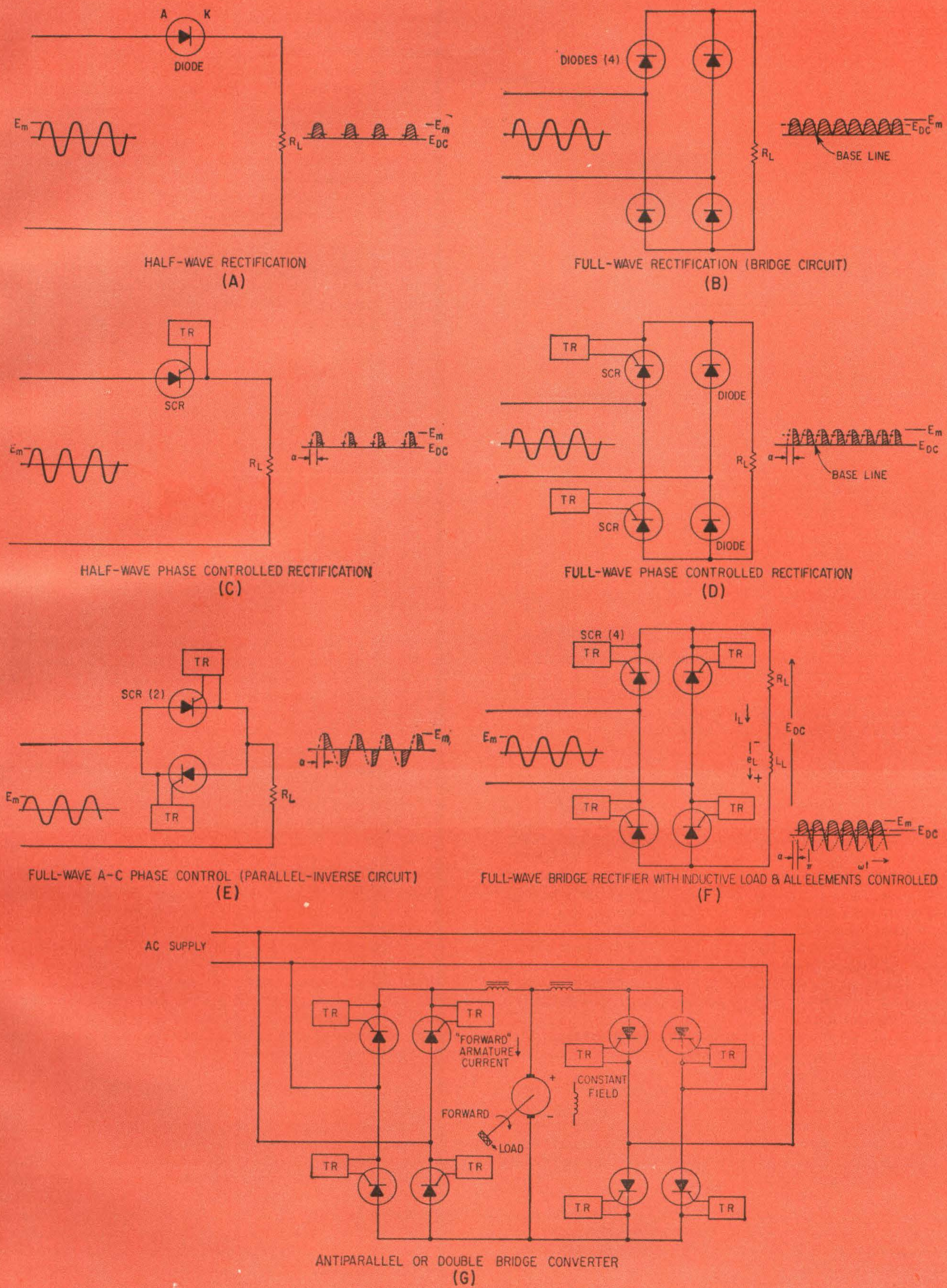
The circuit of Fig. 3E requires twice the power-handling capacity of the load, unlike a motor-generator rotary converter (Ward Leonard drive) that can accomplish the same functional operation at relatively little extra cost and at no extra power-handling capacity. However, the electronic circuit has superior response time and, when accomplished as in Fig. 3G, requires no circuit switching by contactors. The relative merits of the semiconductor approach of Fig. 3G versus rotary conversion must be decided on the basis of response time and the time available for operating reversing contactors.[2]

Inversion—Common to all the circuits of Fig. 3 is the fact that the SCR's are turned off, or commutated, by the a-c supply line. Reversal of the supply voltage forces the SCR to regain its forward blocking ability even though, as in the case of reactive load, turn-off may occur at a time other than line voltage zero.

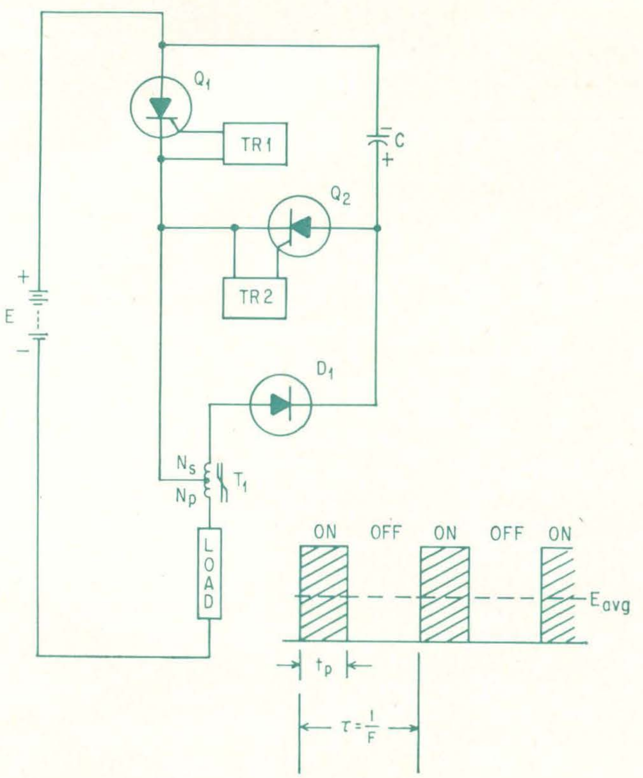
For power inversion from a d-c source it is necessary to use an auxiliary circuit to effect turn-off of the SCR's to retain control over the circuit. The d-c SCR chopper of Fig. 4 illustrates this point.

When Q_1 is triggered, battery voltage E is applied to the load and the primary N_p of saturable autotransformer T_1. Transformed load current charges capacitor C to the polarity indicated. After the desired load pulse width t_p, auxiliary Q_2 is triggered connecting capacitor C directly across load Q_1. This action reverse biases Q_1 and turns it off. After the desired off-time, Q_1 is retriggered and the cycle repeated.

This type of chopper can be operated in two modes. If the ON time, or pulse width t_p, is held constant, and the frequency is varied, time-ratio control results. But if the frequency is held constant, pulse-width modulation occurs. In either case, the average output voltage to the load can be continuously



POWER CONTROL CIRCUITS include: half-wave rectifier (A), full-wave rectifier (B), half-wave controlled rectifier (C), full-wave controlled rectifier (D), full-wave a-c phase control (E), full-wave bridge with inductive load (F) and double-bridge converter (G)—Fig. 3



CHOPPER CIRCUIT using SCRs—Fig. 4

varied by the operation of the triggering control circuits TR_1 and TR_2. When two or more elements of the type shown in Fig. 4 are combined to give a symmetrical output, a basic a-c to d-c inverter results. Figure 9 shows a power inverter circuit with two SCR's working in push-pull.

DEVICE CONSIDERATIONS

In power control and conversion applications, the SCR is a valve between the power source and the load. It must be able to block working circuit voltages up to many hundreds of volts; it must, by its nature and its mode of operatoin, be efficient; its cost, in terms of initial component price, associated control circuits, mechanical equipment and cooling requirements, installation and maintenance expense, must be economical compared to other means of doing the job.

The silicon power semiconductor scores impressively when measured by these criteria against motor-generator sets, mercury-arc tubes, gaseous thyratrons, magnetic amplifiers and earlier metallic rectifiers. These technologies increasingly serve specialized applications.

The use of mercury-arc convertors in high-voltage d-c transmission[3] and the use of hydrogen thyratrons in pulse modulator applications are cases in point. Also, the magnetic-amplifier technology has many fruitful applications in conjunction with semiconductors. However, many areas of power control are already dominated by semiconductor technology based on economic and performance factors. As examples, lamp dimming[4, 5, 6, 7, 8], precision heating control, and d-c and a-c[9] motor control may be cited.

Voltage Blocking—This capability of semiconductors has steadily increased until today blocking-voltage ratings of the order of 1,000 volts are readily available in large power diodes and are becoming available in production quantities in SCR's. A great step forward in circuit reliability was attained with the introduction of silicon power semiconductors featuring a controlled-avalanche reverse-blocking characteristic.

Conventional semiconductors are usually sensitive to transient reverse voltages. This is largely because of the limited ability of the surface of the semiconductor pellet to sustain high surface fields without suffering dielectric breakdown with resultant catastrophic failure of the device. The controlled-avalanche device combines a specially designed surface to give greater surface voltage capability with a bulk avalanche capability like that of a zener diode. This avalanche voltage is controlled in production to lie below the voltage-sustaining capability of the surface.

To qualify as a controlled-avalanche device, the device must also pass a test at its maximum operating junction temperature which subjects it to a specified amount of reverse power. For example, a properly designed and manufactured 250-ampere controlled-avalanche diode can take a 10-microsecond pulse of from 50 to 100 kilowatts peak reverse power with its junction temperature initially at 200 C.

This means that when the device is used in a conventional manner, the probability of failure due to unpredictable reverse voltage transients is drastically reduced. Circuit and equipment designers had already developed application practices for conventional devices that have resulted in low device failure rates due to voltage transients. With the addition of the controlled-avalanche feature, device failures due to reverse voltage transients promise to become extinct. Beyond this, circuit and equipment designers may make the greatest economic use of the controlled-avalanche feature by applying the device closer to its rated capability and coordinating it with other circuit elements.[10]

Efficiency—Power control deals with the flow of power, and hence the mode of operation of the control device is important.

Average device dissipation in the switching mode is less than when operated in the linear mode. Accordingly, a power-control device of a given size, and hence power-dissipation capability, can handle considerably more power in the switching mode than in a linear mode of operation.

However, even in a switching mode there are constraints on present-day semiconductor devices as to their peak-power capability during the switching interval. The peak turn-on power the SCR can handle is related to the speed with which the full active current-carrying area of the device enters into conduction. Thus there is a limit on the rate of rise of current through the device during the turn-on switching interval.[11]

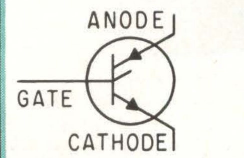
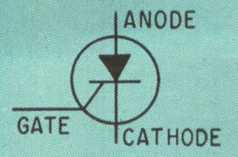
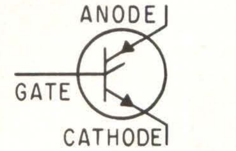
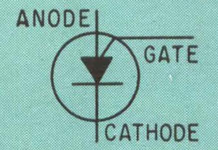
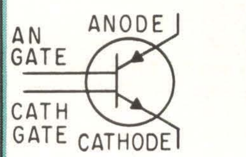
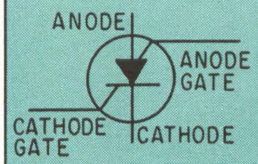
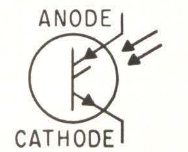
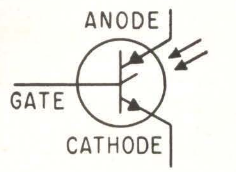
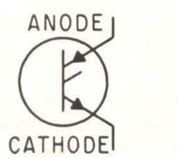
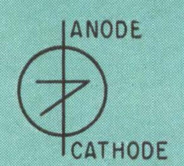
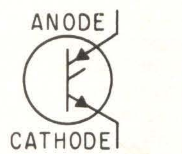
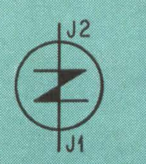
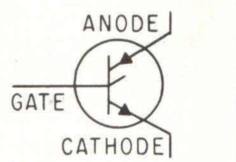
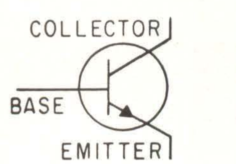
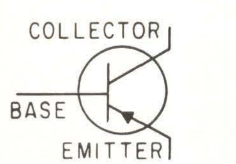
The SCR turn-on dissipation is reduced if the load is initially inductive. Then the current build-up through the device is delayed relative to the fall of the voltage across it. This results in less instantaneous peak power dissipation. When switching capacitive loads, as in pulse modulators, switching dissipation can be reduced by placing a small saturable reactor in series with the SCR so that it will switch the current a few microseconds after the SCR has switched most of the voltage.[12]

The transistor also has switching dissipation limitations. This is due in a large measure to the phenomenon of second breakdown[13, 14, 15]. Thus manufacturers of power transistors specify maximum power curves on the collector *E-I* characteristics. The load line of the load being switched must lie under these curves. Within the rated SCR or transistor switching limitations, however, all but the lowest power level control and conversion circuits operate in a switching mode. From this point of view it is of interest to examine the semiconductor switching devices available today.

SWITCHING DEVICES

The design engineer has available to him a large and growing number of semiconductor power devices. Figure 5 lists types of semiconductor switching devices, their American standard symbols, commonly used symbols, and indicates their most commonly used mode of operation and method of control. They are all devices that are capable of sustaining a rated blocking voltage from which they can be switched into conduction. All devices shown, except the *npn* and *pnp* transistors, are triggered into conduction. Once triggered, they remain in conduction until turned off by the main power circuit.

Devices with a gate terminal are triggered by injecting a pulse of gate current. Triggering by light is accomplished by irradiating the semiconductor pellet with a pulse of light. Nonlight-activated diode switches are pulsed on at their anode

NAME	AMERICAN STANDARD SYMBOLS	COMMONLY USED SYMBOLS	MODE OF OPERATION AND METHOD OF CONTROL
SCR (SEMICONDUCTOR CONTROLLED RECTIFIER)			GATE PULSE TRIGGERED SWITCH
SCR (COMPLEMENTARY)			GATE PULSE TRIGGERED SWITCH
SCS (SILICON CONTROLLED SWITCH)			SCR COMPLEMENTARY SCR TRANSISTOR GATE CONTROLLED SWITCH
LAS (LIGHT-ACTIVATED DIODE SWITCH)			LIGHT TRIGGERED SWITCH
LIGHT ACTIVATED TRIODE SWITCH			LIGHT OR GATE PULSE TRIGGERED SWITCH
UNILATERAL DIODE SWITCH (SHOCKLEY DIODE)			ANODE TRIGGERED SWITCH
BILATERAL DIODE SWITCH (BiSWITCH)			J1 AND J2 TRIGGERED SWITCH FOR BILATERAL CONDUCTION
GATE CONTROLLED SWITCH (GTO, GTS, TRIGISTOR, TRANSWITCH)			GATE PULSE TRIGGERED ON-OFF SWITCH
NPN TRANSISTOR			LINEAR AMPLIFIER OR MAINTAINED TRIGGERED ON-OFF SWITCH
PNP TRANSISTOR			LINEAR AMPLIFIER OR MAINTAINED TRIGGERED ON-OFF SWITCH

TODAY'S TYPES of semiconductor devices—Fig. 5

terminal, or at the J_1 and J_2 terminals of the bilateral switch, which can conduct load current in either direction depending on which terminal is pulsed. Typical gate-triggering levels run from a few tenths to a hundred milliamperes at from one to two volts. Diode switches are triggered by a fast rise time pulse of anode voltage which momentarily exceeds the device's voltage-blocking capability.

When applied in a d-c circuit, the SCR or LAS (light-activated switch) must be turned off at the anode by an auxiliary circuit. The power transistor, of course, can be turned off at its base. The gate turn-off switch (GTO, GTS, Trigistor, Transwitch) can be triggered off at its gate within its limitations of turn-off gain, peak current that can be turned off at the gate, and available power ratings.[21, 22, 23] The present availability of GTO's only in ratings generally under 10 amperes limits their application to low-power circuits.

The SCR and the power transistor are perhaps the best known of the devices shown in Fig. 5. The power transistor, because of its available voltage and current ratings is operated in a switching mode today chiefly in smaller power control applications. The automobile radio inverter is an example. In its linear mode the power transistor has an important field of application, for example, as a series or shunt regulating element in regulated power supplies. The SCR's, on the other hand, are available at blocking voltage ratings around 1,000 volts and at current ratings of up to 300 amperes per cell. This makes operation directly from 120-v a-c, 240-v a-c, or 480-v a-c power practical as well as all the popular d-c voltages. A photo shows a line-up of typical SCR's on the market today.

The SCR's are found in power control applications above approximately 1 kilowatt and at voltages greater than about 100 volts. However the properties of the SCR and of its related devices often lead designers to use these devices even at lower power and voltage levels. In a-c circuits, for example, the inherent half-cycle response of the SCR to a change in control input signal is often an advantage. Many small power supplies and battery chargers use a-c regulation by small SCR's in the 1 to 10-ampere range.

The devices listed in Fig. 5 illustrate the flexibility inherent in the semiconductor art. Using the multilayer (alternate *p*-type and *n*-type) structures, various design parameters and geometries, as well as various process technologies, there has come about a fruitful interplay between the device designer and the circuit designer. For example, the product design need for a single device to control both half-cycles of the a-c supply led to the availability of bilateral semiconductor switches. A popular application of bilateral diode switches is in a domestic wall-lamp dimmer.[16]

In addition to new structures, much work is being done in optimizing device characteristics to meet particular needs.[17] Optimization of switching and triggering characteristics of SCR's for high-power and high-frequency inverters is an example of the work under way. In some equally important areas for certain volume applications not requiring extreme performance over wide temperature ranges, it is essential that the unit cost of the device be low. Following the introduction of the so-called automotive rectifier, SCR's have appeared on the market within the last year designed for volume consumer applications in portable power tools, lamp dimmers and appliances that stress economy in packaging but deliver excellent electrical performance. A photo shows this type of device.

An illustration of the versitality of the multilayer *pnpn* structure is the silicon controlled switch (SCS). It is a four terminal device having all four semiconductor layers accessible.[18] Depending on its characterization, it can be used as an extremely sensitive SCR, complementary SCR, *npn* silicon transistor, *pnp* silicon transistor, gate-turn-off switch (GTO, Trigistor, Transwitch), or as a unidirectional diode switch (Shockley diode).

The light-activated diodes and triodes give the circuit designer the possibility of optical control of power to directly control motors, solenoids or clutches, from, for example, direct card read-out without any intermediate power amplifiers.[19] The light activated devices, however, do not replace linear photoresistive transducers like cadmium-sulfide cells or photovoltaic elements that, in their own right, are useful control devices in the triggering control circuits of SCR power circuits.

APPLICATIONS

Static Switching—This has become an increasingly important area in the application of semiconductor power devices. Where a large number of switching operations are required, or where silent operation is essential,[20] SCR static contactors or relays of the type shown in Fig. 6 can be used. A small pilot device operating in a low-level control circuit actuates a free-running blocking oscillator that supplies a train of pulses to the gates of the two parallel-inverse connected SCR's in the power circuit.

Whichever SCR has positive anode voltage will trigger and thus conduct current to the load. As the a-c line voltage reverses, the other SCR will enter conduction while the previously conducting SCR will block reverse line voltage. When the pilot device is open, the blocking oscillator ceases to supply trigger pulses to the SCR's, whereupon the SCR's turn off. Thus, power is removed from the load. This type of switch lends itself to handling both resistive and inductive loads and currents up to 100 amperes or more.

Light Activated Devices—When used with SCR's, light-activated diodes, can give normally-open or normally-closed contact operation as illustrated in Fig. 7.[19] In the absence of light, the LAS blocks voltage. Thus the SCR in Fig. 7A is kept from triggering. However, in Fig. 7B resistor R supplies trigger current to the SCR as long as the LAS is blocking, or presents a high resistance between the gate and cathode of the SCR. When the LAS is irradiated, the SCR in Fig. 7A turns on, whereas in Fig. 7B the SCR will turn off because its trigger current is being diverted through the LAS. Diode D_1 protects the gate of the SCR from the large negative voltage when the anode is negative.

Phase Control—Alternating-current phase control is an important application of SCR's. Figure 8 shows a full-wave SCR phase-control circuit in which the output to the load is controlled by the setting of resistor R_1. The control circuit consists of a basic unijunction transistor (UJT) relaxation oscillator circuit.[24] The UJT switches into conduction between the emitter E and base B_1 terminal whenever its emitter voltage with respect to base 1 exceeds a specified fraction η (intrinsic standoff ratio) of its base 2 to base 1 (interbase) voltage.

By controlling the time constant R_1-C_1, the UJT may be triggered whenever the voltage across C_1 is equal to the zener diode D_5 supply voltage. When the UJT triggers, the charge on C_1 is available to turn on either SCR through the pulse transformer. Whichever SCR has positive anode voltage at the time the pulse appears will turn on.

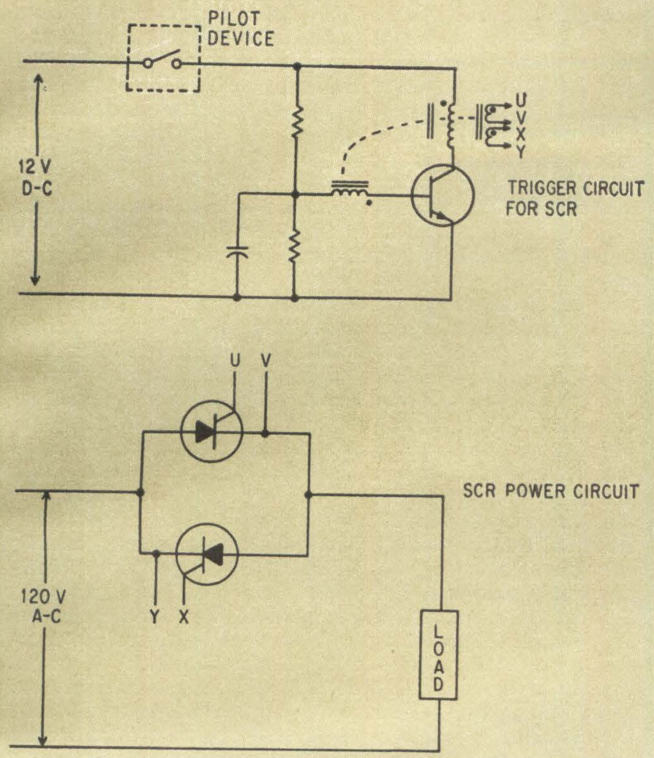
Diode bridge D_1 through D_4 supplies the control circuit with full-wave rectified power which is clipped by the zener diode D_5, with dropping resistor R_2, to a 20 to 30-volt level suitable for operating the UJT. At every zero of the applied line voltage (twice per cycle) the voltage across D_5 will dip. This collapses the interbase voltage of the UJT. Any residual charge on C_1 will trigger the UJT and discharge C_1.

As the line voltage swings positive, C_1 will charge anew through R_1 for another timing half-cycle. This reset action of C_1 ensures synchronization of the timing of the trigger circuit with the a-c supply.

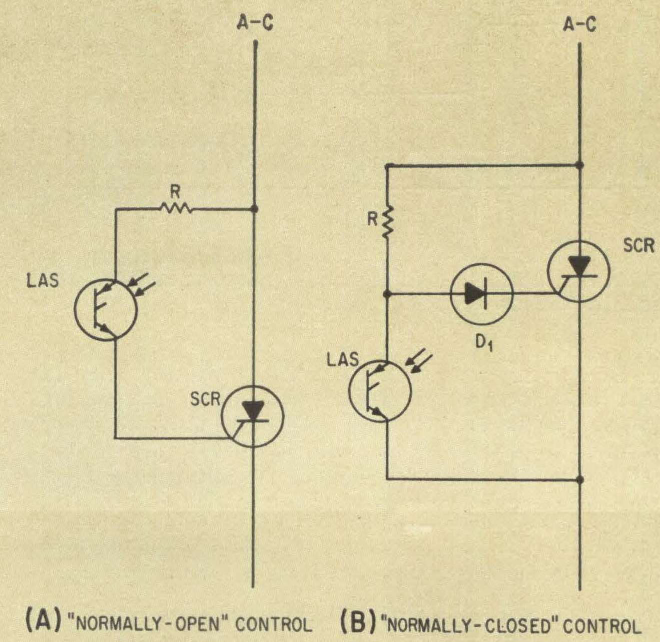
The circuit of Fig. 8 can be controlled manually by adjusting R_1. Thus a small potentiometer may control many kilowatts of output power.[25] Control from low-level signal sources may be effected by connecting a transistor between points A and E or E and B in Fig. 8. This control is appropriate in closed-loop control systems in which an error amplifier can drive the transistor ahead of the UJT SCR trigger circuit.[26]

The trigger circuit used for the SCR's in Fig. 8 is flexible and offers high performance. Phase control using SCR's can also be accomplished with simple R-C trigger circuits not involving the use of a trigger device at all.[27]

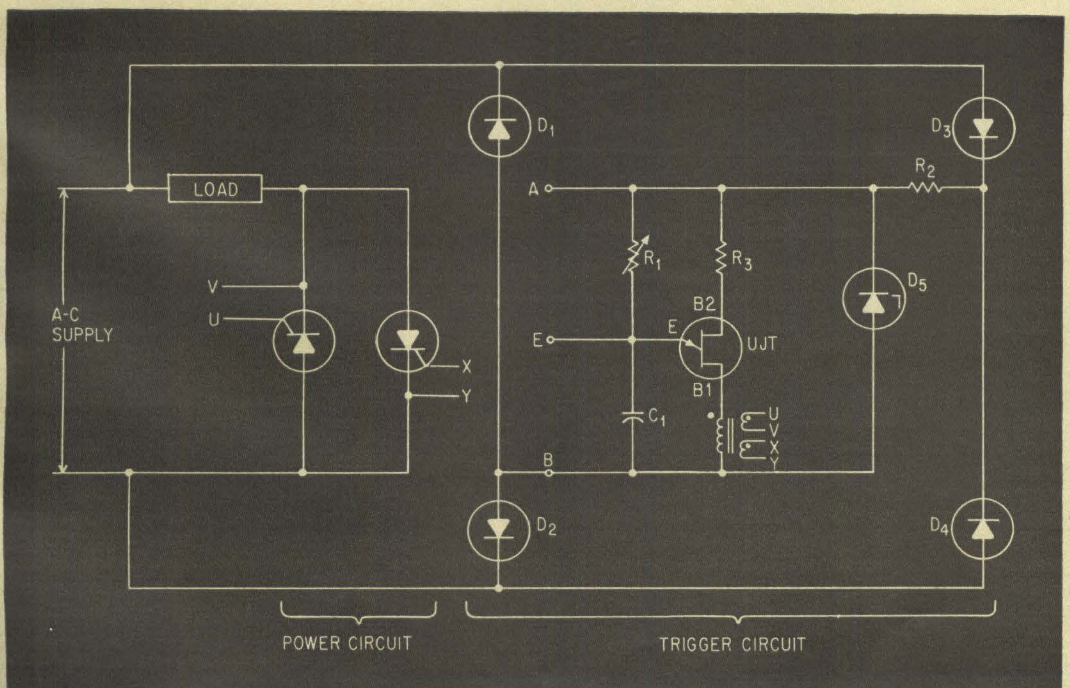
Phase-control operation, although widely used even before the advent of power semiconductors, creates a system problem that must be taken into account. The fast-switching action of



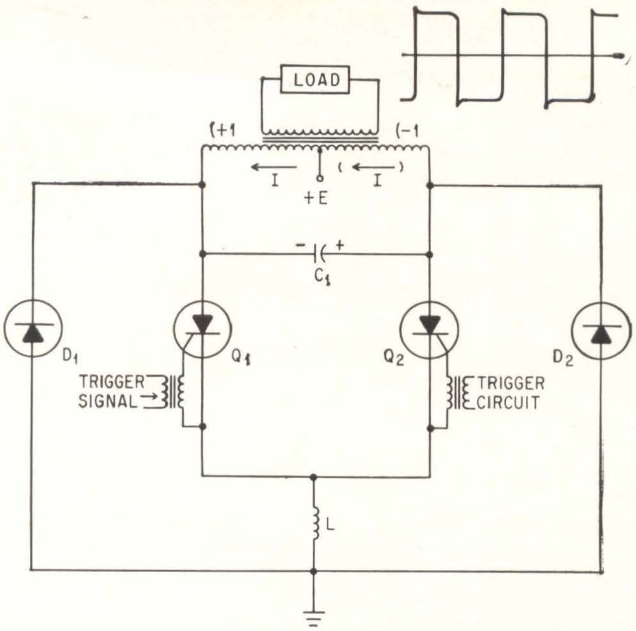
STATIC SWITCH for alternating current—Fig. 6



LIGHT ACTIVATED relay contacts: normally open (A) and normally closed (B)—Fig. 7



PHASE CONTROL circuit using SCR with unijunction transistor trigger—Fig. 8



PARALLEL INVERTER for reactive power uses SCR and feedback diodes—Fig. 9

the SCR or any fast power switch like a mercury relay or thyratron, leads to a rapid rate of rise of current in the supply system. Voltages are developed across the distributed inductance and capacitance of the supply line due to shock excitation. The voltages may interact with other control circuits and give rise to radio-frequency interference (RFI).[28, 29, 30] By suitable suppression techniques, [28] or by preventing shock excitation of the supply line in the first place, the problem is amenable to control.

Inverter Circuits—Sometimes a technology is envisioned but its development has to wait until a component becomes available. This is the case with the static inverter technology. The theory of the parallel inverter was worked out by Wagner[31, 32] and his associates in the 1930's. However, the limitations of tubes available in those days alternately to apply and interrupt the d-c power to the load, arrested the development of the art but not the interest in it.

Since the introduction of the SCR, great strides have been made in static-inverter technology in both the circuit and device areas. There are many types of inverter circuits. Figure 9 illustrates a basic improved[34] parallel inverter with feedback diodes. The resonant discharge of commutating capacitor C_1 through a small inductor L is at a frequency such that half of the period is sufficient to back bias the conducting SCR sufficiently long for it to turn off. This turn-off greatly reduces the size of L and C over the earlier parallel inverter. The addition of feedback diodes D_1 and D_2 allows variable power factor loads and open-circuit operation.

In the circuit of Fig. 9 one or the other feedback diode will supply any reactive current required while the conducting SCR is being turned off. Consider Q_1 conducting with current I flowing in the left-hand half of the transformer. Capacitor C_1 is charged by autotransformer action to twice the polarity of supply voltage E in the polarity indicated. When Q_2 is triggered, C_1 discharges resonantly through L and both cathodes of the SCR's see a positive pulse. This pulse back biases and turns both SCR's off. If the load is assumed inductive, transformed load current I will now flow in the other half of the transformer winding under the action of the counter voltage generated by the transformer in a polarity as indicated in parentheses.

Diode D_2 provides a low impedance path for the reactive load current being returned to the source. For successful operation, the transient source impedance should be low and capable of accepting as well as delivering power. Since the anode voltage of Q_2 is clamped to ground as long as diode D_2 is conducting, Q_2 must be retriggered when the reactive load current ceases to flow. Alternatively, a maintained trigger signal may be applied to the SCR's. By circuit operation, the inverter can maintain a square-wave output waveform over wide ranges of load in both magnitude and power factor.

Inverter circuits of the type illustrated in Fig. 9 with present-day SCR's perform well at power output frequencies up to several kilocycles. Beyond that point efficiency begins to drop off although for certain applications operation may still be practical. Inherently greater efficiency at higher output frequencies can be attained with the series resonant type of inverter.[34] This type of circuit, for example, allows efficient power inversion at 10 kc. However, it is best suited for relatively fixed loads, although auxiliary circuits can allow it to be open-circuited.

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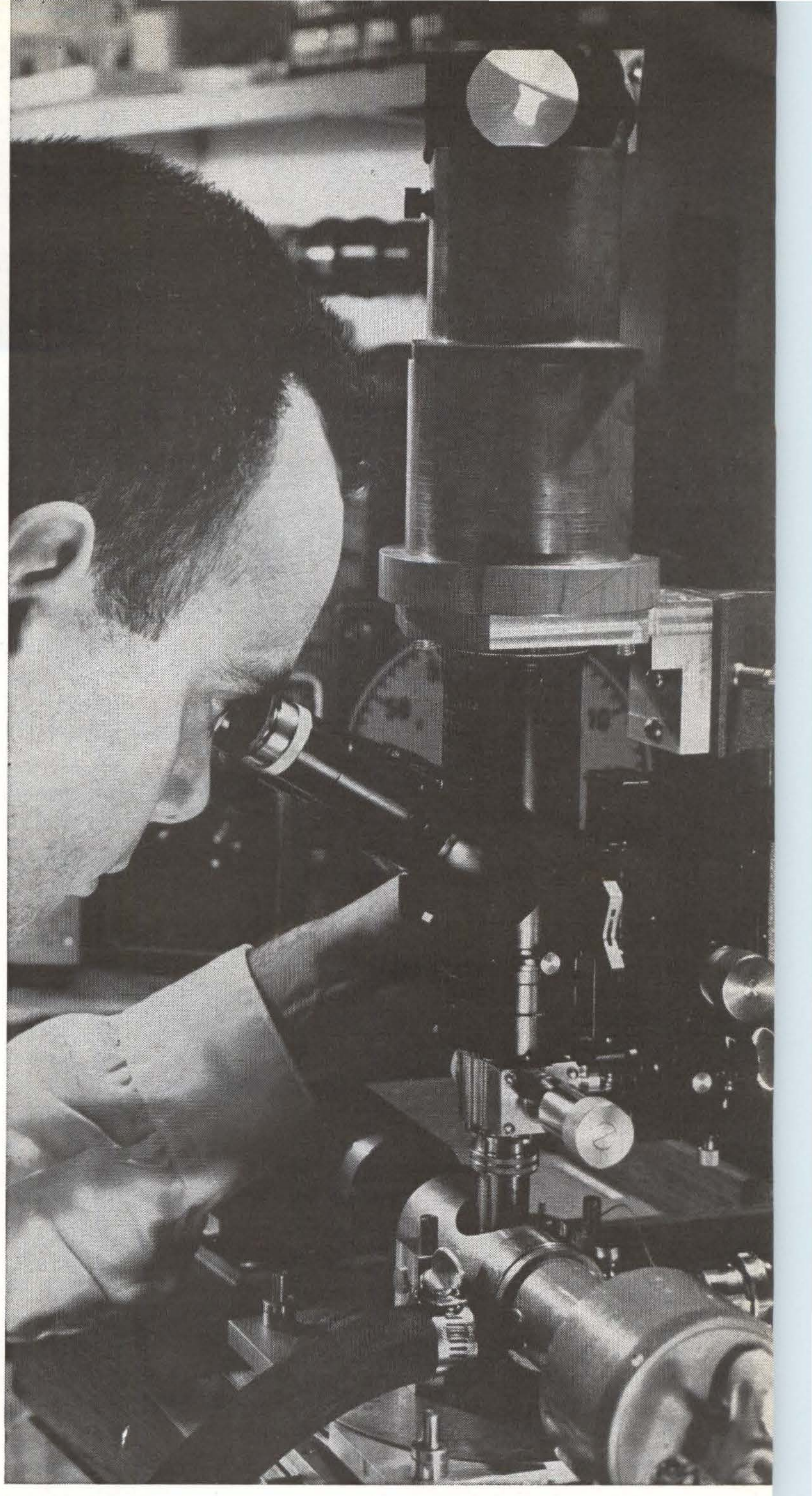

AUTHOR Nathan observes a GaAs injection laser through a combination microscope and snooperscope which converts infrared light from the device into visible light. The image can also be seen at the top of the picture, reflected in a mirror

FIRST OF TWO ARTICLES

INJECTION LASERS:

State of the Art

Here are the principles of operation and properties of a laser that skips the intermediate step of optical pumping and converts d-c power directly into coherent light

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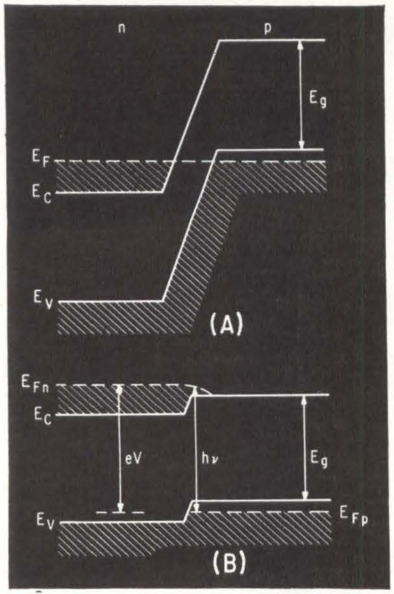
OBSERVATION of laser action in GaAs *p-n* junctions[1-3] was followed by a rapid development in the field of semiconductor junction lasers (injection lasers). These lasers offer the feature that they convert d-c electrical power directly into coherent light, whereas in the more conventional solid-state lasers it is necessary to go through the intermediate step of optical pumping. The injection lasers are thus more efficient and compact, and they offer attractive possibilities for internal modulation.

Operation — An optically pumped solid-state laser usually involves an isolated impurity ion embedded in a host lattice, typically an ionic crystal. The radiative transitions that give rise to the laser action are between discrete atomic states of the impurity. The primary role of the host lattice is to hold the ions in fixed positions at a high concentration. The interaction with the crystal field perturbs the energy levels but usually only by a small amount.

In contrast, in the *p-n* junction semiconductor laser, energy states characteristic of the host lattice are involved in the lasing transition. These states, because of the overlap of the wave functions of the electrons in the atoms, are not discrete energy states, but are merged into groups of continuous states or energy bands. The highest band filled with electrons is called the valence band and the next higher band is the conduction band. In a semiconductor these bands are separated by a region of energy, the energy gap E_g, in which there are no allowed states. Electrons can be excited



P-N JUNCTION, with shaded area indicating states filled with electrons: V = 0 (A); V > hν (B). E_c is the minimum energy in the conduction band, E_v the maximum energy in the valence band, E_F the Fermi energy, E_{Fn} and E_{Fp} the quasi-Fermi energies for electrons and holes respectively—Fig. 1

from the valence band to the conduction band, leaving a hole in the valence band. The radiative transitions that can give rise to stimulated emission are caused by the recombination of these electrons and holes.

As pointed out, the possibility of converting d-c electrical power directly into coherent light is an important feature of the semiconductor laser. Use of injection from a *p-n* junction is one way that this can be done with high efficiency in a semiconductor. The following is a brief description of the relevant properties of *p-n* junctions and how they can be used to obtain a population inversion, which is a necessary condition for stimulated emission and laser action.

An energy band diagram of a *p-n* junction at zero bias is shown in Fig. 1A. The junction shown is degenerate; that is, the impurity densities and hence the densities of electrons and holes are high enough so that the Fermi energy E_F is above the conduction band edge on *n*-side of the junction and below the valence band on the *p*-side. This also means that the impurity concentrations are high enough so that the levels introduced by the impurities are merged with the energy bands of the crystal. The application of a forward bias causes a reduction of the barrier voltage, and electrons are injected into the *p*-region where they can recombine directly with holes emitting radiation of energy $h\nu$. It can be seen in Fig. 1B that if the bias, V, is high enough ($eV > h\nu$) there will be a narrow region near the junction, which we shall call the active region, where there will be a population inversion; that is, a very high concentration of both electrons and holes. In this region photons will stimulate emission of more photons rather than being absorbed.

The thickness of the active region is expected to be, roughly, 10^{-4} cm. Therefore, light propagating in the plane of the junction is most strongly amplified. A resonant structure in the form of a rectangular parallelpiped shown in Fig. 2A is advantageous. Two of the sides perpendicular to the junction are made rough, and two are made optically flat and parallel by cleaving or polishing. This structure is similar to the conventional Fabry Perot laser structure. Oscillation will tend to occur in electromagnetic modes perpendicular to the flat surfaces.

The threshold condition for laser action is for the wave to make a complete traversal of the active region without attenuation; that is, the gain g in the active region must just make up for the end losses as well as the internal losses. Thus

$$R_1 R_2 \exp 2 (g - \alpha_i) l = 1 \quad (1)$$

e is the distance between the flat reflecting faces; α_i is the internal loss; R_1 and R_2 are the reflectivities of the reflecting ends. It can be shown[4] that the threshold current density is

$$j_t = \frac{8\pi e n_o^2 c d \Delta\lambda}{\eta \lambda^4}\left[\alpha_i + \frac{1}{l}\ln (R_1 R_2)^{-1/2}\right] \quad (2)$$

l is the electronic charge; c the velocity of light; λ the wavelength; n_o the index of refraction; η the internal quantum efficiency (number of photons created per recombining carrier); d the thickness of the active region; $\Delta\lambda$ the spontaneous emission line width. The magnitude of the gain usually encountered in the injection laser is about 100 cm^{-1}. Thus, in contrast to optically pumped solid-state lasers, they are small. Typical dimensions range from 0.1 to 1 millimeter.

Properties—In describing some of the experimental properties of the injection laser, GaAs will be used as a prototype since it has been the most thoroughly investigated to date. Gallium arsenide is a direct semiconductor with an energy gap of 1.51 eV at 77 deg K; GaAs *p-n* junctions are observed to emit radiation in a narrow line ≈ 0.02 eV (≈ 100 A) wide at 1.47 eV (≈ 8,400 A) with a high quantum efficiency. The transition that gives this emission at high impurity concentration, $n > 10^{18}$ cm^{-3}, appears to be essentially band-to-band. The lifetime is about 10^{-9} sec. At lower concentration an acceptor energy level separated from the valence band is involved in the transition.

To make a laser, a resonant structure such as shown in Fig. 2A must

Laser Properties—TABLE

Material	λ (μ)	Max. Operating Temp. (°K) (Pulsed)	Max. Output Power Pulsed (Watts)	Max. Operating Temp. (°K) (c-w)	Max. Output Power c-w (Watts)	Power Efficiency 77° K	Beam Angle
GaAs-P	0.65–0.84	77		*	*		
GaAs	0.84	300	10 W	77	1	50%	2° × 5°
InP	0.9	77		20		20%†	
Ga-InAs	0.84–3.1	1.9		*	*		
InAs	3.1	77		2			

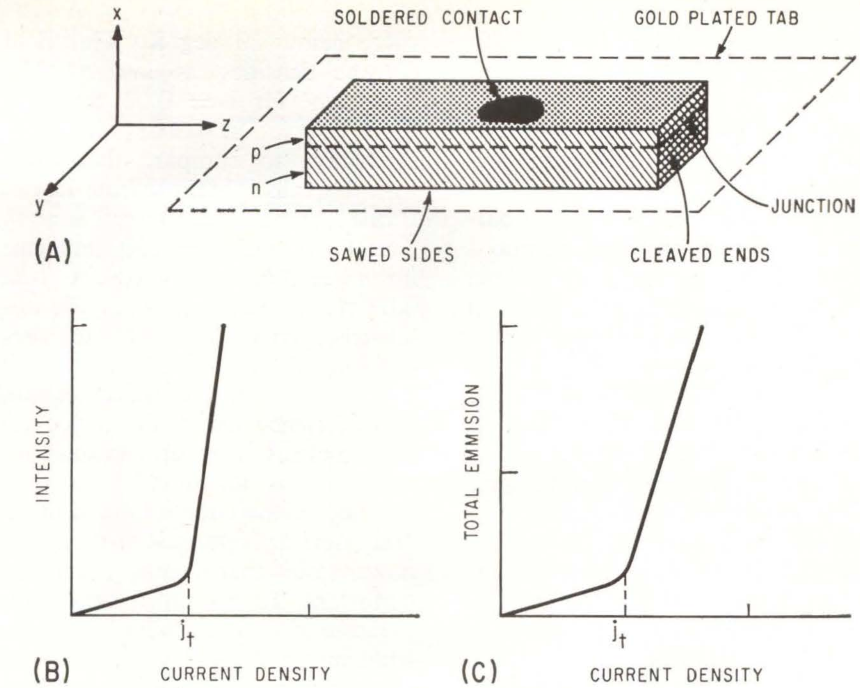
Blank spaces indicate data not available — * Alloy lasers have not been reported to operate cw — † Ref. 25

be fabricated. All the conditions on crystal growth and fabrication favorable to laser action are not known at the present time. However, it is known that at least two things are necessary: (1) flat uniform *p-n* junctions; (2) end faces optically flat and parallel to one another. The first condition tends to minimize the internal losses for modes propagating in the plane of the junction, and the second tends to minimize the end losses.

The *p-n* junctions for lasers usually are made by diffusing a *p*-type impurity such as zinc into an *n*-type wafer doped with Te. Other *n*- and *p*-type impurities can also be used. To obtain good junction planarity, the wafer is polished before diffusion and the diffusion time is kept short —typically a few hours. It is also possible to make lasers by starting with *p*-type substrates and diffusing in *n*-type impurities.[5] Other methods for fabricating junctions, such as epitaxial vapor or solution growth, may also prove useful.

To obtain optically flat ends, two techniques have been used—mechanical polishing and cleaving. No study has been made to determine which technique is superior. Cleaving offers the simplicity that the ends are exactly parallel, since GaAs cleaves along (110) crystallographic planes. However, polishing may give more easily reproducible surfaces.

Contacts are made to the *n* and *p*-regions and lasers are usually mounted on transistor headers. It is not necessary to silver the end faces since the reflectivity at normal incidence is about 0.3. If the radiation is observed as a function of current density in a direction perpendicular to the flat face (Z direction in Fig. 2A), the curve of Fig. 2B is obtained. The intensity is a slightly superlinear function of the current; then a sharp break is observed at threshold, j_t. It is at this current that lasing begins and light output becomes highly directional. If the radiation pattern is examined with a detector placed a large distance from the laser, beams are observed centered along the Z direction in Fig. 2A. In good units, only one beam is observed with widths of 2 deg in the plane of the junction and 5 deg in the perpendicular direction.[6-8] Often, however, much broader beams with side lobes are observed, especially, far above the threshold current density.



LASER structure (A); current density in the Z-direction versus intensity (B) and versus total light out of a laser (C)—Fig. 2

Quantum Efficiency—If the diode is placed in an optical integrating sphere so that all the light being emitted is measured,[9,10] a curve qualitatively similar to Fig. 2B is obtained as shown in Fig. 2C. The break is not as pronounced in Fig. 2C, but it corresponds to j_t in Fig. 2B. From these data, a determination can be made of the external quantum efficiency, η_{ext} (the number of photons escaping from the crystal per carrier crossing the junction). The η_{ext} is the ratio of the ordinate to the abscissa of Fig. 2C multiplied by the junction area and the electronic change, and divided by the photon energy. The η_{ext} differs from the quantum efficiency, η, which appears in Eq. 2 because of absorption of the emitted radiation in inactive regions of the crystal. The *p*-type region is especially highly absorbing.

The increase in η_{ext} at j_t is primarily accounted for by the fact that the radiation below j_t is emitted isotropically and thus is totally internally reflected and absorbed, while above threshold it tends to be emitted in the plane of the junction perpendicular to the cleaved end faces and thus most of it emerges from the crystal. Experimentally, above threshold, values of η_{ext} as high as 70 percent have been measured. The injection laser is one of the most efficient light sources available.

Another type of resonant structure has all four sides perpendicular to the junction optically flat. This structure has proved useful in studying the properties of injection lasers, but it usually lacks the directionality properties and increase in efficiency above threshold just discussed for the Fabry Perot structure.

An important property of lasers is the wavelength dependence of their output radiation. In the injection laser, the spontaneous emission line width $\Delta\lambda$ is determined by the width in energy of the occupied states in the conduction band and of the unoccupied states in the valence band.

For the Fabry Perot structure, axial modes propagating perpendicular to the optically flat surfaces (Z-direction, Fig. 2A) and having an integral number of half wavelengths between the faces will be favored. The condition of the wavelength of these modes is

$$m\lambda = 2nl \qquad (3)$$

where m = mode number, λ = wavelength, n = the index of refraction of the material, l = the cavity length. For a typical laser length l = 0.03 cm, the separation between adjacent modes $\delta\lambda \approx 2.3$ A. This is much less than $\Delta\lambda \approx 100$ A, the spontaneous emission line width, so that many modes can be excited.

Spectrum—The spectrum observed along the axis of a good laser operating at 2 deg K is shown in Fig. 3 (top). As can be seen at low current (2 ma) the spectral output is broad. Even at this current the emission is not a smooth function of wavelength, but there are oscillations in the spectrum due to the interference of the spontaneous emission from multiple reflections between the optically flat ends of the laser.[11] At higher current some of the oscillation became very pronounced as stimulated emission becomes important for some of the modes defined by Eq. 3. At still higher current (40 ma) threshold is reached for one of these modes (see Fig. 3, bottom). This mode increases in intensity rapidly for a small increase in current, and the output is almost completely in this one mode. If the current is increased still further, other modes increase to comparable intensity.

Threshold—The threshold as a function of temperature can be determined by any of the measurements just discussed, for instance, by measuring the light output along the Z-axis as a function of current. The result[12] is that for temperatures greater than about 60 deg K, j_t is proportional to approximately the third power of the temperature. This increase of j_t with temperature is primarily caused by the fact that the semiconductor is not completely degenerate above $T = 0$ deg K so that stimulated absorption as well as emission can occur at the lasing frequency. The observed T^3 dependence can be fit fairly well on this basis.[13] At low temperatures the dependence becomes less rapid and the threshold approaches a constant value below 20 deg K. Threshold current densities as low as 200 amps/cm^2 for $l = 0.03$ cm have been observed at 4.2 deg. K. It is instructive to compare this value with the value obtained from Eq. 2. If one assumes $d = 10^{-4}$ cm, $a_i = 0$, $\eta = 1$, we find $j_t = 130$ amp/cm^2 for $n_o = 3.6$, $\Delta\lambda - 100$ A, $l = 0.03$ cm. $R_1 = R_2 = 0.32$. The observed current densities are very close to the theoretical value for no internal loss and 100 percent quantum efficiency unless the active region thickness is much less than 1μ, which seems unlikely.

Under many circumstances, injection lasers are operated at such high power levels that heating effects are important. To prevent a rapid temperature rise that would cause the stimulated emission to turn off and even burn up the diode, it is often necessary to operate the diode with short pulses. This is especially true at high temperatures (above 77 deg K). Current pulses of several amperes with durations less than 100 nsec must sometimes be used. Such pulses can be obtained with commercial equipment, such as mercury relay pulse generators. Peak pulsed output power higher than 100 watts can be obtained at 77 deg K.[3]

Gallium arsenide injection lasers have been run continuously at 77 deg K and below.[12,14] It is important to ensure that such properties as crystalline perfection, junction planarity, and perfection of the reflecting ends are optimum.[15] Application of reflective coatings to the ends of the laser helps c-w operation by reducing the threshold. For this purpose silver is usually evaporated over a silicon oxide evaporated layer so as not to electrically short the junction. At 2 deg K, c-w output power in the tens of milliwatt range can be obtained without any special fabrication techniques. To obtain higher power, special measures are necessary to get the heat out of the laser. The diode must be placed in good thermal contact with a large mass of material of high thermal conductivity. This can be done by making broad-area soldered contacts to a material that can also serve as electrical connections. It is important to match the thermal expansion of the GaAs. Tungsten has been used for this purpose, and output powers of one watt have been obtained at 20 deg K.[16]

It would be useful, of course, to extend c-w operation to higher temperatures. With improvement in fabrication techniques some progress will undoubtedly be made in this direction. However, because of T^3 dependence of j_t, it appears likely that GaAs or similar injection lasers can operate at room temperature only on a pulsed basis. The main prospect for room-temperature c-w operation appears to be in going to other materials in which sharp emission lines are observed at high temperatures. Recently an observation attributed to laser action was made of a sharp emission line and c-w interference effects at room temperature from SiC *p-n* junctions.[17] However, evidence for laser action is inconclusive.[18]

Other Lasers:—In addition to GaAs, laser action has been observed Ga(As-P) alloys,[19] InAs,[20] InP,[21] (Ga-In)As alloys[22] and InSb.[23, 24] These materials are similar to GaAs, and the properties of their lasers are similar to GaAs. They offer different operating wavelengths, which may be important for some applications. The table summarizes some of the important properties of these lasers. The fact that GaAs appears superior to the other materials in some respects is undoubtedly because most of the work

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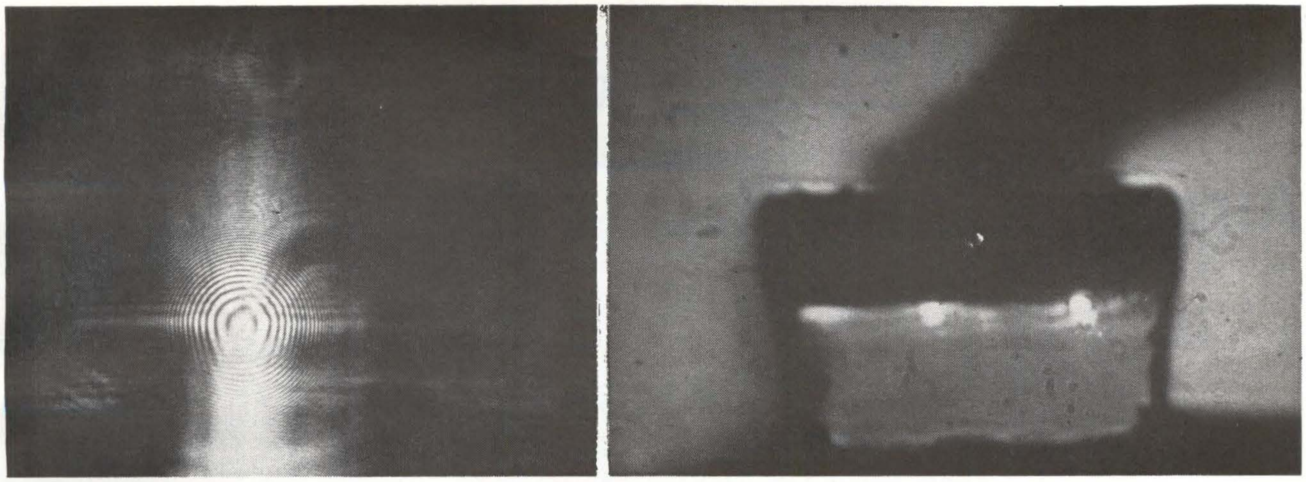


RING SYSTEM (left) produced by interference between infrared light beams from opposite ends of a GaAs laser. Occurrence of the rings demonstrates the fixed phase relationship between the coherent light waves emitted from opposite ends of the diode. Also visible are shadows of the support structure and leads. Coherent emission (right) from a GaAs diode, where the junction between p and n regions is the line where the dark (p-type) and light (n-type) regions meet. The black area at the bottom is the diode mount; the diagonal shadow is the electrical contact. Light is emitted only in a region near the junction, and appears more strongly in spots along the junction

thus far has been done in this material. Except for some inherent difficulties in making the ternary alloys, the other materials are expected to be as good for lasers as GaAs. There is reason to believe that this wavelength range can be extended to higher energies by using 2-6 compounds. It is probable that other methods for injection, such as tunneling through insulating films, will be useful.

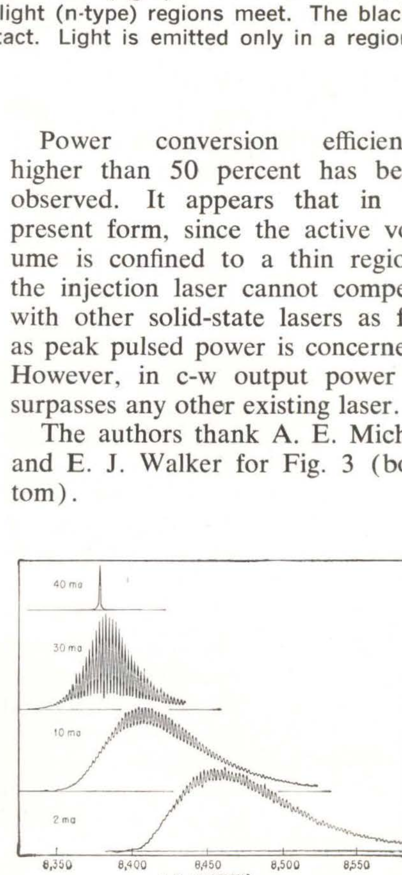
An attractive feature of injection lasers is the ease with which they can be modulated. Amplitude modulation at 200 Mc has been obtained by modulating the current of the incoherent light-emitting diodes.[25] Amplitude modulation can undoubtedly be obtained at very much higher frequencies with coherent diodes. The problem at present is not with the laser, but in getting a detector with a fast enough response.

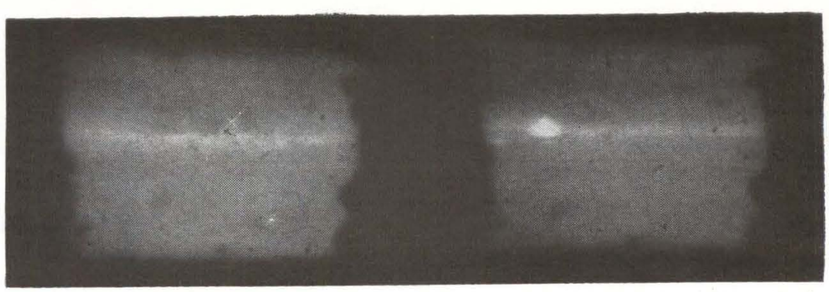
The injection laser is a highly monochromatic source. Interferometric measurements[26] in GaAs lasers have shown the line width of individual modes to be less than 0.008 A at 8,400 A ($\approx$ 300 Mc). This measurement is instrument-limited and theory indicates the line to be much narrower. It is possible to vary the wavelength of the laser; this can be done by the application of a magnetic field.[27, 28] This causes both the individual modes to shift wavelength and also the output to shift from one mode to another. Another method for varying the wavelength is the application of stress. Stresses varying at microwave frequencies can be obtained with ultrasonic techniques, and so this method of modulation offers attractive possibilities.

In summary, the injection laser has several potentially useful properties. It is a very efficient source of light and is very easy to fabricate into a laser. The diodes can be modulated at high frequencies, so they should be useful in the communication field.

Power conversion efficiency higher than 50 percent has been observed. It appears that in its present form, since the active volume is confined to a thin region, the injection laser cannot compete with other solid-state lasers as far as peak pulsed power is concerned. However, in c-w output power it surpasses any other existing laser.

The authors thank A. E. Michel and E. J. Walker for Fig. 3 (bottom).





SPECTRAL characteristics of a laser at 2 deg K (top); the recorder gain is reduced between currents. Laser photographs taken through a microscope with infrared-sensitive film: below the threshold (bottom left), the light emerges uniformly from a narrow region near the p-n junction; above threshold (bottom right), the simulated emission appears to come from small spots—Fig. 3

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F-M Feedback Stabilizes Airborne Solid-State VHF Transponder

Use of semiconductors reduces circuit complexity, power consumption, size and weight. Besides improved packaging, this 6-lb unit affords phase stability within ± 2.5 degrees

By **J. C. WRIGHT,** Electronics Engineer, and **W. L. BLAIR,** Project Manager, Cubic Corp., San Diego, Calif.

A TRANSPONDER is the vehicle-borne portion of a DME (Distance Measuring Equipment) link. It receives and demodulates an r-f carrier, that is f-m modulated by several data tones, and retransmits these tones on an offset carrier-frequency with a highly stable phase delay.

The ground-station receives the retransmitted signal and compares the phase of the received data tones with that of the transmitted tones. The phase difference is then converted to distance. Distances greater than ½ wavelength of the data tone result in ambiguities which are resolved, as range increases, by using longer data-tone wavelengths. In this system, four data tones are used to achieve long range.

Operation—The receiver input (Fig. 1A) is a four-section preselector filter to reject off-frequency interfering signals at the input to the r-f amplifier. The r-f amplifier uses low-noise transistors to improve receiver sensitivity. The r-f filter-amplifier combination isolates the mixer from the transmitter output. The receiver is a single-conversion design, which has two advantages. A single-conversion receiver has no second mixer (a source of spurious responses); and, less complexity increases reliability.

The use of transistors and varactors in the transmitter section also has several benefits. Total power consumed by the transmitter is reduced and less heat is generated, allowing the entire transponder to be mounted in a single package, simplifying mounting and heat dissipation problems. Also, there is no time delay in transmitter turn on.

F-M Feedback-Loop—Data tone phase stability is insured by an f-m feedback-loop. The block diagram shows how the transmitter signal is used as the local-oscillator signal to the mixer. The i-f is the difference between the received and transmitted signals. Since the detected data tones have been remodulated onto the transmitter signal, they either add to or subtract from the modulation (index) of the received signal in the mixer. If the polarity has been chosen for positive feedback, the whole receiver-transmitter loop will oscillate at a data frequency. However, when the loop is adjusted for negative feedback, as is normally the case, a high degree of phase stability is achieved ($< \pm 2.5$ degrees for all conditions).

All circuits are in the f-m feedback-loop except the r-f preselector filter, and r-f amplifier. The open-loop elements are broadband for minimum phase errors. Feedback-loop gain is 30-db for reduction of phase errors in the other circuits.

The transponder is divided into eight rfi-sealed modules to minimize cross-talk and maximize interchangeability.

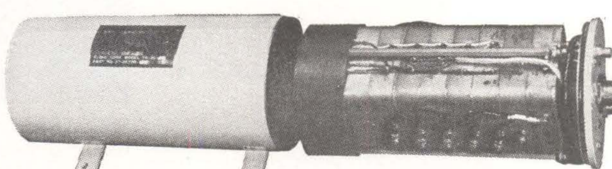
The design (extensive shielding and filtering isolate input from output) is stable, independent of termination at input or output jacks. The transponder can be used with one- or two-antenna systems with equal performance, by adding an external diplexer for single-antenna operation.

The 4-section preselector filter (Fig. 2A) reduces unwanted r-f responses to image and spurious frequencies. In addition, it rejects the transmit frequency by 60-db. This rejection limits local oscillator signal to its intended path to the mixer. The bandwidth is 10-Mc to assure small phase error.

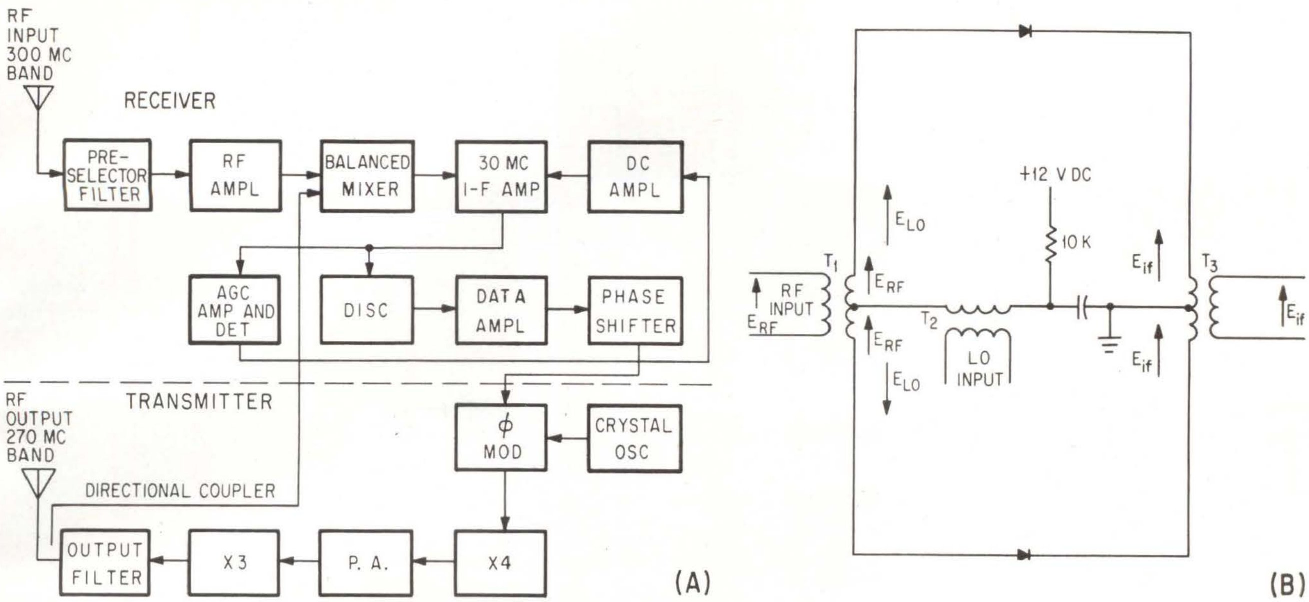
The two-stage r-f amplifier uses low-noise transistors to achieve maximum receiver sensitivity. In addition to assuring a low noise figure, this amplifier further isolates the mixer from the unwanted transmitter signal. The amplifier has a 4-db noise figure and 15-db gain. The overall receiver noise figure is

$$NF = NF_{r\text{-}f} + \frac{NF_{\text{mixer}} + 1}{G_{r\text{-}f}} + \text{preselector loss}$$

$$NF = 2.5 + \frac{7.3}{15.9} + 1.6 = 4 = 6\text{-db}$$



AIRBORNE portion of DME link is 9 by 4.5 inches, divided into 8 rfi-sealed modules; power output 2-watts



PRESELECTOR and r-f amplifier are only circuits not in f-m feedback loop (A) of transponder. Balanced mixer (B) eliminates the effects of the local-oscillator noise sidebands by cancellation in output—Fig. 1

Balanced Mixer—The balanced mixer eliminates the effect of local-oscillator noise sidebands. This mixer employs a 3-db hybrid junction and two crystals which permit the desired i-f output signal to add, while the a-m local oscillator noise components cancel by subtraction. In the mixer (Fig. 1B), the local-oscillator signal divides equally in the hybrid and arrives at the crystal mixers in-phase. The input signal, isolated from the local-oscillator, also divides but arrives at the two crystals out of phase. The output to the i-f is push-pull and the crystals are reverse balanced. In the mixer output, therefore, the local-oscillator noise cancels.

Figure 1B shows E_{LO} split across the secondary of T_1. If T_1 is balanced, E_{LO} cancels in the primary of T_1 thus isolating the r-f signal from the local-oscillator signal. In this application, both of these properties are useful in maintaining a stable f-m feedback-loop. The output of the mixer is fed, by a 50-ohm cable, to the agc adjusted i-f amplifier. This amplifier amplifies weak i-f signals to usable levels, and also maintains a constant i-f signal amplitude due to its agc.

Automatic gain control is applied to all three stages in a reverse-mode to achieve an essentially constant output over a range of 70-db. The detector module contains an i-f stage followed by an f-m discriminator. In addition, the narrow-band amplifier, detector, and d-c amplifier are agc adjusted.

The i-f stage (Fig. 1A) further amplifies the signal from the i-f amplifier and feeds this f-m signal to the discriminator stage where the data tones are detected.

ARE YOU THERE? WHERE?

Pinpoint navigation, whether continental or intercontinental, requires accurate DME (distance measuring equipment) transponders. Here are the details on a new unit, produced under government contract, which uses an f-m feedback-loop for high stability under all environments, has a range in excess of 600-miles and a range error of ± 2-meters

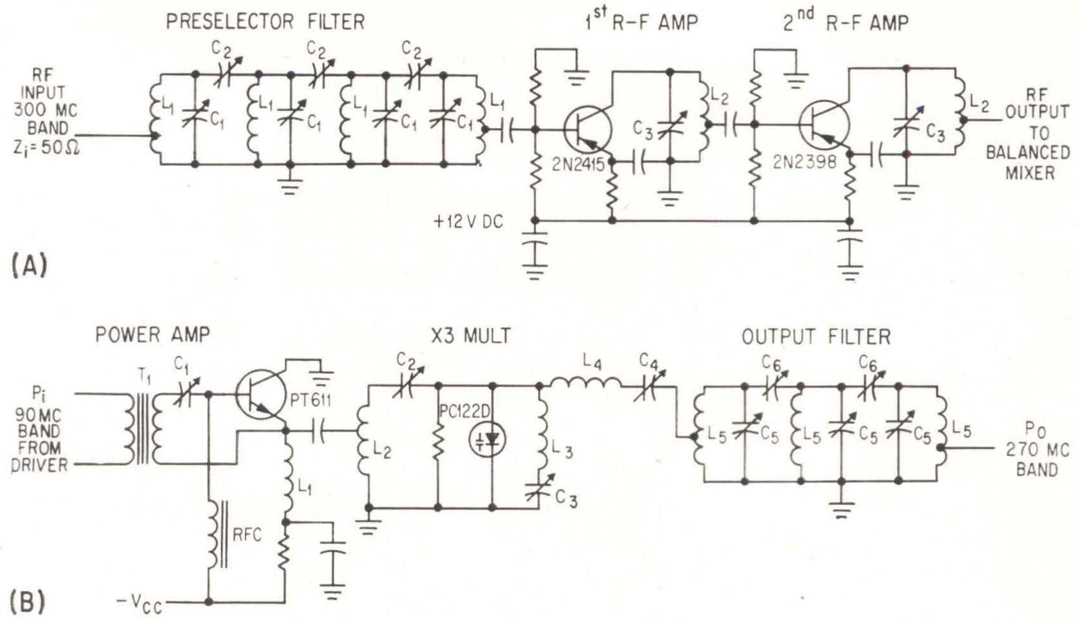
The tones are then fed through a 50-ohm cable to the data amplifier. A portion of the i-f stage output is also fed to a high-gain narrow-band amplifier to generate the agc signal. This amplifier is narrow-band, compared to the discriminator, so agc threshold occurs before data threshold. The output of the narrow-band amplifier provides the control voltage for the first three i-f stages. Bandwidth of the agc-loop is 3-kc to wipe-off low-frequency amplitude variations in the received signal.

Data Amplifier—The data amplifier performs several functions that are of prime importance.

The detected data tones are fed into the data amplifier through a gain-control which adjusts the f-m feedback-loop gain. The tones are then passed through a narrow-band crystal filter which shapes the waveform and wipes-off much of the noise output of the detector. These clean data tones are amplified and fed to a phase shifter which adjusts the feedback phase to 180 degrees. The output of the phase shifter is isolated by an emitter follower which feeds the transmitter phase-modulator. The action of the data amplifier filter reduces the post-detection bandwidth to 12-kc. The phase- and gain-controls permit screwdriver adjustment of the f-m feedback-loop parameters, for optimum performance.

The exciter module contains a crystal oscillator, phase-modulator, and ×4 multiplier. The output of the crystal oscillator is phase modulated by the output of the data amplifier. This signal is multiplied and amplified to give an output power of 20 mw, which drives the transmitter power amplifier.

The power amplifier (Fig. 2B) raises the 20 mw of exciter power to 5 watts, to drive the output tripler. The power amplifier uses three stages; the first is operating class A; the second and third are class C. Transformer coupling into the power amplifier permits drive to the base with respect to the emitter in what is really a conventional common emitter circuit. However, the collector may in this way be connected both



SIMPLIFIED schematics of the preselector filter and r-f amplifier (A); and the power amplifier, varactor multiplier, and output filter (B)—Fig. 2

electrically and mechanically to the chassis for optimum heat flow to the heatsink. Overall performance shows a large improvement over vacuum-tube models in both efficiency and reliability.

Varactor Tripler—The tripler (Fig. 2B) uses a combination of fixed-and self-bias, on a varactor diode operating in the shunt configuration, to achieve maximum efficiency and temperature stability. Components L_2, C_2 and the varactor are resonated at the fundamental, while L_3, C_3 and the varactor idle the second harmonic current. The second harmonic and the fundamental mix in the varactor to generate the third harmonic, which is coupled through the third harmonic tuned circuit, composed of L_4 and C_4, to the three-section output filter, which reduces harmonic content of the output signal. The tripler and output filter have an efficiency in excess of 75 percent. Overall efficiency of the module is approximately 46 percent to give an output power of 2.3 watts.

The local-oscillator signal for the receiver is derived from the output of the 3-section filter, thru a directional coupler which assures only forward power is used for the local-oscillator signal. Power reflected from the antenna is attenuated by the coupler. This coupler further reduces input-to-output inter-actions and helps make the transponder stable under any antenna mismatch conditions.

The power supply is a conventional d-c to d-c converter with outputs of +12 v d-c and —30 v d-c for inputs of 27-37 v d-c. The converter performs two functions. The first is to regulate the transmitter and receiver supply voltages, reducing phase errors. The second is to provide a floating input for operation from either a common positive or common negative electrical system. Radio-frequency interference filtering is included to prevent conducted interference on the primary input leads.

Reliability—During prototype development circuit schematics and parts lists were reviewed for stress analysis and reliability prediction. Failure rate for the transponder was predicted to be 2.83 percent/1,000 hours (0.0283 failure per 1,000 hr), an MTBF of approximately 35,000 hours.

Reliability of the transponder, for a total countdown period of 10 hr, results in a success probability of 99.97 percent. Under stringent assumptions, probability of mission success should be 99.90 percent.

Performance—The transponder underwent extensive testing to determine operational limits as well as compliance with required specifications. Vibration, sine and random, and shock tests have shown the design meets required specs.

Major sources of error due to temperature are the data filter crystals, which drift in center-frequency as a function of temperature, causing phase errors. The 30-db f-m feedback-loop reduces these errors and keeps range errors due to temperature at less than ±2 meters from —10 to +60 C. The transmitter power output variation is less than 1-db over this same range, and transmitted frequency drift is ±2,600-cps maximum.

With a fixed modulation input to the receiver, the transmitter output index is constant from —90 to —28 dbm input power: transmitted data is still usable at —100 dbm. The system range error is within ±2 meters from —102 dbm to —28 dbm. The range error is within ±0.5 meter from —95 dbm to —50 dbm.

Performance of the transponder is uneffected by signals up to 0-dbm at transmit and image frequencies. At one-half and one-third, the received frequency spurious responses were noted. Since the power required to generate these responses is 60-db or greater above threshold, they cause no problem to normal operation.

The power supply and transmitter sections have been tested to destruction in the Triga reactor at General Atomic. The power supply failed at approximately 1×10^{11} NVT while the transmitter power-amplifier failed at 1×10^{13} NVT. The transmitter exciter section did not fail.

Circuit With a Twist: THE CASCODE FOLLOWER

Designed for driving very low impedance loads this novel circuit also improves stability over the usual cathode follower

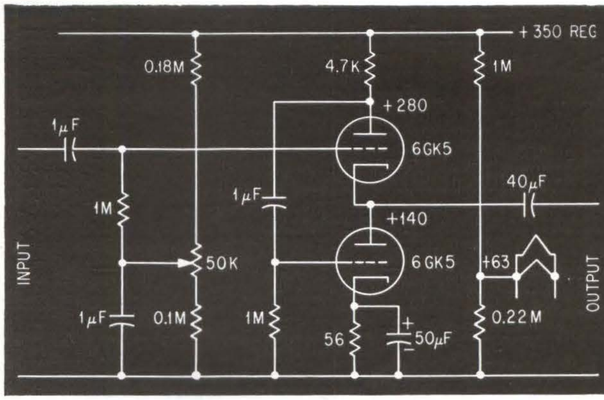
By **R. W. JOHNSON,** Consulting Engineer, Anaheim, Calif.

VARIOUS means have been described for improving linearity, gain stability, and other characteristics in cathode followers by employing a cascode arrangement. In these, an additional tube section serves as the cathode load, or regulates the current to the cathode follower. In all published circuits, however, the grid of the extra tube section is held at some constant potential. An analysis and some limited tests have been performed on what might be termed the cascode follower in which the grid of the extra tube is not held constant, but is driven out of phase with the remaining tube section.

The results are interesting, and show that the cascode follower has a gain about 5 percent higher and an output impedance about $1/\mu$ times the corresponding values for the same two tubes connected in parallel as a cathode follower. Measured output impedances in the order of 2 ohms and voltage gains of 0.98 have been obtained using high-transconductance triodes.

APPLICATION NOTE

The cascode follower will find application in driving low impedance loads. Here it drives the input resistor of an operational amplifier in which the resistor is varied and stable calibration is necessary. A transistor version of the circuit should be possible



BASIC cascode follower circuit as used in practice—Fig. 1

The circuit tested is shown in Fig. 1. It delivers 20 volts peak-to-peak to a load resistance of 1,000 ohms down to low frequencies in the order of 5 cps. Agreement between measured and calculated values is good. The output impedance is less than 2 ohms and the voltage gain is 0.98.

Analysis—Figure 2 shows the circuit for analysis, stripped of biasing and coupling arrangements. Applying the familiar triode relationship for linear operation, the following three equations are obtained

$$i = \frac{\mu_1}{R_{P1}}\left(e_s - e_0 + \frac{e_1}{\mu_1}\right) \qquad (1)$$

$$\left(i - \frac{e_0}{R}\right) = \frac{\mu_2}{R_{P2}}\left(-\,i\,R_1 + \frac{e_0}{\mu_2}\right) \qquad (2)$$

$$e_1 + e_0 + i\,R_1 = 0 \qquad (3)$$

Rearranging, the determinantal coefficients are

$$\left.\begin{array}{cccc} i_p & e_0 & e_1 & \\ \dfrac{R_{p1}}{\mu_1} & 1 & -\dfrac{1}{\mu_1} & = e_s \\ R_1 + \dfrac{R_{p2}}{\mu_2} & -\dfrac{1}{\mu_2}\left(1 + \dfrac{R_{p2}}{R}\right) & 0 & = 0 \\ R_1 & 1 & 1 & = 0 \end{array}\right\} \qquad (4)$$

For which the determinant is

$$-D = \left(\frac{R_{p2}}{\mu_2} + R_1\right)\left(\frac{1+\mu_1}{\mu_1}\right) + \left(1 + \frac{R_{p2}}{R}\right)\frac{1}{\mu_1\mu_2}\left(R_{p1} + R_1\right) \qquad (5)$$

And for e_o

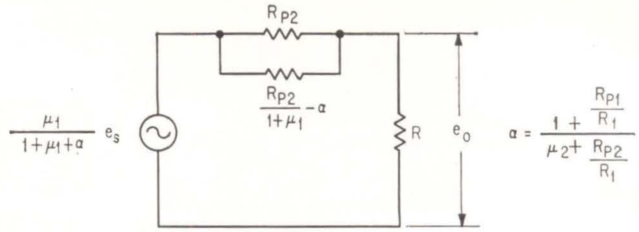
$$-D_{e0} = e_s\left(\frac{R_{p2}}{\mu_2} + R_1\right), \quad e_0 = \frac{D_{e0}}{D} \qquad (6)$$

The voltage gain is then

$$A_v = \frac{\mu_1}{1+\mu_1}\;\frac{1}{1 + \dfrac{\left(1 + \dfrac{R_{p2}}{R}\right)(R_{p1} + R_1)}{(R_{p2} + \mu_2 R_1)\,(1 + \mu_1)}}$$

which after some rearranging to place in equivalent circuit form becomes

$$A_v = \frac{\mu_1}{1+\mu_1+\alpha}\,\frac{R}{R+\left(\dfrac{1}{R_{p2}}+\dfrac{1}{\alpha\cdot\dfrac{R_{p2}}{1+\mu_1}}\right)^{-1}} \quad \text{where } \alpha = \frac{1+\dfrac{R_{p1}}{R_1}}{\mu_2+\dfrac{R_{p2}}{R_1}} \qquad (7)$$



EQUIVALENT cascode follower circuit described in text —Fig. 3

The equivalent circuit is shown in Fig. 3. Where $\mu_2 >> R_{p2}/R_1$ and R_{p1}/R_1 is around a practicable value of 1 (considering d-c potentials), the equivalent circuit shows that the output impedance is multiplied by about $2/\mu_2$, which is the approximate value of α for practical situations. Consider the pair of 6GK5 tubes shown in Fig. 1. For operation at a plate-cathode voltage of 135 volts and current of 15 ma, this tube has $\mu = 80$, $g_m = 18{,}200$ μmhos and $R_p = 4{,}400$ ohms. If both tubes are operated at the same plate voltages and for $R_1 = 4.7$K as in Fig. 1, then

$$\alpha = \frac{1+\dfrac{4.4}{4.7}}{80+\dfrac{4.4}{4.7}} = \frac{1.936}{80.936} = 0.024$$

$$R_0 = \frac{4{,}400}{81} \times 0.024 = 1.3 \text{ ohms}$$

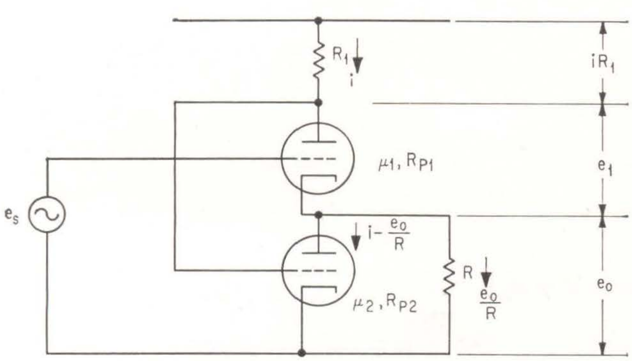
$$A_v = \frac{80}{81.024} = 0.988 \text{ (for } R \gg 1.3 \text{ ohms)}$$

The same pair of tubes in parallel as a conventional cathode follower would have an output impedance of simply $2{,}200/81 = 27.2$ ohms, operating at the same quiescent point.

Low Impedance—The cascode follower is not unlike a two-stage amplifier with output fed back to the input cathode at a unity feedback factor and it is well established that a lower output impedance can be obtained by this arrangement than by a conventional cathode follower connection, with comparable stability. Its operation may be visualized by noting that the voltage across the upper tube is 180 deg out of phase with that across the lower tube and nearly equal to it. The operation is similar to a potentiometer in which the upper portion is the upper tube and the lower portion is the lower tube, with the output terminal swinging between the two extremes.

As with any cathode follower, the operating point must be chosen to furnish the required peak current to whatever load is used. Thus the direct current through the tubes must be greater than the peak current to be passed to the load, to maintain linear operation. It is useful to know the a-c grid voltage applied to the lower tube; that is, iR_1. This value can be found from the matrix of Eq. 4 to be

$$|e_{o2}| = i_p R_1 = \frac{1+\dfrac{R_{p2}}{R}}{\mu_2+\dfrac{R_{p2}}{R_1}}\, e_0 \qquad (8)$$



SIMPLIFIED circuit configuration used for analysis—Fig. 2

From Eq. 8 it is seen that the grid excursion on the lower tube increases as the load R decreases. For the example cited earlier and shown in Fig. 1, the a-c grid voltage given by Eq. 8 works out to be 0.067_{e0}. The grid bias of the lower tube is about 0.8 volt, so it is apparent that operation is still linear for a peak output swing of 10 volts in either direction. If the load impedance is reduced, then the signal must be reduced.

The effect of omitting the bypass capacitor from the bias resistor in the lower tube has been investigated. Removal raises the output impedance by about $\alpha\ R_k$, which is nearly $2R_k/\mu$ in most practical situations. In the circuit of Fig. 1, omitting the bypass capacitor had no measurable effect. The error in measurement of the very low output impedance was comparable to the change owing to the bypass. Omitting the bypass capacitor in Fig. 1 should raise the output impedance by about 1.35 ohms.

Biasing—Various biasing connections can be used with the cascode follower. That shown in Fig. 1 was convenient in the test situation. The lower tube can be returned to a negative supply to keep the d-c level of the output terminal at ground potential, with the heaters biased negatively. The grid resistor for the upper tube can be returned to the output terminal, with biasing added between this point and the upper cathode. In this particular case, the input impedance is raised just as in the conventional cathode follower, except that now the gain is much closer to unity. As a result, the effective input impedance with this connection is very closely $(1+\mu)$ times the grid resistor.

In setting bias levels, it is advisable to provide some adjustment for bias on the upper tube to have the plate-cathode potentials of both tubes about equal. Such adjustment simplifies linearity problems considerably. Also, some form of d-c coupling (such as high-voltage zeners) could be used between the upper plate and the lower grid.

Frequency response, noise and hum have not been thoroughly investigated with this circuit. The circuit behaved just as a cathode follower having a transconductance of about 0.5 mho would be expected to behave. Gain variations owing to power supply and tubes should be much less with this circuit because of the much lower output impedance.

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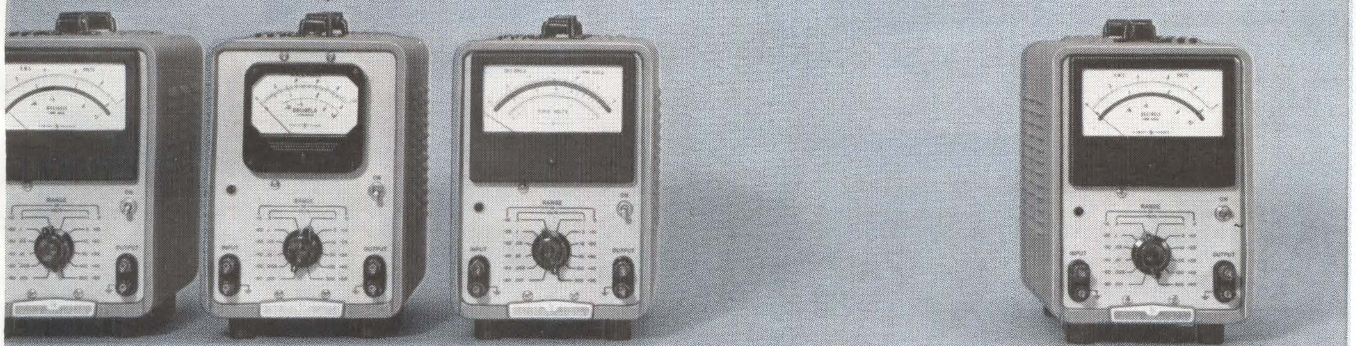

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Long Term Stability:	Reduction in Gm of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 50 cps to 1 mc		
Calibration:	Reads rms value of sine wave; voltage indication proportional to average value of applied wave; linear voltage scales 0 to 3 and 0 to 1; db scale −12 to +2 db, 10 db between ranges		Reads rms value of sine wave; logarithmic voltage scales 0.3 to 1 and 0.8 to 3; linear db scale, −10 db to +2 db, 10 db between ranges
Input Impedance:	10 megohms shunted by 15 pf on ranges 1 to 300 v, 25 pf on ranges 0.001 to 0.3 v		
Amplifier:	Output approximately 0.15 v maximum; internal impedance 50 ohms; maximum gain approximately 150 on 0.001 range		
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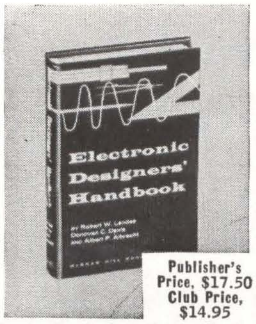

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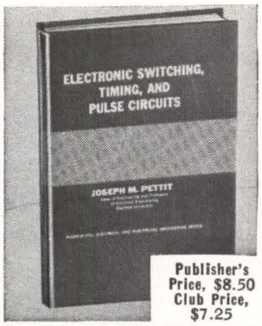

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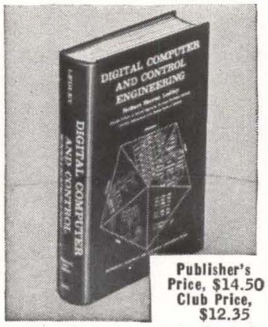

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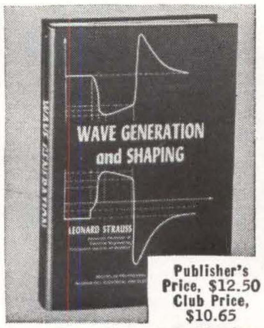

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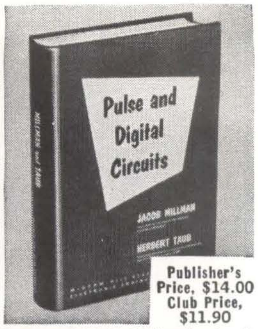

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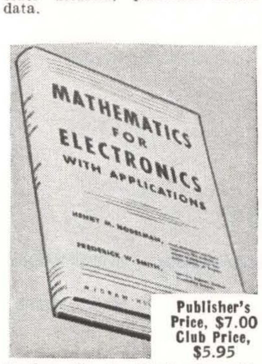

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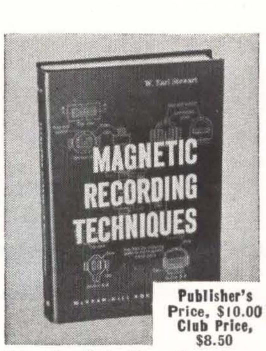

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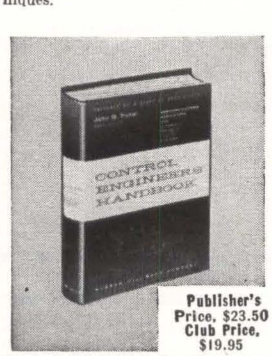

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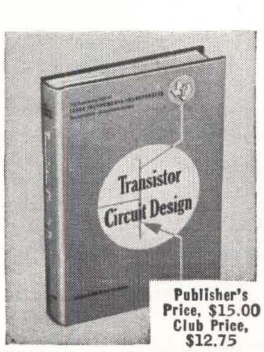

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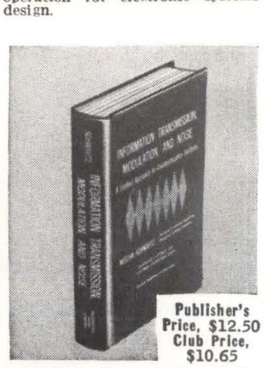

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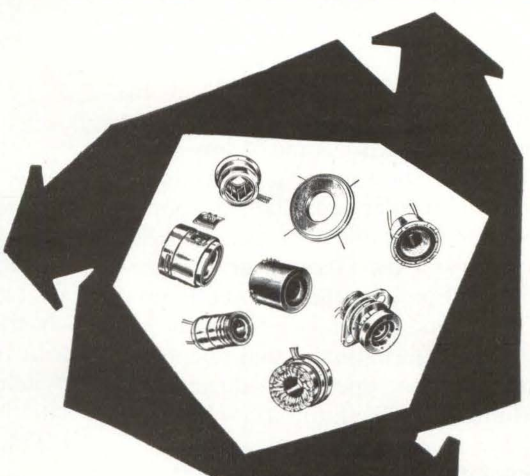

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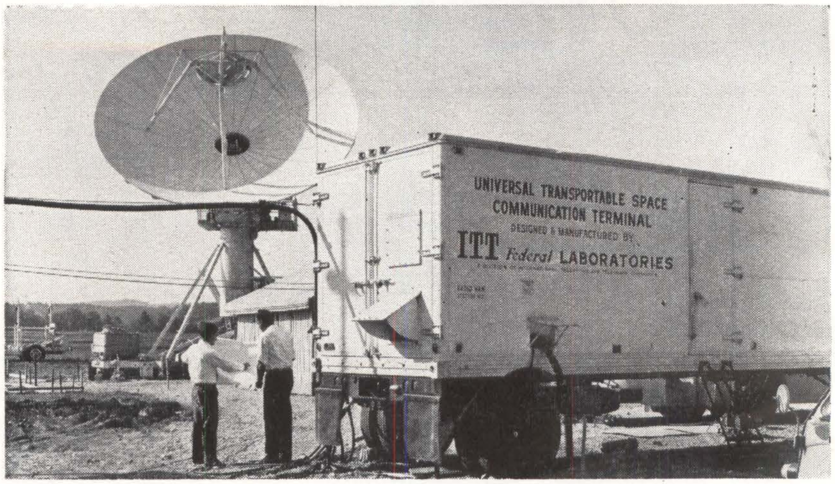
Germany Begins Satellite Communications

First transmissions are made by mobile station with Cassegrain dish

By **RICHARD MIKTON**
McGraw-Hill World News



TRANSPORTABLE STATION at Raisting, Bavaria, operates at both Telstar and Relay satellite frequencies. The American-made equipment was installed by Standard Elektrik Lorenz, ITT affiliate

BONN—While the first antenna of West Germany's planned 4-antenna satellite station in the Bavarian Alps (ELECTRONICS, p 30, Dec. 7, 1962) neared completion, scheduled for Spring 1964, the Federal Post Ministry last month initiated a series of test satellite transmissions on the same site using a mobile antenna station made by International Telephone & Telegraph Corp.

West Germany's first direct satellite communication with the U. S. was a 16-minute conversation, via Relay I, between Federal Post Minister Stuecklen and NASA's James Webb.

Following the transmission, Stuecklen said that the $1.25 million spent by the Federal Post Office in 1963 for satellite station equipment will jump to $10 million in 1964 and eventually be $25 million annually. A large percentage of the equipment will come from U. S. sources. The rapidly growing international telephone traffic is responsible for this rapid increase, he said.

In 1964 the German ground station will pick up the Tokyo Olympic Games and in 1965 Germany hopes to put international dial-telephone service into operation during the Munich Traffic Exhibition.

Satellite Station—With its 30-ft collapsible parabolic reflector, the $1.25-million mobile unit has an antenna gain of 40 db at 1,725 Mc and 55 db at 6 Gc. It provides 6 channels for microwave transmission of telephone and teletypewriter messages and other forms of data using either Telstar or Relay satellites.

Control and guidance consoles and the 4-man operational team for the mobile installation are located in three vans, some 70 ft away.

MADE IN U.S., USED IN GERMANY

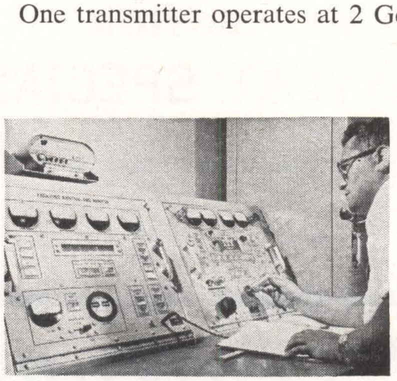
BONN—As West Germany's consumer-product-oriented electronics industry slowly shifts its R&D interest to space-age applications, reliance on U.S. equipment for sophisticated systems continues to be the keynote.

Although German electronic research since World War II has not been dormant, a combination of postwar reconstruction, Allied prohibitions on weapons work and an insatiable consumer demand for tv sets, radios and hi-fi equipment long kept the industry's labs out of the space and military fields.

Within the past two years, however, increasing financial aid from Bonn and growing cooperation among European nations have given impetus to West German space research and satellite applications

Immediately behind the antenna are two 10-kw f-m transmitters with klystron output stages, which rotate with the reflector. These can be switched in and out according to the satellite being tracked.

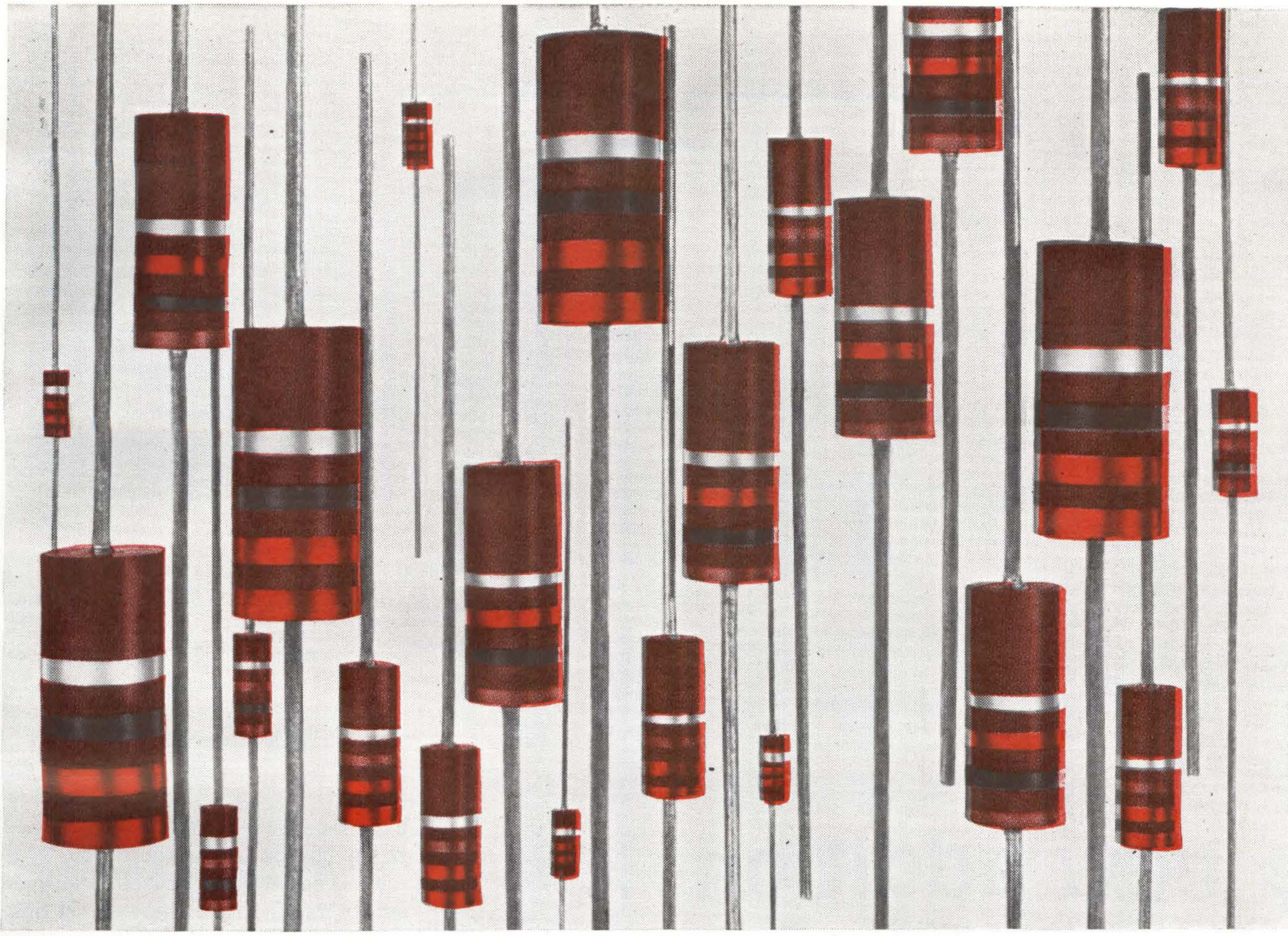
One transmitter operates at 2 Gc for Relay, the other at 6 Gc for Telstar. An intermediate frequency of 70 Mc is used for communications between the control vans and the antenna.



ENGINEER operates antenna-control section of control console in van

The power supply for the transmitter uses dry rectifiers which deliver 19 kv d-c at 2.2 amp for the power klystron and all other equipment. The total station power amounts to 200 kva. A heat exchanger with 35 kw capacity is used for cooling the klystron, which maintains the coolant temperature at a constant 122 deg F.

Receiver—The installation includes a low-noise (3-db) parametric receiver, an oscillator, an i-f amplifier and a demodulator. All microwave equipment is located as closely as



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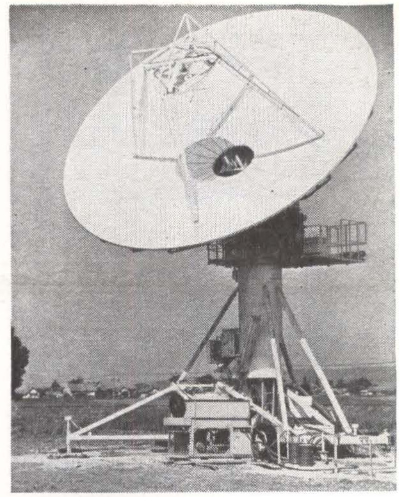

CASSEGRAIN reflector is collapsible

possible to the antenna.

Because the satellite signal at the receiver is less than 10^{-10} mw, a special phased feedback circuit is included which improves receiver sensitivity by 3 db compared with a standard f-m receiver.

To link the mobile station with the nation's telephone net there is a 2-Gc 120-channel directional-beam station linked into the system. The station's reflector, atop a nearby mountain, forms a direct link with Munich, some 25 miles away.

Cassegrain Reflector—The ITT reflector employs the Cassegrain principle.

The feed arrangement is a combination of two feed elements for the 2-Gc transmitter, one for the 6-Gc range, and four for the 4-Gc receiver. The receiving array serves for receiving the satellite signal, tracking the satellite and guiding the antenna.

Tracking—Incoming tracking signals are separated according to azimuth and elevation and then fed to two receivers, whose output voltages are proportional to the variation of the antenna direction from the true direction of the satellite. These voltages are used to control the antenna's hydraulic drive and to correct the antenna's position. Automatic tracking begins when the satellite appears on the horizon and continues until it disappears. To aid tracking, the satellite sends out a 136-Mc signal. The reflector can be set to an accuracy of 0.02 degree and held there during tracking.

Tracking accuracy and directional

adjustment of the antenna average ± 0.15 deg, even with wind velocity of more than 40 mph, and a maximum rotational speed of 10 deg/second in azimuth and 6 deg in elevation. The minimum rotational speed is less than 1/100 deg second, which corresponds to 360 deg in 24 hours.

Minuteman Standards Basis of National Code

RELIABILITY STANDARDS initiated by North American Aviation for the Minuteman ICBM will be unified and applied to the products of all military and space component suppliers next year, the firm says. The standards cover resistors, capacitors, diodes, and transistors, as well as integrated circuits and parts packaging, under the specifications code Mil-R-38100. They are the result of work begun by the firm's Autonetics Division in 1958. The Air Force's Ballistic Systems Division later asked to have them compiled into the new, unified series for all electronics sources.

Retrieval System Held Engineering Time Saver

HUNTSVILLE, ALA.—Army Missile Command estimates DOD could save some 16 million man-hours of engineering time annually by adopting an information-retrieval system to identify required components. AMC's EDS-0009 system, developed by Brown Engineering, stores components data on microfilm. Upon inquiry, it will select a part meeting exact specifications, or one that is suitable with minor redesign. The computer that indexes the parts also checks for duplications in the Federal Supply Lists, so duplicate parts can be weeded out.

Echo 2 on Schedule Despite Inflatant Change

WASHINGTON—The inflatant and balloon material for Echo II have been changed, but the passive communications satellite will still fly as scheduled, some time during the first quarter of next year, NASA says. Pyrazole, an organic compound that does not absorb water from the atmosphere like acetamide, the earlier inflatant, will be used to achieve the same ultimate high pressure. The r-f reflective material now goes through a preshrinking process during manufacture. Echo II will undergo a static inflation test at Lakehurst, N. J., in December.

Vanguard's Voice Changes

VANGUARD I has suffered a frequency change, five years after launch, but is still chattering. NASA believes radiation damaged the structure of one of two transmitter quartz crystals, causing frequency to drop from 108.03 Mc to 108.017 Mc. Radiation effects on crystal are being studied at Lewis Research Center with a 60-inch cyclotron.

When launched March 17, 1958, Vanguard carried no killer timer—these came a year later. One of the satellite's two transmitters shut down unexpectedly soon after that, but the second keeps sending data—data that's not needed, says NASA. How long will it continue? Said the spokesman: "The life of the satellite. Maybe 200 years, maybe 2,000, or it could shut off tomorrow." He claims it's no problem, however. Most of the 20 U. S. satellites in orbit broadcast on 136 Mc.

Laser Dental Drill—Patients Feel No Pain

LOS ANGELES—Lasers may replace conventional dental drilling equipment if experimental techniques developed at North American are perfected. Working with a local dentist, scientists are drilling holes in teeth with neodymium-glass, high-repetition-rate, pulse-type lasers. The drilling is so rapid that there is no heating, no vibration or possible nerve damage, and no temperature rise in adjacent areas of the mouth. No anaesthetic is required. Size of the holes is determined by the focus of the laser, and the depth is controlled by the amount of energy expended.

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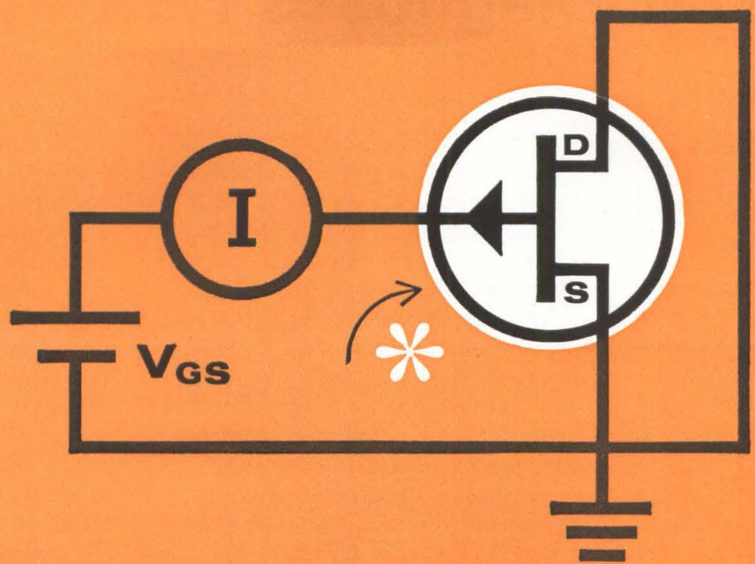

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Computer Diagnoses Heart Disease

Russian laboratory uses machine to select tests and evaluate symptoms

SCIENTISTS at the A. V. Vishnevsky Institute of Surgery in Moscow have been using a computer to diagnose congenital heart disease. In diagnosing 125 cases, the computer provided correct diagnosis in 106 cases and erred in two cases; one of which was based on an incorrect examination. In a number of cases where the computer diagnosis did not agree with doctor's diagnosis, operations later confirmed the computer diagnosis.

The system, although developed for congenital heart disease, is universal in nature. It is based on probability mathematics and the theory of sets, and has the additional capacity for learning. Changing from one class of disease to another requires only changing the tapes carrying the medical memory.

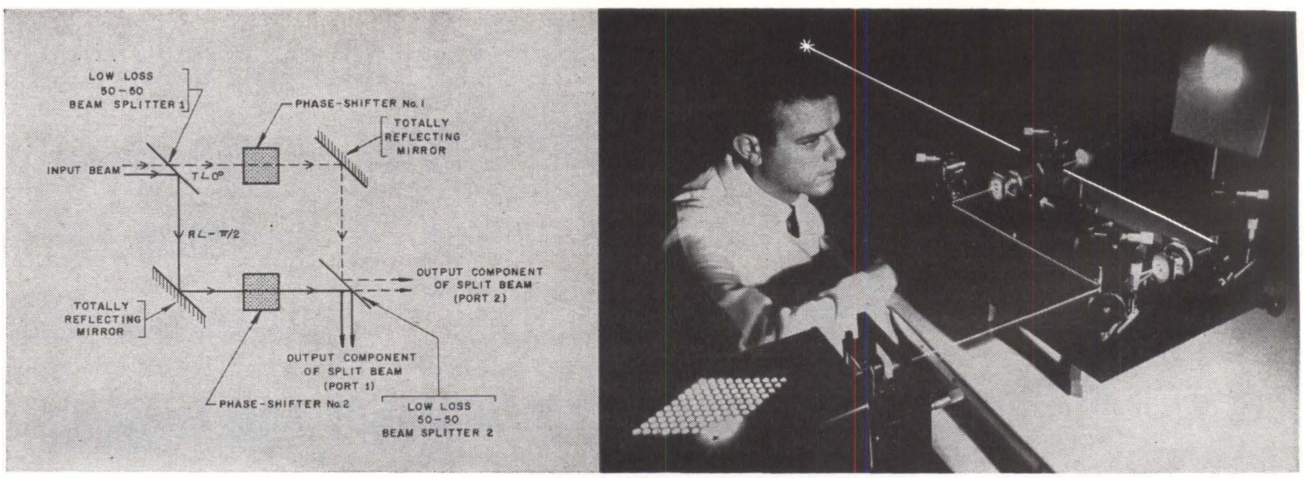
The computer method has been found to surpass human diagnostic skill in cases where the patient's symptoms indicate several diseases are present simultaneously. This is because the machine's logic can evaluate a large number of minor symptoms, or deviations from normal, better than a human mind.

A special cybernetics laboratory equipped with the latest electronic computers was set up two years ago at the Institute of Surgery in Moscow. Most progress was achieved in two areas: the first involves the development and establishment of a dynamic diagnostic system which, drawing on the extensive information obtained from the examination of the patient by electrocardiography, phonography, X-ray, probes, etc., permits a build-up of an exact picture of the patient's state at the given moment; the other is the development of an automatic medical information system.

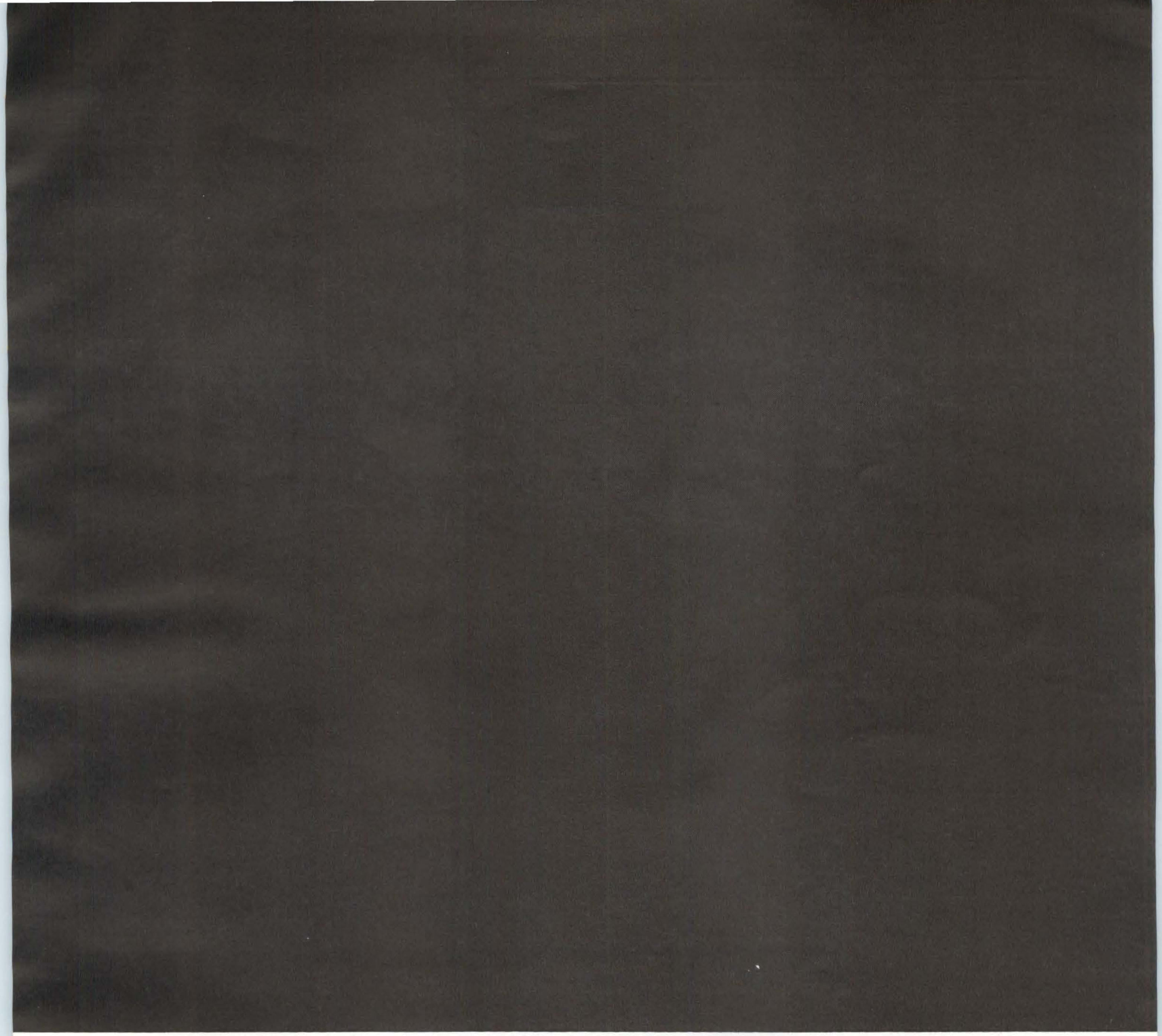
The logical process of diagnostic reasoning comprises two stages: a) deterministic logic, and b) probability logic. That is, first the computer checks the input symptoms and rejects those diseases that are excluded by the particular clinical picture. After this, there remains a group of diseases that the patient might have. The computer then determines the probability of each of the remaining diseases.

Dynamic Analysis—The diagnostic process is not a single-moment act, but a dynamic procedure. Therefore, there is no need to subject the patient to all the tests and examinations at once and then perform the process of diagnostic reasoning. This keeps to a minimum examinations that are strenuous or dangerous. The simple tests, such as elec-

Optical Circuit Controls Laser Beam



INTERFEROMETRIC module, developed for the Air Force by Electro-Optical Systems, Inc. (see **Electronics,** p 19, Nov. 1) uses two gas cell shifters to shift, power-divide and attenuate a laser beam. Path of laser beam through system is shown in diagram at left. Phase shifter cell gas pressures are simultaneously controlled by a bellows system and nonlinear programmed cam drive. Photo at right shows incoming beam from helium-neon laser passing through interferometric device where it is split and controlled in relation to original beam. Split and controlled beams are seen at top of photo. Output beams equal intensity of input beam and can be controlled in ratio to each other without degradation of laser coherence. Unit may become important component of future optical surveillance radars



How do you take a picture of something you can't see?

Transient oscilloscope traces in the sub-nanosecond range move too fast for the human eye. How can you study them?

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Your pictures are fully developed in 10 seconds. If you are studying sequential traces, you can click off a full roll (8 exposures) in 20 seconds. Simply let the film stay in the camera back for 2 seconds, then pull the tab, repeating the process for each exposure. Strip away the negative and you've got eight finished pictures.

The catalog name for this film is Polaroid PolaScope Type 410. It's panchromatic, responds best to blue phosphors such as P-11. The film's extreme sensitivity lets you use small camera apertures and low beam intensities too, so your trace pictures are really sharp.

Try Type 410 Land film the next time you need oscilloscope pictures. And see.

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trocardiography, phonography, and X-ray, are given first. Drawing on the results of these simple examinations, a diagnostic evaluation is made. If these data prove to be sufficient, then the system makes a final diagnosis with a given probability that is correct. If not, the system indicates what other examinations must be performed to obtain the data essential for diagnosing the disorder. These examinations are then performed, and a new evaluation is made. If the data obtained from the new examination is sufficient, the process is stopped. If diagnosis proves impossible, then yet further examinations or tests are indicated, and the process continues. The diagnostic process, therefore, includes both the evaluation of the medical information on the patient's condition, and the control of the diagnosing process proper.

Talk-Along Checkout Patterned by Weathercaster

COLUMBUS, OHIO — An automatic weather broadcaster is already blazing one trail toward talk-along checkout machines. Random access digital-to-voice readout is provided by Ordered Random Access Talking Equipment (ORATE) introduced during last month's Automatic Checkout Equipment & Techniques Seminar at Battelle Memorial Institute.

ORATE has been under study and development for the FAA over the past year and a half, according to Douglas Durie and Elmer Clune, Avionics division of Bell Aerosystems, Buffalo, N. Y.

Film strips store a versatile 896-word vocabulary inexpensively. Each of four strips, carrying 32 variable-width sound tracks, is wrapped around a transparent transport cylinder. Reading heads and the associated optical light collection systems permit 50-millisecond access to words and phrases in seven progressively larger 0.6-second increments. Readout is by electromechanical switching of light to a reading slit over the appropriate track. A solenoid motor or spring return positions matrix blades between a light source and the reading slit plate. A servo controls longitudinal travel extremes—representing either binary zero or binary one

—of the seven blades, each with its own binary-related hole pattern.

Hole patterns on the seven blades are such that for any binary combination of extreme blade positions only one continuous light path is opened from the light source to any reading slit. Matrix illumination of the reading slit over a particular track casts a narrow beam of light on the moving sound track. The moving, variable-width sound track modulates this beam of light, which is then collected and focused on the cathode of a photo multiplier tube and there translated into electrical audio signals.

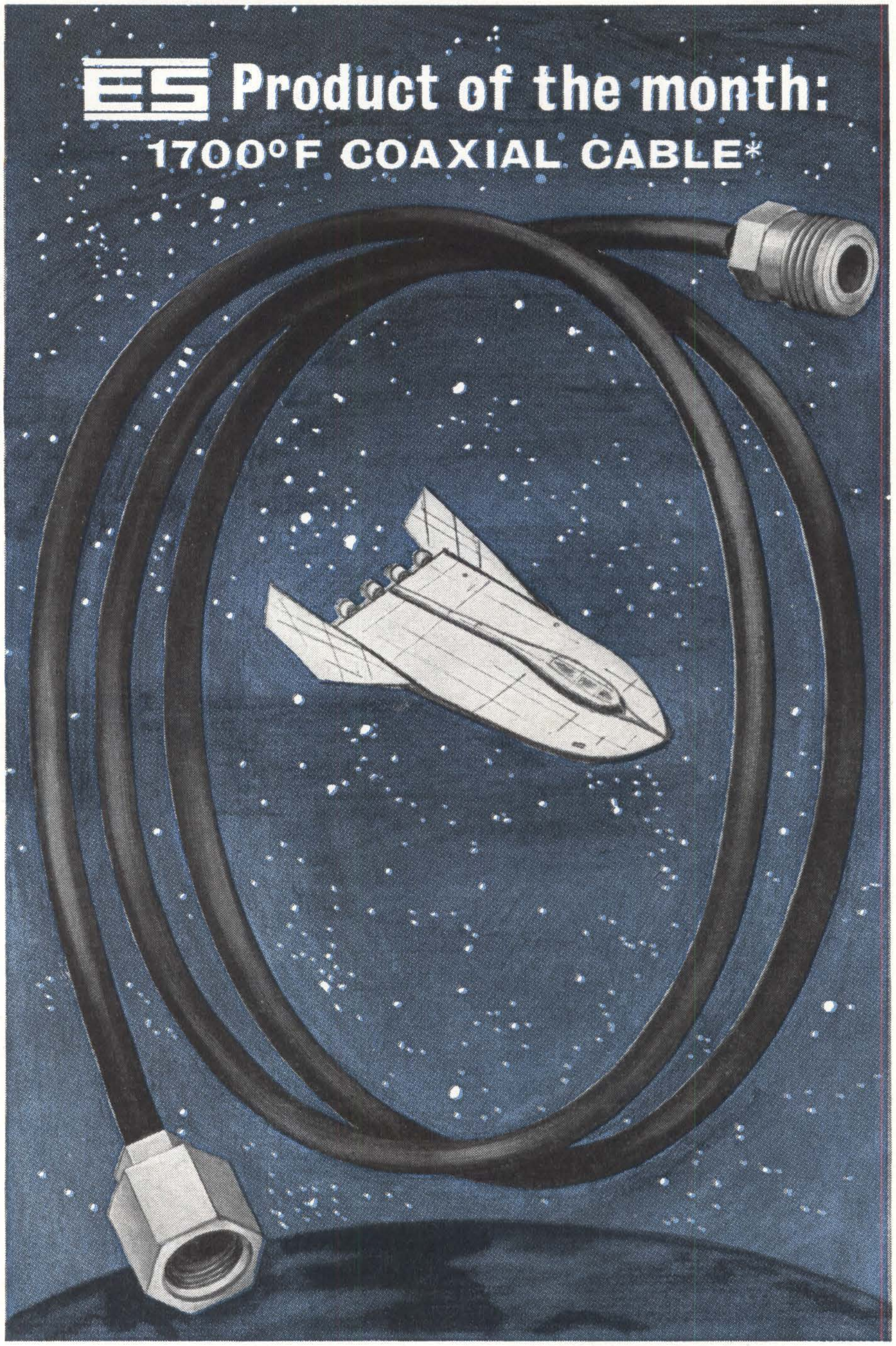
A versatile checkout system of the future could combine a small general-purpose computer, digital tape storage and a random access audio playback device such as ORATE, Durie and Clune suggested. Complete trouble analysis computer routines could be written for each segment of checkout of a system. These routines could be kept in inexpensive tape storage until ORATE required them, to supply an operator with aural readout of the trouble analyses they contained.

Test sequences can be repeated considerably faster, using such a computer-random access voice checkout system. Test setup instructions and the results required could also be spelled out aurally.

Push-Pull in Lasers Decreases Distortion

USING TWO diode lasers with output radiators collimated on the same optical path and the input modulation signals at 90 deg relative phase shift, ITT scientists in Nutley, N. J. have obtained balance of the second-harmonic sidebands in modulated light output. Net decreases of more than 20 db in the percent of second-harmonic distortion resulted.

The new technique may be compared to push-pull amplifiers in which the signals are fed in phase opposition and extracted as the difference of the two outputs. In gallium-arsenide diodes, the procedure is modified—the light outputs are added rather than subtracted. The technique results in a greater dynamic range of modulation for a prescribed maximum percent distortion, as well as in increased operational efficiency.



Electronic Specialty's new High Temperature Coaxial Cable provides the aerospace industry with a cable assembly superior to those now available. Capable of operation from extremely high temperatures to cryogenic temperatures, the cable assembly is highly radiation resistant. The cable itself is a copper inner conductor with a stainless steel sheathed outer conductor. The dielectric between is pure powdered silica. The high temperature connectors and hermetic seals are the result of extensive research and development at Electronic Specialty, and are attached to the cable by a proprietary process. The completed cable assembly is highly resistant to vibration, crushing, and abrasion. Electrically, it has very low loss—only 3 db per 100 feet at 400 MC, with a noise level much lower than conventional coaxial cables. Assemblies are available in five different diameters. For further information, call or write William Marcy, Director of Marketing, at the address shown below.

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ES is a diversified, dynamic, multi-divisional organization serving defense and industry over a broad range of vital areas with advanced systems, sub-systems, and state-of-the-art components. Major contributions are currently being made in the following:

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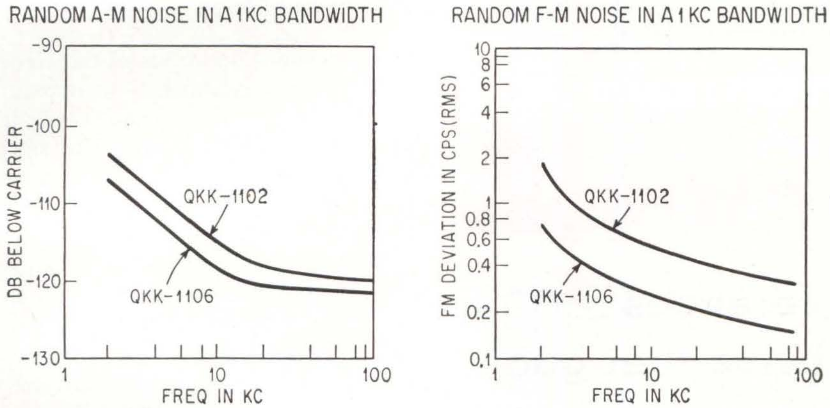
Low-Noise C-W Klystron Oscillators Meet Doppler Radar Requirements

Latest data on gridless, two-cavity types show how they have improved

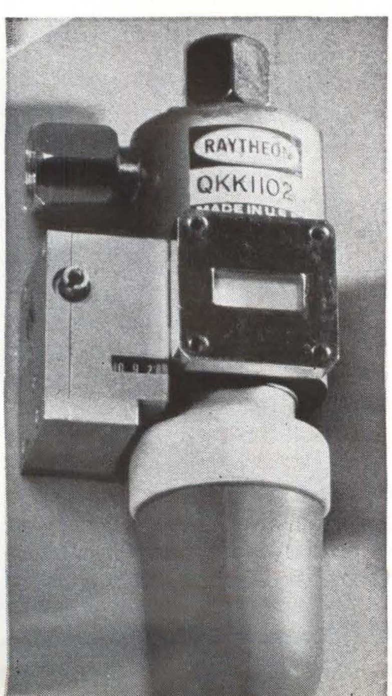
By J. J. HAMILTON
Spenser Laboratory, Raytheon Co., Burlington, Mass.

Performance of Two Low-Noise C-W Klystrons

Characteristic	QKK-1102	QKK-1106
Beam voltage, kv	10	3.9
Beam current, ma	90	25
Power output, W	100	1.5
Temp coeff, kc/°C	100	10
Dc heater pushing, kc/v	800	80
Ac beam pushing, kc/v	1.7	4
Freq pulling mc	1.5 (VSWR-1.5:1)	0.150 (VSWR-1.1:1)
Mechanical tuning	2.5%	Fixed Freq



TYPICAL noise figures for two c-w klystron oscillators, Fig. 1



KLYSTRONS designed for cw Doppler and mti radar transmitters represent state-of-the-art

UNIQUE nature of moving-target information obtained by Doppler radar, has resulted in its widespread use in aerospace systems. Up to now, security restrictions have prevented the publication of much information relating to equipment use and performance of these radar systems and their components. It is now possible to share some of the interesting facets of this work, and some of the results.

Microwave tubes for modern Doppler navigation systems must be virtually noise-free. The availability of noise-free tubes has led to improved Doppler systems.

One of these tubes is a medium-power klystron oscillator whose output is fed directly to an antenna, or used to drive a high-power microwave amplifier. Inasmuch as a ceiling is set on ultimate sensitivity, oscillators for c-w Doppler and moving target information transmitters should be free from all incidental modulation. All forms of frequency modulation must be reduced to negligible levels, within the limits of operating modulation frequencies of the tube which usually lie between 1 and 200 kc per second.

The gridless, two-cavity klystron has geometric simplicity and functional sturdiness for such an application. Electrostatic focusing permits compact and lightweight design, and dissipation of the electron beam outside the microwave resonator region leads to excellent thermal stability. Elimination of grids alleviates noise contributions that arise from ion instability.

Two state-of-the-art low-noise klystron oscillators are shown in the photo. Design and processing techniques have reduced noise in these tubes to a small fraction of the noise-level encountered in conventional klystrons of comparable microwave performance. Better performance comes from improvements in electron-beam control, mechanical ruggedness, and tube vacuum.

Noise generated by perturbations in the admittance of the electron beam can be diminished in several ways. Perturbations of the beam may be caused by the presence of ions, improper electron-gun design or emission of secondary electrons in the vicinity of the resonator gaps.

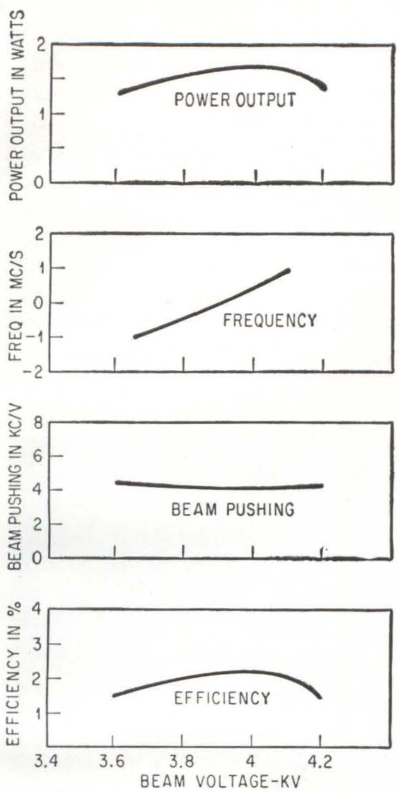
The incidence of ion instabilities is greatly reduced by selecting a gridless gap design.

The entrance conditions of the electron gun are established with care, and beam grazing within the drift space is thereby avoided. The collector is also designed to minimize the noise contribution of secondary electrons.

Mechanical resonances and microphonics induce noise components in the tube, wherever their location. These noise sources are virtually eliminated by designing an extremely rugged structure with its fundamental mechanical resonances falling far above the vibration requirements of the oscillator, and preferably above its highest modulating frequency.

The background noise level of a klystron oscillator is related to its state of exhaust. High standards of component cleanliness are required to attain the best possible vacuum in the tube. Improved processing and pumping techniques, yielding vacua two orders of magnitude superior to the techniques used in manufacturing ordinary microwave tubes must be applied. Significant degradation in vacuum or the accidental inclusion of foreign particles can lead to serious deterioration of noise level.

The principal operating characteristics of two X-band low-noise c-w



ADDITIONAL performance data for the QKK 1066 oscillator, Fig. 2

klystron oscillators geared to Doppler requirements, are given in the Table. Noise curves are shown in Fig. 1. Noise curves for the QKK 1066 represent the greatest known advance in low-noise klystrons to date. Data in Fig. 2 show that noise suppression has not detracted from microwave performance in other areas.

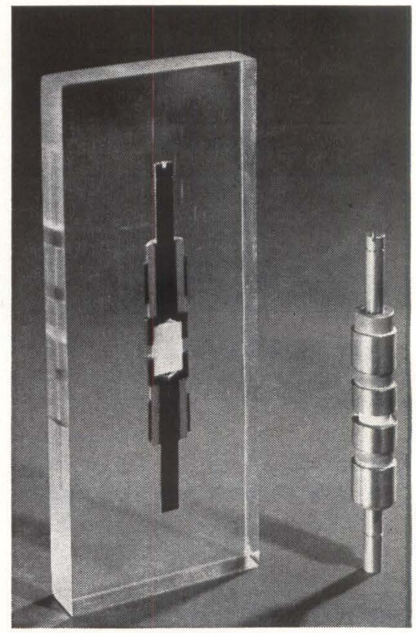
Efficiency of the tube is good, considering operating beam voltage and power output. The beam-pushing characteristic is excellent. The QKK 1106 has thermal stability of only 10 kc per deg C. Prolonged exposure to severe aerospace environments causes no permanent damage in the tube, although its noise level rises temporarily during operation while such condition exists.

For optimum sturdiness, low-noise klystrons have been restricted to fixed-frequency operation—up to now. Present mechanical design permits restitution of tuning flexibility, as in the case of the QKK 1102.

The ultimate capability of low-noise c-w klystrons is not precisely known. New techniques of circuit stabilization, as well as continuing investigation of phenomena observable only in the quietest tubes now available, are expected to lead to noise improvements of one to two orders of magnitude in the near future.

This should not obscure the fact that few devices can match the stability of the klystron oscillators described.

By-Pass Capacitor Built Into Uhf Tuner Shaft



CUTAWAY of combination tuner shaft and capacitor. Ceramic section at center of shaft insulates the two halves. Ceramic sleeves with metal rings fixed to each end of shaft provide capacitance required

RADIO-FREQUENCY by-pass capacitor function has been built into the tuning shaft of transceivers. Integrated design is said to increase component reliability. Design eliminates need for a set of wiping contacts in the capacitor assembly, circumventing the possibility of poor r-f bypassing. No leads are required, eliminating the problem of high-frequency inductance, common in uhf operation.

Ceramic and metal shafts are used in the power amplifier assemblies of two military units.

Integrated tuner shaft was conceived by M. R. Hubbard, Collins Radio design engineer. Unit is built by American Lava. Actual design of the shaft to meet electrical and dimensional requirements was carried out by American Lava.

DROPOUT PROTECTION

MINCOM SERIES CM-100 RECORDER / REPRODUCER

Data loss from dropouts is practically eliminated in the CM-100, due to this unique system's predetection recording capability. In ordinary post-recording, a dropout more than 6 db down is generally considered a data loss; the CM-100's operational predetection performance retains such signals through superior phase characteristics and extended bandwidth. **Mincom's CM-100 Recorder/Reproducer,** performing longitudinal recording with fixed heads up to 1.5 mc at 120 ips, also offers 7 or 14 tracks, trouble-free dynamic braking, complete modular plug-in assembly, built-in calibration, instant push-button selection of six speeds. Versatile, reliable, a model of simple maintenance and operation, the CM-100 is tops in its field. Write today for detailed specifications.

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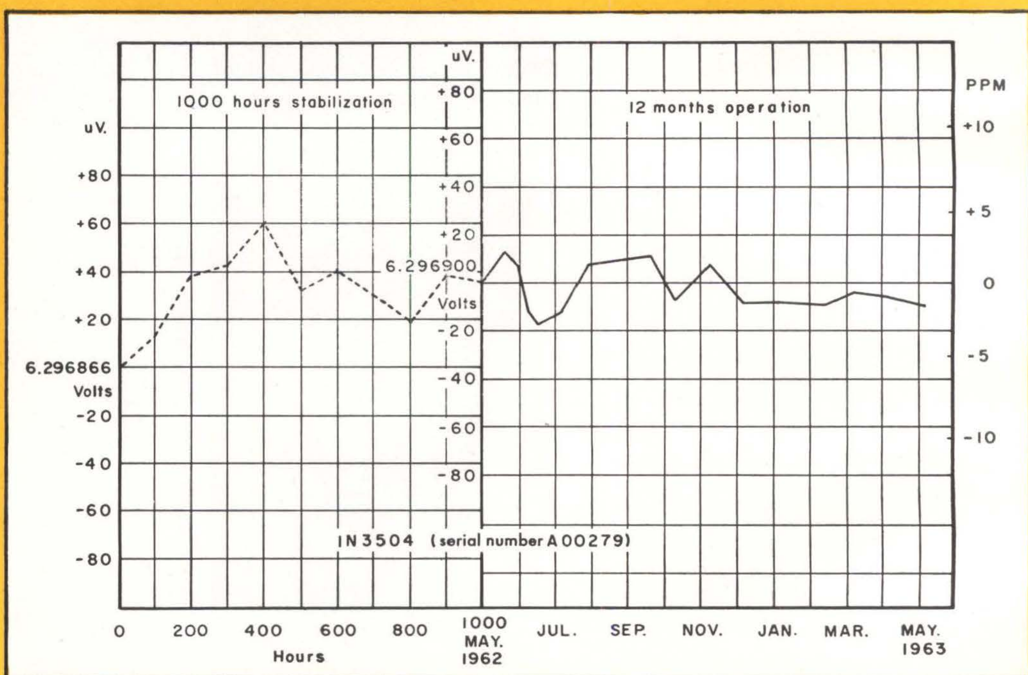

Every Transitron subminiature glass reference has this stability potential

Every one of Transitron's broad family of subminiature glass voltage references — commercial, military and CVR — is made on the same production line. After passing basic tests, most of these temperature-compensated zener devices — like the 1N821-829 Series — are used in such OEM applications as power supplies and instruments. Other references are put through the rigid tests that lead to the USN1N821-827 designation. A few others undergo severe and lengthy testing to prove their CVR capabilities.

Individually power-aged, temperature-cycled and documented for more than 1000 hours, Transitron's ultra-stable CVRs, such as the 1N3501-3504A Series, are being used in many top priority, high reliability space and military programs. Ideal for all sophisticated circuits requiring extreme stability over long periods of time, CVRs are now available for immediate delivery in quantity.

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Self-Setting, Parallel-Gap Welder Saves Time and Rejects

Feedback adjusts energy to gap resistance as microcircuit is welded

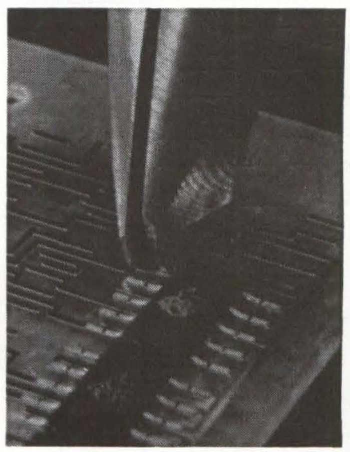
By JIM SHANK
Texas Instruments Incorporated, Dallas, Texas

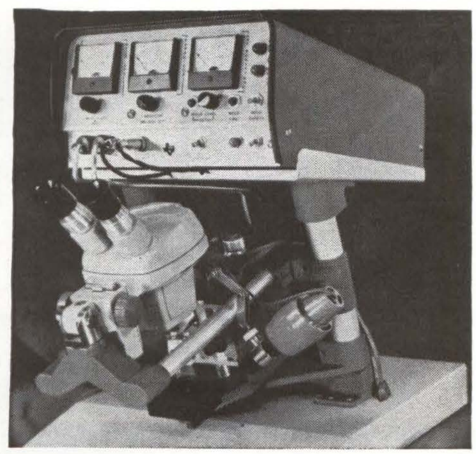
Welding gold-plated leads of integrated circuits requires time consuming computations. Parameters of the work are variable in production causing high reject rates and serious loss of time. Successfully solving this obstacle to efficient assembly of integrated networks is a new dynamically controlled welder that welds without scheduling for variations and adjusts itself continually during the process.

Parallel-Gap Welding—The basic principle of this new method is to regulate the energizing current through the weld in an inverse relationship to the resistance across the gap of the electrodes. A signal at 2.5 kc is applied to the electrodes and is taken off as close to the gap as possible. It is applied to a voltage comparator and compared to a reference voltage. Any resulting error voltage varies a shunt across the welding transformer, changing the loading on the power supply. Thus the weld current across the gap is continually changing in accordance to variations in static resistance of integrated circuit leads during the weld pulse while the voltage remains constant.

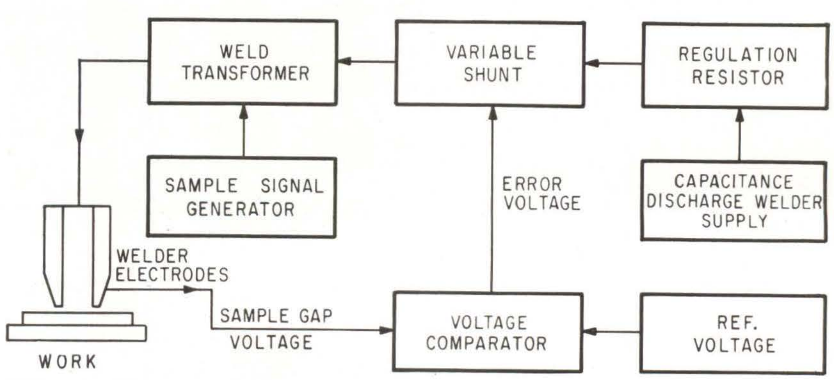
Dynamic Resistance—The heat of the weld causes the gold plating to separate through sagging and vaporization of the molten gold. This separation of the gold path, which carries a large portion of the weld current, is one cause of the dynamic resistance characteristics of the SCN lead. Another cause is the temperature coefficient of the lead. It is not unusual for the total preweld gap resistance to double upon welding. The gap resistance should not be confused with the joint resistance between the network lead and the etched circuit.

Power Supplies—When a power supply is furnishing weld power to parallel-gap welding electrodes with a gap resistance of less than 10 milliohms, it has a relatively high impedance. Thus, the conventional welding supply is basically a constant current source, and it is evident that the power delivered to the weld is directly proportional to the resistance of the material in the gap. This is a very undesirable





PARALLEL GAP WELDER developed by Texas Instruments Incorporated, welds without scheduling for variations in plating thickness



ZERO-IMPEDANCE WELDER is very nearly approached by this dynamically controlled parallel-gap power supply. It provides a nearly constant current source for the welding transformer and shunt. The voltage across the weld is held to a preset value by controlling the shunt current to an inverse function of the gap resistance situation. If the energy setting (the voltage to which the capacitors are charged) of the welder is just right for a gap resistance of 2 milliohms the same setting will probably burn out all the material in a gap whose resistance is 5 milliohms. For any given energy setting, a lead of smaller cross section will actually receive more power than will a lead of a larger cross section. So an adjustment of the energy setting is required to compensate for network leads whose resistances differ due to different cross sections or plating thicknesses. In addition, the situation is further complicated by the dynamic resistance characteristics of the plated leads. This dynamic resistance makes the duration of the welding pulse highly critical when welding the average lead and with possible pecularities in geometry, a catastrophic failure is impossible to predict or avoid.

If the weld pulse duration is such that high current is still being delivered to the weld after the gold path has separated, the increased power being generated in the weld is very likely to cause a "burn out." This failure can be avoided through measurement of lead dimensions and careful adjustment of total energy setting.

Setting the Welder—With the new system, preweld tests measure the total resistance of the material in the gap, and, if this resistance exceeds a set maximum, the welder cannot fire. The maximum might be exceeded, for example, if the network lead falls well out of tolerance or if the welding electrodes need dressing. This "hold" on the welder's ability to fire can be overridden once the reason for the hold has been investigated.

The lower limit of this resistance range is determined by the upper limit selected for the preweld test. Since the resistance in the gap increases with the welding, threshold level may be critically set so that this increase switches the hold-weld relay to hold.

The upper limit is set into a Schmitt trigger so that a gap resistance greater than the maximum resistance level will energize a postweld test relay.

Weld Head—The firing of the supply closes a valve locking the weld

WHAT MAKES AN INSTRUMENTATION CABLE FAIL?

It can pass inspection perfectly one minute and fail miserably the next. Simply manufacturing it to spec isn't good enough. Insurance against failure must be built into the cable at every step from diagram to installation.

Where can it go wrong? At almost any point not adequately safeguarded. Here are four of the most common trouble spots:

(1) Incompatible Plasticizers
(2) Filler Material
(3) Component lay-factors
(4) Shielding

INCOMPATIBLE PLASTICIZERS A unique form of chemical warfare within cable materials has fouled more than one missile program. Plasticizer materials have to be added to compounds to obtain the required flexibility. These additives are seldom compatible with each other. Incompatible plasticizers used in systems in contact with each other without control may attack each other with disastrous effects. (As a prime example, additives in low temperature neoprene jackets are not always compatible with the insulating materials.)

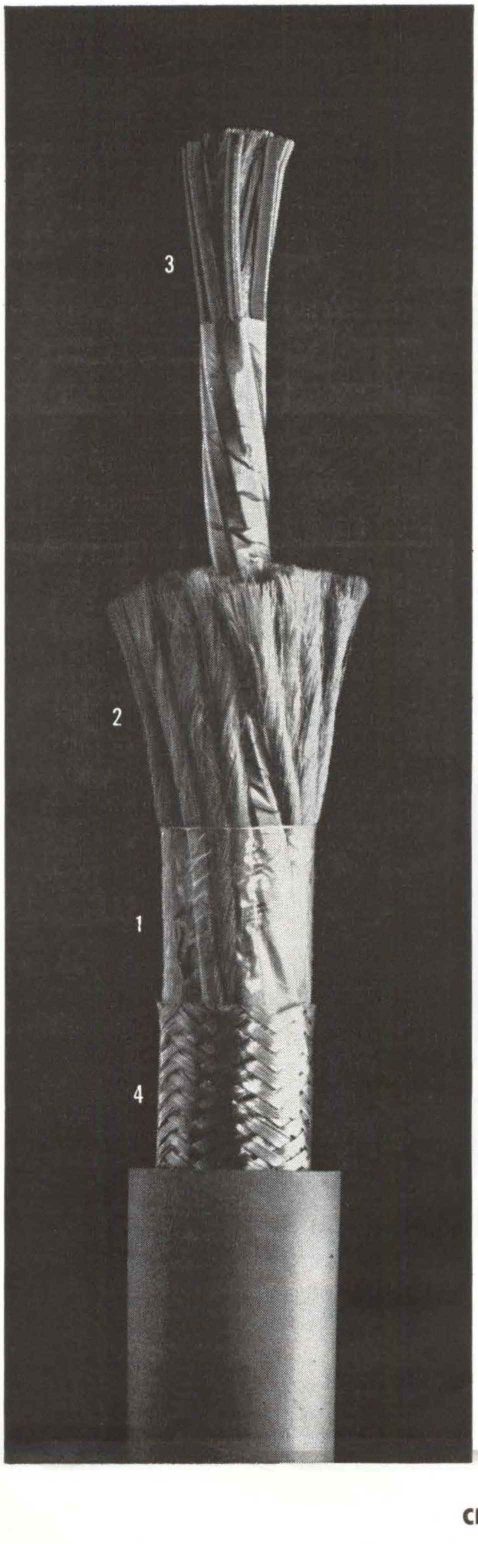
Manufacturers can control plasticizer migration problems by selecting proper materials and by using suitable barriers between components. Many specifications make the use of barrier material optional and a manufacturer whose only concern is price will leave it out.

Rome-Alcoa, as a result of its wide experience with materials, always uses barriers where migration could be a problem.

FILLER MATERIALS When spurious signals arrive at your display, recording or control panel, the fault could be in the improper selection of filler material. Compatibility between insulations and filler materials is of prime importance.

In the case of some plastics or rubbers, the material's "memory" can cause it to shrink disproportionately, creating undue stresses internally in the cable. This can cause kinking of the insulated conductors; electrical failures follow.

Only experience can tell a cable manufacturer how to compensate for "memory" and how to control compatibility in filler materials. Experience in areas such as this has given Rome-Alcoa its remarkable record of instrumentation cable reliability.



COMPONENT LAY-FACTORS Conductor kinking can also be a result of mistakes in the twisting of component conductors. Inconsistent tensions and improper sequence of lay-up can create uneven tensions in the assembled conductors.

In such cases, individual conductors may actually push through their insulations, causing electrical failures.

Obviously, these mistakes should be avoided during cabling. At this stage in cable construction careful, experienced workmanship can provide safeguards against possible trouble later on. Such careful craftsmanship sometimes costs a little more, but it can make the difference between success and failure.

SHIELDING Constructed of many ends of fine strands, shielding braids are prone to having broken and loose ends. These can break through insulations and short out component conductors. Improperly treated, they are the most common cause of shielding failures.

It's cheaper to let such loose ends remain in the braid—but it can also be disastrous. Experience on thousands of such shieldings has taught Rome-Alcoa the exact tensions which must be maintained, as well as methods of protecting and treating loose ends.

HOW TO AVOID FAILURES No manufacturer can promise you 100% reliability at every development stage. But it's only logical that the one way to be sure of maximum reliability is to have your cable planned and manufactured by a company with depth of experience and a record of reliability in the field.

Rome-Alcoa is, frankly, one of the few companies that qualify. We've been designing and constructing these cables since their first conception—long enough to know what can cause a cable failure, and how to avoid it. If you're planning to design or install instrumentation cable soon, call us.

As a starter, send for our 24-page booklet titled "Instrumentation Cables, Cable Assemblies and Hook-up Wires." In it, we describe instrumentation cable constructions, production, military specifications and our qualifications. For your copy, write Rome Cable Division of Alcoa, Dept. 27-123, Rome, N.Y.

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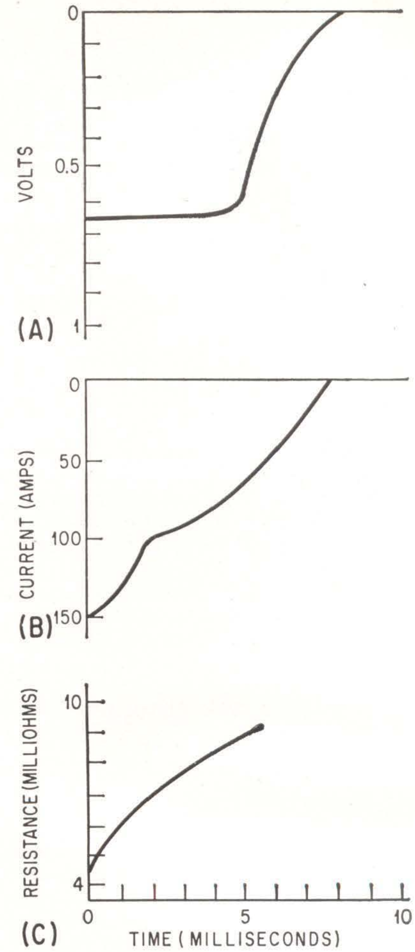


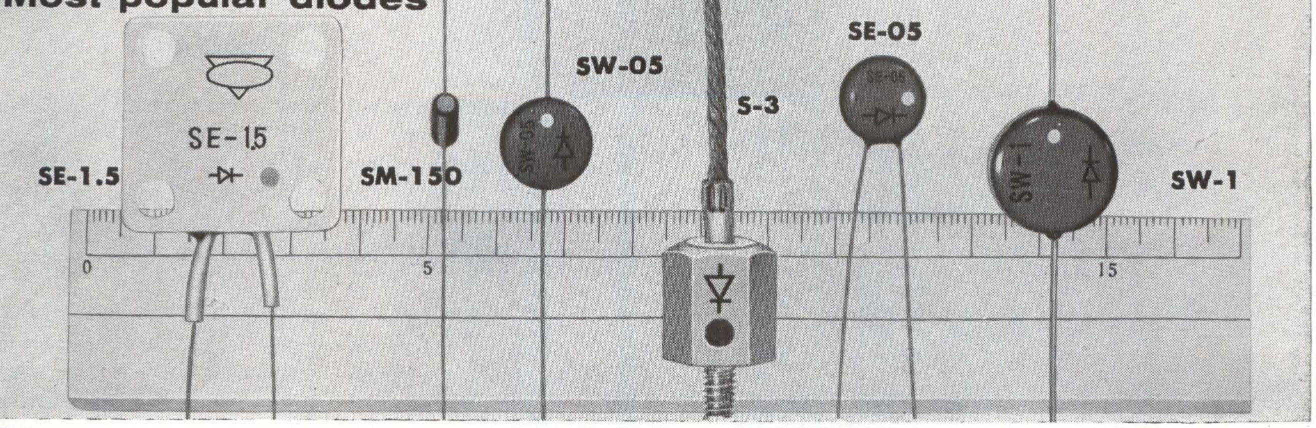
ACTUAL MEASUREMENTS—Voltage (A) current (B) and resistance (C) show actual changes that take place during a typical parallel gap weld

head in its position at the time of firing. The weld head is locked in this position unless the weld-hold relay is in the hold position (lower resistance limit—okay), and the postweld test relay is in the unenergized condition, (upper resistance—okay). If these conditions are met, the weld head is released, and the weld can be assumed to be satisfactory. The closing of a holding valve serves another purpose—when the preweld conditions are not met and the pressure firing switch is thrown the welder will refuse to "fire", thus the weld head can not be damaged by increasing the pedal pressure.

To determine the proper setting for welding network leads to a particular thickness of circuit material, the operator simply reduces the power setting to minimum and increases it slowly while firing the welder repeatedly. The welder may be repeatedly discharged through the same weldment without damage to the joint to allow the operator to

Origin silicon diodes

Most popular diodes



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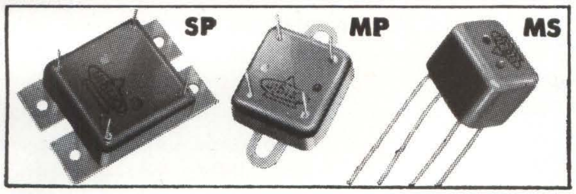
SM-150
Available in 4 physical configurations. PIV: 400-1000 volts. Max. AC input voltages (RMS) of 280, 420, 560 and 700 volts. Max. reverse leakage current (PIV) 10μA. Max. average rectified current (Single-phase, half-wave) 150mA. Surge current (for 1 cycle) 10A.

S-3
Available in 5 physical configurations. PIV: 300-1000 volts. Max. AC input voltages (RMS) of 210, 280, 420, 560 and 700 volts. Max. average rectified current (Single-phase, half-wave) 3 A. Surge current (for a half-cycle) 300 A.

SW-05 (SE-05)
Available in 4 physical configurations. PIV: 400-1000 volts. Max. AC input voltages (RMS) of 280, 420, 560 and 700 volts. Max. average rectified current (Single-phase, half-wave) 500mA. Surge current (for 1 cycle) 16 A.

SW-1
Available in 4 physical configurations. PIV: 400-1000 volts. Max. AC input voltages (RMS) of 280, 420, 560 and 700 volts. Max. average rectified current (Single-phase, half-wave) 1 A. Surge current (for 1 cycle) 30 A.



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Custom power design is our specialty. Grafix engineers will gladly assist you in specifying your supply.

Illustrated is a power supply group with new breakthroughs in reliability. All solid state; short-circuit and salt spray proof; ruggedized and efficient. Case of anodized aluminum. Low frequency vibration or shock to 20 G's will not harm units. Potting of high voltage section allows efficient operation in high humidity or at high altitudes.

Model 209 Model 210 Model 215

COMMON FEATURES

Input: 25-32 V; **Regulation:** ±5% with load — ±.2% with input; **Ripple:** .1% RMS; **Temperature Stability:** ±1%, 0°C to 50°C; **Operating Temperature:** −10°C to 60°C; **Basic Size:** 4" x 4" x 3½". Output can be shorted continuously.

Model	Main Output	Other Outputs	Total Output Power	Weight	Price
209	4 KV, 10VA	+200 to +500, −200 to −500	25VA	3#	$455 ea
210	6.3VAC*, 60 or 400 cps	117VAC, 60 or 400 cps	30VA	3¼#	$420 ea
215	10 to 20 KV		10VA	2½#	$675 ea

*Insulated for 8 KV — Delivery 5 weeks ARO

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GRAFIX inc.
Dept. 63-1, Box 3296
Area Code 505, 265-6903
Albuquerque, New Mexico

reweld any joint that might appear to be questionably "cold".

Will Nuclear Irradiation Dope Integrated Circuits?

NUCLEAR REACTOR at Oak Ridge, Tenn., has been used for the fabrication of semiconductor electronic devices by a new process, called neutron transmutation doping by Fundamental Methods Associates, Inc., of New York City.

Silicon wafers were doped in controlled spatial patterns. Direct nuclear transmutation of the silicon took place using reactor neutrons, to produce *p-n* junctions in patterns whose typical dimensions are measured in thousands of an inch. These devices exhibited electrical properties, including rectification characteristics, comparable with those required in conventional semiconductor electronic equipment, the company reports.

Process Goals—Neutron doping has potential economic importance as a simple, controllable, one-step process for making transistors and other devices by direct exposure of the semiconductor in a nuclear reactor, the company says. The fabrication of complex microelectronic integrated circuits within a single chip of silicon appears to be within the capability of the process, possibly permitting significant cost reductions for specialized microcircuits, as well as for simpler devices.

The term "neutron transmutation doping" derives from the fact that reactor neutrons produce the electronically active impurities which dope the semiconductor by directly transmuting the atoms of the semiconducting material. In the case of silicon, phosphorus is produced by the neutron transmutation. Precise spatial control of the doping is attained by enclosing the semiconductor within a radiation die which is impervious to neutrons everywhere except through a previously prepared slit pattern. A one week irradiation is required, followed by a one month wait for radioactivity to decay. The final device has no residual radioactivity.

The company is developing the process under AEC Isotopes Development Division contracts.

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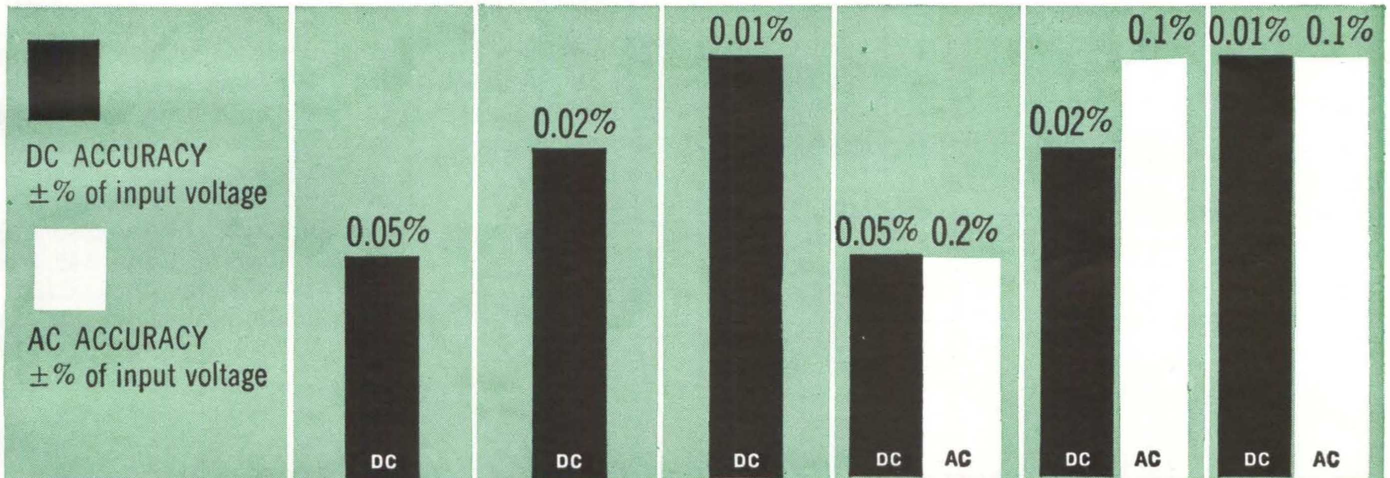
FLUKE

offers the most complete line of differential voltmeters on the market

Features common to all models are infinite input resistance at null; in-line readout with automatic lighted decimal; front panel DC polarity switch; standard cell reference (zener diode optional); taut band suspension meter and flow-soldered glass epoxy printed circuit boards.

Choose the degree of accuracy that meets your need...



Models	801B	825A	821A	803B	803D	823A
INPUT RANGE	**0-500V**	**0-500V**	**0-500V**	**0-500V**	**0-500V**	**0-500V**
FREQUENCY RANGE	....	....	....	**20 cps-10 kc**	**5 cps-100 kc**	**5 cps-100 kc**
MAXIMUM FULL SCALE SENSITIVITY	**10 mv**	**1 mv**	**1 mv**	**10 mv DC 1 mv AC**	**1 mv**	**1 mv**
MAXIMUM METER RESOLUTION	**50 uv**	**5 uv**	**5 uv**	**50 uv DC 5 uv AC**	**5 uv**	**5 uv**
REFERENCE	**Std. cell (zener diode optional)**	**Std. cell (zener diode optional)**	**Standard cell**	**Std. cell (zener diode optional)**	**Std. cell (zener diode optional)**	**Standard cell**
PRICE Cabinet model	**$485.00**	**$590.00**	**$795.00**	**$875.00**	**$1,100.00**	**$1,300.00**
Rack model	**$505.00**	**$610.00**	**$815.00**	**$895.00**	**$1,120.00**	**$1,320.00**

Prices and data subject to change without notice. Prices f.o.b. factory.

MILITARIZED — DC DIFF. VOLTMETER

Meets all environmental requirements of Mil-T-945A. Provides accurate voltage measurements (0 to 500V) under adverse environmental conditions.

MODEL 8011A
PRICE: $1745.00

Complete technical data on all FLUKE voltmeters available upon request.

PARTIAL 8011A SPECIFICATIONS

ACCURACY: ±0.05% of input from 0.1 to 500V
±0.1% of input or 0.5 mv, whichever is greater, below 0.1V
NULL RANGES: ±10, ±1, ±0.1, ±0.01V
INPUT IMPEDANCE: Infinite at null from 0 to 500V
MAXIMUM METER RESOLUTION: 50 uv
REFERENCE: Temperature controlled Zener diode

John Fluke Mfg. Co., Inc., Box 7428 Seattle 33, Wash.

FLUKE INSTRUMENTS

PR 6-1171 TWX 206-879-1864 TLX 852 Cable: FLUKE

Microwave Signal Sources Are Solid State

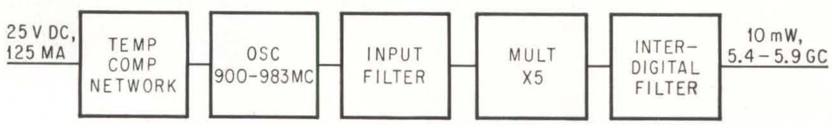
C-band unit will also be available for X-band in near future

MODEL MS-100 solid-state microwave signal source is designed to compete with low-power klystrons between 5.4 Gc and 5.9 Gc. Frequency may be varied through the range with a single-screw L-C adjustment. Fundamental frequency is between 900 Mc and 983 Mc generated by an oscillator using a special silicon planar transistor. Output is at the 6th harmonic from a planar diode multiplier and a mechanical filter.

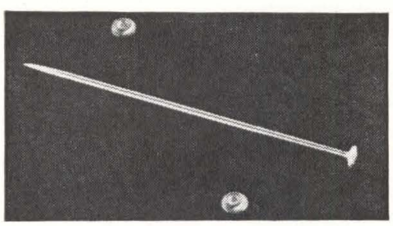
Input power is 25 volts d-c at 125 ma and output is 10 milliwatts minimum over the operating frequency range. Average output power is about 20 milliwatts and stability is 4 parts in 10^3 maximum between -55 C and $+100$ C.

According to the manufacturer, both reliability and life expectancy far exceed specifications of any comparable klystron. While only the C-band unit has been developed to date, an X-band model is expected to be completed by mid-1964 and units for other ranges are also in development. Fairchild Semiconductor, Div. of Fairchild Camera & Instrument Corp., 545 Whisman Rd., Mountain View, Calif.

CIRCLE **301,** READER SERVICE CARD



Tiny Tunnel Diodes Have Low Package Capacitance



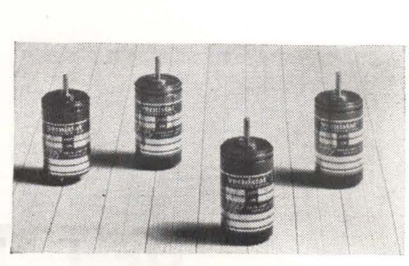
GERMANIUM tunnel diodes are available in two series in DOT packages for use in amplifiers, down converters, detectors and oscillators. Featuring low package inductance, low package capacitance and high resistive cutoff frequencies, units have control of peak currents to $\pm 10\%$ and are available with peak currents of 1, 2, 5, 10, 50 and 100 ma. Typical negative resistance of the 2 ma unit is 65 ohms. Resistive cutoff frequencies are up to 32 Gc.

The DOT package is 0.050-inch in diameter and 0.030-inch high. Moreover, the D-5071 series features tiny end pins for use where accurate alignment is necessary. Prices of the 2-ma units in quantities between 1 and 9 range from \$30 to \$130. Sylvania Electric Products Inc., 1100 Main Street, Buffalo, N.Y. **(302)**

Potentiometers Feature Low Output Impedance

POTENTIOMETERS with high input impedance and very low output impedance are available in four models. Units have high resolution and terminal linearity as well as low phase shift, multi-turn continuous rotation and no backlash. Designed for use in computers, these 10-ohm Vernistats® have broad applications in analog computers, navigation and fire-control computers and synchro-resolver computer systems.

Maximum input voltage at 400 cps is 15 v for model 445, 10 v for model 446, 20 v for model 447 and 30 v for model 448. Nominal input impedance is 2K, 4K, and 3K respectively, with 10-ohm maximum output impedance throughout. Absolute linearity is ± 0.05 percent and theoretical resolution is ± 0.013 percent. Units weigh 2 ounces and have continuous 12-turn mechanical rotation. The 10-ohm Vernistat is priced at \$295. Perkin-Elmer Corp.,



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CTS will mass produce loudspeakers to your exact requirements—with the well-known built-in CTS quality. Its new, highly efficient automated manufacturing facility (106,000 sq. ft.) is entirely devoted to loudspeaker production. The CTS loudspeaker engineering staff will gladly help you solve unusual application problems.

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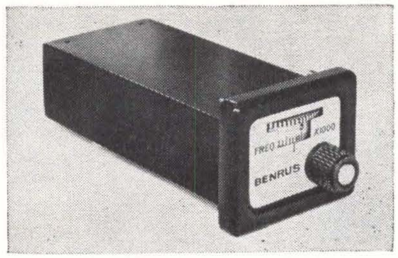
CIRCLE **303,** READER SERVICE CARD



Audio Oscillator Is Ultra-Compact

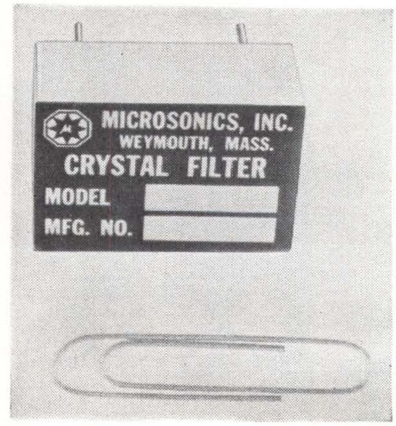
SOLID-STATE, small-size variable frequency oscillator is completely encapsulated and can be supplied in 16 models with output frequency ranges between 10 cps and 33 cps and 30 kc and 100 kc.

Specifically designed for rack panel mounting, units achieve ±1% stability through encapsulated circuits and the use of silicon transistors. Output frequency is continuously variable across the range by means of a vernier panel control and is indicated to an accuracy of ±2% by a drum-type indicator. Output distortion is below 2%.

With face dimensions of only 2¾ × 2¼ inches, as many as 12 oscillators may be grouped on a standard 5¼-inch by 19-inch rack panel. Benrus, Technical Products Div., 30 Cherry Ave., Waterbury, Conn. **(304)**

Megohmmeter Features High Accuracy

MODEL 710V Megatrometer, which measures up to 7.5 x 10^{16} ohms, is a direct reading instrument intended primarily for use by physicists for basic investigation of effects on insulation, semiconductor and other materials of ion migration, nuclear radiation, magnetic strip and other environments. Accuracy is 3 per cent upper half scale. Accuracies in the order of ½ percent to 2 percent can be obtained, depending on the accuracy of the resistance standard selected. Neither the instrument nor electrometer circuitry can be damaged by short circuits. Mid-Eastern Electronics, Inc., 32 Commerce St., Springfield, N. J. **(305)**



Crystal Filters Meet MIL Specs

NEW CRYSTAL FILTERS measure 1 in. by ¾ in. by 0.400 in. The thickness of 0.400 in. affords ready adaptability to printed-circuit boards and modular-type construction. Present designs are available from 5 to 50 Mc. Units conform to rigid military specifications. Microsonics, Inc., subsidiary of Sangamo Electric Co., 60 Winter St., Weymouth, Mass. **(306)**

D-C Volt/Ammeter Has Built-In Calibrator

SENSITIVE d-c volt/ammeter, model 365, has a voltage range of 1 μv to 1,000 v, and a current range of 0.01 μa to 1 ampere. Its single 5-in. voltage/current scale has the same needle deflection at bottom scale as at full scale for a given percentage change in the reading. This resolution makes possible the use of the full 5 inches of the scale with the assurance of both ability to read and the accuracy of the result. As a d-c amplifier, the instrument has a 100 db gain with output of 0.1 v d-c to 1.0 v d-c for each range selector

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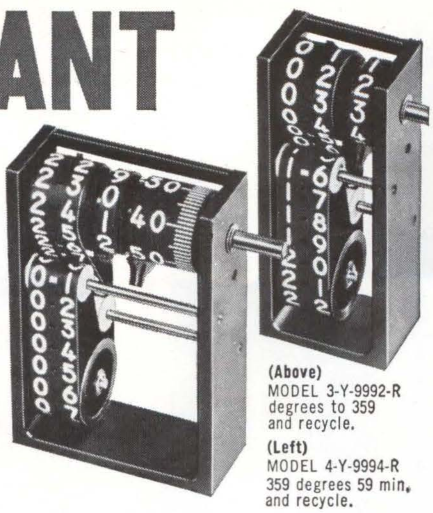
bearing degree or angle counters



(Above)
MODEL 3-Y-9992-R degrees to 359 and recycle.

(Left)
MODEL 4-Y-9994-R 359 degrees 59 min. and recycle.

Design your navigation instruments, ground support equipment, ground approach systems, or gauging instruments with the Durant Counters as integral equipment. Direct, continuous (no gears) drive, adding or subtracting at high speeds (up to 1500 RPM intermittent) and much less noise due to Durant's Hi-Speed Geneva Index mechanism. Fiberglass and nylon tape for 00 to 35 digits. Figures meet Mil Spec 33558, entire instrument checked out to Mil Spec 5272, including humidity and salt spray. Models shown above in stock; variations available on special order.

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HEAD OFFICE : Uehara Bldg., Oikedori, Karasumahigashi-iru Nakagyo-ku, Kyoto, Japan

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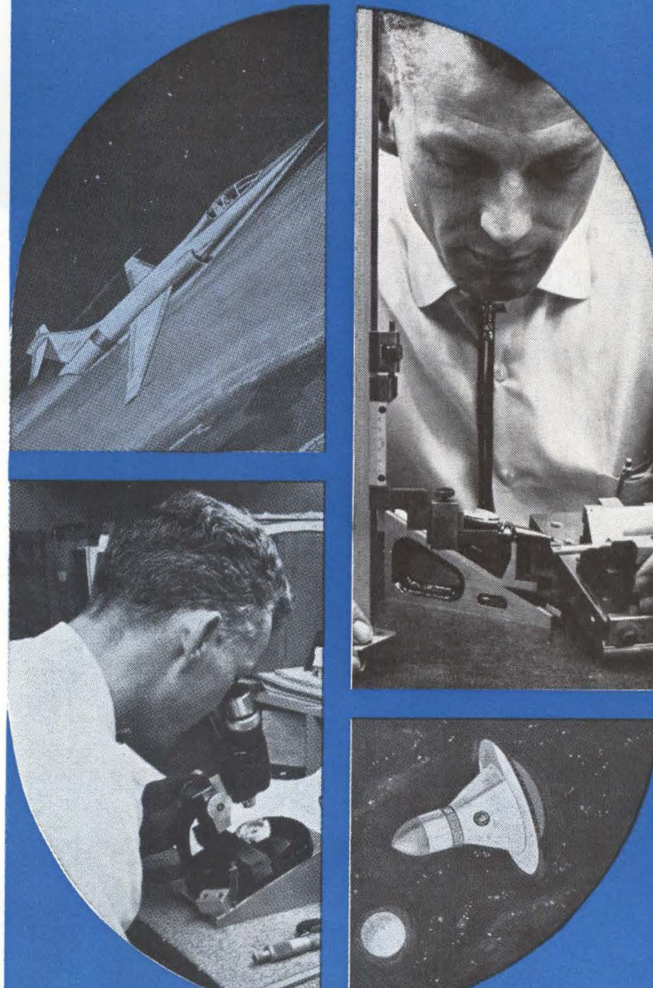
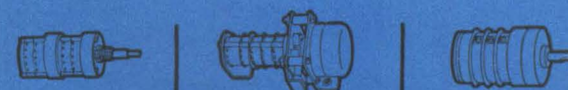


UNDERSTANDING SWITCHING TECHNIQUES THROUGH KNOWLEDGE



Janco's understanding of switches lies in the knowledge gained from its experience in making switches that function properly under conditions beyond the normal electrical, mechanical, or environmental standards. This experience provides a comprehensive knowledge of switching techniques. This means that proven performance is inherent in every Janco switch. ■ Janco's continuing research and development programs are dedicated toward meeting tomorrow's requirements today. Years of service with high performance military aircraft and missile systems is conclusive evidence of Janco's superior knowledge and experience.

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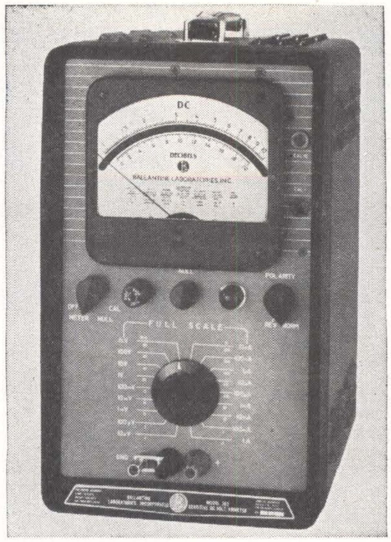
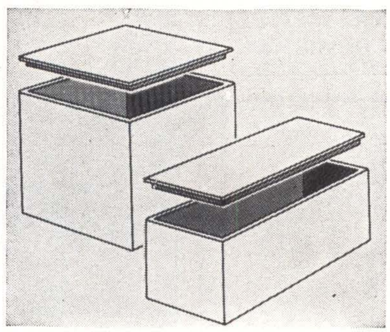
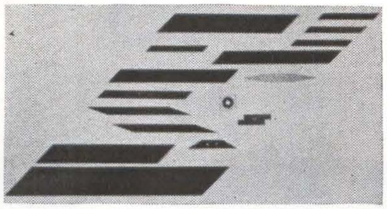


step. This d-c output may be applied to a digital voltmeter for measurement of very low voltages or currents. Model 365 may be operated with signal ground isolated from system or panel ground, or connected to ground if desired. Ballantine Laboratories, Boonton, N. J.
CIRCLE **307**, READER SERVICE CARD



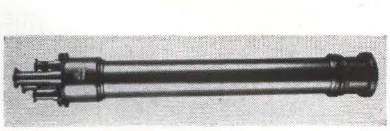
Header Plates and Potting Shells

GLASS EPOXY LAMINATED header plates are now available—without tooling costs—for use with over 800 sizes of square and rectangular tubing for potting forms. Header plates are made in a 0.030-in. thickness in glass epoxy—Class F material—either natural color or black pigmented. The edges of the bottom side are shouldered so that 0.020-in. thickness recesses into the open end of the tube and 0.010 in. thickness lays on the wall of the tube. The top side is flat. Both tubes and header plates are free of mold release contamination and offer good compatibility with epoxy cements and potting compounds. Glass laminated construction offers excellent strength and shock resistance. Stevens Tubing Corp., 86-88 Main St., East Orange, N. J. **(308)**



Resistance Cards Come in Varied Sizes

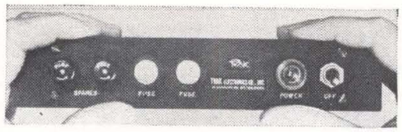
COMPLETE LINE of metal film resistance cards with fiberglass-epoxy substrates, high vacuum deposited resistive coatings, and environmental-protective overlayers are available. Series TFT-C resistance cards can be attached and incorporated into assemblies in many fashions, including epoxy cementing and fastening through eyelets. Typical applications include elements for attenuators, mode suppressors, and terminations. Offering homogeneous and uniform evaporated layers throughout each card, resistances from 10 to 1,000 ohms per square can be obtained with 25, 50, 100, 125, 150, 180, 200, 250, 300, 377, 400 and 500 ohms per square as stock values on 6 by 12 in. cards, including silver terminal strips. Three standard thicknesses, 0.062 in., 0.032 in. and 0.025 in., are ideal for frequencies below C-band, from C- to X-band, and above X-band, respectively. Metavac, Inc., 45-68 162 St., Flushing 58, N. Y. **(309)**



TWT Amplifiers Feature High Power

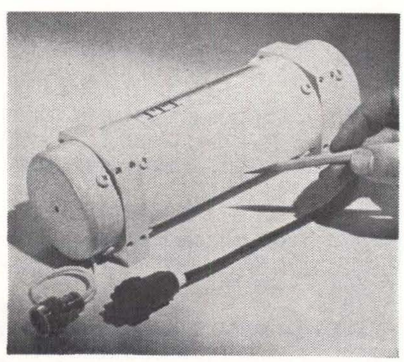
TWO new high-power traveling-wave-tube amplifiers for use in broad band frequency diversity radar systems have been introduced. Types QKW574 and QKW575 are designed for pulse operation in the uhf frequency band. Their frequency range is 570-690 Mc. The QKW574 has a peak power output rating of 3.0 kw, while the QKW575 delivers a peak power of 300 kw. The QKW574 has a 30-db gain, 8.0-μsec pulse width and peak current of 2.5 amperes. For the QKW-575, gain is 21 db, pulse width 7.5 μsec, and peak current 50 amperes. Raytheon Co., Waltham, Mass. 02154.

CIRCLE **310,** READER SERVICE CARD



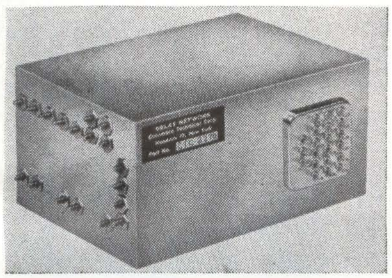
Antenna Multicoupler Uses Transistors

COMPACT, all-solid-state wideband antenna multicoupler for use in h-f direction finding or communications systems is being offered. Model 308 operates from 2 to 32 Mc and permits simultaneous operation of up to 8 receivers from a single antenna with an output isolation of 40 db. It offers an 8 to 1 space advantage over comparable vacuum tube units and produces less than 10 percent of the heat of conventional devices. Power requirement is only 15 w. Intermodulation - distortion products are kept low through the use of linear transistor circuitry. Input and output impedances are 72 ohms with low vswr to give increased control of phase and amplitude when employed in direction finding systems. Trak Electronics Co., Inc., 59 Danbury Road, Wilton, Conn. **(311)**



Voltage-Tunable BWO's Cover 1 to 12.4 Gc

LINE of 12 voltage-tunable backward-wave oscillators covering the 1- to 12.4-Gc range is announced. The compact series F-2500 have power outputs ranging from 25 to 250 mw. They are permanent-magnet focused for high stability and various models use unifilar and bifilar helixes. No cooling is required when the environment is below 60 C. Operating voltages are low, of the order of 250 to 1,000 v, and cathode currents are also low, none being higher than 25 ma. The tubes are usable for swept signal sources in signal generators, as master oscillators for frequency diversity transmitters, and as local oscillators in radar and countermeasure receivers. ITT Electron Tube Division, Clifton, N. J. **(312)**

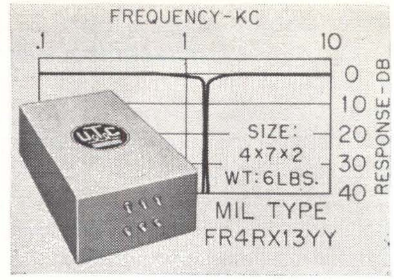


Delay Line Has 18 Adjustable Taps

A DELAY LINE with 18 independently adjustable taps in a single unit is announced. Nominal delay ranges from 80 nsec to beyond 800 nsec overall. Each tap is adjustable over a range of 5 nsec, with a resolution of 0.5 nsec. Since the adjustment of any one delay value has no effect on the others, adjustment is truly independent. Frequency response is 9 Mc at 3 db. Temperature coefficient is 50 ppm/deg C. Size is 3½ in. by 4¾ in. by 6¼ in. Price is $450. Columbia Technical Corp., Woodside 77, N. Y. **(313)**

Separation Filter Does Two Jobs

NOW AVAILABLE are sharp cutoff low and high pass filters, with common inputs connected in parallel, packaged in one case. The source is 600 ohms. The load for each filter is 600 ohms. The low pass filter is within 3 db from d-c to 1,350 cps, has at least 14-db attenuation at 1,410 cps, and is down at least 40 db at 1,465 cps and higher

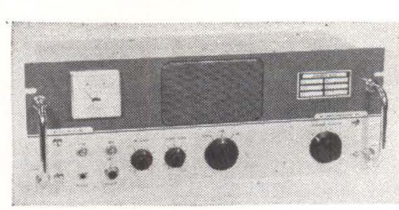


frequencies. The high pass filter is within 3 db from 100 kc to 1,470 cps, has at least 14-db attenuation at 1,410 cps, and is down at least 40 db at 1,355 cps and lower frequencies. Unit is hermetically sealed and guaranteed to MIL-F-18327B; MIL type designation is FR4RX13YY; size, 4 in. by 7 in. by 2 in.; weight, 6 lb. United Transformer Corp., 150 Varick St., New York 13, N.Y.

CIRCLE **314,** READER SERVICE CARD

Power Supplies for Vacuum Applications

A LINE of solid state glow discharge power supplies for vacuum applications has been introduced. These units are available in 5,000 v 500 ma or 3,000 v 300 ma ratings, and are suited for cathodic etching, sputtering or glow discharge work. Allen-Jones Electronics Corp., 17171 South Western Ave., Gardena, Calif. **(315)**



SSB Receiver Is a Fixed-Channel Unit

MODEL RF-503 can be set to six fixed tuned crystal controlled channels in the frequency range of 1.6 to 28 Mc. The receiver has capa-

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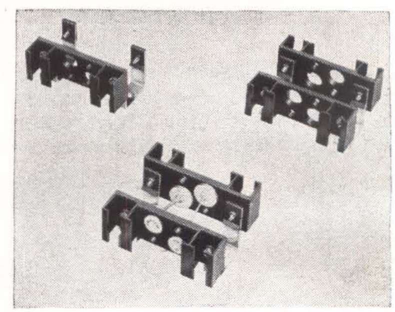
bility for receiving upper or lower sideband, c-w or a-m signals. A built-in speaker is provided and 600-ohm balanced audio output is also available. Stability of the receiver is 2 ppm. Unit is intended to be used with the company's line of ssb communications systems for monitor purposes. Another application is to receive WWV and other standard signal transmissions. The RF-503 measures 7 in. high by 19 in. wide by 8 in. deep and weighs 15 lb. List price is $800. RF Communications Inc., 1680 University Ave., Rochester 10, N.Y.
CIRCLE **316,** READER SERVICE CARD

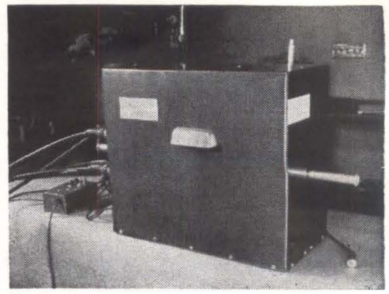


Heat Sinks Feature Fin Design

DESIGNED for press fit rectifiers, the inexpensive model 2510, natural convection rectifier bridge assembly, provides high thermal efficiency and improved component reliability. The mounting hardware variations permit a wide range of applications in the assembly of bridge circuits. These units are available as assemblies including hardware, or as individual heat sinks. The fin design optimizes the largest effective heat dissipation surface in the smallest volume. Heat sink dimensions are $2\frac{7}{8}$ x 1 x $\frac{11}{16}$. Astro Dynamics, Inc., Second Ave., Northwest Industrial Park, Burlington, Mass. **(317)**

Pulsed Ruby Laser Has 500-Joule Output

MODEL 3300 pulsed ruby laser has a guaranteed output of at least 500 joules. It is capable of firing better than once every five minutes. Price, complete with ruby rod and four flashlamps, is $12,500. Fabrication of the ruby rod is optionally flat or



TIR type. The rod is 0.04 percent to 0.05 percent chromium doped and measures 7 in. by ⅝ in. It is encapsulated in a multi-elliptical cavity with highly polished mirror finished surfaces. Model 3300 is equipped with a Q-switching device to provide an output of greater than 60 megawatts in approximately 40 nsec. Maser Optics, Inc., 89 Brighton Ave., Boston 34, Mass.

CIRCLE **318,** READER SERVICE CARD

Chopper Driver Has 94-CPS Output

TYPE CD231 chopper driver provides a 94-cps chopper excitation frequency with a 5 to 7 v d-c signal applied. Of solid-state design, the

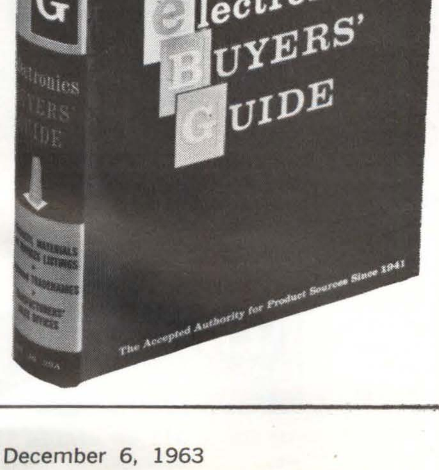
chopper driver requires but 100 mw of drive power at 5 v d-c. Temperature range is 0 to 80 C. The 94-cps output will not vary more than 1 cycle over a 5 to 7 v d-c input or 0 to 60 C temperature range. Airpax Electronics Inc., Cambridge, Md. **(319)**

HOW TO USE YOUR ELECTRONICS BUYERS' GUIDE*

The Two-Way Product Locater

* * *

Most products advertised in the ELECTRONICS BUYERS' GUIDE are listed twice for your convenience. After the Product Heading, advertising page numbers appear where appropriate (when advertisements of one kind are grouped together in the book). Next to the individual product listing, the page number of associated advertising material is cited. Thus you can locate all of the advertisements for a particular product category, or any specific advertisement, quickly, accurately, and conveniently. Keep your ELECTRONICS BUYERS' GUIDE close to your work area at all times.



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Wiring problems can't always be answered by standard materials, even from the broad range of wire products available today. Markel's capacity for engineering high temperature wire and cable constructions to meet particular needs has grown steadily with the demand. The toughest requirements in temperature, corrosive atmospheres, flexing, corona effect, etc., can be solved—*with long range economy and reliability* — by specially designed products from our FLEXLEAD Division.

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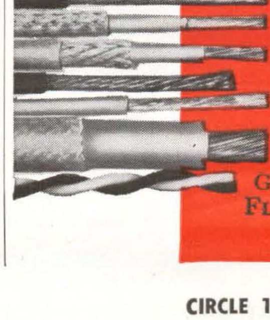

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HIGH TEMPERATURE WIRE AND CABLE

Get more facts. Write or call for a FLEXLEAD Wire and Cable Selector

LITERATURE OF THE WEEK

VAPOR SPRAY SYSTEM Zicon Corp., 63 E. Sanford Blvd., Mount Vernon, N. Y. Bulletin describes advantages of Chemtronic system for spraying conformal and protective coatings on printed circuit boards and electronic components.
CIRCLE **360,** READER SERVICE CARD

MINIATURE FANS Globe Industries, Inc., 1784 Stanley Ave., Dayton, Ohio 45404. A line of miniature precision fans are described in single-page brochure 115. **(361)**

INSTRUMENT REFERENCE GUIDE Industrial Instruments Inc., 89 Commerce Road, Cedar Grove, N. J., offers a quick reference catalog on a line of amplifiers, automatic test, insulation and measuring equipment. **(362)**

PROCESS CONTROLLER Corning Glass Works, Corning, N. Y. Bulletin CE-13.03 covers an advanced solid-state process controller for laboratory and industrial applications. **(363)**

SWITCHING DIODES Microwave Associates, Inc., Burlington, Mass. Data sheet covers a line of microwave silicon PIN switching diodes. **(364)**

METAL-CASED CAPACITORS Aerovox Corp., New Bedford Division, New Bedford, Mass. Bulletin 121B2 Rev. 1 describes a line of miniature metal-cased capacitors. **(365)**

CENTRIFUGAL CASTINGS Janney Cylinder Co., 7401 State Road, Philadelphia 36, Pa., has available a catalog describing centrifugal castings of ferrous and nonferrous alloys. **(366)**

LOW-FREQUENCY CRYSTALS Monitor Products Co., Inc., 815 Fremont Ave., So. Pasadena, Calif. Six-page brochure gives specifications and characteristics on low-frequency quartz crystals in the 1 to 1,000-kc range. **(367)**

VARIABLE DELAY LINES Helipot Division of Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. Data sheet 64037 covers all models of Helidel variable delay lines. **(368)**

SYNCHRO TESTING Theta Instrument Corp., Saddle Brook, N. J. A 40-page catalog describing a complete line of synchro and resolver test equipment has been released. **(369)**

STANDARD SOLENOIDS Pickering & Co., Inc., Plainview, N. Y., has published an 8-page guide to standard-design d-c solenoids. **(370)**

MAGNETIC TIMERS Leach Corp., 1123 Wilshire Blvd., Los Angeles 17, Calif., has available a solid state magnetic timer data sheet. **(371)**

TUBE SHIELD Magnetic Shield Division Perfection Mica Co., 1322 No. Elston Ave., Chicago, Ill., 60622. Data sheet 165 illustrates and describes a new sophisticated scintillator photomultiplier tube shield. **(372)**

WIRE AND CABLE Tensolite Insulated Wire Co., Inc., West Main St., Tarrytown, N. Y. An expanded catalog of PVC (poly vinyl chloride) insulated wire and cable to MIL-W-16878 is available. **(373)**

CONNECTORS Winchester Electronics Inc., Willard Road, Norwalk, Conn., offers a brochure on the WT series miniature round Trilock environmental connectors. **(374)**

BAFFLE BROCHURE NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass. Brochure BCT-1 on vacuum baffles and cold traps is now available. **(375)**

TRIMMING POTENTIOMETERS Techno-Components Corp., 18232 Parthenia St., Northridge, Calif. A 2-page catalog sheet covers a line of subminiature, square trimming potentiometers. **(376)**

DECOMMUTATION SYSTEM Telemetrics, Inc., 12927 So. Budlong Ave., Gardena, Calif. Data sheet No. 119 provides full description and specifications of the new model 640 pam/pdm decommutation system. **(377)**

VARIABLE INDUCTOR Nytronics, Inc., 550 Springfield Ave., Berkeley Heights, N. J. Data sheet shows a slug-tuned miniature variable inductor for printed circuits. **(378)**

GYRO COMPONENTS Vernitron Corp., 52 Gazza Blvd., Farmingdale, N. Y., has released 41 technical data sheets covering recent gyro components, motors, pots, synchros and resolvers. **(379)**

OSCILLOSCOPES AND CAMERAS DuMont Laboratories, Divisions of Fairchild Camera and Instrument Corp., 750 Bloomfield Ave., Clifton, N. J. Short form catalog No. 129 illustrates and describes high, medium and low-frequency oscilloscopes and scope cameras. **(380)**

NANOVOLT INSTRUMENTS Astrodata Inc., P.O. Box 3003, 240 E. Palais Road, Anaheim, Calif. 92803. Technical bulletins describe a nanovolt meter, amplifier and integrator. **(381)**

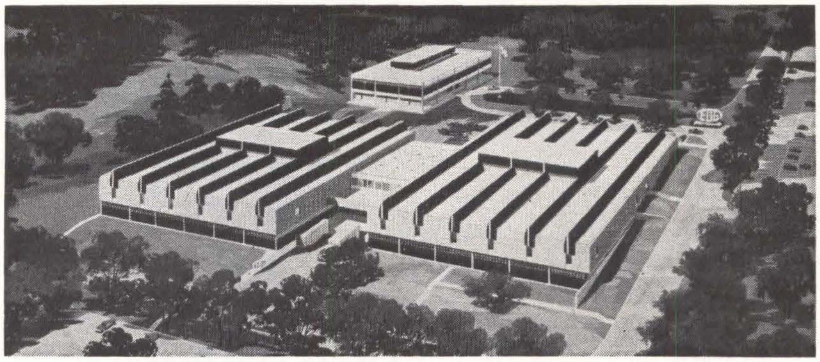
ZENER DIODES TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif. Series 6100 technical sheets on 500-mw and 1-w zener diodes are available. **(382)**

MICROWAVE SIGNAL GENERATORS Strand Labs Inc., 143 Main St., Cambridge, Mass. Microwave signal generators are discussed in detail in a new 19-page brochure. **(383)**

MULTIPLEXER Harman-Kardon, Inc., Plainview, N. Y. A new solid state multiplexer, for precise high speed multiplexing of 20 or more channels of analog data, is described in a technical data sheet. **(384)**

PRECISION ANGLE ENCODING Datex Corp., 1307 S. Myrtle Ave., Monrovia, Calif. Brochure describes precision angle encoding techniques. **(385)**

PLOTTER CONTROL UNIT White Electromagnetics, Inc., 4903 Auburn Ave., Bethesda 14, Md. Brochure describes method of automating rfi and field-intensity receivers to yield X-Y plotter outputs with the use of the model 10A plotter control unit. **(386)**



EG&G Expands in East and West

EDGERTON, GERMESHAUSEN AND GRIER, INC., Boston-based electronics firm, will occupy early in 1964 new headquarters in Bedford, Mass., adjoining Route 128. The company will continue existing Massachusetts operations in Boston and Salem.

The first three buildings (picture) being built on the Bedford site will house corporate headquarters, corporate R&D, and also the research, development and engineering laboratories of EG&G's Eastern operations. The three buildings will provide 165,000 square feet of floor space and the site can eventually accommodate 500,000 square feet.

At the same time, a new building now being completed at McCarran Field in Las Vegas, Nevada, will bring under one roof all of EG&G's Las Vegas R&D and administrative operations. And in Santa Barbara, Calif., the company recently occupied a new research and development facility for West Coast operations.

Founded in 1947 by a trio of MIT scientists who had been associated in scientific R&D since 1934, EG&G started out as contractor for the AEC in performing timing and control operations for the earliest nuclear fission tests. The AEC has continued until 1968 EG&G's contract for R&D and technical activities in connection with AEC programs. For fiscal 1964, the company's work on AEC programs is covered by a $32-million contract.

In addition to its work for the AEC, EG&G's activities include R&D in nuclear radiation effects, electronic flash systems, packages and components for laser, strobe-flash and high-energy-switching applications; electronic and electro-optical measuring instruments for R&D, and electronic and photographic systems for oceanographic studies.

The firm employs more than 2,000. In 1962, sales doubled over 1961 to a total of $38 million and net earnings rose from $421,852 to $1,013,035. President Kenneth J. Germeshausen told shareholders that a decrease in weapons test activities is assumed in current predictions and that 1963's volume will probably be in the neighborhood of 1962's.

Vice president A. M. Clark estimates the company will do $40 million worth of business by year's end and net will be about $1,150,000.

The three principal officers of the firm are pioneers in ultra-high-speed photography, and the stroboscopic and other flash techniques which they developed in the 1930's prepared them for the earliest diagnostic studies of nuclear explosions.

Harold E. Edgerton, chairman of the board, is professor of electrical engineering at MIT. Germeshausen is holder of basic patents on the hydrogen thyratron. Herbert E. Grier, executive vice president, directs the Western operations.

IBM Promotes Two Executives

INTERNATIONAL BUSINESS MACHINES Corporation has announced that Gardiner L. Tucker, director of research, will head the company's newly formed Research Division.

The firm also announced that Andrew H. Eschenfelder has been named general manager of the Components Division. He was assistant director of research for the company.

Tucker joined IBM in 1952 as a physicist. He has served as manager of research analysis and planning at the company's Poughkeepsie, N. Y., research laboratory, manager of the San Jose, Calif., research laboratory, and director of development engineering for the IBM World Trade Corporation. He was named director of research last January.

Eschenfelder joined IBM in 1952. He was resident manager of the IBM research laboratory at Poughkeepsie and director of solid state science at the company's research center in Yorktown, N. Y., prior to becoming assistant director of research in 1961.

GI Names Pascuzzo Group Vice President

APPOINTMENT of J. R. Pascuzzo as group vice president for Defense and Engineering Products of General Instrument Corp. is announced. He had been vice president of GI's Radio Receptor Division, the biggest unit in the Defense and Engi-

Investment Opportunity

The hand holding the hammer will someday make products for you.

Long years of training will have to go into making those chubby fingers productive. Much care, much love, much planning and money.

But no matter how lean and hard and skillful they become, it will signify little if the fruits of their skill are produced in anything but a free society.

You have an investment in those hands. To protect your investment, you can join with other leading American businessmen to promote the Treasury's Payroll Savings Plan for United States Savings Bonds. The Treasury Department's Plan works for soundness in our economy, strength in our defenses, and thriftiness and self-reliance in our thinking.

When you bring the Payroll Savings Plan into your plant—*when you encourage your employees to enroll*—you are investing in the hands of tomorrow's tool makers and tool users. You are investing in America's next generation of machine operators, mechanics, metal workers—in all of America's skilled labor force. You are investing in America's future. In freedom itself.

Don't pass this investment opportunity by. Call your State Savings Bonds Director. Or write today to the Treasury Department, U.S. Savings Bonds Division, Washington 25, D.C.

in your plant...promote the PAYROLL SAVINGS PLAN for U.S. SAVINGS BONDS

The U. S. Government does not pay for this advertisement. The Treasury Department thanks, for their patriotism, The Advertising Council and this magazine.

neering Products Group.

The Defense and Engineering Products Group has plants and laboratories at Hicksville, N. Y., Westwood, Mass., Woodbury, Conn., and Brooklyn, N. Y.

Sullivan Accepts Key Litton Post

DAVID C. SULLIVAN has been appointed to the newly created position of vice president and director of new markets development for the Guidance and Control Systems division of Litton Industries, Woodland Hills, Calif.

Sullivan was formerly director of government market planning for Raytheon Company.

Chapman Joins Hallicrafters

ARTHUR L. CHAPMAN has been appointed executive vice president and general manager of The Hallicrafters Co., Chicago, Ill. He will be responsible for all company development, manufacturing and marketing activities in both military and commercial areas.

Chapman is a former vice president of Sylvania Electric Products, Inc., where he was employed for 24 years; president of CBS-Hytron (later known as CBS Electronics), and member of the board of directors of Columbia Broadcasting System, Inc. Prior to joining Hallicrafters, he was executive vice president of Pacific Mercury Electronics, Sepulveda, Calif.

Simmonds Precision Elevates Edwards

HARRISON F. EDWARDS, executive vice president of Simmonds Precision Products, Inc., Tarrytown, N. Y., has been elected a director of the company, a manufacturer of electronic systems.

Edwards joined Simmonds in 1953 as a field engineer. In the ensuing years he served as manager of applications engineering, chief engineer, general manager of the company's manufacturing division and vice president of manufacturing. He was named executive vice president of Simmonds in April of this year.

Backinoff Joins Dranetz Engineering

IRVING BACKINOFF has been appointed vice president and elected to the board of directors of Dranetz

Engineering Laboratories, Inc., Plainfield, N.J. He will head product design and production.

Backinoff was formerly with the Kearfott division of General Precision Aerospace and the Daven division of General Mills, Inc.

Dranetz Engineering Laboratories, Inc., designs and manufactures advanced electronic instrumentation for oceanographic, sonar and environmental test programs.

PEOPLE IN BRIEF

Fred Johnson leaves GE to join the Electron Products div. of Marshall Industries as mgr., applications engineering. **Martin L. Barton** advances to chief engineer, and **Raymond D. Egan** to mgr. of the research dept. at Granger Associates. **William E. Taylor** promoted to operations mgr. for materials by Motorola Semiconductor Products div. **Gary G. Gould,** formerly with Autonetics, appointed mgr. of European operations for the Data Systems div. of Litton Industries. **Wayne C. Stevenson,** previously with Loren Patrick Associates, named vacuum products mgr. of Allen-Jones Electronics Corp. **Warren J. Nichols,** from Ryan Aeronautical Co. to Space-General Corp. as mgr. of the Material div. **Stanley H. Autler,** ex-Lincoln Laboratories, MIT, now heads cryophysics research at Westinghouse Research Laboratories. **Weston A. Anderson** raised to director, research, for the Analytical Instrument div. of Varian Associates. He replaces **Martin Packard,** who has been made g-m of the div. **Robert A. Rosenberg** moves up to president of Mitron Research & Development Corp., replacing **Marvin H. Frank,** who was elected chairman of the board. **Robert W. Sproul,** from National Co., Inc. to The Singer Co., Metrics div., as chief engineer for electronic instruments. **Robert W. Hawkinson** elevated to president of Belden Mfg. Co., succeeding **Charles S. Craigmile,** who becomes chairman of the board and chief exec officer.

EMPLOYMENT OPPORTUNITIES

electronics

WEEKLY QUALIFICATION FORM FOR POSITIONS AVAILABLE

ATTENTION: ENGINEERS, SCIENTISTS, PHYSICISTS

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

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

STRICTLY CONFIDENTIAL

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

WHAT TO DO

1. Review the positions in the advertisements.
2. Select those for which you qualify.
3. Notice the key numbers.
4. Circle the corresponding key number below the Qualification Form.
5. Fill out the form completely. *Please print clearly.*
6. Mail to: Classified Advertising Div., ELECTRONICS, Box 12, New York, N. Y. 10036. (No charge, of course).

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ACF INDUSTRIES INC. Albuquerque, New Mexico	124	1
ATOMIC PERSONNEL INC. Philadelphia, Pa.	59*	2
BARNES ENGINEERING CO. Stamford, Conn.	124	3
INTERNATIONAL BUSINESS MACHINES CORP. Poughkeepsie, New York	123	4
LING-TEMCO-VOUGHT, INC. Dallas, Texas	106	5
MARQUARDT CORP. Van Nuys, Calif.	37*	6
MELPAR, INC. Sub. of Westinghouse Air Brake Co. Falls Church, Virginia	104	7
SPACE & INFORMATION SYSTEMS Div. of North American Aviation, Inc. Downey, Calif.	102, 119	8
SYLVANIA ELECTRONIC SYSTEMS—West Mountain View, Calif.	122, 123	9
P-3435	123	10

* These advertisements appeared in the November 29th issue.

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

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

Personal Background

NAME ....

HOME ADDRESS ....

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

HOME TELEPHONE ....

Education

PROFESSIONAL DEGREE(S) ....

MAJOR(S) ....

UNIVERSITY ....

DATE(S) ....

FIELDS OF EXPERIENCE (Please Check) 12663

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

CATEGORY OF SPECIALIZATION

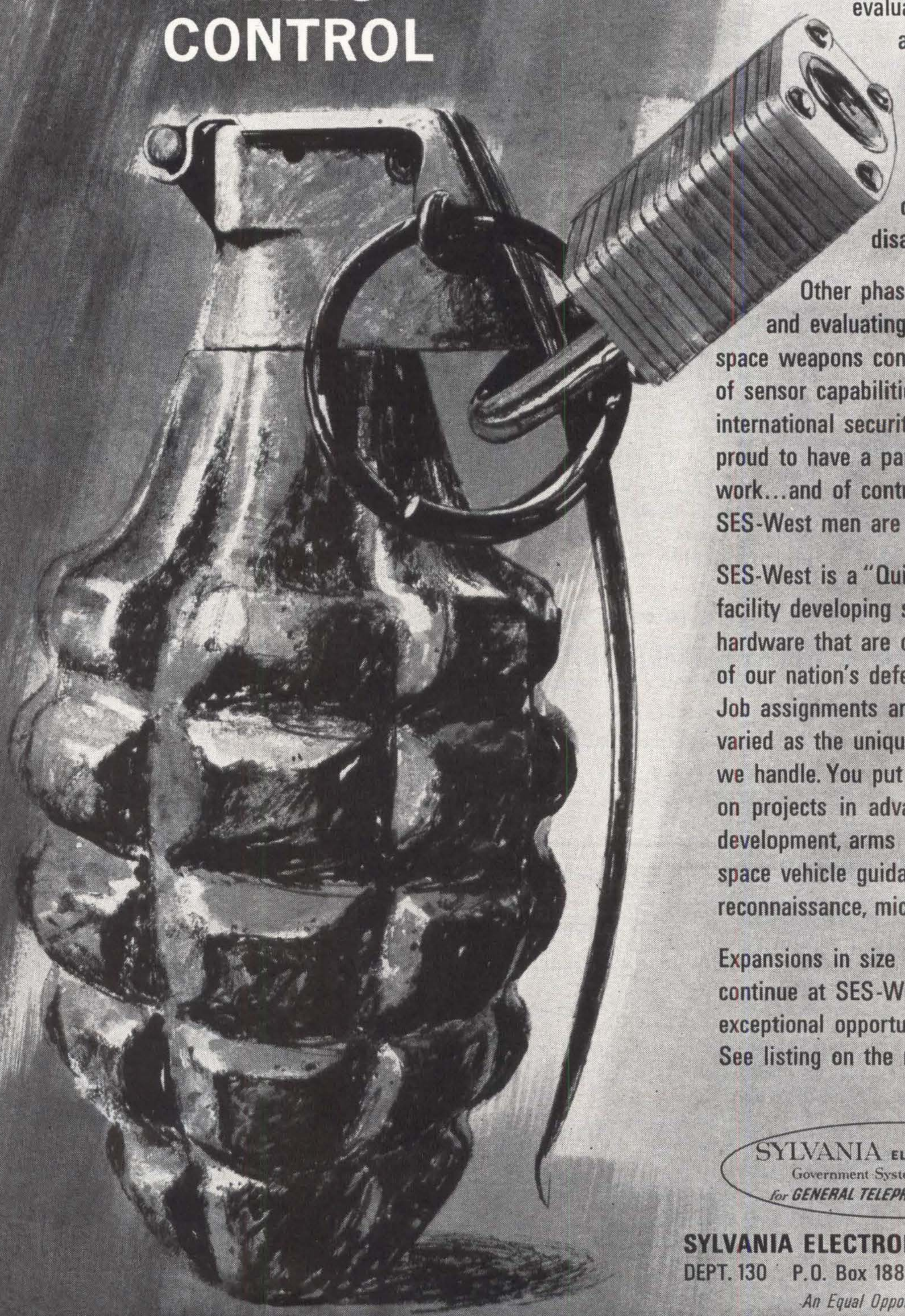
Please indicate number of months experience on proper lines.

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

CIRCLE KEY NUMBERS OF ABOVE COMPANIES' POSITIONS THAT INTEREST YOU

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

ARMS CONTROL



Briefs on the Kind of Assignments You Can Expect at SES-West

Arms control and disarmament present a compelling challenge to the scientific mind. Under the U.S. Arms Control and Disarmament Agency, SES-West is meeting this challenge... evaluating many areas of arms control, including inspection systems to verify various possible arms control and disarmament measures.

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for GENERAL TELEPHONE & ELECTRONICS

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8964

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We have openings for:

ELECTRICAL/ELECTRONIC ENGINEERS

to participate in the development and testing associated with nuclear propulsion and other programs in the nuclear field. Experience level required varies, ranging from three years upward. Some are supervisory positions.

BSEE degree and U. S. citizenship required

Albuquerque, a city of 260,000, provides an attractive working environment with excellent schools, two universities (we have a liberal educational benefits plan for those who wish to continue their studies), numerous churches, a complete range of cultural and recreational activities and a sunny, dry, healthful climate that remains pleasant and mild winter and summer.

Send resume to: **General Supervisor, Professional Recruiting
Albuquerque Division,
ACF Industries, Incorporated
P. O. Box 1666,
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SAN FRANCISCO, Cal. 94111: 255 California St.*

POSITION VACANT

Editors of translated electronics publications. EE's or Physicist, solid technical background and ability to write good technical English. Knowledge of Japanese and/or Russian preferred. Full and part-time positions. P-3380, Electronics.

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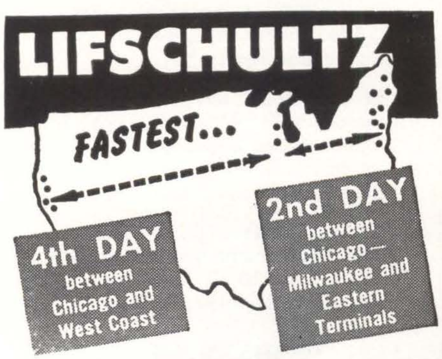

Specialists in Shipment of Electronics Products

LIFSCHULTZ FAST FREIGHT
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HOLYOKE — BALTIMORE — BLOOMFIELD, N. J.
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Your Inquiries to Advertisers Will Have Special Value . . .

—for you—the advertiser—and the publisher, if you mention this publication. Advertisers value highly this evidence of the publication you read. Satisfied advertisers enable the publishers to secure more advertisers and—more advertisers mean more information on more products or better service—more value—to **YOU.**

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KEYSTONE ELECTRONICS CORP. 49 BLEECKER ST. NEW YORK 12 N. Y.

CIRCLE 953 ON READER SERVICE CARD

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P. J. PLISHNER — Call JU 6-4691
550 5th Ave. — New York 36, N. Y.

CIRCLE 954 ON READER SERVICE CARD

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550 5TH AVE., NEW YORK 36, N. Y. — JU 6-4691

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$13. to $13,000. New Catalog
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CLASSIFIED ADVERTISERS INDEX

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electronics

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Market Research Manager

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electronics Buyers' Guide

R. S. QUINT (2335)
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RICHARD J. TOMLINSON (3191)
Business Manager

THEODORE R. GEIPEL (2044)
Production Manager

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Trinity 5-0523 (area code 404)

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William S. Hodgkinson
McGraw-Hill Building, Copley Square,
Congress 2-1160 (area code 617)

CHICAGO, ILL. 60611
Harvey W. Wernecke,
Robert M. Denmead
645 North Michigan Avenue,
Mohawk 4-5800 (area code 312)

CLEVELAND, OHIO 44113
Paul T. Fegley
55 Public Square, Superior 1-7000 (area code 216)

DALLAS, TEXAS 75201
Frank Le Beau
The Vaughn Bldg.,
1712 Commerce St.
Riverside 7-9721 (area code 214)

DENVER, COLO. 80202
John W. Patten
Tower Bldg., 1700 Broadway,
Alpine 5-2981 (area code 303)

HOUSTON, TEXAS 77025
Kenneth George
Prudential Bldg., Halcombe Blvd.,
Riverside 8-1280 (area code 713)

LOS ANGELES, CALIF. 90017
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Donald R. Furth (212) 971 3616
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LOcust 8-4330 (area code 215)

SAN FRANCISCO, CALIF. 94111
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Douglas 2-4600 (area code 415)

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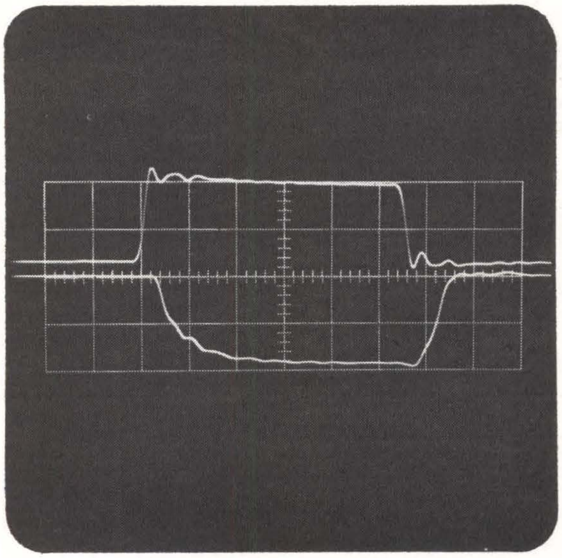
FASTEST CORE

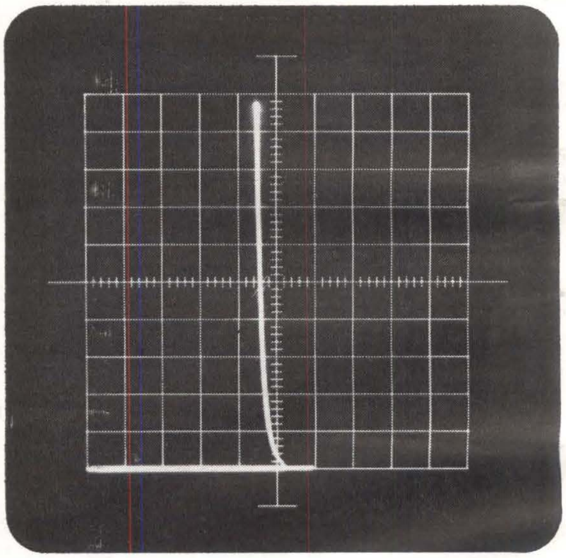
HIGH SPEED



- $t_{on} = 40$ nsec max
  $t_{off} = 40$ nsec max
  @ $I_C = 150$ mA, $I_{B_1} = I_{B_2} = 15$ mA

Photo above shows typical 500 mA switching @ $I_{B_1} = I_{B_2} = 50$ mA
Scale: Horizontal = 20 nsec/division

HIGH VOLTAGE



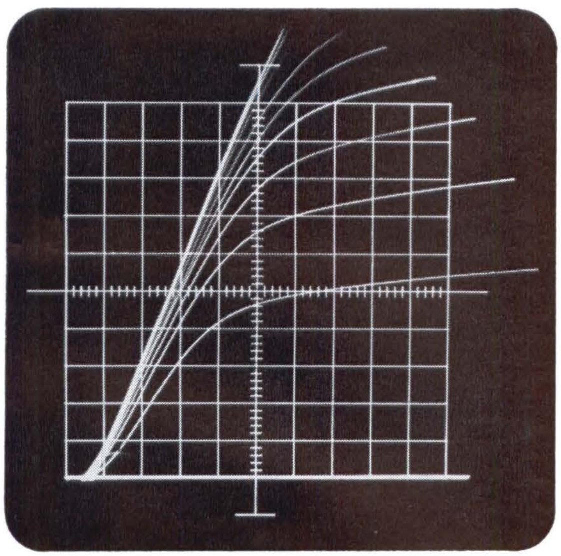
- V_{CEO} (sust) = 30V min
  @ $I_C = 30$ mA, $I_B = 0$

Scale: Vertical (I_C) = 5 mA/division
Horizontal (V_{CE}) = 10V/division

F/P-M-2263-B(1)

DRIVERS

LOW SAT.



- V_{CE} (sat) = 1V max
  @ I_C = 500 mA, I_B = 50 mA

Scale: Vertical (I_C) = 50 mA/division
Horizontal (V_{CE}) = 0.1V/division
Ten I_B steps: 5 mA/step

The unique geometry utilized in the Fairchild 2N2845 Series results in ideal characteristics for both high-speed core driving and general purpose applications. The series of four Planar* transistors – 2N2845 through 2N2848 – covers both medium and low voltage requirements. For the 2N2845, a PNP complement is available: Fairchild's 2N2696, a Planar device of the same geometry. The 'scope photos to the left show characteristics of the 2N2845.

AVAILABLE DIRECTLY FROM DISTRIBUTOR STOCKS

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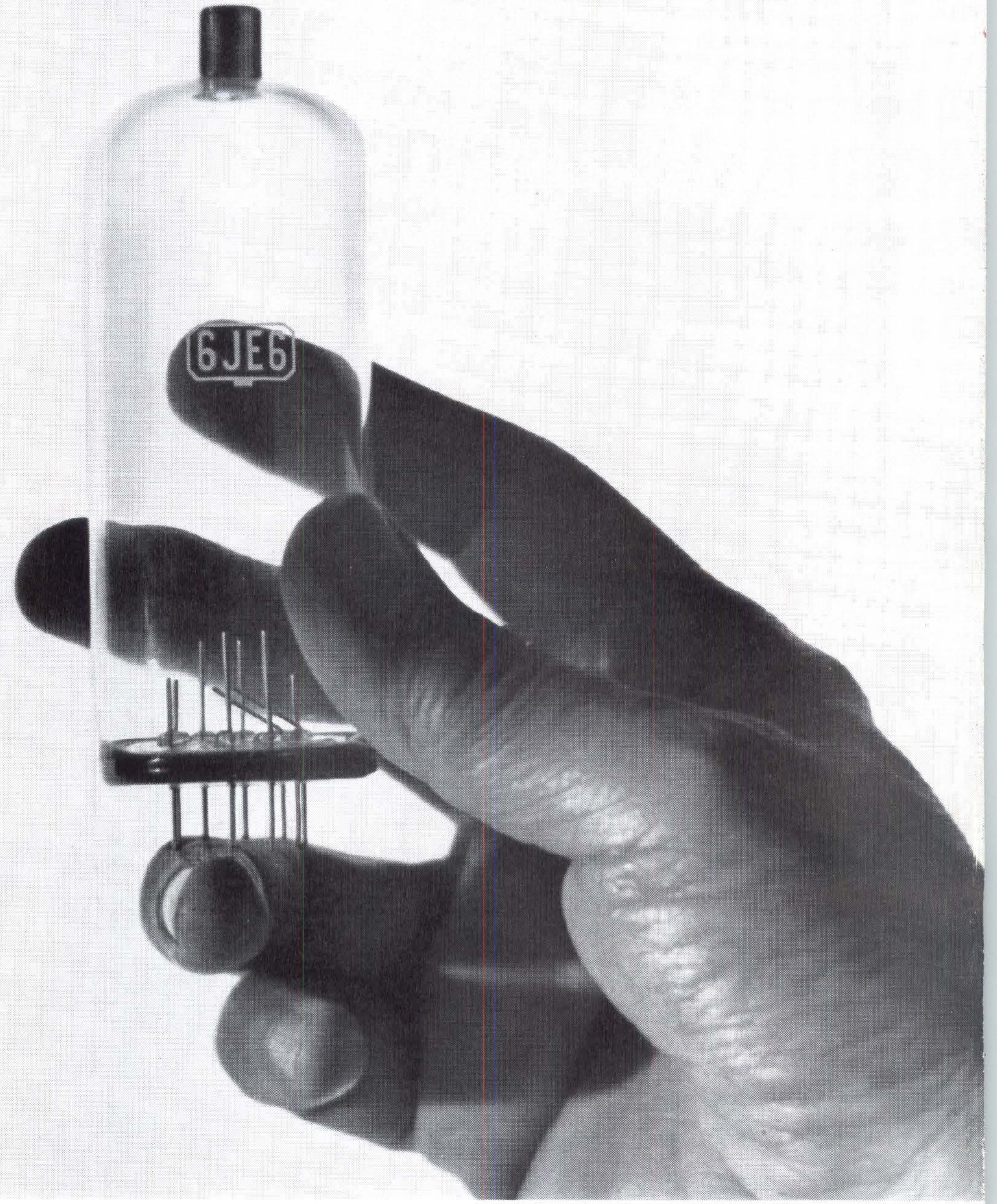
CIRCLE 901 ON READER SERVICE CARD

RCA eliminates a tube problem where you'd least expect to find one:

IN THE GLASS ENVELOPE



the problem:

The envelopes of most glass receiving tubes are made of dissimilar types of glass in stem and bulb. The combination normally is satisfactory.

However, in tubes operated in circuits where high-voltage gradients and high bulb temperatures are encountered (as in horizontal-deflection-amplifier sockets of color-TV receivers) electrolysis can occur at the interface of the bulb and stem glass. Under severe conditions, it will result in a crack at the seal.

This type of failure usually does not occur until after many hundreds of hours of tube operation and will not show up under production-line testing or during normal receiver life-testing. Therefore, it is particularly troublesome when this happens within a color-TV set's warranty period—possibly necessitating a costly tube replacement.

what RCA has done about it:

RCA is the acknowledged pioneer in developing unique new receiving tubes for black-and-white and color television sets. With its vast experience and know-how, RCA was able to anticipate and pinpoint this potential problem in the horizontal-deflection-amplifier sockets of color-TV receivers. The development of the RCA-6JE6 NOVAR Beam Power Tube followed. This new tube, with special materials and processing, virtually eliminates the possibility of glass cracks at the bulb-to-stem seal of the glass envelope due to electrolysis. The 6JE6 also gives the TV-circuit designer additional benefits in power output and "snivet" control.

Always at the forefront of the electronics industry, RCA is aware of the needs of the circuit designer and answers these needs with products of the highest quality. By using RCA receiving tubes in your circuitry, you know that you are safeguarding the quality of your products.

For further information on the RCA-6JE6 contact your nearest RCA Field Office, or write: Commercial Engineering, Section I-19-DE-1, RCA Electronic Components and Devices, Harrison, N. J.

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