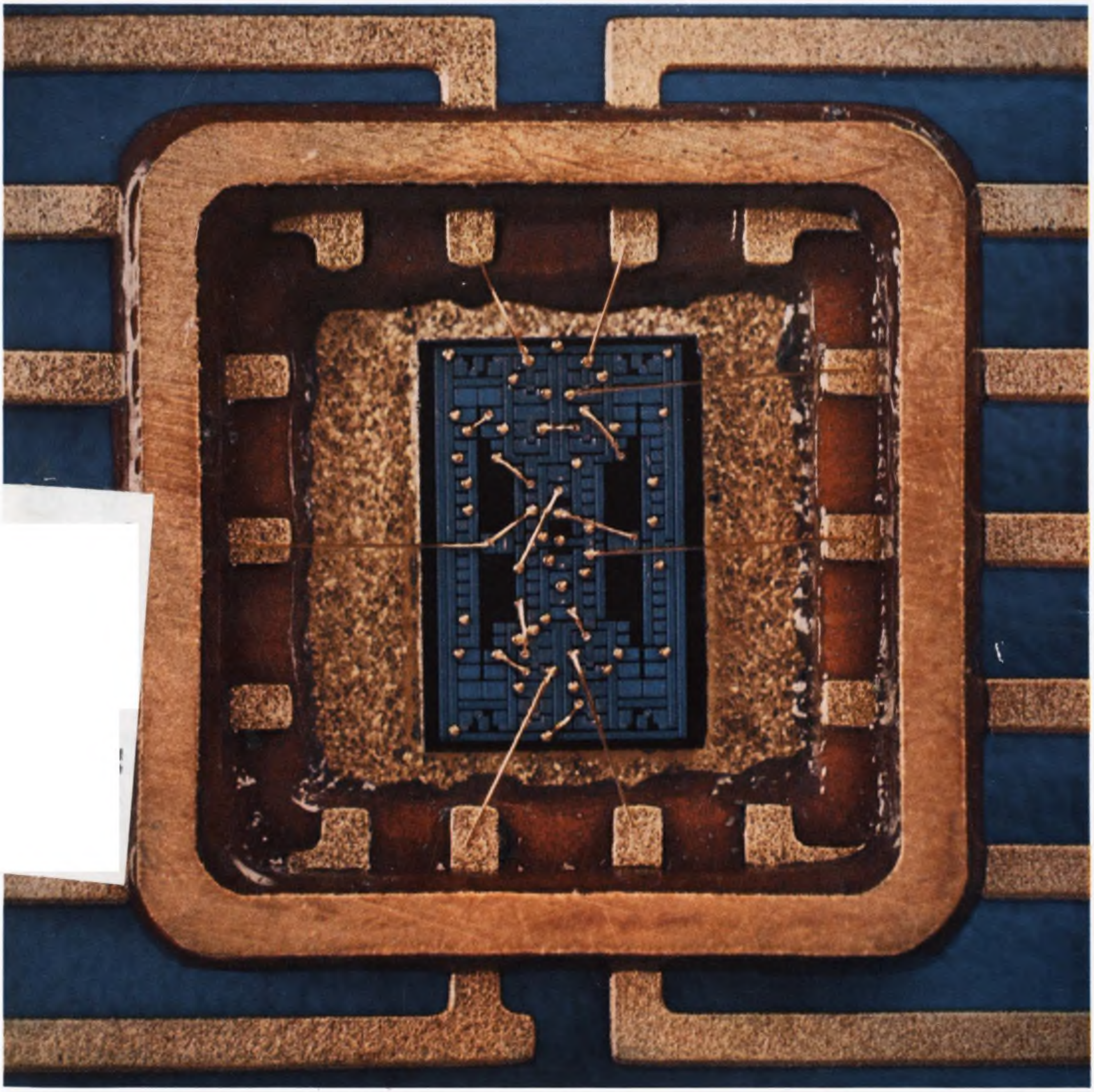
# Electronic Design 14

VOL. 14, NO. 14

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JUNE 7, 1966

**Build your own IC** with this easy-to-use breadboard. A ball- or wedge-bonder is all that's needed to interconnect any of eight transistors, five zener diodes, or 44 individual resistors that are available on the chip. The interconnection pattern eliminates the need for unreliable bird's-nest wiring (page 66).




instant systems

VOL. 14, NO.

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THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JUNE 7, 1966

## NEWS



## TECHNOLOGY



## PRODUCTS



## Departments



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One thing all these films have in common is a sharp, high-contrast image that's easy to read. Because the films are so sensitive, you can use small camera apertures and low-intensity settings.

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You can get complete information by writing to Polaroid Corporation, Technical Sales Department, Cambridge, Massachusetts 02139, or by writing to one of the manufacturers mentioned above.

It will probably take a little longer than 10 seconds, but we promise the information won't be a waste of time.

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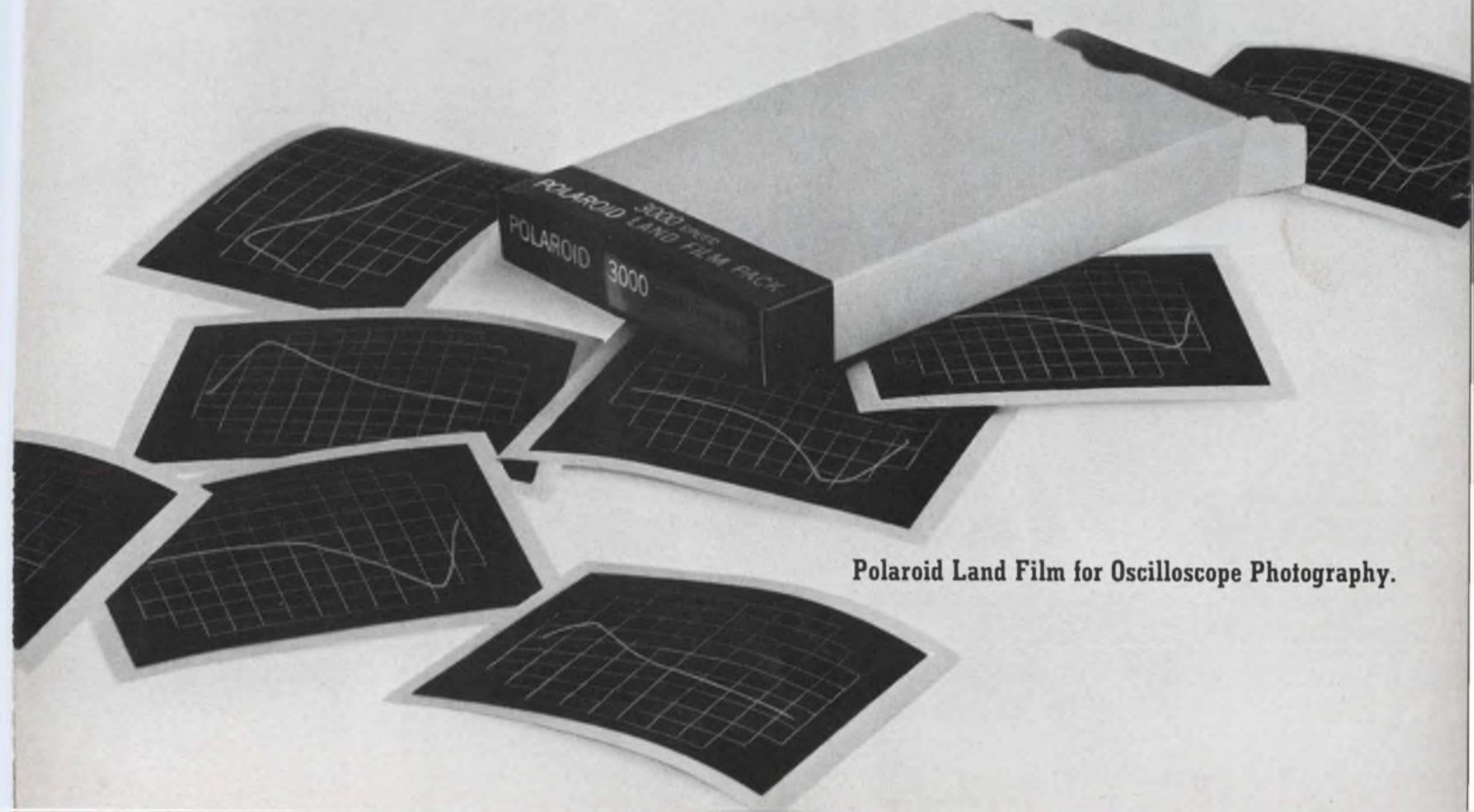


**Polaroid Land Film for Oscilloscope Photography.**

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How would you like an anti-snivet tube for your color TV horizontal deflection circuits? That's right—an anti-snivet tube would eliminate the need for snivet-suppression circuitry with its extra components and extra costs.


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Life-expectancy and reliability of the 6KG6 is far above that of ordinary output pentodes in similar service due to its lower bulb temperature at maximum operating conditions; it operates about 50°C. cooler than comparable tubes in similar service. But in spite of its low operating temperature, the 6KG6 packs plenty of reserve power and added safety factors. It has a max. 7,000 V peak plate voltage, 34 watts max. plate dissipation and 1.4 amps peak anode current.

The 6KG6 is but one of the growing family of new Amperex tubes for color TV that make possible lower costs, higher quality and more reliable performance. Other new tubes in this family include the 6EC4 damper diode, a matching companion to the 6KG6 for horizontal deflection circuits, the 3BH2 high voltage rectifier diode and the ED500 shunt stabilizer.

For data and applications information, write to the company *still doing new things with receiving tubes:* Amperex Electronic Corporation, Semiconductor and Receiving Tube Division, Dept. 371, Slatersville, Rhode Island, 02876.

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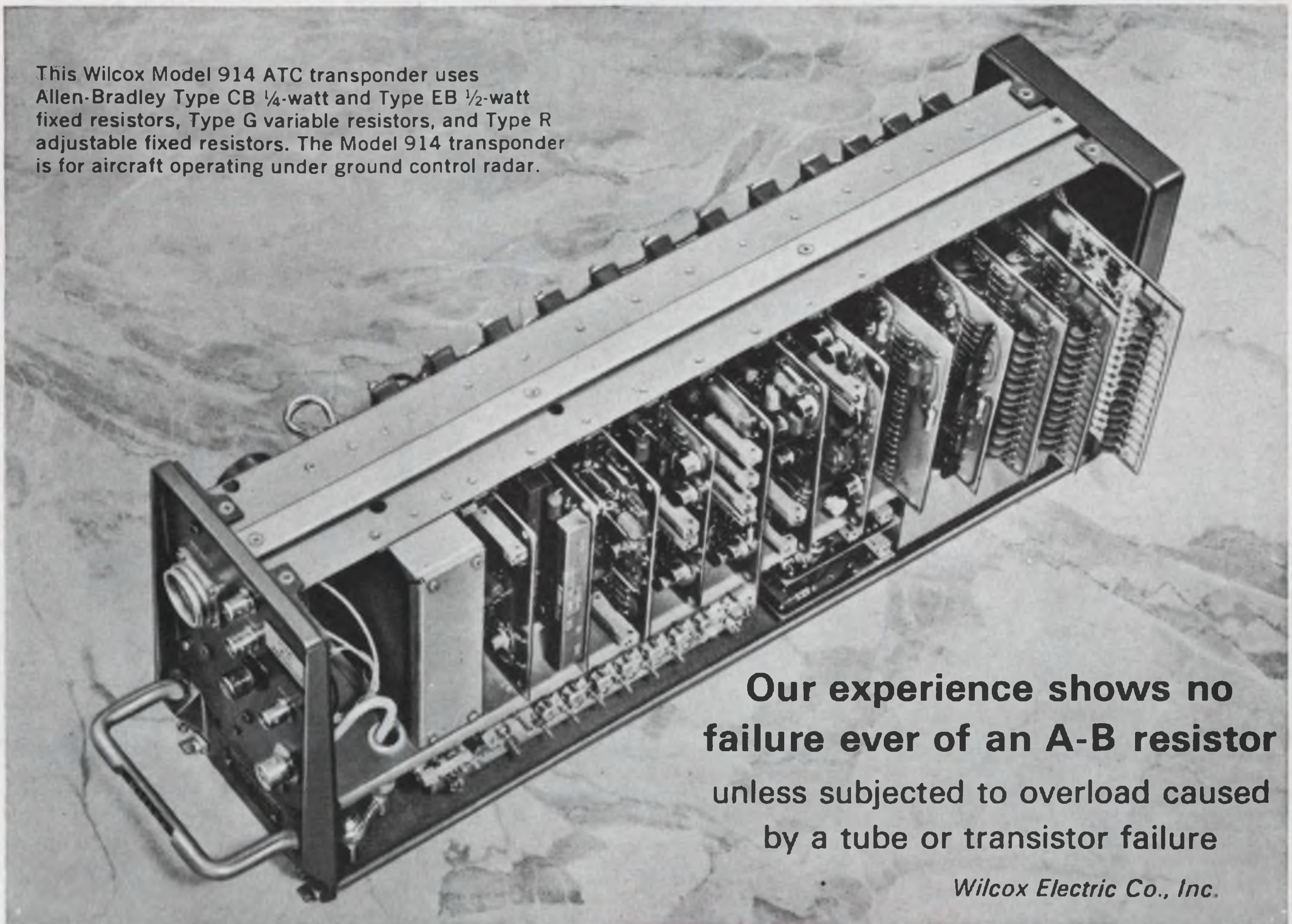


Prompt shipment of HOT MOLDED FIXED RESISTORS in all standard EIA and MIL-R-11 resistance values and tolerances. Values above and below standard limits can be furnished. Resistors are shown actual size.


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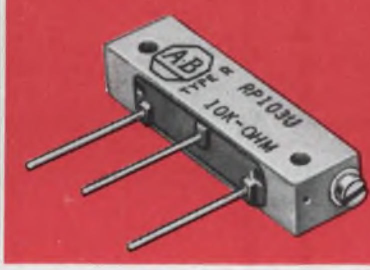


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Type R adjustable fixed resistors also have a solid molded resistance track. Adjustment of resistance is so smooth, it approaches infinite resolution. Settings will remain fixed under severe vibration or shock. The Type R molded enclosure is dustproof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

For more complete details on the full line of A-B quality electronic components, please write for Publication 6024: Allen-Bradley Co., 1344 S. Second Street, Milwaukee, Wisconsin 53204. In Canada: Allen-Bradley Canada Ltd. Export Office: 630 Third Ave., New York, New York, U.S.A. 10017.

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ON READER-SERVICE CARD CIRCLE 5

# You Can Get All These Microcircuits from Sprague Electric:

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

J Package

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

**ON READER-SERVICE CIRCLE 181**

## *SERIES SU300, LU300 UTILOGIC*

K Package

For use in commercial, industrial, ground support applications. Available in two operating temperature ranges, —20 C to +85 C, and +10 C to +55 C. Propagation delay of 15 to 40 nanoseconds.

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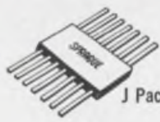
**ON READER-SERVICE CIRCLE 182**

## *SERIES SE400, NE400 LOW POWER LOGIC



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## *SERIES SE500 LINEAR AMPLIFIERS

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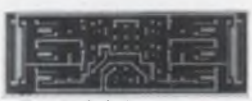
**ON READER-SERVICE CIRCLE 184**

## UNICIRCUIT® RCTL LOGIC



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Sprague Series US-0100 . . . a complete line of silicon monolithic digital building blocks featuring low power consumption (2 mW typ.)

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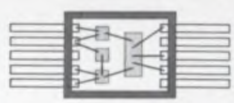

Combine monolithic silicon circuits with tantalum or Ni-Cr alloy resistors. Close resistance tolerances, low temperature coefficient. Resistor matching, ±½%.

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UT-1000—Four-bit ladder network
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***Series SE100, NE100, CS700, SU300, LU300, SE400, NE400, SE500 are all available from Sprague Electric under technology interchange with Signetics Corp.**

For data sheets on the microcircuits in which you are interested, write to:

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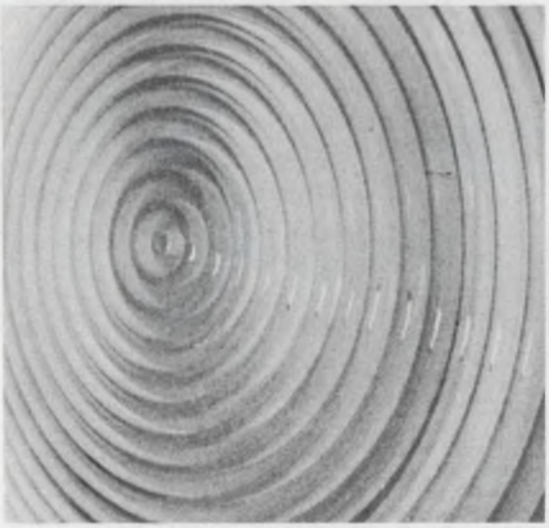
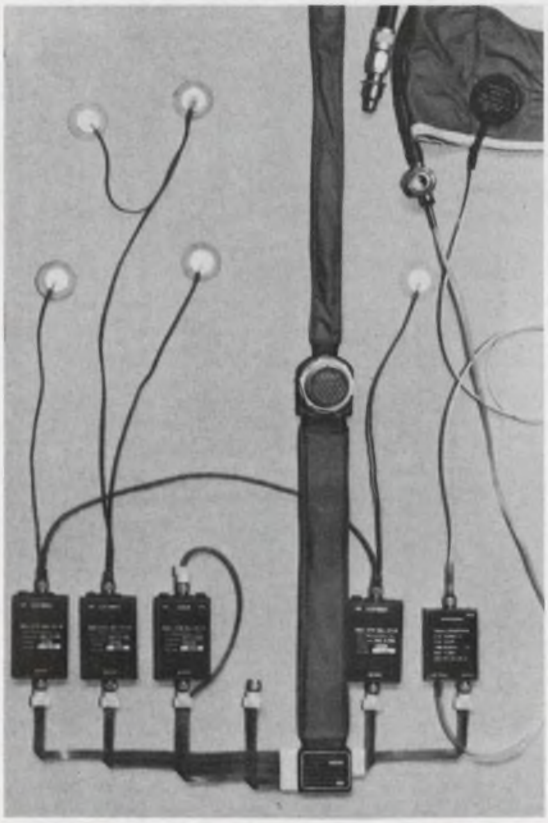
# ED News





Focusing in on rocket exhaust . . . 24



Long-distance blood pressure . . . 17

Gallium arsenide—a "growing" business . . . 21

Adding fuel to fuel cell

# News Report

## Army develops air-breathing fuel cell

An air-breathing fuel cell for use by front-line troops was demonstrated by the Army at the recent Annual Power Sources Conference at Atlantic City, N. J. The cell uses the nitrogen-hydrogen compound hydrazine for fuel and extracts its oxygen directly from the atmosphere.

The new power source was built by Monsanto Research Corp. under the technical direction of the U.S. Army Electronics Command. It weighs less than 12 pounds, has an output of 60 watts and can operate for 12 hours on one pound, or pint, of fuel.

According to Army spokesmen, the cell's introduction into field use is expected to have a major impact on military portable electrical power equipment. This is because of the fuel cell's silent operation, simple maintenance, low operating temperature and high efficiency for converting fuel into current. In demonstrations, the cell has powered an Army AN/VRC-12 vehicular radio, an Army AN/PPS-4 ground surveillance radar and a Marine Corps manpack radio AN/PRC-47.

## Northeast Corridor may acquire branch line

The state of Pennsylvania is investigating the feasibility of a high-speed ground transportation system that would link up with the Federally-sponsored Northeast Corridor high-speed rail system. An $80,000 contract has been signed with the Westinghouse Air Brake Company to study the possibility of creating a Keystone Corridor, as the east-west rail link would be called.

Westinghouse will investigate and analyze the effect of the various systems under consideration for the Northeast Corridor (ED 6, March 15, 1966, pp. 22-26) on a Keystone Corridor. The company will also study possible routes for 150-mph and 300-mph service across the state, as well as possible rates and schedules for both 150- and 300-mph service.

The Westinghouse contract represents only part of the $200,000 that Pennsylvania has made available for transportation studies under the Urban Mass Transportation Assistance Act. According to Pennsylvania Secretary of Commerce John K. Tabor, "This is a unique Pennsylvania accomplishment, and marks the first such state sponsored program in the nation."

## Thick-film transistor announced

A new technique for manufacturing solid-state active devices has been announced by the National Aeronautics and Space Administration. The exploratory work, performed jointly at NASA's Langley Research Center and RCA's Defense Microelectronics Activity, involves the use of deposited thick films to produce majority-carrier field-effect transistors (FETs).

An array of 50 individual FETs, manufactured at RCA's Sommerville plant by this process, was recently evaluated at Langley. NASA physicist Robert Stermer reported that, though the devices did not have the performance of diffused FETs, the practicality of the process had been demonstrated and further research would be undertaken. Stermer indicated that the measured transconductance was greater then 800.

He said that the devices were at present being made with a "wet spray" technique. Powdered cadmium sulfide is first doped and then made into a slurry with water. The slurry is sprayed on to an insulating substrate and deposition of insulating material and aluminum metallization follow. Stermer pointed out that the devices are actually formed by applying voltages to the metal electrodes and accumulating charge carriers along the surface. The cadmium sulfide's inherently high impedance was what made the technique possible, he said. The original idea was jointly conceived by Stermer and Dr. Franz Huber, Group Leader at the RCA Activity, but it was the RCA group that did much of the actual work. As a result, RCA was awarded a $35,000 contract to continue the materials investigation and further refine the fabrication technique.

The first phase of the contract, Stermer said, will concentrate on study of the doping method (consistency, predictability, etc.) and the possibility of screening the semiconductor material into the substrate, rather than spraying it on.

## High-speed logic slows IBM production

Production difficulties with their advanced solid-logic technology (ASLT) circuit packages will delay initial delivery of IBM's super-computer, the System/360, Model 90. Deliveries of the Model 90, which is the largest and fastest member of the System/360 family, were planned to begin in 1967. According to the company, earliest shipments will now be delayed two to three months because of a "production bottleneck".

The ASLT circuit packages (ED, Nov. 8, 1965, pp. 12-15) have delay-time speeds of 1.5 ns, compared with 5 to 30 ns for the solid logic technology (SLT) circuit packages used in the other models of the System/360. The increase in speed is achieved by use of current-steering circuitry and high packaging density. The ASLT packages are designed to be produced on the same automated production line used for the SLT packages.

## Klystron amplifier delivers 21 kW cw

The most powerful klystron amplifier known to date has been successfully tested at Varian Associates. The tube puts out 21 kW cw at 18 GHz over a band of 50 MHz with a gain of 60 dB.

"I don't know what the power limitations of the tube are," designer senior engineer Bill A. James said. "100 kW cw seems extremely difficult, but not impossible, with present-day technology". He explained that cryogenic cooling and other improvements could boost the output power considerably. "There is no magic in the design. We simply optimized the well-known design of the beam optics and the electron gun," he added.

The tube's power capabilities are especially important in plasma research, in space communications and in radio astronomy, James claimed.

## Nimbus II scores several firsts

The Nimbus II experimental weather satellite, launched recently by NASA, embodies several features not included in any of the other weather satellites now in operation. The two most significant are its capacity for transmitting night-time infrared pictures to simple ground stations, and its inclusion of a code on each transmitted picture to allow ground stations to determine the time it will be in position and angle to beam in the station's antenna.

Besides photographing the Earth's cloud cover, Nimbus II will measure for the first time the heat balance budget (albedo) of the entire 200-million-square-mile area of the Earth every day. Although the primary purpose of Nimbus II is research and development, data collected will be forwarded to the Commerce Department's Environmental Services Administration for operational weather-forecasting purposes.

## Sylvania will light up stamps

A phosphor that has particles of unusually minute size has been developed by Sylvania Electric Products, Inc., and will soon be incorporated in the ink used to print all U.S. postage stamps. The phosphor will make it possible for machines to differentiate between regular stamps and air-mail stamps and thus facilitate the automatic processing of mail.

Six different phosphors were tried during a two-year test by the Post Office Department at Dayton, Ohio. On the basis of this test, two of the phosphors were chosen for nationwide use: an orange-red phosphor for airmail stamps and a green phosphor for regular stamps. There are 204 machines, currently in use in 40 cities, capable of identifying the "tagged" stamps.

## Mariner IV back in range

The Mariner IV spacecraft, which took the world's first close-up pictures of Mars last year, is again in contact with Earth, reporting on the space environment and its own operating performance after 18 months of flight. On October 1, 1965 telemetry contact with the spacecraft in its orbital path around the sun was lost at the then unprecedented distance of 191 million miles. Since then NASA has put into operation its new 210-foot diameter antenna at Goldstone, California, and on May 21, 1966 the 210-foot dish began receiving Mariner telemetry signals from a distance of 197.5 million miles.

The new signals indicate that all spacecraft systems are operating properly. Mariner IV is now transmitting over its low-gain antenna, since the high-gain antenna used during the Mars flyby is no longer pointing towards the Earth.

A preliminary analysis of the signals received by the Goldstone antenna indicate that Mariner IV has exceeded its designed life by more than 100 per cent.

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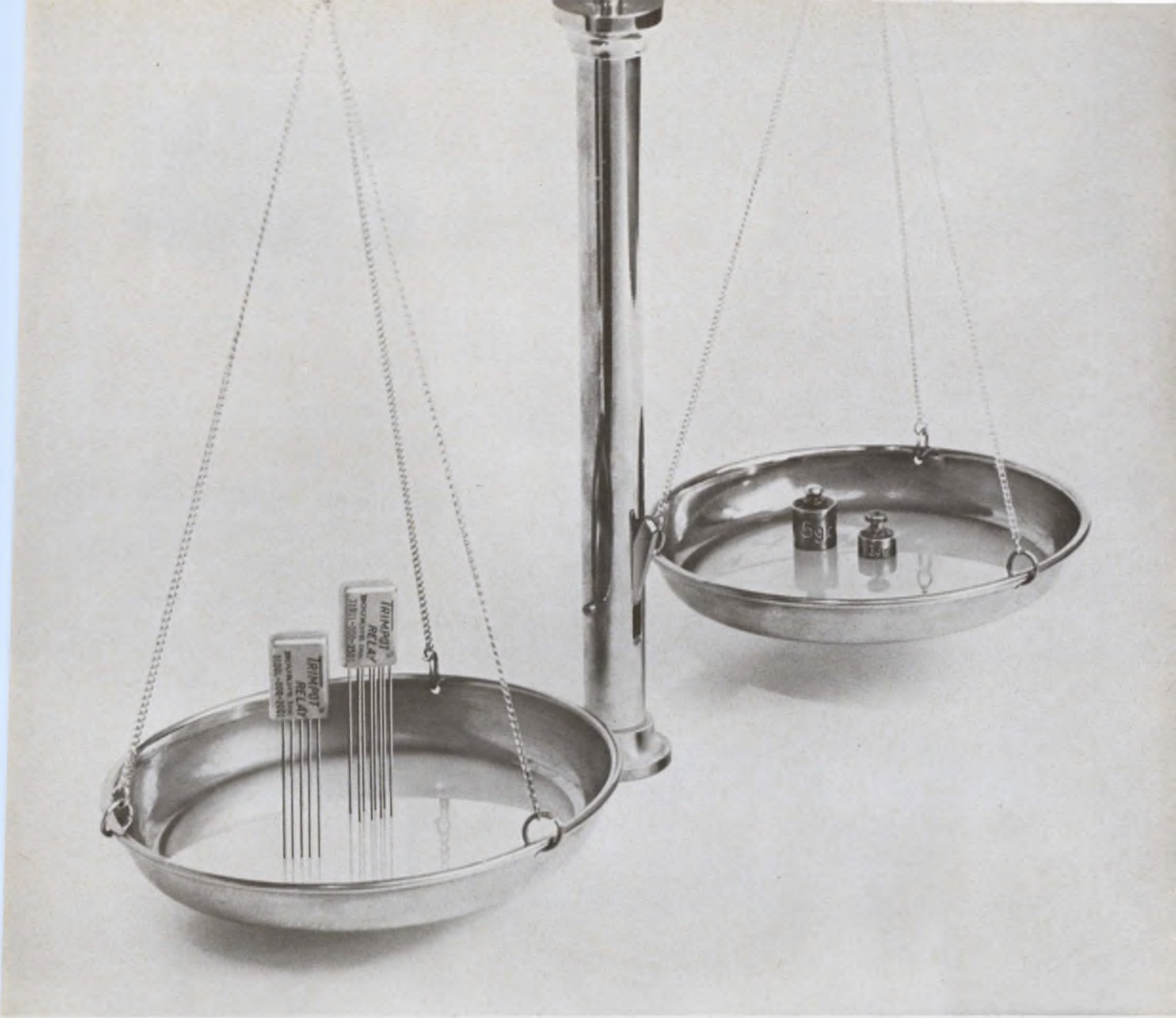
**An updated "Who's who"** in electronics manufacturing in the western states has been published by the Western Electronic Manufacturers Association (WEMA). Copies can be obtained for $5 from WEMA, 3600 Wilshire Blvd., Los Angeles, California 90005.



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You can cut problems down to size with the Bourns TRIMPOT® Model 3100 SPDT and Model 3101 DPDT relays. These proven units give you MIL-Spec reliability and 160 mw sensitivity in a package size of less than 1/20 cubic inch. Punish them with 150G shock or 40G, 3000 cps vibration, and you still get the performance that's on the published data sheet. Features include highly efficient magnetic circuit, rotary balanced armature, hermetically sealed case and self-cleaning contacts. Environmentally they exceed requirements of MIL-R-5757D.

With these relays, there is little chance of "infant mortality" in your circuits. Bourns double-checks each unit with a 5000-operation run-in followed by 100% final inspection for all important characteristics, including mass-spectrometer leak testing. Furthermore, Bourns tests samples quarterly in the famous Reliability Assurance Program that it created for TRIMPOT potentiometers. In short, you can trust the name TRIMPOT in relays, too.

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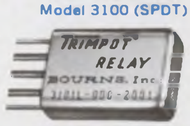
Model 3100 (SPDT)




Model 3101 (DPDT)

units shown actual size

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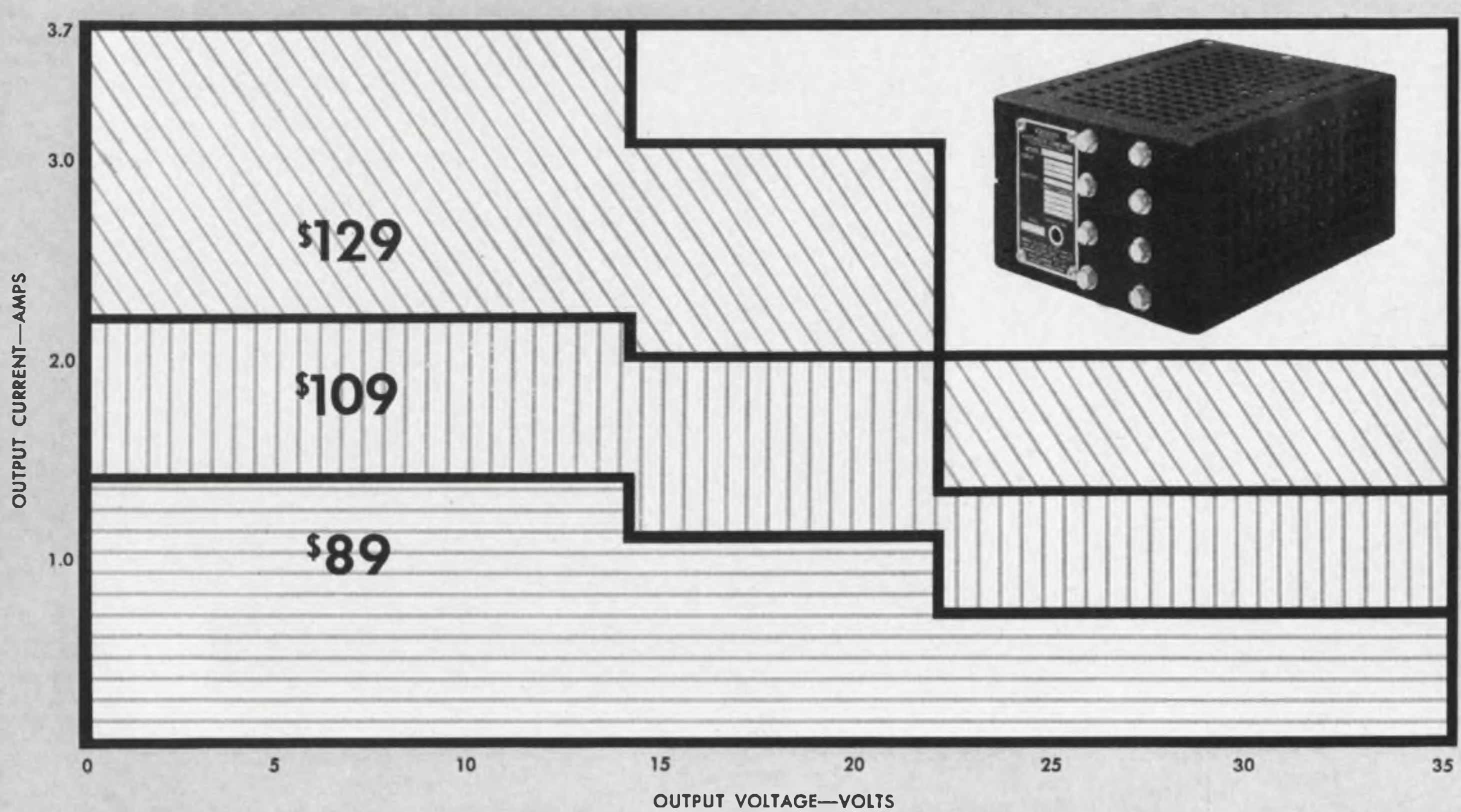


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# Medical electronics: design deficiencies cited

## Communications gap between engineer and physician discussed at biomedical symposium

**Ralph Dobriner**
West Coast Editor

Though the role of electronics in medicine continues to grow apace, so too does the communications gap between physicians and electronic designers.

This apparent contradiction was evident at the recent Biomedical Sciences Symposium in Anaheim, Calif. There, a variety of new bioelectronic monitoring systems, sensory devices and specialized computer systems to aid in medical diagnosis and research were discussed. Yet, many of those present felt that much of the equipment—such as the large automated physiological monitoring systems—are expensive, rather complex to operate and often designed by engineers unfamiliar with medical requirements.

### Only 1% of patients benefit

Dr. David Davis, Professor of Surgery at the University of North Carolina School of Medicine, said: "In spite of fantastic improvements in instrumentation and considerable publicity attending the use of such instrumentation in patient care, it is doubtful that more than 1% of patients deserving this 'improved' care actually receive it."

"What could be done has not been done," he observed, adding that the number of people that benefit from modern instrumentation was questionable. The principal cause for this lack of clinical application of instrumentation, according to Dr. Davis, has been the failure of the clinician and designer to get together on the design requirements.

It is simply a lack of education, he said, noting that physicians, physical scientists and engineers simply do not speak the same language: they don't think alike and there is no contact in the literature of each profession.

The surgeon said that the average practicing physician, no matter how skillful and successful, is absolutely unfamiliar with such terms as strain gauge, spectrophotometer, analog or rectifier. On the other hand, the physical scientist and engineer has usually had no exposure to biological systems, and, for example, the variable responses of a cell, Dr. Davis said.

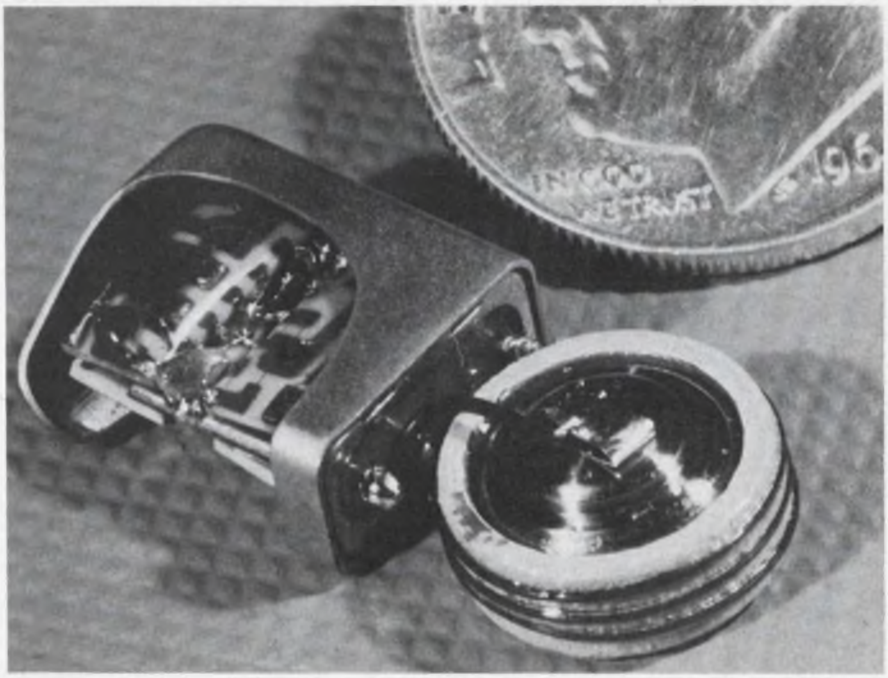
### Reasons for lack of use

Why have so-called monitoring systems not become widely used? Dr. Davis gave the following reasons:

■ *The instrumentation is incompatible with clinical situations.* The designers of medical instruments have no place to go to test their prototypes. Mostly their hospital connections are few and the family physician may be their only source of friendly advice. For example, many transducers function beautifully in aqueous solutions. Blood is principally an aqueous solution, but it also possesses the important and lifesaving property of clotting. A surprising number of designers have neglected this well-known fact.

■ *The instrument does not present information in an intelligible or useful manner to the physician.* The well-known electrocardiogram, for example, provides the instrument designer with a signal relatively easy to obtain, being essentially nothing more than a low-frequency series of pulses in the millivolt range. But the recording represents only a brief period in the patient's life and marked and significant changes may take place in seconds as well as over years.

Techniques for the continuous display of the electrocardiogram on oscilloscopes have been developed and many devices are on the market. The information, however, is significant only if observed and interpreted in a patient who is under constant surveillance by a physician



**Microminiature temperature transmitter,** designed to be implanted in a human body, is said to be capable of detecting temperature changes of 1/100 to 1/1000°C. Developed by NASA's Ames Research Center, the transmitter contains four hybrid integrated-circuit chips mounted inside a hermetically sealed can for protection from body fluids. The circular portion contains the battery and antenna and is usually left outside the body.

**(biomedical,** ***continued*****)**

trained in electrocardiographic interpretation.

What this means, then, is that, regardless of improved data collection techniques, better means of data storage and recall are needed and, more important, methods of cross-correlation data. Attempts have been made to use large multipurpose computers for this, but little has been done with small, specialized computers.

■ *The information presented is not particularly important to the existing clinical situation.* Many instruments have been developed which display information in which the physician is not particularly interested. For example, few physicians require minute-by-minute measurements of body temperature in clinical situations. Also, many monitoring devices are developed around a physiological function that is easy to measure but which may mean little.

■ *Many medical monitoring instruments are unreliable.* The requirements of instrumentation used in clinical care may exceed even those imposed by military specifications. Any instrument the size of a cigarette package is surely, within a week, dropped on the floor, sent to the laundry or steam-sterilized. An instrument that cannot withstand these stresses is useless.

## Equipment must meet needs

Drs. Stewart Wilber and William Derrick of the University of Texas cited the great need for reasonably priced instrumentation for simple, straightforward monitoring of patients in critical care areas, including all major operating rooms. Apparently, the only way to get this type of equipment, they said, is through a joint effort by the whole electronic industry and medical profession to establish standards.

They referred to studies that show that there would be buyers for equipment that met the biological, clinical and economic needs of doctors and hospitals. The medical-care dollar will be spent on purchasing instrumentation that is basic in function and adaptable to several uses. Hospitals and research institutes are not willing to pay large sums of money for equipment that does not fill medical needs, they said.

Another important consideration mentioned by the doctors is simplicity and ruggedness of design.

"There is not time for calibration and setting of the base lines and plate currents, especially in what is considered the minimum monitoring equipment required for clinical critical-care use. If this is necessary, the cause is lost and the equipment is not used," the physicians said.

They also stressed the need for explosion-proof miniature electronic systems that are compatible with all types of biological signals and free from interference from X-rays, cauteries and ground loops of numberless variety.

This includes telemetering systems for data-acquisitioning in the operating room. The doctors suggested that wireless telemetry of data directly from the patient into the computer would be useful.

The toughest instrument problem in clinical investigation, they felt, was that of transducers. These simple and sometimes delicate devices may be affected by noise created by the subject or the instrument itself.

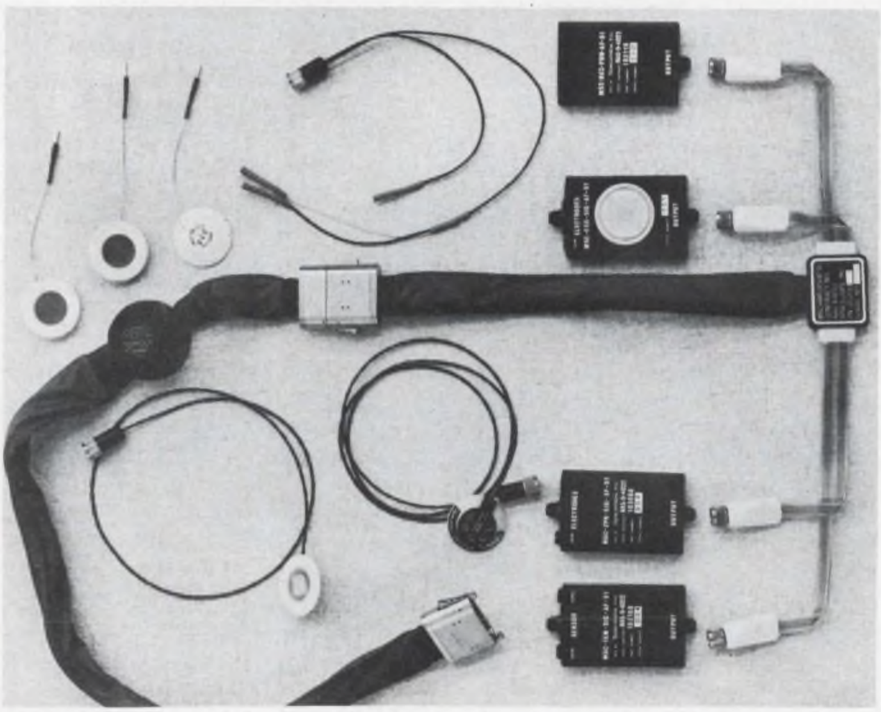
"The confounding noise created by modulation of the desired signal by other biological activity of similar frequencies creates severe problems," the doctors said.

## Army studies biological armor

Among the newest and most unusual applications of medical electronics discussed at the symposium was a current program sponsored by the Army Medical Material Div. to develop a transportable type of biological equipment.

The instrumention, referred to as "biological armor" by Moses Berlin of Sylvania Electronic Systems, Needham, Mass., is designed to help the soldier to combat the exotic condition he is liable to encounter in various parts of the world, such as weather extremes and endemic diseases.

Instead of using medical equipment originally designed for fixed hospital uses—and therefore bulky and fragile—, the Army is focusing on the design of special-purpose, compact transducer and telemetry gear. Equipment carried by the soldier would constantly radio back to a central computer the soldier's physiological responses to varying



**Apollo bioinstrumentation system** to be worn by astronauts records and radios back to earth physiological measurements, such as body temperature, respiration and heart rate. Developed by Spacelabs Inc., Van Nuys, Calif., the system is now undergoing qualification tests.

(**biomedical,** *continued*)

conditions in the field. The computer would analyze and interpret the information to help predict the soldier's performance and to improve self-aid and first aid.

### Astronaut behavior monitored

Berlin also described an unusual application of a computer that would determine the psychological reactions and behavior of astronauts during long space voyages and so prevent failures that might jeopardize the trip.

A preprogramed digital computer would be put aboard the spacecraft and, with adequate inputs derived from previous experience and known psychological behavior patterns, help to predict the astronauts' reactions. The psychological environment can then be programed to make the pilot's adaptation easier and his performance more reliable, Berlin said.

For example, he observed it may be necessary to provide a diurnal-nocturnal cycle to simulate night and day in the space vehicle so that the pilot could sleep. The computer would program the duration of each phase of the cycle and control the conditions which constitute night: darkness, less humidity, cooler temperature, lower noise.

The occurrence of fatigue in the astronaut could be determined by measurement of blood sugar content and periods of rest scheduled optimally. If more than one spaceman was aboard, the relative psychological condition of each could be evaluated and an alternating assignment of command established. ■ ■

## Accuracy

The author points out that in "Bootstrap action yields high $Z_{in}$ wideband amplifier" (ED 10, Apr. 26, 1966, p. 93) the last line of the third paragraph should read: ". . . The 1.1-$\mu$F and 33-$\mu$F (*not* 3-$\mu$F) capacitors."

The two photographs appearing on pp. 21 & 22 of ED 11, May 10, 1966, were wrongly captioned. The caption under photograph 1 applied to 2 and vice versa.

# New process boosts gallium arsenide devices

## Vapor phase growth makes possible GaAs devices that cannot be easily produced by other processes.

**René Colen**
Microelectronics Editor

"Vapor phase growth will do for gallium arsenide what alloying did for germanium and diffusion did for silicon," said Dr. Fred D. Rosi, associate director of the Materials Research Program at RCA Laboratories, as he announced RCA's development of a practical process for manufacturing gallium arsenide solid-state devices.

He added that experimental devices had already been made by this process that could not be made by any other. These devices are: an extremely bright photoemitting diode (red); a visible-light laser operating at room temperature; a high frequency Gunn-effect oscillator (up to 40 GHz); an electro-optical modulator for visible laser beam communications; and varactor diodes possessing high voltage and high cut-off frequency ratings.

### Process uses gaseous sources

Rosi, speaking at an RCA news conference late last month, stated that this development involves the use of gaseous sources to form complete semiconductor devices in crystals of gallium arsenide and its alloys.

Rosi pointed out that both the impurity doping and the crystal growth is accomplished simultaneously in a single continuous operation. Beside being inherently simple, he said, this process avoids the contamination that is often found in alloying and diffusion technologies, where processing is accomplished in a number of discrete steps.

Describing the process, Rosi said that a gallium arsenide substrate is placed in a glass tube through which the various vapors are passed. Connected to this tube are a set of gated inlets that provide any combination of gases desired. The accompanying table summarizes Rosi's description of the gases used and their purpose.

He pointed out that by adjusting the gas flows, any sort of growth may be accomplished: phosphide may be grown on gallium arsenide and doping may be changed from n-type to p-type. In addition, he noted, it is possible to control the crystal concentrations very accurately as a function of time, and thus form graded impurity concentrations and alloy growths.

This is highly desirable, he explained, since, in the former case, any sort of junction types may be made, and, in the latter case, the two crystal structures can be closely matched at their interface to prevent any crystal strain.

Dr. James Tietjen, developer of the vapor-phase process, claimed that hyper-abrupt junctions, where the impurity concentration goes from high to low to high, could theoretically be manufactured by this process. He wistfully added, however, that such work had not been performed yet.

### Experimental devices produced

Tietjen, and his supervisor, Dr. Leonard Weisberg, demonstrated and showed a number of the devices built by this process. Among these were some of the photo-diodes, mounted in a standard pocket flashlight case, which emitted a bright red light, even in the presence of a high ambient incandescent light. RCA specifications on these devices indicate that the measured brightness at room temperature is over 500 foot-lamberts (@6000Å) with a current density of 1 amp/mm$^2$. Weisberg pointed out that a number of these devices had been made and that by varying the dopant gradient, a continuous improvement in efficiency had been achieved.

Also shown were some cut-away samples of the varactor diodes that were made by this process. Weisberg pointed out that 1000 of these diodes had been made and that the over-all yield, including handling, had been about 40%. The diodes, composed of a 5-mil heavily doped (selenium) N$^+$ region, a 0.2-mil undoped N region, and a 0.5-mil heavily doped (zinc) P$^+$ region, have a breakdown voltage rating of 60-to-100 volts, a cut-off frequency of 120-to-220 GHz, and a junction capacitance of 0.3-to-0.7 pF.

Rosi described the laser device as the first injection laser ever to emit visible light at room temperature. He claimed that the laser had a peak power output (@7260 Å) during a 20-ns current pulse of 60 amperes. He noted that the device was made from a gallium arsenide-phosphide alloy with a 33% phosphorus concentration.

According to Rosi, the opto-electronic modulator has one basic advantage over already existing types of optical modulators: it can be transversely modulated. Since the quality of modulation varies inversely with length, the longer the crystal is, the better it is, he pointed out. By being able to modulate transversely, an extremely long crystal can be used without the need for inordinately high driving voltages. Aside from this advantage, the device is also claimed to be rugged, insensitive to temperature and moisture, and to have a rela-

**Chemicals used in growth process**

| Chemical & use | How formed |
|---|---|
| Gallium (Ga)-Ga growth. | Passing HCl vapor over molten Ga. |
| Arsenic (As)-GaAs growth. | Cracking arsine gas ($AsH_3$). |
| Phosphorous (P)-GaP growth. | Cracking gaseous phosphine ($PH_3$). |
| Selenium (Se)-n-dopant. | Cracking gaseous selenide ($H_2Se$). |
| Zinc (Zn)-p-dopant. | Cracking zinc vapor. |
| Hydrogen ($H_2$)-carrier. | (ultra-pure) |

**(gallium arsenide,** ***continued*****)**

tively low dielectric constant.

Rosi indicated that the answer to making high-frequency Gunn-effect devices is to make the middle layer of the three-layered device as thin as possible. He supported this by describing RCA's measurements on the devices they made: with a 10-$\mu$ thickness, the diode oscillated at 14 GHz; with a 5-$\mu$ thickness, the diode oscillated at 25 GHz; and with a 1-$\mu$ layer it went to 40 GHz. He added that these diodes had been pulse-operated with a 40% duty cycle and that he expected to have a continuous-wave device soon.

Dr. Joseph Donahue, manager of RCA's Industrial Semiconductor Operations Dept., announced that a group of 15 people had been formed to handle the development work on these devices. He expects that the photo-emitting diodes will be made available on the market by next fall. ■ ■

## Data fits into lulls in telephone talk

A new system stores data, compresses it and then transmits it at high speed over telephone lines during the pauses and silences in normal conversation.

Studies have shown that lines carry signal only 36% of the time in ordinary conversation. The remaining 64% is dead time. Silence between speakers accounts for 48% of total transmission time, and normal speech pauses comprise 16%, according to ITT, New York, creators of the system.

They call it Automatic Alternate Voice/Data. Its heart is a rotating magnetic drum. The telephone conversation is actually recorded and played back in transit between talker and listener, but this takes place so rapidly that an utterance is delayed only a small fraction of a second.

The device detects an utterance during this delay and switches the line from its data channel to its speech channel. As soon as the speaker pauses, the data transmission is resumed. Speech is always given priority over data. ■ ■

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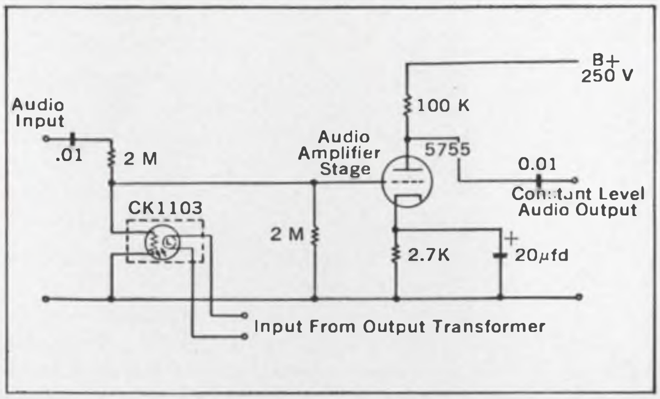


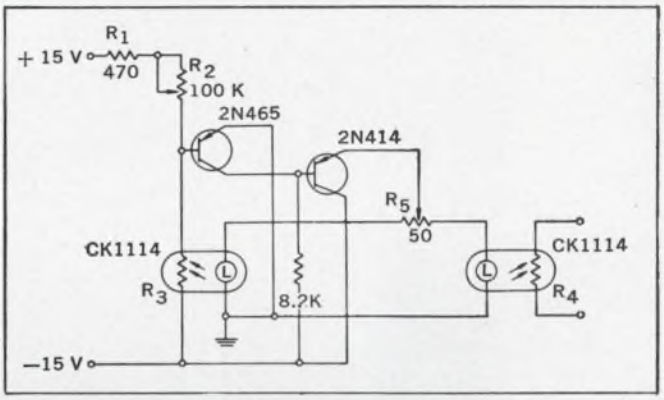


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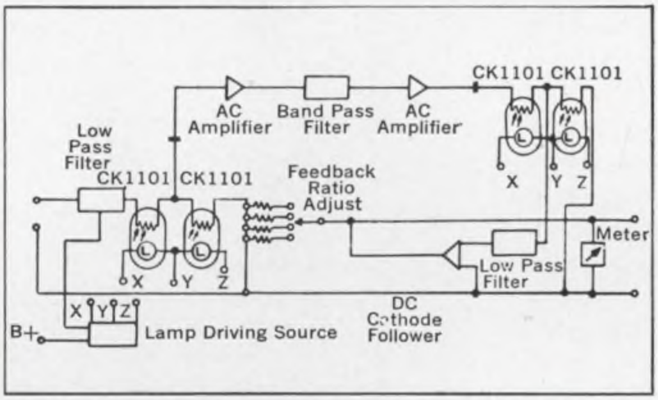
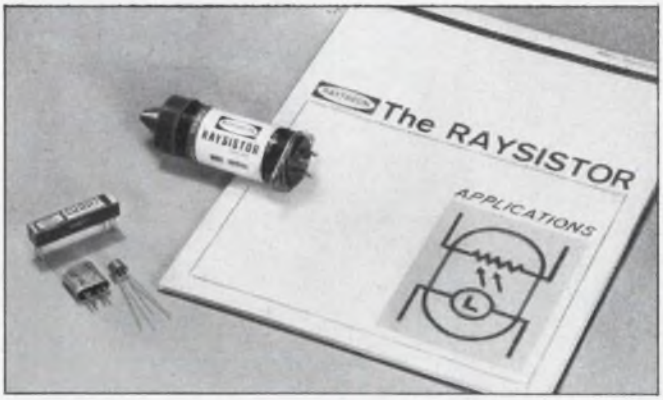
**2. As a remotely controlled linear potentiometer.** The Raysistor can be used as a remotely controlled linear potentiometer when used in the circuit shown above. Here the Raysistor forms a voltage divider between the positive and negative voltages.

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ON READER-SERVICE CARD CIRCLE 9

## Microwaves used to study rocket plumes

Microwaves are being employed to measure the intensity of radio interference and noise generated by rocket-motor exhaust combustion by-products.

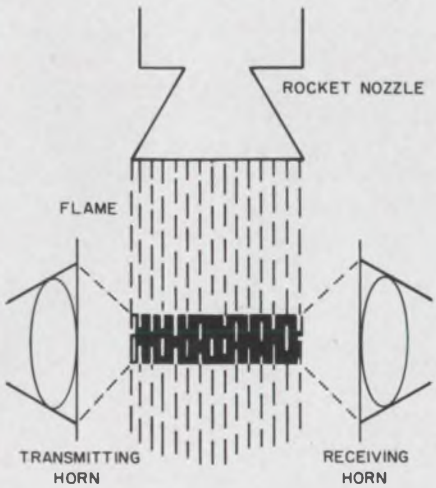
The work is being conducted at the new Microwave Interference Test Facility at Lockheed Propulsion Corp., Redlands, Calif.

Interference caused by combustion by-products may interrupt communications between a missile or spacecraft and ground control stations, according to a Lockheed spokesman.

Two lens-corrected horn antennas, built by DeMornay-Bonardi, Inc., Pasadena, Calif., focus the microwaves through the heart of the rocket exhaust plumes.

The horns are mounted on opposite sides of an equipment ring through which the exhaust is passed. One of the horns transmits the energy, concentrating it within a selected area, while the other horn acts as a receiver. The difference between the signal transmitted and that received is detected by an interferometer. The effect of the exhaust upon the microwave signal helps to determine the degree of ionization of the exhaust plume.

Other antennas, high-speed cameras and infrared detectors are mounted on a movable cart and propelled down the length of the plume. ■ ■

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**Radiation RM-30 Diode Matrix***

| CHARACTERISTIC | TYP LIMITS | TEST CONDITIONS |
|---|---|---|
| Forward drop | | ($T_A = +25°C$) |
| $V_F(20)$ | 1.0 v | $I_F = 20$ ma |
| $V_F(1)$ | 0.7 v | $I_F = 1$ ma |
| Reverse breakdown $BV_R$ | 60 v | $I_R = 100\ \mu a$ |
| Reverse current $I_R$ | 7 na | $V_R = 25$ v |
| Reverse recovery $t_{rr}$ | 7 nsec | $I_F = 10$ ma to $I_R = 10$ ma Recover to 1 ma |
| Crosspoint capacitance $C_{cp}$ | 1.9 pf | $V_R = 5$ v, f = 1 Mc |
| Coupling coefficient $I_{CL}$ | 20 na | |

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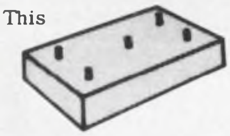
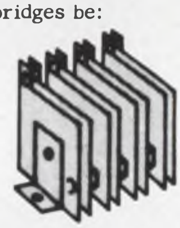
Bob has the job of designing power supplies for his company, an electronic equipment manufacturer. Requirements vary considerably from one piece of equipment to the next, with ratings all the way from 1 to 10 amps in both single and three phase configurations. He had a dilemma--what should the physical arrangement of his bridges be:

This

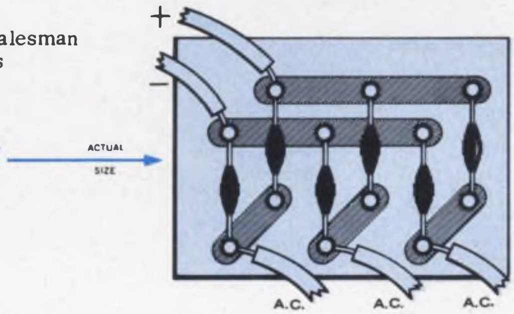


or this



Both were bulky, and--worse yet--each was a custom design requiring long vendor lead times, not to mention the expense. One day, a Compar salesman suggested that if Bob used Unitrode UT 4000 series diodes, he could make his own bridges with only this comparative space required...

...TO GET 10 AMPS AT 500 VOLTS without additional heat sinking.




Space and lead time were both saved. In addition, Bob's production department could produce the bridges using individual diodes for far less than vendors were charging for special bridge assemblies ...and the work stayed in-house.

Also Bob could supplement his small laboratory stock by drawing on Compar's substantial inventory of Unitrode semi-conductors. No more weeks of waiting. Now he could instantaneously breadboard any bridge he needed.

There were other bonuses from the Unitrode rectifiers: reliability, stability, ruggedness and ...the controlled avalanche feature ensuring the diodes' ability to absorb reverse transient surges as high as 0.8 joules. And Bob's regulation problems were solved as well--with Unitrode 5 watt zeners in the same small package.

YOU CAN SAVE SPACE AND TIME ON YOUR BRIDGE DESIGNS TOO

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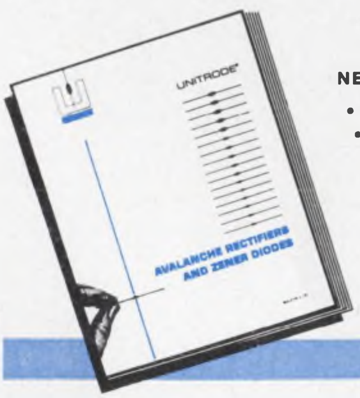


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Electronic system brings help

# Washington Report

S. DAVID PURSGLOVE, WASHINGTON EDITOR

## Maryland tests Hoffman road alarm

Hoffman Electronics is supplying equipment for an experiment that may lead to installation of a motorist-in-distress alarm system along all 41,000 miles of federal interstate highways within five years.

The Commerce Department's Bureau of Public Roads has contributed 90% of the $379,298 awarded by Maryland's State Roads Commission to set up the Hoffman Highway Emergency Call System and Safety Satellite alarm system.

A total of 324 of the coded-signal transmitters will be erected along the 43-mile section of the Washington, D.C., Capital Beltway, I-495, that lies in Maryland. The post-mounted, spherical, aluminum call boxes are powered by storage batteries recharged by solar cells. They each contain a transmitter that registers on a central emergency switchboard as soon as a distressed motorist touches a clearly labeled button. The signals are coded according to the type of aid needed, the location of the box and the side of the median on which it is located.

The Highway Emergency Call System contains buttons for police, ambulance, fire or maintenance service. About 100 will be installed. The boxes of the Safety Satellite system contain only police and fire buttons. They will form the bulk of the call boxes, which are to be set up and operational by September.

Hoffman also received a $96,000 contract to conduct a program of research into traffic patterns and the response time of the emergency equipment. The Baltimore Beltway, an interstate circumferential highway very similar to the Capital Beltway, will be used as a control. No automatic emergency devices will be erected on the Baltimore loop.

### Industry will bid for federal contracts

A Department spokesman said the Maryland experiment may well be the forerunner of similar systems to be set up nationwide. He pointed out that, while Hoffman has an edge in this field, it will have to be opened up for competitive bidding from other firms. The Commerce Department or a new Department of Transportation will have to set standards and specify the system to be used.

The Chairman-Director of Maryland's State Roads Commission, John B. Funk, said that highway alarm systems will have to be a government responsibility. "Private enterprise, operating on uncertain schedules and without public control, could make a farce of a motorist distress call system," he said. He also believes that, "states rights" notwithstanding, this is a field that must be governed by the Federal Government. The Federal Bureau of Public Roads would act jointly with state roads units: the Bureau to set standards, the states to award contracts.

### Hoffman outlines details of systems

Hoffman has been circumspect about technical side of its systems, but some detail was revealed at the time that the Maryland contract was announced.

The Satellite system boxes have no transmitters, but are wired to the nearest Highway Emergency Call System boxes. These generally use HCA-1 non-directional antennas; their silicon solar cells are HCS-1 models.

Under the contract, Hoffman will provide a service engineer on 24-hour duty for one year and will train state maintenance engineers.

## Nike-X raises MOL issues

As everyone in Washington except the Administration pushes for establishment of a missile defense system, the question of the real status of the Air Force manned orbiting laboratory (MOL) has again come up. In the competition for the limited funds available for military missile and space programs, the Army—developers of the Nike-X missile defense system—has won out over the Air Force—rather uncommitted developers of a military MOL.

The White House and Defense Department still insist that they do not want the money that Congress is pressing on them for missile defense. But they will probably spend more on engineering development and long-lead production than was planned when the budget for fiscal 1967 was originally taking shape.

A modified Nike-X system to cope with an accidentally fired ICBM or a small-scale attack from an "Nth Country" is beginning to look attractive to Administration advisers who a year ago opposed deployment of any system. If for budgetary reasons a choice has to be made, the MOL is the clear loser, they say. There is far wider popular and political support for a system that is billed as protection for the citizens than there is for a surveillance satellite, the mission of which seems ill-defined to the public. Defense Department officials concede that this is all the more true when an MOL looks as though it duplicates the work of NASA and the unmanned Samos reconnaissance satellites.

Administration thinking is that a further advantage of an anti-missile system over the MOL is that development of the former would channel money into a much broader segment of the electronic industry than the MOL would.

Yet despite the current upsurge of interest in a Nike-type system, the MOL was obviously in difficulties, despite assurances to the contrary from the White House.

### What of MOL's future?

It would be facile to say that only the President or Secretary McNamara know what the future holds for MOL. But it would be misleading, for even they do not know. There is no question that MOL has already been greatly downgraded in size and mission. The next step depends upon the vagaries of war and the economy. But MOL appears to be heading for a merger with NASA post-Apollo projects and some other programs.

The Office of the Director of Defense, Research and Engineering, an influential Pentagon power center, is on record as favoring a "multipurpose satellite" system. It would combine communications, navigation, early ICBM warning, weather surveillance and nuclear test detection. Daniel J. Fink, deputy DDR&E director for strategic and space systems, recently said: "We have concluded that these functions are compatible and could be married into a single, newly proposed satellite, thereby increasing the cost-effectiveness of any one alone. Consequently, during the past year we have reoriented each of these programs toward such a common goal."

Fink did not mention intelligence-reconnaissance in the list of functions that an all-purpose satellite would carry out, but it is understood to be included. Neither did he state whether the satellite would be manned or unmanned, nor whether it would substitute for MOL. Many observers believe, however, that it will initially be unmanned and use existing sensors. Later, they believe, any Defense Department manned space program may take the shape of a manned multipurpose satellite program.

## New DOD agency in the air?

Yet another blow for the Air Force may come out of this sort of Defense Department thinking: "An Army company is pinned down and needs support from a missile battalion 85 miles to the rear. The C.O. radios his request via tactical communications satellite."

Whose should such a satellite be? Air Force because it is in space? Or Army because it answers an Army need? Is it a strategic system because it was originally launched half a world away by a large booster? Or is it tactical because it supports front-line elements?

DOD is beginning to say it is both and belongs to neither. The Department has begun to take a very preliminary look at the possibility of a new DOD agency to serve all the services, rather as the Defense Communications Agency, Defense Intelligence Agency and Defense Supply Agency do. It would control intelligence-weather-communications-navigation satellites, launch them and design them. The nucleus of such an agency would likely draw on major elements of the Air Force as well as some elements of the Army and Navy technical organizations.

DOD publicly denies that this is in the offing, but officials privately admit that it is in the thinking stage. A high DOD official commented: "Some years ago I said categorically, but in good faith on my part, that the Army would never lose the von Braun team."

## Airlines communicate by satellite

An airplane can now communicate to distant ground stations even while flying over open ocean. The transmission is received and rebroadcast by the Syncom satellite.

The system was recently displayed by its manufacturer, the Bendix Corp., at a Communications Satellite Seminar held at the U.S. Department of State.

The simple, light equipment carried aboard the plane is powerful enough to reach ground stations directly if it is in direct line of sight with them.


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ON READER-SERVICE CARD CIRCLE 13

# What's happening in computer-aided design?

The digital computer promises to become one of the most powerful tools available to the electronic design engineer. Like any other tool, however, its functions, capabilities and limitations must be understood before the prospective user can employ it effectively and intelligently.

Only a small proportion of the design community has made extensive use of this design aid to date, and as a consequence there is a paucity of general information about it. The designer looking for material written about it will not have an easy time.

Why this lack of information? There are several reasons. For one, computer-aided circuit design—unlike circuit *analysis*—is still in its infancy. For another, many organizations engaged in research and experimentation are unwilling to publicize their work in this field. And perhaps most important, there has been no common meeting ground for engineers using the computer as a design tool.

Time alone should take care of the first of these as the use of computers for designing becomes more widespread. To solve the second problem, we can only urge those organizations involved to bear in mind the crying need for some hard facts to be published on the successes—and failures—of computer-aided design.

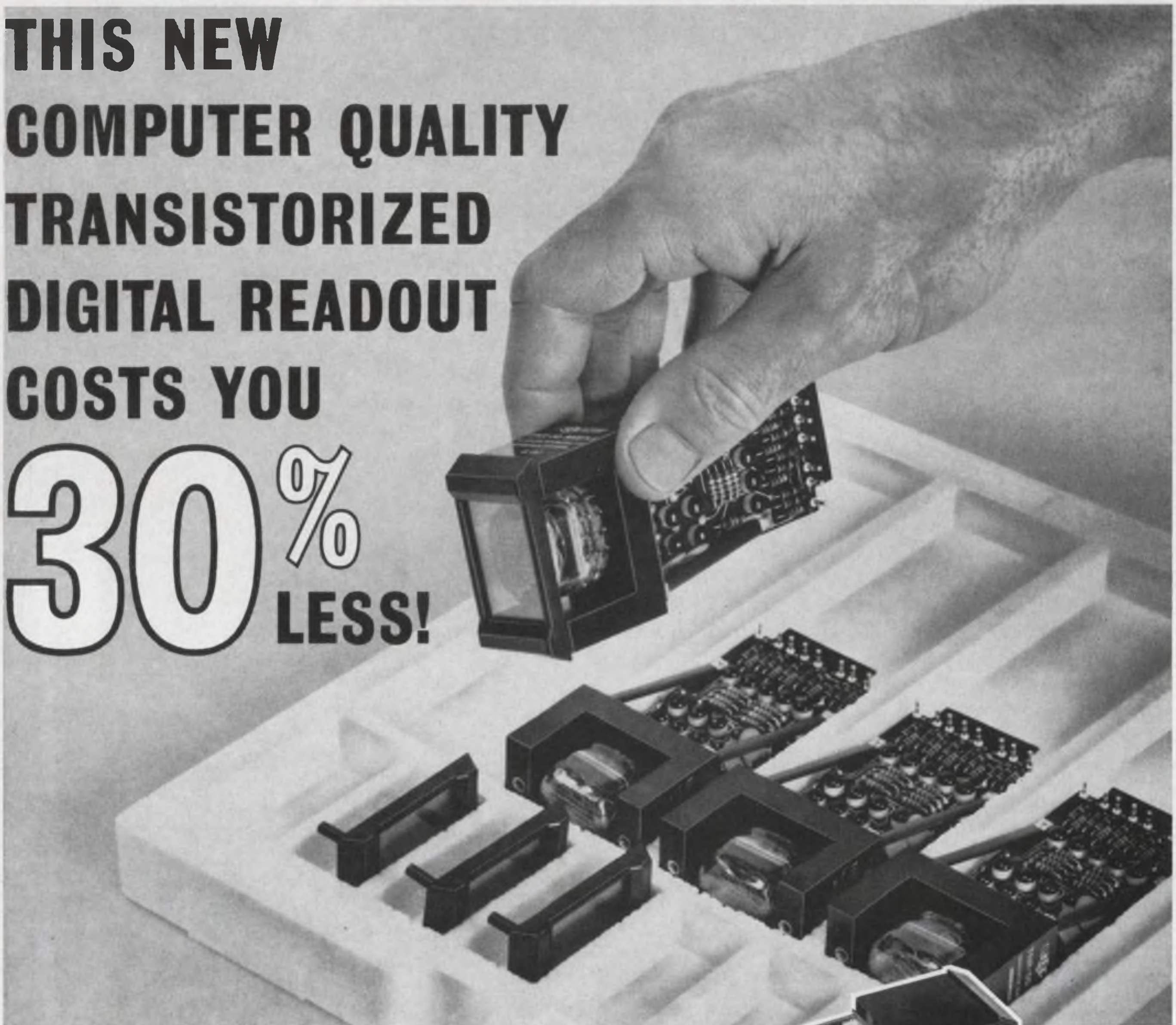
Happily, the first steps have already been taken toward eliminating the third reason for lack of data. An initial exchange of ideas and experience took place at the Conference on Computer-Aided Solid-State Circuit Design held at the University of Wisconsin in early May. Dr. William W. Happ, Chief of the Design Criteria Branch at NASA's Electronic Research Center, Cambridge, Mass., stressed to the delegates the need to discuss common problems and compare ideas. Happ believes that this engineer-to-engineer communication is one of the most useful means of spreading knowledge of semiautomated design techniques. And to help foster and supplement person-to-person exchanges, NASA is conducting a survey of available computer programs used for electronic design. The results of this survey can't come too soon.

We believe it is time for engineering schools and institutions to follow the lead given by the University of Wisconsin and NASA. The continuing professional-studies courses of engineering schools would fill a great need by adding computer-aided circuit design to their curriculums. Industry, for its part, should boost in-house training in this field.

The rapid pace of modern technology demands more effectual and accessible dissemination of information than has hitherto been the case.

JOSEPH J. CASAZZA

# THIS NEW COMPUTER QUALITY TRANSISTORIZED DIGITAL READOUT COSTS YOU 30% LESS!



### FOR INTEGRATED OR DISCRETE COMPONENT CIRCUITS

Identical electrical characteristics, identical driver-decoder functions, identical 1-inch mounting centers—yet these new digital readouts using NIXIE® tubes cost you 30% less than fully enclosed (with metal case transistors) TEC-LITE TNR-10 and TNR-30 Series models. New simplified single board design and use of plastic encased silicon transistors substantially reduce assembly time, allowing this far lower price.

**TNR-40 Series**—Provides decimal readout from decimal input signals of low level. Internal circuits of four standard models are controlled by input signals as small as 3.5 volts. Special versions can be controlled with signals as small as 2 volts or less. High voltage to fire the neon tube's numeral elements is confined to the unit and to the panel area.

Price (0-9 display) in 100-299 quantities: $18.85 less tube.

For fully enclosed readout, request data on TEC-LITE TNR-10 Series.

**TNR-50 Series**—Decimal readout is available in 8 standard models to handle 8-wire and 4-wire binary coded decimal input as small as 3.5 volts. A variety of other input codes and signal levels can be accommodated on special order. All-transistor circuitry eliminates diode decoders to reduce the number of components and increase reliability.

Price (0-9 display) in 100-299 quantities: $24.90 less tube.

For fully enclosed readout, request data on TEC-LITE TNR-30 Series.

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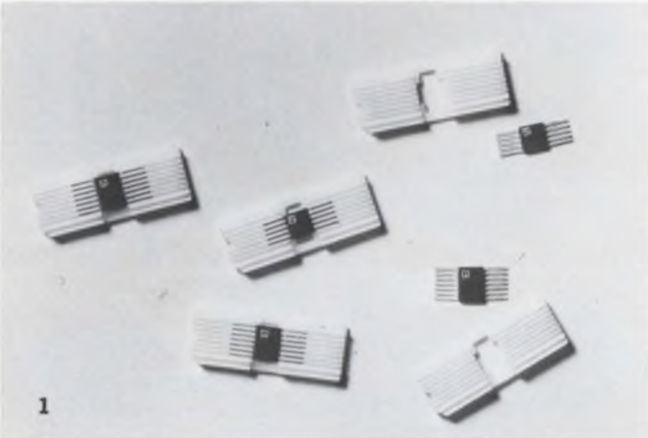
ON READER-SERVICE CARD CIRCLE 14

# SIGNETICS

INTEGRATED CIRCUIT NEWS AND APPLICATIONS

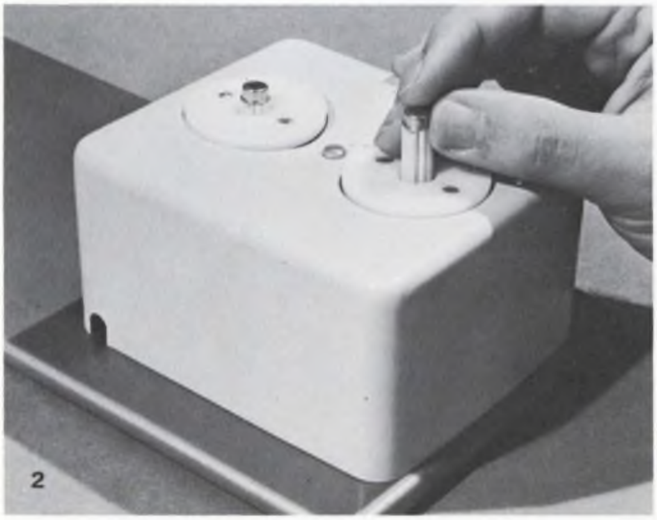
## SIGNETICS USER-ORIENTED PACKAGING

All integrated circuit users face the problem of reliably testing, sorting, and handling these products during assembly without incurring damage to the leads of the device. Endeavoring to ease this problem, Signetics provides device carriers which are designed with the user in mind. Ease of test, storage, and minimum carrier cost to provide the "throw away" feature are all part of this program.



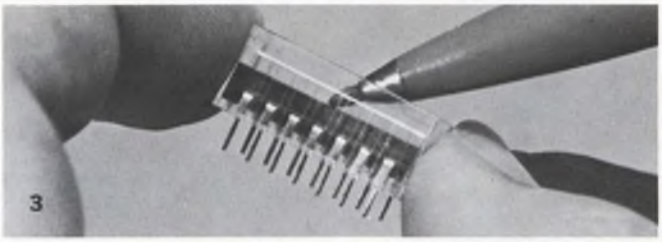
1

The outcome of this program is a group of throw-away plastic carriers designed for each type of circuit package. The flat package carrier, Figure 1, will accommodate either the ¼ by ¼-inch 10-lead flat package, (TO-91), or the ¼ by ⅜-inch 14-lead flat package (TO-88). The package body opening in this carrier is under-cut so that the package snaps in and is retained even if the carrier is accidentally turned over. The flat, ribbon-like leads are fully protected within the grooves of the carrier body which also serve to guide the wipers of a multi-point test head into contact with them.



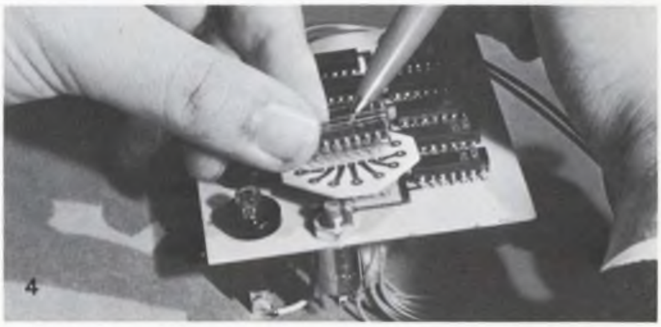
2

A similar approach was taken in designing the carrier for the familiar modified JEDEC TO-5 can. In this case the carrier is a grooved plastic cylinder. Carrier and circuit plug into a Signetics-designed test socket as shown in Figure 2.



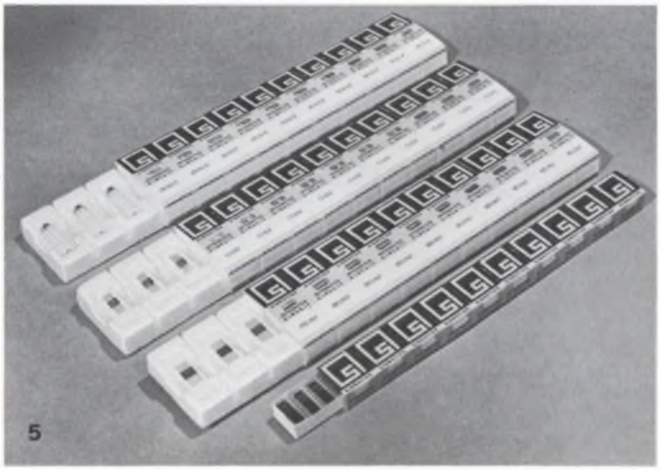
3

The carrier designed for Signetics' new "A" package, a solid plastic 14-lead dual in-line type, serves, as do the others, to protect the leads and guide the test head. It has one additional outstanding feature. This new carrier also serves as a throw-away alignment jig for insertion of the circuit into a PC board. As indicated in Figure 3 a slight downward pressure on the package body is used to extend the leads slightly beyond the bottom of the carrier. The leads can then be easily registered in the hole pattern in the PC board. A final downward push seats the circuit in the board, Figure 4. The carrier is then discarded.



4

This carrier is equally useful whether hand or machine insertion is involved. It should be noted that for machine insertion, the normal shipping box for Signetics dual in-line packages serves as a throw-away magazine for loading automatic machinery.



5

Shipping containers for each type of circuit package are shown in Figure 5.

**Signetics Data Circle 250**

SIGNETICS INTEGRATED CIRCUITS

## NEW SAGE I ELECTRONIC CALCULATOR USES SIGNETICS INTEGRATED CIRCUITS

A new, low-priced electronic desk-top calculator designed for general purpose business and engineering use has recently been introduced by Dero Research and Development Corporation of Huntington, New York. Called Sage I, the 12-pound portable-typewriter-sized unit performs computations in fractions of a second, in complete electronic silence. Featuring a simplified 10-key keyboard, the machine has a 20-digit capacity and displays results in ⅞-inch high numerals on a brightly illuminated screen.

The self-contained Memory of Sage I permits storage and recall of entries and results, facilitating continuous calculations and the accumulation of products and quotients. A number need only be entered once for raising to powers or for repetitive use. The device has four registers — entry, answer, memory and accumulate — and its typical speed is 0.008 seconds for addition and subtraction, and 0.25 seconds for multiplication and division.

Sage I operates in the same sequence in which a normal problem is expressed and thus no special instructions are required to learn how to operate the machine. The unit "remembers" both the last number and command entered, permitting an automatic repeat of either or both. Sub-totals are automatically indicated and any result may be further operated upon without re-entry. Automatic reciprocal division is also possible.

A special "double precision" feature of Sage I permits calculation capacity to 20 digits on its 10-digit display, with the 10 most significant digits presented first, and the remaining least significant digits presented when the "D" key is pressed. A second press of the "D" key returns the most significant digits to the display.


This advanced electronic desk calculator uses Signetics integrated circuits in the new easy-to-handle dual in-line plug-in package. The low cost of these units and the manufacturing economies they permit have helped keep the price of Sage I below $1000, which makes it less than the cost of many conventional mechanical calculators.

**Signetics Data Circle 251**

**Sage Data Circle 252**

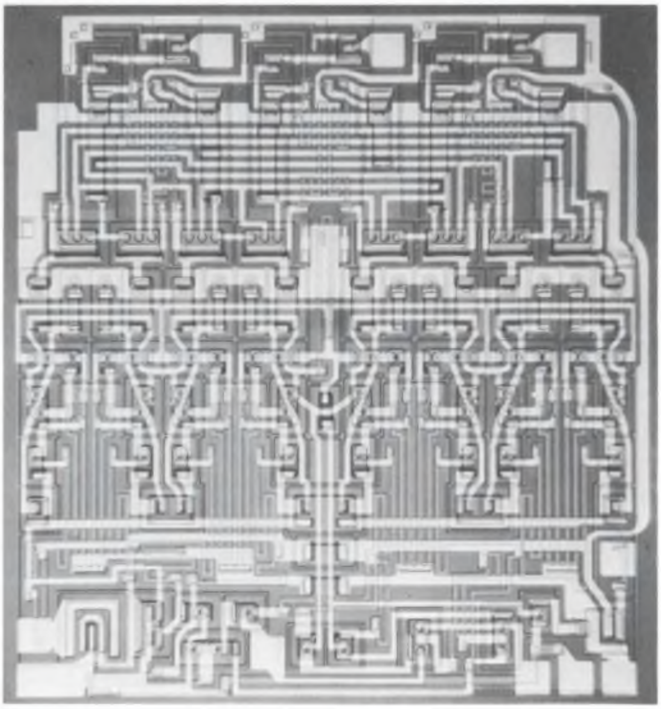
## SIGNETICS 8-BIT MEMORY ELEMENT IN SDS SIGMA 7 COMPUTERS

The remarkably high Input/Output rate of Scientific Data Systems' new Sigma 7 family of computers (up to 160 million bits per second) can be attributed in large measure to the liberal use of very high speed scratch pad memories assembled from Signetics 8-bit memory elements. These new monolithic I/C's incorporate 8 flip-flops, decoding and write networks, and an output buffer all on a single chip.

The principle function of the scratch pad memories is to speed up system response to multiple inputs by reducing dependence on the much larger and slower main memory. The basic scratch pad building block is a PC board carrying 16 of the 8-bit memory elements, and drive circuitry to form a 16 byte module of 8 bits per byte.

Sigma 7 features a total capability for both business and scientific data processing and is uniquely designed for real time computation while operating in time sharing, multiprocessing and multiprograming environments. Because of its extensive use of monolithic integrated circuits, Sigma 7 is considered a third generation computer.

A 12-page reprint of an article describing the SDS Sigma 7 and the function of the Signetics 8-bit memory element in it is available on request.



**Signetics Data Circle 253**

**SDS Data Circle 254**

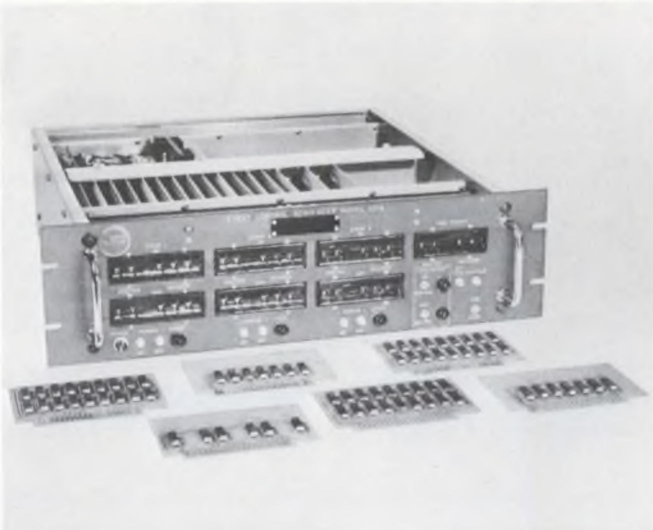
## VITRO LABS TIMING AND CONTROL SYSTEM FEATURES SIGNETICS DTL IC'S

High reliability, compactness and low cost are the major advantages of a new Event Control Sequencer manufactured by Vitro Laboratories of West Orange, New Jersey. Designated model 3219, this device was designed by Vitro to fill the need for more reliable data timing and control systems. It provides means for separate on-off control of three independent events to a resolution of 0.1 sec., operating on a time base of one hour. A seven-segment incandescent display indicates elapsed time in minutes, seconds and tenths of seconds. Outputs consist of three independent relay closures. These have mercury-wetted contacts rated at 28 volts, two amperes DC.

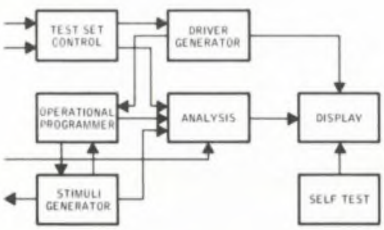
The 5¼" x 19" x 17" 30-pound unit, designed for rack mounting, is assembled using Signetics DTL integrated circuits in the new dual in-line plastic package on standard Vitro micro-circuit board assemblies. All components are mounted on one side of 3x5-inch epoxy-glass plug-in printed-wiring boards for standardization and ease of manufacture and maintainability.

**Signetics Data Circle 255**

**Vitro Data Circle 256**



## INTEGRATED CIRCUITS REDUCE SIZE OF MINUTEMAN PORTABLE TEST SET

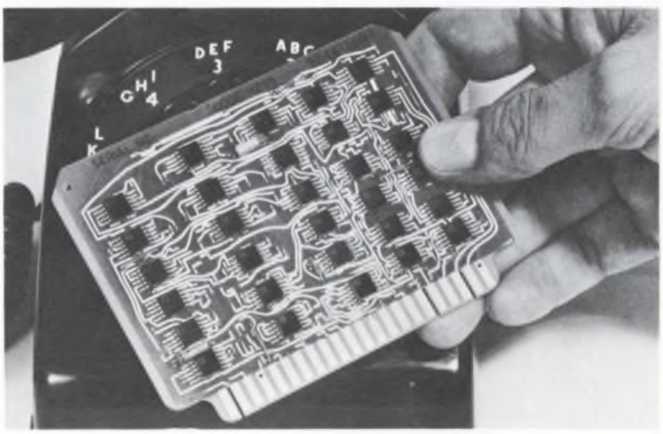



A portable automatic digital test set using Signetics integrated circuits has been designed by Sylvania Electronic Systems Division for part of the Minuteman ground electronic system. By using IC's, a volume reduction of 30 times and a weight reduction of 6 times has been achieved. If the test set were designed for conventional solid state printed circuit construction it would weigh 90 pounds and occupy 5 cubic feet of space. At 14 pounds, this set is light enough to be plugged directly into a rack connector, eliminating the need for cables.

Designed to limit operator decision-making (and thus minimize personnel training requirements) the test set is an automatic go/no-go readout unit capable of isolating a malfunction in a communications subsystem to one of seven drawers by simple indicator lamps. The unit automatically tests itself and then proceeds to program a series of tests on the subsystem. It is capable of performing the self test plus analysis of 42 test points required to check the subsystem in 20 seconds.

Two techniques are used for subsystem analysis. One is direct comparison of digital type signals from the subsystem with similar signals generated by the test set. The second technique is the checking of analog signals with a threshold level detector which indicates a no-go condition if signal voltages fall below a minimum preset level.

A block diagram of the test set is shown in the accompanying figure. Test start and stop signals, gating functions and synchronization are provided by the "Test Set Control." Clock pulses and pulse rates are developed in the "Driver Generator," and the "Operational Programmer" provides duplicating and controlling of the subsystem operations. The "Self Test" function checks for proper basic timing rates in the test set and assures that all analysis and readout circuits are capable of a no-go indication.



Signetics SE100-Series DTL circuits in "G"-type package are used extensively in this test set, and are shown on a typical circuit board in the accompanying photograph.

**Signetics Data Circle 257**

**Sylvania Data Circle 258**

SIGNETICS
INTEGRATED
CIRCUITS

## DUAL J-K FLIP-FLOP ADDED TO SE800-SERIES TTL FAMILY

Signetics has added a 35 Mc dual J-K flip-flop to its TTL family. Introduced at the IEEE convention in March, the new monolithic element, designated SE826 provides opportunities for greatly reducing can counts in TTL systems. Each of the two flip-flops has independent Preset, J, K, Q, $\overline{Q}$, and clock inputs. Average power dissipation is 40 mW per flip-flop, and 1.0-Volt noise margins are typical.

The 800 series also includes six different NAND gate configurations, single, dual, triple and quad; a gate expander, an Exclusive-OR, and a 30 Mc single J-K Binary Element that offers unusually great input logic flexibility.

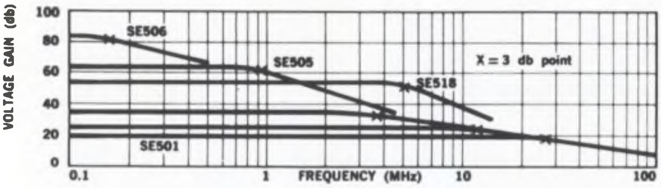
The series is offered in Signetics glass-Kovar 14-lead TO-88 flat package, and is available in two temperature ranges: the SE800 series for −55°C to +125°C application, and the NE800 series for a range of 0°C to 70°C.

## 800 SERIES TTL

| Element Catalog Number | Description | Package Type | Available In 0°C to 70°C Range |
|---|---|---|---|
| SE806 | DUAL 4-INPUT EXPANDER | J | X |
| SE808 | 8-INPUT NAND GATE | J | X |
| SE816 | DUAL 4-INPUT NAND GATE | J | X |
| SE825 | MASTER-SLAVE J-K FLIP-FLOP | J | X |
| SE826 | DUAL HIGH SPEED J-K FLIP-FLOP | J | X |
| SE840 | EXCLUSIVE-OR GATE | J | X |
| SE855 | DUAL 4-INPUT POWER GATE | J | X |
| SE870 | TRIPLE 3-INPUT NAND GATE | J | X |
| SE880 | QUAD 2-INPUT NAND GATE | J | X |

Signetics Data Circle 259

## SIGNETICS LINEAR FUNCTION SET




As shown in the accompanying graph, Signetics SE500-Series Linear Function Set provides all of the most frequently required circuit functions over a broad spectrum of gain and bandwidth combinations. The most recent additions to Signetics linear family are the SE506 Differential Operational Amplifier featuring an open loop gain of 17,000 and bandwidth of 170 KHz and the SE518 Analog Comparator which provides 5 MHz bandwidth and an open loop gain of 1700. All SE500 series elements are available in two temperature ranges (−55°C to +125°C and 0°C to 70°C).

Signetics Data Circle 260

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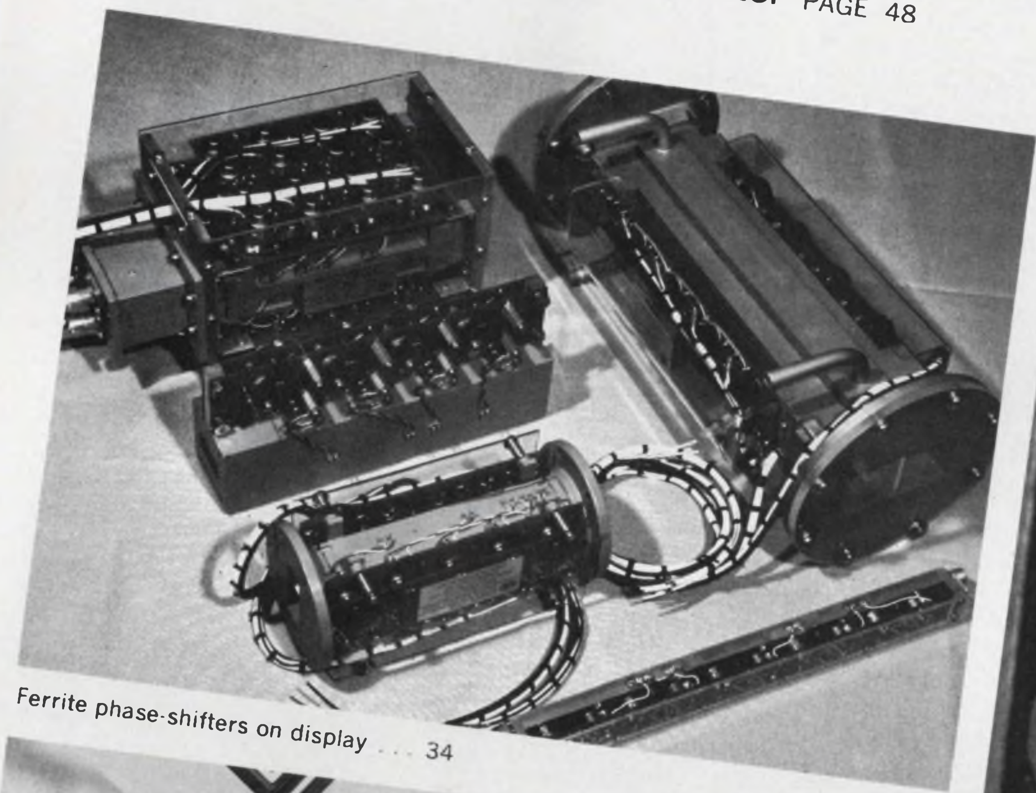
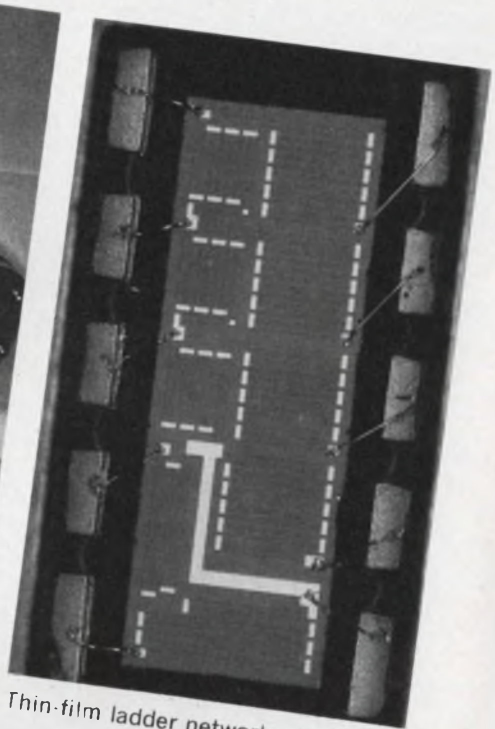
**Subsidiary of Corning Glass Works**

# E|D Technology

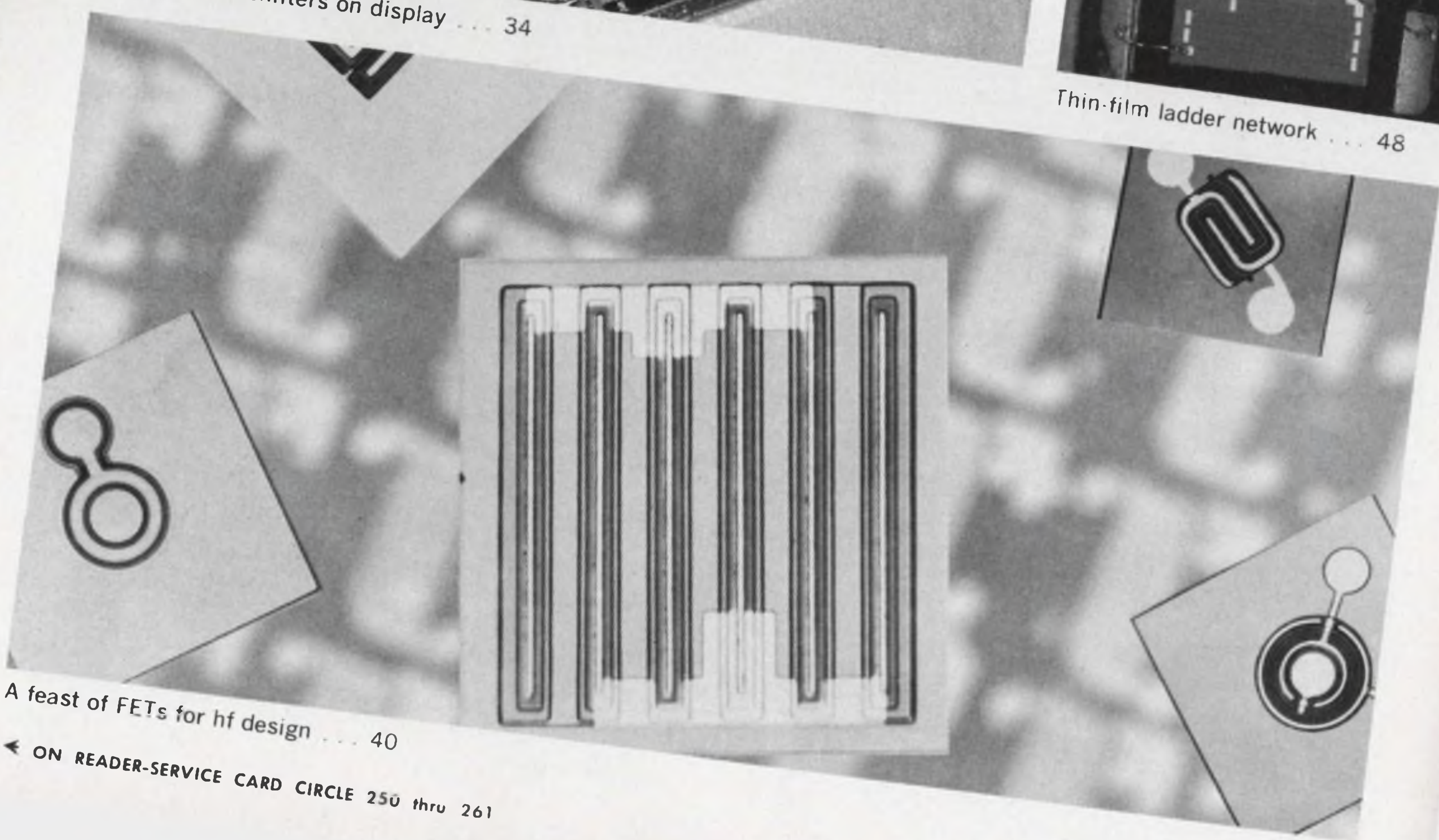
Ferrite phase-shifters are best for high power PAGE 34
Select the right FET for low-noise and hf applications PAGE 40
Use thin-films for a D/A converter PAGE 48



Ferrite phase-shifters on display . . . 34



Thin-film ladder network . . . 48



A feast of FETs for hf design . . . 40

◄ ON READER-SERVICE CARD CIRCLE 250 thru 261

# **Use ferrite phase-shifters** for high-power phased arrays. The latching types operate without holding current and are efficient even at 1 GHz.

For powerful, long-range phased-array radars, ferrite phase-shifters are a must. The efficiency of ferrite phase-shifters is greatly improved with latching, or digital, design. This approach does not use holding currents and makes possible efficient operation at frequencies above 1 GHz.

The power levels of ferrite phase-shifters can be as high as 1000-W average and 100-kW peak. Diode phase-shifters do not even approach these power levels yet (ED13, May 24, 1966, p. 46). Another point favoring ferrites at higher frequencies is the fact that the insertion loss of diodes increases with frequency. However, there is no firm demarcation line between diode and ferrite types—careful consideration must be given to each application.

There are two ways to obtain phase shifts from magnetized ferrites in the geometry being considered:

- Keep the direction of the magnetic field fixed and change the direction of the propagating RF.
- Change the direction of the magnetic field and keep the RF field in the same direction.

In each case, the phase shift is nonreciprocal, or differential.

Nonreciprocity limits the speed of operation. Switching time between transmit and receive states is limited by the time needed to change the direction of magnetization. Recognizing this limitation, many companies are working on reciprocal ferrite phase-shifters. Some success has been reported, but insertion loss of reciprocal types is still about double that of the nonreciprocal.

Only nonreciprocal types will be discussed, since reciprocal types have not achieved practical performance yet.

The external magnetic fields may be eliminated by forming a ferrite toroid. The toroidal geometry[1,2,3] reduces the demagnetizing fields of the slabs in the direction of the magnetization and preserves the desired direction of magnetization for a phase shifter (Fig. 1).

The operation of a ferrite phase-shifter is based on the ability of the ferrite or garnet to "remember" its past magnetization. The memory, defined as $B_{remanent}/B_{max}$ (the remanent magnetic moment divided by the maximum moment), is typically 0.80 to 0.50 for a toroid.

A portion of the magnetized toroid sees a circularly or elliptically polarized magnetic field resulting from the incident RF signal. The field is either positive or negative for one direction of magnetization of the toroid. Switching the direction of this magnetization reverses the sense of the polarized magnetic field and thus produces a differential phase shift. The switching field is generated by a current pulse in the wire that threads each core.

The two remanent states of magnetization, represented by the top and bottom of the loop, are the normal operating positions. The difference in the RF permeability of the two states determines the amount of differential phase shift.

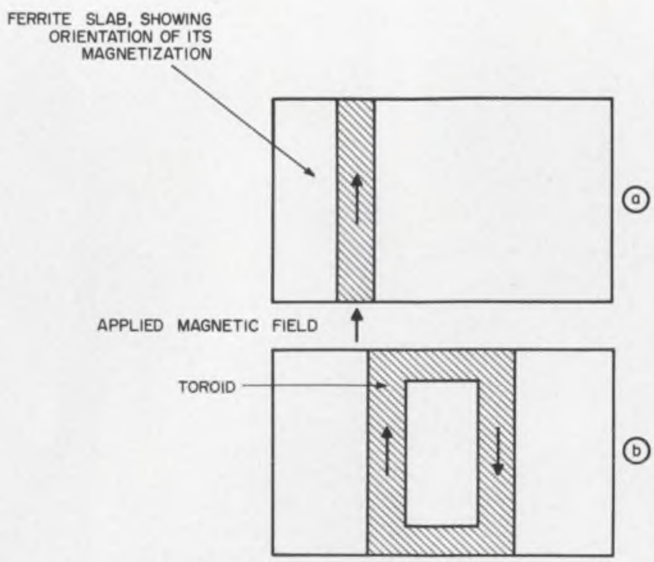
To obtain digital phase shift, the toroids must be composed of good microwave materials, with square or nearly square hysteresis loops.

### Design with proper core-lengths

By cascading appropriate lengths of toroids, each individually switched by current pulses, one can assemble a phase-shifter that has as many discrete values as required. For example, assume that a phase-shifter is needed to cover 360° in 11.25° steps. One toroidal core, or bit, is required for each phase shift of 180, 90, 45, 22.5 and 11.25°. Each successive core is one-half the length of the previous one, since the length is proportional to the phase shift:

$$\Delta\phi = K\, 4\pi M_s\, R_r\, L, \qquad (1)$$

where the symbols represent the following:




1. **A single-slab ferrite,** when magnetized, shifts the phase of an incoming RF field if either the direction of the magnetic field or the RF field is changed (a). Toroidal geometry does not need external magnetic field (b) to provide phase shift.

**Julian Brown, Jr.,** engineering section head, Sperry Microwave Div., Clearwater, Fla.

$\Delta\phi$ = differential phase shift,
$K$ = a constant of proportionality for a given geometry,
$4\pi M_s$ = saturation magnetization,
$R_r$ = remanent ratio = $4\pi M_r / 4\pi M_s$,
$L$ = length of core, and
$M_r$ = remanent magnetization.

Since the toroidal core exhibits a nearly square hysteresis loop, the switching current must produce a magnetic field greater than the coercive field of the material (Fig. 2). After the current pulse, the magnetization falls into the remanent state and holds. It is essential to drive the toroid beyond point 4 in Fig. 2. Otherwise the resulting remanent flux depends too much on the exact value of the peak current.

With this latching design, a command signal can establish a new phase state in 1 to 5 $\mu$s, and no holding current is required for either state.

The short switching time and absence of holding current ensure low average power consumption and low heating. Nevertheless, the materials must provide good phase-shift accuracy over a moderate temperature range and with a moderate variation in average power.

### Loss depends on material

The ferrimagnetic materials used in the toroids determine the loss, the switching time and switching power, and the power-handling ability of the phaser.

Insertion loss in the digital phase-shifter comes primarily from three mechanisms: magnetic loss, dielectric loss and wall losses in the RF structure. The first two can be minimized by proper material selection. In general, the dielectric loss tangent of the material should be as low as possible. Values less than 0.0005 have been achieved and these materials are acceptable for most applications.

Since the operating point in the digital phase shifter is one of the two stable remanent points of the hysteresis loop, the material is never completely saturated (single domain); therefore, the toroidal material is composed of a number of domains separated by domain walls. (Experimental results indicate that circular domains predominate.) In an unmagnetized, domain-filled ferrimagnetic material, so-called low-field magnetic losses have been predicted, and it has been experimentally verified that they occur up to a maximum frequency given by:

$$\omega_{max} = \gamma(H_{anis} + 4\pi M_s), \qquad (2)$$

where:

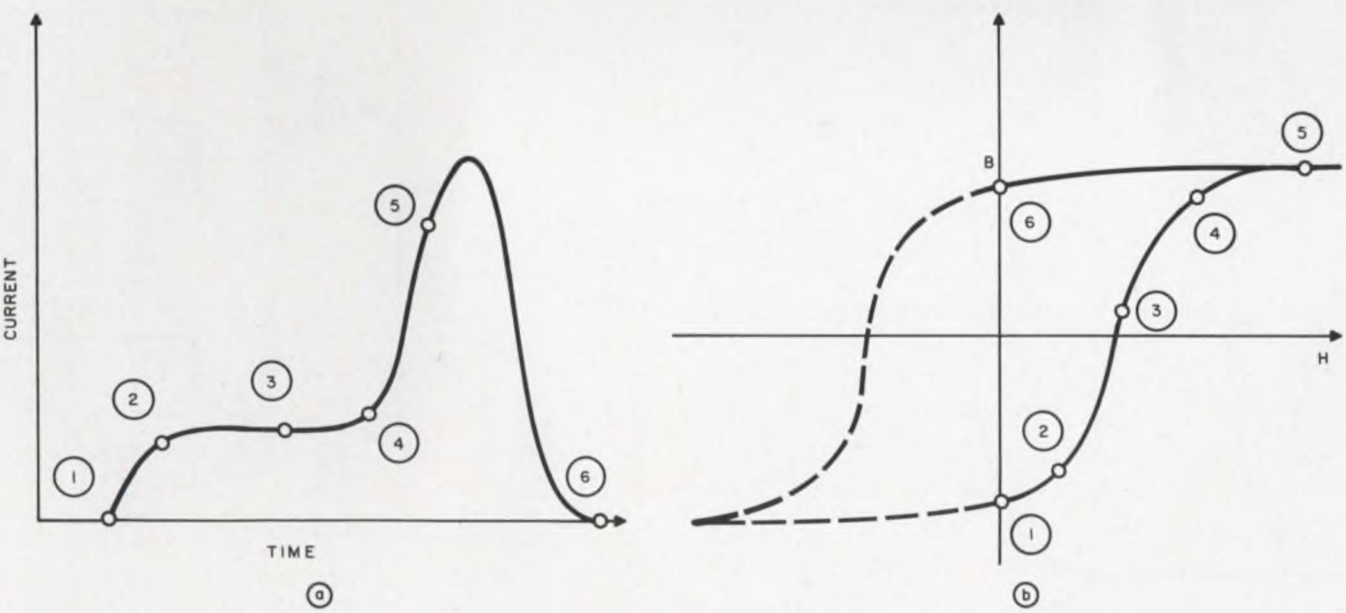
$\gamma$ = gyromagnetic ratio in MHz/Oe, and
$H_{anis}$ = anisotropy field in Oe.

The gyromagnetic ratio is nearly constant and equal to about 2.8 MHz/Oe. The anisotropy field is due to the fact that it is easier to magnetize the crystal along certain directions than others. Along these so-called easy axes, the magnetization requires the smallest amount of magnetic field. The hard axes are those directions that require the largest fields for magnetization. The anisotropy field is essentially the difference in the fields in the easy and in the hard directions.

Magnetic losses in ferrimagnetic materials are generally confined to a narrow band of frequencies which is related to the linewidth of the material.

Phase shifters operate off-resonance and in the case of most remanent phasers, above the resonant frequency. Sharpening linewidth cuts losses. To overcome linewidth broadening resulting from such factors as composition and porosity of the sample and the anistropy field, operating frequency should be well above the value given by Eq. 2.

Magnetization is usually chosen so that the ratio




2. **Switching current changes with time** (a) as one-half of the hysteresis loop (b) is transversed. The current must be large enough to drive the toroid beyond point 4. to make the value of the remanent flux somewhat independent of the exact value of the peak current. With this design, no holding current is needed for either state.

$\gamma 4\pi M_s/\omega$ is between 1/3 and 3/4 where $\omega$ is the operating frequency. The phase shifter's high-power limits must also be considered.

## Spin waves limit power

As power increases, spin waves are beginning to oscillate at both the fundamental operating frequency and at one-half of this frequency.

Instabilities appear in the precessing motion of the electrons. The result is an exponential coupling of energy to the spin-waves and a concurrent line-width-broadening and decrease in output power. Since the half-frequency waves have greater effects, the material should be selected to eliminate their influence. The power-handling capability can be increased and stabilized by selecting the ratio of $\gamma 4\pi M_s/\omega$ to be less than about 0.4 by doping the garnet material with rare-earth substitutions. The latter step increases the resonant linewidth and the spin-wave linewidth. This also increases insertion loss of the device. Therefore, peak power can best be controlled by adjusting $4\pi M_s$.

A high remanence ratio is desired in the material, because it reduces the magnetic losses and allows the use of a larger saturation magnetization.

The squareness of the hysteresis loop, $S_D$, is the ratio of $4\pi M_{RD}$ and $4\pi M_D$ (Fig. 3). $4\pi M_{RD}$ is the remanent magnetization at the drive field, and $4\pi M_D$ is the magnetization at the drive field, as shown in Fig. 3.

Typical $S_D$ values for better materials are in the 0.85 to 0.9 region, and typical values for $R_r$ range from 0.5 to 0.8.

The switching time and the needed switching energy also depends on the drive field and on the ferrimagnetic material. Switching, or reversal, time, in $\mu$s, is given by:

$$t \approx \frac{6.4 d\, \lambda (10^{-2})}{\delta g^2 M_s (H_m - H_o)}, \qquad (3)$$

where the symbols represent the following:

$d$ = mean distance from one domain wall to another, in cm,
$\lambda$ = damping parameter of material, in sec$^{-1}$,
$\delta$ = domain-wall thickness in cm,
$g$ = g-factor of material $[g=\gamma/(e/2mc)]$, and
$H_m, H_o$ = drive and threshold fields in Oe.

The threshold field is approximately equal to the coercive field of the material.

The inverse switching time is a linear function of the applied switching field.[4]

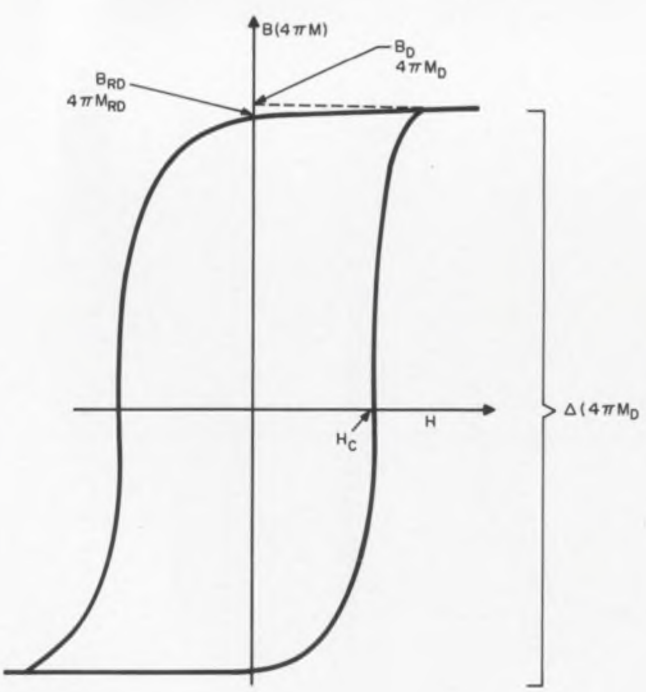
$$S_\omega = t(H_m - H_o), \qquad (4)$$

where $S_\omega$ is the switching coefficient, a constant at a given temperature; and $H_m - H_o$ is the actual drive field in oersteds. Typical values of $S_\omega$ range from 0.1 to 1.0 Oe-$\mu$s.

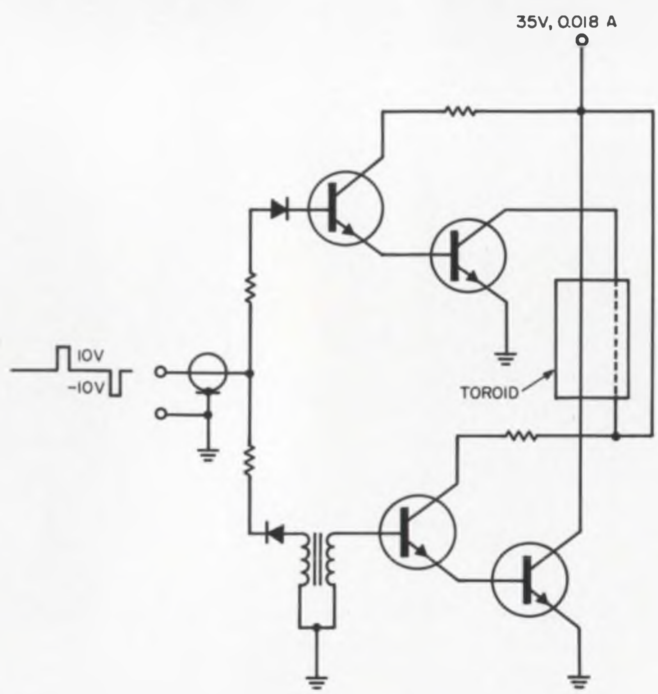
To show how switching power depends on the magnetic properties of the material, assume that the magnetic material has a square hysteresis loop, is toroidal in shape, and is threaded with a single switching coil of $N$ turns. (In many applications, the coil has only a single turn.) During the switching of such a core, its impedance is almost entirely resistive.[5] The needed switching current $I$ is:

$$I = \left( \frac{S_\omega}{t} + H_o \right) \frac{5D}{N}, \qquad (5)$$

where $D$ is the average diameter of the core in centimeters. Typical switching currents range from 5 to 15 A. Using this expression for $I$, the average resistance of the core can be computed. With all other characteristics the same, the fastest




3. **Hysteresis loop of typical ferrimagnetic material** shows the magnetization, $4\pi M_R$, and the remanent magnetization, $4\pi M_{RD}$, at the drive field.




4. **Typical transistor driver** can best satisfy switching requirements of 1 to 5 $\mu$s and switching rates of about 5 kHz. Energy required depends on square of wavelength.

switching material will be the one having the highest resistance.

The average power $P$ dissipated by the core is given by:

$$P = \frac{DA\Delta B}{t}\, r(S_\omega + H_0 t)10^{-1}, \qquad (6)$$

where
$A$ is the cross-sectional area of the core in square cm,
$B$ is the change in flux density (similar to $\Delta M_r$), and
$r$ is the switching rate of the material in Hz.

Equation 6 covers one complete trip around the hysteresis loop, which involves two switching actions. For a given core size and switching time, the driving power can be reduced only by choosing a material with a low $S_\omega$ and small flux density. The energy dissipated in the core can become very high for large cores that require fast switching time or high repetition rates, and the resulting heat can change the properties of the material. The typical core loss should be less than one watt.

### Too many materials—be careful!

For square hysteresis loops and low coercive fields, the particle size should be large. Large remanent magnetization usually requires thin-walled toroids.

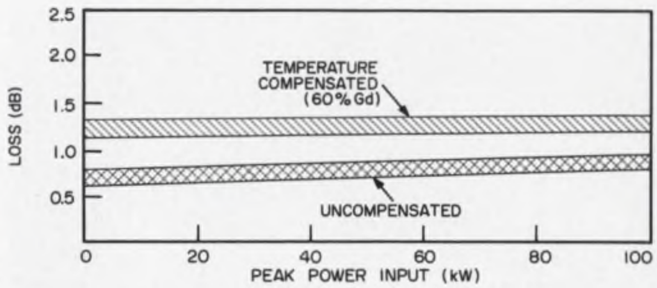
A wide range of saturation magnetization values is available in good square-loop materials. Following are some general guidelines for selection of the proper materials.

Aluminum substitution in yttrium iron garnets (YIG) produces a family of compositions having magnetization values from 1780 gauss (for YIG) down to 200 gauss (for 25% aluminum substituted YIG). Gadolinium substitutions produce compositions having stable magnetization as a function of temperature. For increased peak power dysprosium substitution is helpful in garnet materials, however lowering $4\pi M_s$ with aluminum is the preferred way.

Nickel zinc ferrites may have saturation magnetizations as high as 5000 gauss.

Lithium ferrites that exhibit square hysteresis properties have been compounded. These materials are particularly inviting because they have high Curie temperatures—in the neighborhood of 680°C. (Beyond the Curie temperature, ferrite materials lose their magnetic properties). Although their dielectric loss tangents are extremely high, they can be used for temperature compensation in composite toroids. Here, the active portion of the core is composed of a good microwave material, while the legs completing the toroidal geometry (outside the RF fields) are lithium ferrite. Nickel ferrites, too, have remanence ratios markedly lower than those of the garnets.

In applications where mechanical loads are expected, the selected material should have zero, or near zero, magnetostrictive constants. Otherwise mechanical loads can alter the hysteretic properties of the material and affect the reproducibility of the digital phase-shifter. In these areas some ferrite materials, in particular the magnesium manganese ferrites, are usually preferred over garnet types.




5. **Insertion losses of ferrites** increase with increasing peak powers. Temperature-compensated materials show somewhat higher losses.

### Efficiency depends on switching current

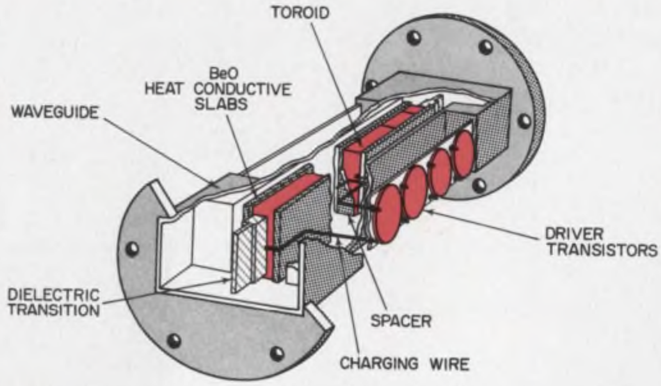
The toroid can be switched in a short time by applying a high voltage, or in a longer time with lower voltage. The energy delivered to the toroid is essentially the same, but the difference in driver efficiency is proportional to the square of the current ratio. Typical energy, time, and rate requirements are best satisfied with a transistor driver (Fig. 4). The toroid energy requirements are approximately proportional to the wavelength squared. The magnitude of the current is related to the variable permeability of the toroid during switching. A large portion of the energy is consumed during the last half of the switching cycle (mostly in the driver), but it is this part that contributes least to the total amount of differential phase shift.

Although most phasers will handle 10-kW peak power and work with average power levels from near zero to 100 W, some requirements will be as high as 100-kW peak and 1000-W average. In spite of these levels, each phaser must be insensitive to burn-out. Operation at higher power levels increases the inherent insertion loss (Fig. 5). The compensated curve in Fig. 5 represents the loss from a 60% gadolinium material that provides maximum temperature stability. The designer must choose between lowest possible loss accompanied by phase-shift variations as a function of temperature, or higher loss with relatively constant phase shift as a function of temperature. The usual compromises lead to a material with a moderate amount of temperature-compensation characteristics and a loss of 1 dB or less.

The presence of several objects—ferrimagnetic cores, dielectrics, and charging wires—in the waveguide can cause E-field arc-over if proper precautions are not observed. Arc-over is most likely to occur at the interface between the toroid and the waveguide walls and around the charging wires.

### How to build a phase-shifter

The essential features of a ferrite phase-shifter




6. **Typical S-band 4-bit phase-shifter** uses dielectric transitions to match the ferrite section to the waveguide. A dielectric load may be placed inside the toroid, to increase the phase shift.

are shown in Fig. 6. The dielectric spacers between toroids eliminate magnetic interactions. Dielectric impedance transformers (steps) match the waveguide impedance to the ferrite-loaded section. Either two charging wires are used in this case for each toroid so that only positive current pulses are needed from the driver, or a single wire and a driver capable of supplying both positive and negative pulses is required. Although these wires are at right angles to the E-field of the RF signal, some RF energy leaks on to them and must be removed by radiation suppressors or absorbers.

## Use a square waveguide

The most efficient waveguide size, when loaded with toroids, is approximately square, measuring about one-third wavelength on each side. This small size makes it possible to contain the entire phaser, including the driver, in a square whose edge dimension is one half the free-space wavelength of the operating frequency. Thus the phaser can be mounted in the array in line with the radiating elements—all about a half-wave-length apart. Present drivers are too large to implement this optimum size above 6 GHz, but only slight miniaturization of the drivers and microwave housings is required to reach the higher-frequency range. It is expected that it will be possible to fabricate a microminiaturized driver from integrated circuits to allow half-wavelength stacking in the X-band or beyond. ■ ■

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# Gain insight into FET amplifiers. Learn which parameters govern performance and how to handle the design of low-noise and high-frequency circuits.

*Part 2 of a three-part article.*

Filling an amplifier need with a field-effect transistor (FET) no longer need be difficult or time-consuming. In all FET-amplifier applications just a few parameters are critical. Consult these first and you quickly determine both the FET's suitability for the job and the major portion of the circuitry required.

Four major FET-application categories* remain in this theme of segregating governing parameters to facilitate selection. They are:

- Low-noise amplifiers (where signal levels are a few millivolts or less).
- High-frequency amplifiers (video and RF types).
- Differential amplifiers (conventional and low-drift types).
- Low-drift, single-ended amplifiers (including zero temperature coefficient operation).

We will now consider the first two application classes. Part 3 will cover the final two circuits, which are generally lower frequency applications.

The order of treatment for each application class will be first to consider the important characteristics peculiar to it; then to call out and use the key design parameters; finally to give the step-by-step design procedure for a typical circuit.

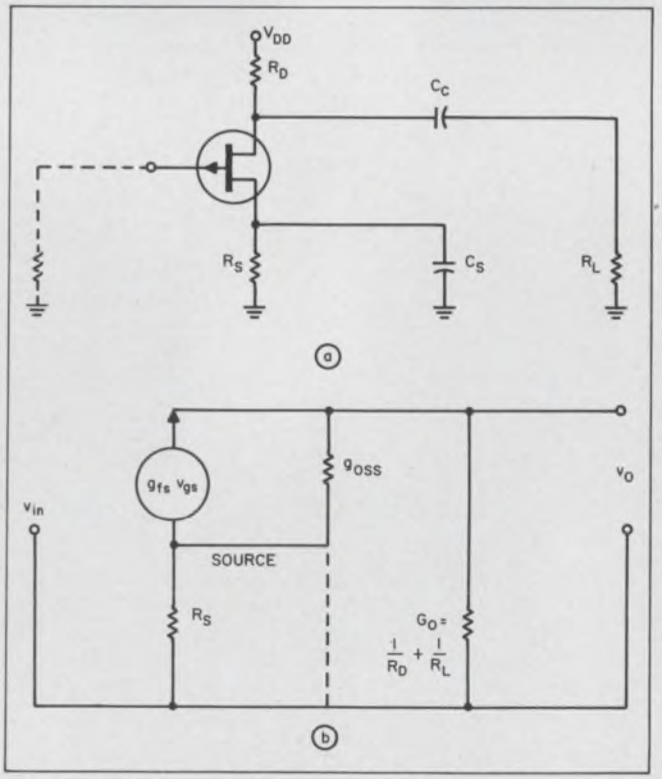
### FET source for low-noise amplification

A low-noise amplifier is but a variation of the general-purpose amplifier. Dc and ac design procedures are the same, except that amplifier noise becomes a paramount consideration. Signal levels are typically in the range below a few millivolts. A FET amplifier (shown at right) will be used to consider the audio- and sub-audio applications.

The FET may be described by the noise-equivalent circuit of Fig. 1a; it is characterized by an equivalent short-circuit noise voltage and an equivalent open-circuit noise current referred to the input.[2] Both $\bar{e}_n$ and $\bar{i}_n$ are functions of frequency as shown in Fig. 1b. The specified $i_n$ includes the effect of gate-source capacitance in the equivalent circuit. Thus, when making noise calculations due to $\bar{i}_n$, $C_{iss}$ is not included in the path of $\bar{i}_n$ (See Table 1).

Noise figure ($NF$) measurements include the effects of both $\bar{e}_n$ and $\bar{i}_n$, although the effect of $\bar{i}_n$ is usually insignificant when the generator resistance is below several megohms. $NF$ measurements must always include a generator resistance ($R_{gen}$) specification, as well as frequency and bandwidth. Either $\bar{e}_n$ or $\bar{i}_n$ need include only frequency and bandwidth specifications. $NF$ should always be specified with an $R_{gen}$ low enough to give an $NF>1$ dB; otherwise, the $NF$ measurement is not of sufficient accuracy to be meaningful.

The fact that the FET exhibits a minimum $NF$ with a specific $R_{gen}(R_{opt})$ at a given frequency does not mean circuit output noise is a minimum under these conditions. It simply means that for the specified $R_{opt}$ the FET contributes a minimum percentage of the total noise; the remainder is generated by the signal source and its internal re-




**A FET RC-coupled amplifier** (a) and its equivalent circuit (b) are analyzed for noise sources in text.

*Consult ED 11, May 17, 1966, Semiconductor reference issue, pp. 94 ff., for a detailed background treatment of field-effect parameters. Part 1 of this article, "Take the fog out of FET design," appeared in ED 12, May 24, 1966, pp. 38 ff. It covered three other major types of FET and MOS switching and amplifying applications.

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sistance ($R_{opt}$). In fact, it is axiomatic that output noise increases with generator resistance.

The important FET parameters for low-noise applications are $NF$, $\bar{e}_n$, $\bar{i}_n$, $C_{iss}$, $g_{fs}$ and $C_{rss}$. Any two of the three noise characteristics will describe FET noise performance. However, it is best that $\bar{e}_n$ be specified in the excess noise region for applications below several hundred Hertz. An additional specification at or above 1 KHz is important for audio-frequency applications. For the high-frequency region, we take note of the curves of Fig. 1b. At high frequencies, $\bar{e}_n$ becomes independent of frequency. In the excess noise region below a few hundred Hertz, the noise power increases as $1/f$, hence the name $1/f$ noise. It is to be noted, although not the rule, that the noise power of FETs manufactured by some processes increases as $1/f^2$ over a significant portion of the spectrum. A single-frequency noise specification does not, therefore, necessarily provide adequate noise-performance information. It is only from curves of typical performance, such as those shown in Fig. 1b, that the FET devices can be adequately described.

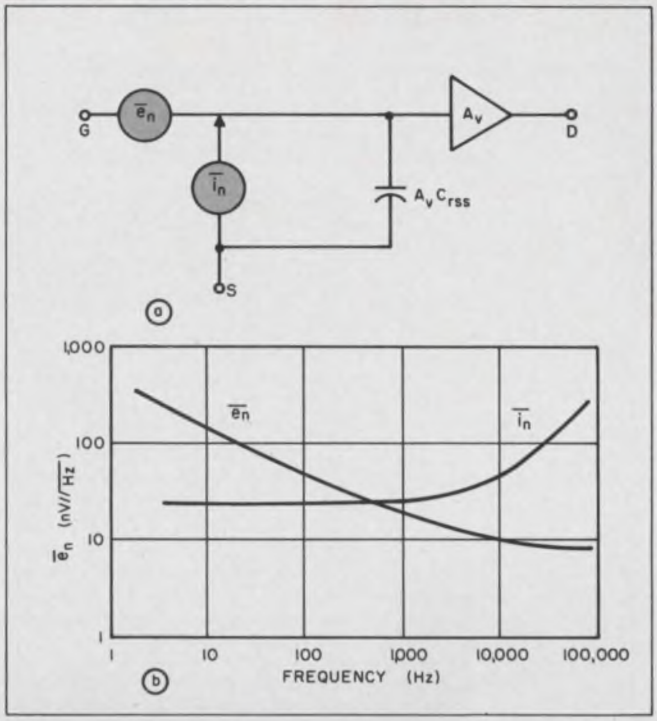
In the $1/f$ region, $\bar{e}_n$ increases as $1/\sqrt{f}$, and the equivalent noise resistance increases as $1/f$. FET noise voltage at any given frequency may also be expressed as an equivalent noise resistance, $R_N$. This is because the noise produced by a FET may be equated to the thermal noise produced in a resistor. Thermal noise is plotted as a function of resistance in Fig. 2a and is expressed by the relationship

$$\bar{e}_n^{\,2} = kTRB \text{ or } \bar{e}_n = \sqrt{kTRB}, \qquad (1)$$

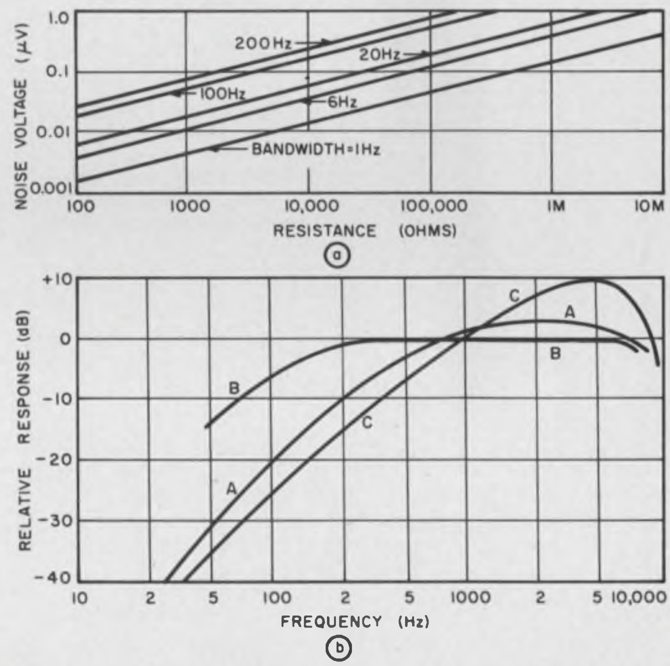
where $k$ is Boltzman's constant, $T$ is the temperature in degrees Kelvin (usually 298°K or 25°C),

**Table 1. FET Noise Parameters**

| Parameter | Test conditions (must be specified) | Meaning of specification |
|---|---|---|
| $\bar{e}_n$ | $V_{DS}$<br>$V_{GS}$ or $I_D$<br>frequency<br>bandwidth | Common-source equivalent short-circuit input noise voltage. Measured at the output with the input shorted, and referred to the input. Expressed as rms volts per root cycle, $\mu V/\sqrt{Hz}$. A function of frequency, so frequency value must be stated. |
| $\bar{i}_n$ | $V_{DS}$<br>$V_{GS}$ or $I_D$<br>frequency<br>bandwidth | Common-source equivalent open-circuit input noise current. Expressed as $pA/\sqrt{Hz}$, a function of frequency. |
| NF | $V_{DS}$<br>$V_{GS}$ or $I_D$<br>$R_{generator}$<br>frequency<br>bandwidth | Noise figure. This represents a ratio between input signal to noise and output signal to noise. NF is a function both of frequency and of generator resistance $R_S$. Both must be stated or the specification is meaningless. When properly qualified, NF includes the effects of both $\bar{e}_n$ and $\bar{i}_n$. |



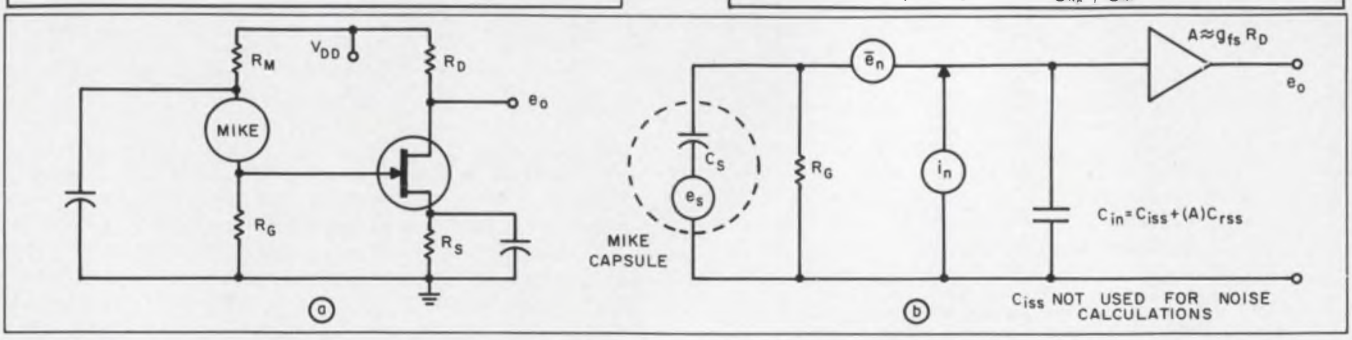

1. **When FETs are used for low-noise amplifier applications,** the noise equivalent circuit (a) must be consulted. The equivalent short-circuit noise voltage ($e_n$) and equivalent open-circuit noise current ($i_n$), as referred to the input, are functions of frequency (b).




2. **Thermal noise in FETs** can be plotted as a function of resistance (a) according to the relationship $e_n^2 = kTRB$. To obtain a specified noise-response characteristic, filters are used (b), particularly in measurements of sound-reproduction equipment. Curve A is an ASA recommendation; Curve B is a standard used by the Radio Manufacturers' Association; curve C is a German standard (DIN #45-405). All three display filter characteristics for noise measurements.

**Table 2. Small Signal Characteristics of FETS**

| Parameter | Test Conditions (must be specified) | Meaning of specification |
|---|---|---|
| $r_{ds(on)}$ | $V_{GS}$<br>$V_{DS} = 0$ or $I_S$<br>frequency | Drain-to-source resistance when biased to full ON condition (max operating $I_D$). |
| $\|y_{fs}\|$ | | Magnitude of common-source forward transfer admittance. Sometimes the magnitude signs are omitted. Measured at $V_{GS} = 0$, unless otherwise specified. |
| $\|g_{fs}\|$ | | Magnitude of common-source forward transfer conductance. Sometimes the magnitude signs are omitted. This is perhaps a more informative term than $y_{fs}$. At 1kHz, $y_{fs} \approx g_{fs}$. However, at high frequencies $y_{fs}$ includes the effect of gate-drain capacity. hence may be misleadingly high. The term $g_{fs}$ should be used for all high-frequency measurements. |
| $g_{fsx}$ | $V_{DS}$ & $V_{GS}$<br>or<br>$V_{DG}$ & $I_D$<br>frequency | Same as $g_{fs}$ but a particular set of operating conditions is implied. |
| $\frac{g_{fs1}}{g_{fs2}}$ | | Match in $g_{fs}$ for differential pairs. Expressed as a fraction. |
| $\frac{g_{fsx1}}{g_{fsx2}}$ | | Match in $g_{fsx}$ for differential pairs. |
| $g_{fsz}$ | | Same as $g_{fsx}$ but often used to denote $g_{fs}$ when biased for zero temperature coefficient operation. |
| $g_m$ | | Mutual conductance. Sometimes used in lieu of $g_{fs}$. |
| $g_{mo}$ | | Same as $g_m$, but specifically at $V_{GS}=0$. |
| $y_{iss}$ | | Common-source input admittance with output shorted. Important for high-frequency operation. |
| $g_{iss}$ | $V_{DS}$<br>$V_{GS}$<br>$v_{ds}=0$<br>frequency | Common-source input conductance with output shorted. This must be specified for high-frequency applications as $g_{iss} \propto 1/\omega^2$. |
| $Re\|y_{iss}\|$ | | Real part of $y_{iss}$. Identically equal to $g_{iss}$. Sometimes used instead of $g_{iss}$. |
| $g_{is}$ | | Same as $g_{iss}$. |
| $y_{oss}$ | | Common-source output admittance with input shorted. |
| $g_{oss}$ | | Common-source output conductance with input shorted. |
| $Re\|y_{oss}\|$ | $V_{DS}$ & $V_{GS}$<br>$V_{DG}$ & $I_D$<br>$v_{gs}=0$<br>frequency | Real part of $y_{oss}$. Identically equal to $g_{oss}$. Sometimes used instead of $g_{oss}$. |
| $g_{os}$ | | Same as $g_{oss}$. |
| $Im\|y_{oss}\|$ | | Imaginary part of $y_{oss}$. Output susceptance $b_{oss}$. Identically equal to $1/\omega C_{oss}$. Sometimes used in lieu of $C_{oss}$. |
| $C_{iss}$ | $V_{DS}$<br>$V_{GS}$<br>$v_{ds}=0$<br>frequency | Common-source input capacitance, output shorted. $C_{iss} = C_{dg}+C_{gs}$. (Fig. 6). |
| $C_{is}$ | | Same as $C_{iss}$ if $v_{ds}=0$. |
| $C_{gss}$ | | Same as $C_{iss}$. |
| $C_{rss}$ | $V_{DS}$<br>$V_{GS}$<br>$v_{gs}=0$<br>frequency | Reverse transfer capacitance, input shorted. |
| $C_{rs}$ | | Same as $C_{rss}$. |
| $C_{dg}$ | | Same as $C_{rss}$, actual value of drain-gate capacitance. |
| $C_{gs}$ | Values in equivalent circuit not measurable directly. | Actual value of gate-capacitance. |
| $C_{ds}$ | | Actual value of drain-source capacitance, essentially header capacitance. |
| $C_{oss}$ | $V_{DS}$<br>$V_{GS}$<br>$v_{gs}=0$<br>frequency | Common-source output capacitance, input shorted. $C_{oss} = C_{rss}+C_{ds}$. However, $C_{ds}$ is essentially header capacitance. |
| $C_{os}$ | | Same as $C_{oss}$ if $v_{gs}=0$. |
| $C_{dgs}$ | | Same as $C_{oss}$. |
| $C_{sgs}$ | $V_{DS}$<br>$V_{GS}$<br>$v_{dg}=0$<br>frequency | Source-to-gate capacitance, gate and drain shorted. $C_{sgs} = C_{gs}+C_{ds}$. |
| $C_{dgo}$ | $V_{DO}$<br>$V_{GS}$ or $I_S=0$<br>$i_s=0$<br>frequency | Drain-to-gate capacitance with source open. $C_{dgo} = C_{rss} + \frac{C_{gs}\,C_{ds}}{C_{gs}+C_{ds}} > C_{rss}$, cut $< C_{dgs}$. |
| $C_{sgo}$ | $V_{GS}$<br>$V_{DS}$ or $I_D=0$<br>$i_d=0$<br>frequency | Source-to-gate capacitance with drain open. $C_{sgo} = C_{gs} + \frac{C_{dg}\,C_{ds}}{C_{dg}+C_{ds}} > C_{gs}$, but $< C_{sgs}$. |




3. **The FET can be put to advantage** in capacitor microphone preamplifier applications (a). Referring to the equivalent circuit (b). $C_{in}$ (across mike) must be minimized to provide high S/N ratios. Capacitance at $R_s$ is $C_s$.

$R$ the resistance in ohms and $B$ the bandwidth in Hertz.

As $\bar{e}_n$ is proportional to $\sqrt{B}$, the units used are $\mu V/\sqrt{Hz}$. The conversion from $\bar{e}_n$ to $R_N$ becomes an easy one with Fig. 2a. The characterization of a FET by $R_N$ is equivalent to specifying a $NF$. Thus, when a FET is said to have an equivalent noise resistance of 20 kΩ at 1 kHz, this is tantamount to saying $NF = 3$ dB at 1 kHz with $R_{gen} =$ 20 kΩ.

### How to spot noise in narrow bands

Narrow-band $NF$, $\bar{e}_n$, and $\bar{i}_n$ are usually specified either as NB-noise or spot-noise measurements. This means simply that the bandwidth is sufficiently small for a change in bandwidth not to affect the $NF$ of $\bar{e}_n/\sqrt{Hz}$. In a wide-band measurement, over a frequency range of 0.1 to 5 kHz for instance, this may not be true. From Fig. 1b it is seen that the integral of $\bar{e}_n$ in this band is a function of bandwidth. On the other hand, from 1 to 50 Hz or from 10 to 100 kHz, the integral of $\bar{e}_n$ is essentially independent of bandwidth. For this reason, it is important to note the bandwidth specified for any noise measurement. Alternatively, it must be stated that the parameter is a spot noise measurement.

When selecting a FET for use in sound-reproduction equipment, a noise specification at or above 1 kHz is desirable. A noise specification at 20 or 100 Hz for audio equipment will most often result in over-specification and will increase component cost. As the ear is progressively less sensitive to frequencies below a few kilohertz, noise measurements on sound-reproduction equipment are ordinarily carried out with wide-band equipment possessing a certain specified response characteristic.

The characteristics of several filters used for this purpose appear in Fig. 2b. Curve A is recommended by the American Standards Association for low-level noise measurements.[2,3] Curve B is most useful for noise analysis in offices and factories, although it is recommended by the Radio Manufacturers' Association for noise measurement on sound reproduction equipment.[4] Neither of these two curves is *universally* applicable as each was generated from single-frequency measurements. Curve C, a standard (DIN 45-405) used for this purpose in Germany, appears to be more applicable, as it includes the effect of the high frequency's masking of low frequencies.

It is most meaningful, therefore, to specify noise measurement for sound-reproduction equipment at a frequency from 1 to 5 kHz or over a broad band, regardless of whether one of the weighting curves (A, B or C) is used.

### $C_{iss}$ affects signal-to-noise ratio

Although $NF$, $\bar{e}_n$, and $\bar{i}_n$ specify noise performance of the FET, there are those applications where $C_{iss}$ can significantly affect circuit signal-to-noise ratio ($S/N$). For a given $\bar{e}_n$ and $\bar{i}_n$ it is desirable to have a high $g_{fs}$ so that the output $S/N$ is high enough to reduce the effect of second-stage noise. Consider, for example, the capacitor microphone preamplifier, of Fig. 3. As the signal source is a small capacitor, $C_{in}$ of the amplifier and the microphone capacitance become a voltage divider. It is thus important to minimize $C_{in}$ for a high $S/N$. Also, the gate-return resistor $R_G$ should be as high as practical to extend the low-frequency cut-off; therefore, $\bar{i}_n$ should be low to minimize current noise in $R_G$ and $C_S$. Assuming a noiseless microphone, the noise performance of the preamplifier may be determined by a step-by-step procedure.

Referring to Fig. 3, we use the following circuit characteristics:

- $g_{fs} = 1000$ μmhos at operating point.
- $\bar{e}_n = 0.05\ \mu V/\sqrt{Hz}$ at 1 kHz.
- $\bar{i}_n = 0.001\ pA/\sqrt{Hz}$ at 1 kHz.
- $C_{iss} = 4.5$ pF;
- $C_{rss} = 1.5$ pF;
- $C_s = 27$ pF;
- $R_G = 100$ MΩ
- $R_D = 10$ kΩ
- $e_s = 1$ mV at 1 kHz

Note that $R_G$ is negligible in comparison to the 1-kHz reactance of the $C_{in}$ and $C_s$ combination. Also, the correlation between $\bar{e}_n$ and $\bar{i}_n$ is neglected.

Now for the design:

1. Determine amplifier gain:

$$A = g_{fs} R_D = 10.$$

2. Determine the input capacitance:

$$C_{in} = C_{iss} + A\,C_{rss} = 19.5 \text{ pF}.$$

3. Determine the input signal level at the frequency of interest:

$$e_{in} = e_s\left(\frac{C_s}{C_s + C_{in}}\right) \approx 0.6 \text{ mV at 1 kHz.} \quad (4)$$

4. Determine the total equivalent input noise, total $\bar{e}_n$. Observe that $\bar{e}_n$ divides between $Z_{gen}$ and $Z_{in}$ in the same manner as does $e_s$. Thus,

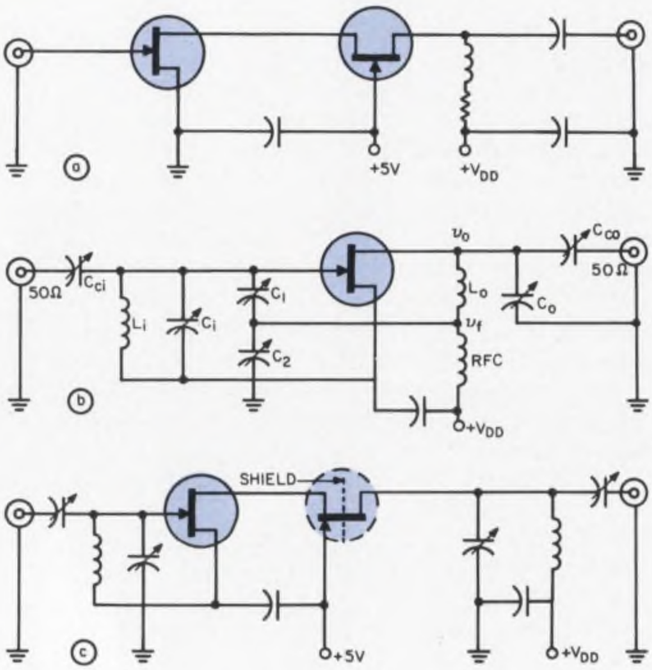
$$\text{Total } \bar{e}_n^{\,2} = \left[\bar{e}_n \frac{C_s}{C_s + C_{in}}\right]^2 + \left[\frac{\bar{i}_n}{\omega\,(C_s + AC_{rss})}\right]^2, \quad (5a)$$

and

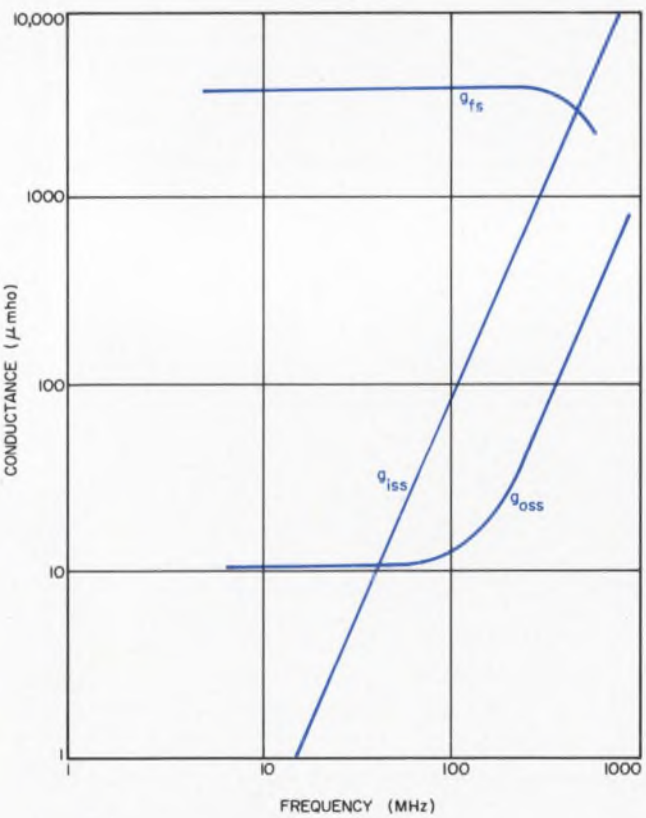
$$\text{Total } \bar{e}_n \approx 9.77 \text{ nV}/\sqrt{Hz} \text{ at 1 kHz.} \quad (5b)$$

5. Determine $S/N$ in the bandwidth 1-10 kHz. Assume $\bar{e}_n$ and $\bar{i}_n$ to be constant with frequency. Use no weighting function. Note that total $\bar{e}_n$ is due principally to $\bar{e}_n$ and not $\bar{i}_n$. One may then assume total $\bar{e}_n$ is constant with frequency in the range of interest. Thus,

$$S/N = 20 \log \frac{e_{in}}{\text{total } \bar{e}_n \sqrt{9000}} \approx 76 \text{ dB.} \quad (6)$$




4. **FETs are suitable for high-frequency amplifying** applications. A cascode video amplifier (a), a 100-MHz neutralized amplifier (b) and a 30-MHz cascode amplifier (c) all exhibit good gain, low noise and little harmonic distortion.




5. **Maximum available gain** (MAG) in FET high-frequency amplifiers is calculated from the master chart. It exhibits the conductance vs frequency relationship of FET devices now on the market. Shown are the input ($g_{iss}$), output ($g_{oss}$) and transfer ($g_{fs}$) conductances.

This completes the low-noise amplifier class of FET applications. We now turn to the high-frequency type (FETs operated above 1.0 MHz).

**FETs suitable for RF operation**

A high-frequency amplifier is arbitrarily defined as one which is operating at frequencies above 1 MHz. Included in this definition are both video and RF amplifiers (Fig. 4). The small-signal FET characteristics are of prime importance (See Table 2). They establish the suitability of a particular FET and govern design of FETs in high-frequency amplifiers.

For the video designs the major parameters are $g_{fs}$, $C_{iss}$, $C_{rss}$ and $C_{oss}$. Each of these terms is critical in RF amplifier design, where the values of $g_{iss}$, $g_{oss}$ and $NF$ also exert a major influence. The video amplifier is characterized by its gain-bandwidth ($GB$) product. This is expressed as

$$GB = \frac{g_{fs}}{\omega[C_{in} + C_{out}]} = \frac{g_{fs}}{\omega[C_{iss} + (1 + A)C_{rss}]} \tag{7}$$

For the cascode connection this becomes[5]

$$GB = \frac{g_{fs}}{\omega[C_{iss} + 2C_{rss}]} \tag{8}$$

Note that $C_{oss} \approx C_{rss}$ and $C_{iss} = C_{gs} + C_{rss}$.

The $GB$ is important for RF amplifiers; however bandwidth is ordinarily limited to a few megahertz at most, rather than the tens of megahertz required of a video amplifier. An RF amplifier is limited in power gain by the real part of its input and output impedances. When these are matched to source and load, maximum available gain ($MAG$) is realized. For the FET

$$MAG = \frac{|y_{fs}|^2}{4g_{iss}\,g_{oss}} \tag{9}$$

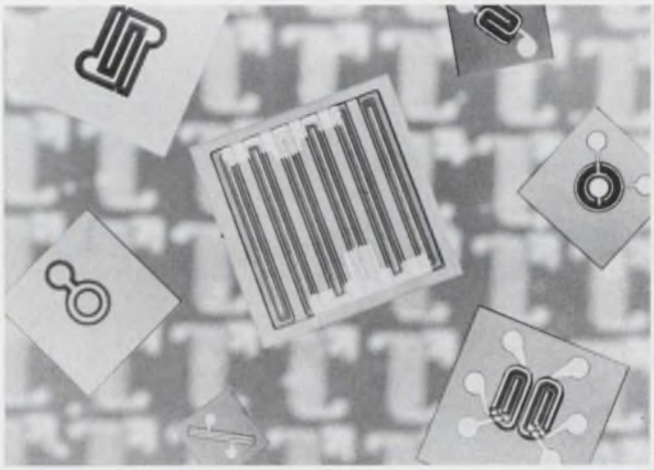
FET performance as a small-signal RF amplifier is also limited by its high-frequency noise characteristics. The value of $C_{rss}$ is important, as its effect must be neutralized for stable amplifier operation.

An important advantage of the FET in RF circuitry is its almost perfect square-law transfer characteristic. Because of this, amplifier cross-modulation figures are at least an order of magnitude better than those of bipolar transistor designs. In most cases a substantial improvement is obtained even over vacuum-tube circuits.[2,3]

FET transconductance remains essentially constant to several hundred MHz. Both $g_{iss}$ and $g_{oss}$ increase with a nearly square relationship to frequency. With available FETs, $MAG$ is less than unity at that frequency where $g_{fs}$ begins to decrease. $MAG$ can be calculated from the curves in Fig. 5—which represent the characteristic obtainable with current FETs.

Recent improvements in the control of device input and output impedances at high operating frequencies has made possible the production of both MOS and FET units with acceptable performance to 500 MHz.[6] The MOS has a very low value of $g_{iss}$ at high frequencies, thus permitting excellent hf operation. However, its output conductance rises in the same manner as that of the FET, limiting the *MAG* obtainable.

FET high-frequency noise figure (*NF*) for properly designed practical circuits is 2 dB or better at 10 MHz (with an $R_{gen}$ = 1 kΩ), and good noise performance extends to the vicinity of 500 MHz. In contrast to bipolars, these same FETs exhibit a typical *NF* of 5 dB at 10 Hz (with an $R_{gen}$ = 1 MΩ). MOS high-frequency noise performance is approaching that of the FET, with at least one available unit specified with a *NF* of 4.5 dB at 450 MHz.



**FET geometries** vary from unit to unit. Knowing which of the many parameters best reflect device suitability for high-frequency applications simplifies FET selection.

### Designing a 100-MHz cascode amplifier

FET amplifier circuits resemble the triode-vacuum-tube types. Practical use of the cascode circuit is limited to about 100 MHz for good noise performance with maximum gain, unless cumbersome circuitry is added. Here is the step-by-step design procedure for a 100-MHz amplifier. We will use a FET with the following parameters:

- $g_{fs}$ = 3500 μmho at 100 MHz
- $g_{iss}$ = 100 μmho at 100 MHz
- $g_{oss}$ = 15 μmho at 100 MHz
- $C_{iss}$ = 4.5 pF
- $C_{rss}$ = 1.5 pF
- $f_o$ = 100 MHz

The procedure refers to the circuit of Fig. 4b.

1. Calculate output-circuit component values. The network $C_{oss} + C_o$ and $C_{co}$ match the output conductance to the load conductance. The output conductance is the sum of $g_{oss}$ plus the tuned-circuit conductance, $1/Z_p$. As $1/g_{oss}$ = 67 kΩ, and the 100-MHz tuned-circuit *Q* is such that $Z_p \approx 5$ kΩ, the latter determines the actual output conductance at 100 MHz. Then, $R_o$ = 5 kΩ and $R_L$ = 50 Ω. If $C_o$ = 1.2 pF, the matching capacitor value are determined by

$$C_{oss} + C_o \approx C_{rss} + C_o = 2.7 \text{ pF}, \qquad (10)$$

$$C_{co} = \frac{1}{\omega\sqrt{R_o R_L}} \approx 3 \text{ pF}, \qquad (11)$$

$$L_o = \frac{1}{\omega^2 (C_{oss} + C_o + C_{co})} \approx 0.45\ \mu\text{H}. \qquad (12)$$

2. Input circuit calculations are similar. Assume input circuit *Q* is such that $R_i$=1 kΩ to achieve optimum noise figure. With $R_{gen}$=50 Ω and $C_i$= 1.2 pF, $C_{rss}$ is subtracted from $C_{iss}$ to obtain actual FET input capacitance because $C_{rss}$ is neutralized. Thus,

$$C_{iss} - C_{rss} + C_i = 4.7 \text{ pF}, \qquad (13)$$

$$C_{ci} = \frac{1}{\omega\sqrt{R_i R_{gen}}} \approx 1.3 \text{ pF}, \qquad (14)$$

$$L_i = \frac{1}{\omega^2 (C_{iss} - C_{rss} + C_i + C_{ci})} \approx 0.42\ \mu\text{H}. \qquad (15)$$

3. The circuit is neutralized using the "sloppy bypass" technique as follows: The fraction of $v_o$ appearing out of phase on $C_2$ is

$$v_f = v_o \frac{C_{out}}{C_2} \qquad (16)$$

where $C_{out}$ is the sum of $C_{oss}$, $C_o$ and $C_{co}$. The fraction of $v_f$ appearing at the gate is approximately

$$v_g = \left[\frac{1/j\omega C_1}{R_{in} + 1/j\omega C_1}\right] v_f. \qquad (17)$$

This must be set equal to the fraction of $v_o$ appearing in phase at the gate. Note that the fraction is due to the feedback function of $C_{rss}$. The latter term is given by

$$v_{fb} = \frac{1/j\omega C_{rss}}{R_{in} + 1/j\omega C_{rss}} (v_o). \qquad (18)$$

Equating (16) and (17) and using Eq. 18 yield

$$\frac{1/j\omega C_{rss}}{R_{in} + 1/j\omega C_{rss}} = \frac{C_{out}}{C_2}\left[\frac{1/j\omega C_1}{R_{in} + 1/j\omega C_1}\right], \qquad (19a)$$

$$1 + j\omega C_1 R_{in} = \frac{C_{out}}{C_2}(1 + j\omega C_{rss} R_{in}). \qquad (19b)$$

For all practical purposes, it is only the imaginary terms which must be set equal. Doing this establishes the relationship,

$$C_1 C_2 = C_{out} C_{rss}. \qquad (20)$$

This wraps up the higher-frequency FET amplifier applications. In Part 3 (ED 15, June 21) we will take up the low drift, single-ended and differential FET circuits. ■ ■


**References:**

1. A. van der Ziel. "Thermal Noise in Field-Effect Transistors," *Proc. IEEE*, L (Aug., 1962), 1808.
2. *American Standard for Noise Measurement* (American Standards Assn., Z24.2 [1942]).
3. *American Standard for Sound Level Meters* (American Standards Assn., Z24.3 [1944]).
4. *Amplifiers for Sound Equipment* (American RMA Standard SE-101-A [July 1949]).
5. *FET Cascode Circuits Reduce Feedback Capacitance*, Application Tip (Siliconix Inc., Feb. 1, 1966).
6. George Pierson, "A FET Operating at UHF?", ELECTRONIC DESIGN, XIV, No. 7 (March 29, 1966), 48-53.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# Semiconductor Report

**NEW PRODUCTS, DESIGN AND APPLICATION INFORMATION FROM MOTOROLA**

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| TYPE† | CAPACITANCE VALUE (pF) (1 MHz & 4V Typ.) | FIGURE OF MERIT (Q) (50 MHz & 4V dc Min.) | PRICE (100-up) |
|---|---|---|---|
| 1N5139 | 6.8 | 350 | $3.90 |
| 1N5140 | 10 | 300 | 3.90 |
| 1N5141 | 12 | 300 | 3.90 |
| 1N5142 | 15 | 250 | 3.90 |
| 1N5143 | 18 | 250 | 3.90 |
| 1N5144 | 22 | 200 | 3.90 |
| 1N5145 | 27 | 200 | 3.90 |
| 1N5146 | 33 | 200 | 3.90 |
| 1N5147 | 39 | 200 | 3.90 |
| 1N5148 | 47 | 200 | 3.90 |

† "A" versions are priced at $4.30 (100- up)

## NEW MOTOROLA EPICAP* DIODES GREATLY SIMPLIFY ELECTRONIC TUNING

If you've been struggling with cumbersome mechanical assemblies, or low Q electric tuning devices, and "living with" limited reliability in your tuning circuits — RELAX!

Now, you can enjoy all the advantages of automatic, electronic tuning — at about half the price you might expect to pay — with new, high Q EPICAP diodes from Motorola.

For example, in Electronic Countermeasures (ECM) equipment, the EPICAP diode can be used with a "saw-tooth wave" design to automatically sweep a broad frequency range (200 to 400 MHz); and, in the process, eliminate the need for a clumsy sweep generator motor. (Drop a note to our applications group if you'd like more information on this one.)

You'll also find EPICAPS well-suited for difficult tuning jobs in other RF applications such as FM tuning, aircraft radio, etc. In fact, in *every* application above 200 MHz, you'll get faster, more reliable performance — the highest performance /lowest cost combination in the industry, for applications up to 500 MHz.

These new voltage-variable capacitors feature improved fabrication techniques which yield a low leakage and a Figure of Merit (Q) that's specified at a minimum of 200 at 50 MHz and a bias of 4 volts dc. In addition, EPICAPS boast a 20 nanoamp reverse leakage current, due to the good, "clean" surfaces you'd expect in a high quality diode — your assurance of maximum reliability. And, the rugged, new Ramrod* (straight-through) DO-7 glass diode package adds another measure of increased reliability.

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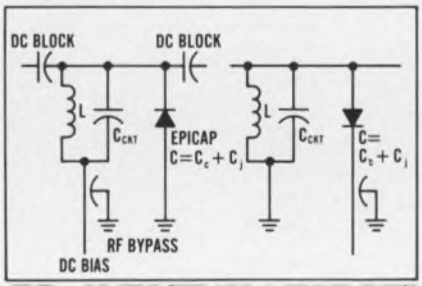


FIGURE 1 – TWO EPICAP TUNED PARALLEL RESONANT CIRCUITS

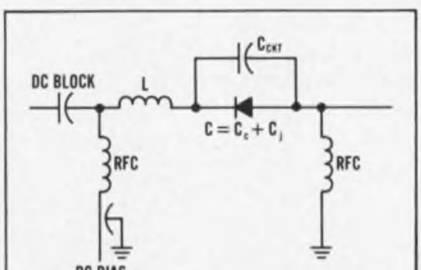


FIGURE 2 – EPICAP TUNED SERIES RESONANT CIRCUIT

*Trademarks of Motorola Inc.

## "HOW TO TUNE RESONANT CIRCUITS" COVERED IN NOTE

A comprehensive report that details a step-by-step design procedure and helps you select the optimum EPICAP for your specific application is the subject matter of Motorola Application Note 196. Circuit schematics, equations and a family of curves are used for determination of tuning range as a function of maximum EPICAP capacity to circuit capacity as a parameter.

Figures 1 and 2 (left) show the most common forms taken by EPICAP resonant circuits. The equations and graphs of the report apply to both. For example, a graph has been developed to predict tuning range, using the voltage tunable capacitance and external circuit parameters. The discussion and use of that graph is the major thesis of AN 196. You're sure to find this well-written technical report a valuable addition to your semiconductor library. Write for it today, to Technical Information Center, Motorola Semiconductor Products Inc., P. O. Box 955, Phoenix, Arizona 85001.

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# D/A converter uses thin-films to get high precision and maintain the flexibility needed for low-volume production.

If your microelectronics application calls for high accuracy, look beyond the popular monolithic integrated circuits. Hybrid thin-film circuits offer greater advantages.

One such application is in the digital-to-analog converter, where hybrid circuits provide the following:

- High resistance accuracy.
- Wide selection of active devices.
- Well matched resistance values.
- Improved temperature coefficients.
- Design flexibility.
- Economical low-volume production.

### Four-bit D/A converter requires three ICs

An integrated digital-to-analog (D/A) converter can be made by connecting three integrated circuits (a buffer amplifier, a ladder switch and a ladder network) in series. If each of the integrated circuits is designed to handle 4 bits, the complete circuit will perform as a 4-bit D/A converter. Two sets of each will form the 8-bit D/A converter shown in Fig. 1, and three sets can be used to form a 12-bit converter. All the circuits are mounted in flat-packs, and their leads are arranged as shown to facilitate assembly.

The converter interprets a set of digital input pulses and converts it to an analog output signal. The buffer amplifier (normally ON) is turned OFF by a positive input signal. As the output of the buffer amplifier goes more negative, a turn-on drive current is supplied to the pnp transistor of the next stage, the ladder switch. The complementary npn transistor is simultaneously biased off and the output of the ladder switch goes to the reference voltage level. This negative reference voltage feeds the ladder network where it is divided down to the correct analog output. The output of the ladder network represents the sum of the various input signals.

With no input signals to the converter, the buffer amplifier is ON. This in turn sets the output of the ladder switch at zero volts (the offset voltage can be made extremely low) by driving the pnp transistor OFF and the npn transistor ON. With zero volts into the ladder network, the output of this stage also remains at zero volts.

**Richard D. Tatro,** Applications Engineer, Semiconductor Div., Sprague Electric Co., Concord, N. H.

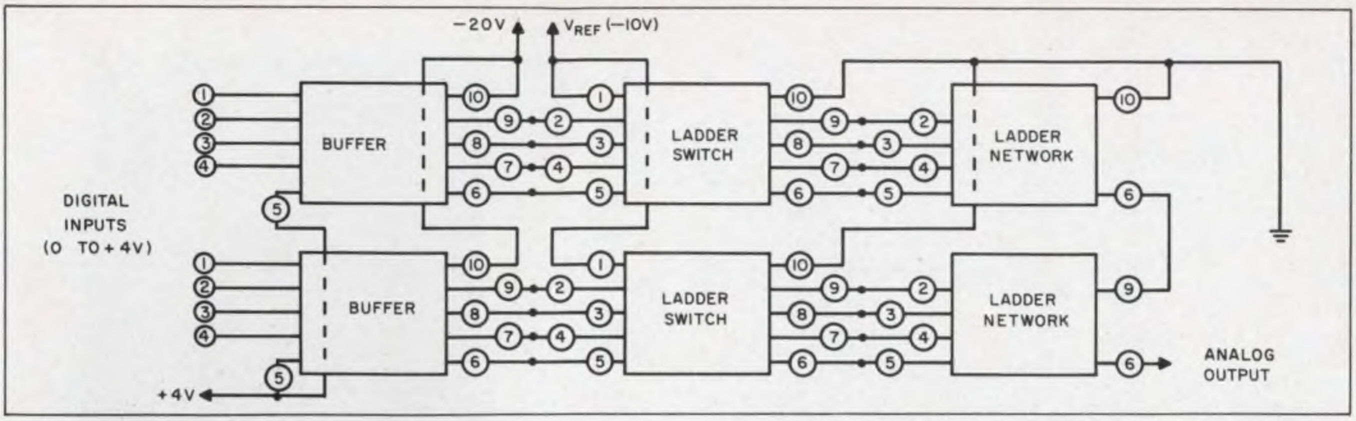
The circuits described here are available as standard catalog items (buffer amplifier-UD4025; ladder switch-UD4001; ladder network-UT1000), and thus do not necessarily represent the best approach to D/A conversion for all applications. They do, however, show a practical method of designing microelectronic converters that are compatible with present-day silicon microcircuits.

### Buffer uses individual transistor chips

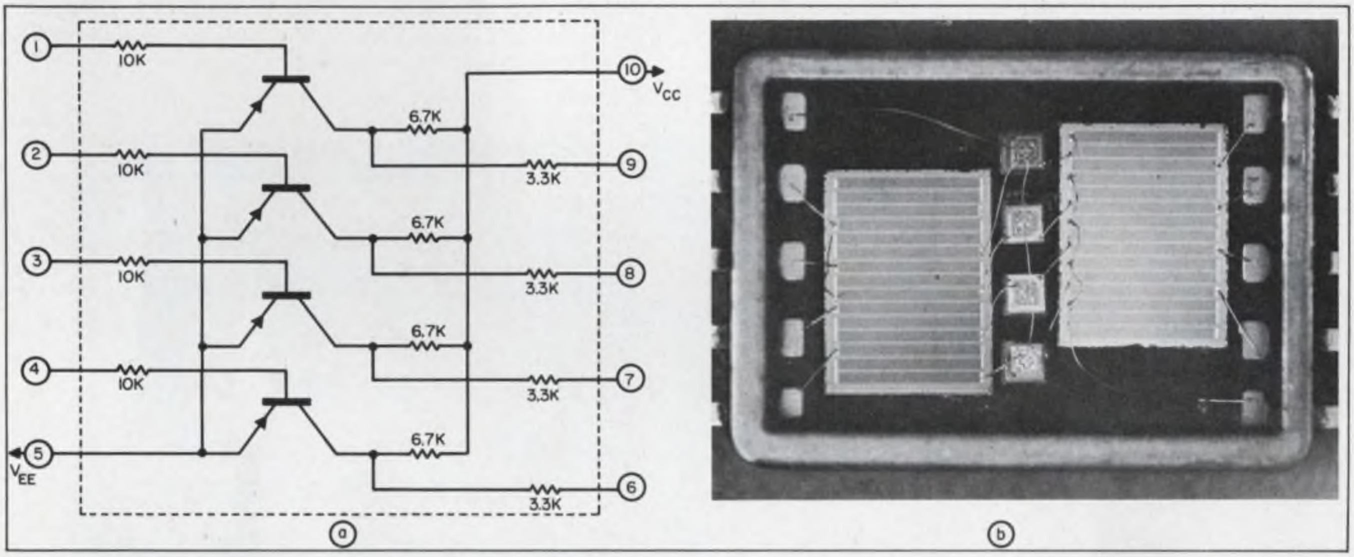
The buffer amplifier is used to convert the digital input signal (0 to $V_{CC}$) into positive and negative current drives to the ladder switch. Though the buffer is designed for a rather restricted range of applications, the inherent design flexibility of thin-film circuits makes modifications simple to achieve when low-volume quantities are involved. Where large-volume use of a particular buffer circuit is indicated, a monolithic approach may be more practical.

The typical buffer circuit, shown in Fig. 2a, drives the complementary-transistor-pair ladder switch. When the buffer transistor is turned OFF, the pnp-transistor-side of the ladder switch is turned ON. With $V_{CC}$ set to $-20$ volts, approximately 1 mA of current will flow into this transistor. To gurarantee turn-off, the input signal must be at least as positive as the $V_{EE}$ supply; if an input high level of 4 to 6 volts is anticipated, the $V_{EE}$ supply should be set at $+4$ volts. If the input signal is lower then $V_{EE}$, the buffer amplifier will remain turned ON and thus drive the npn-transistor-side of the ladder switch also ON. With $V_{EE}$ equal to $+4$ volts, approximately 1 mA of current will flow into this transistor. The circuit can handle input high levels as low as 1.5 volts if the $V_{EE}$ supply is correspondingly lowered. Base drive to the pnp transistor when $V_{EE} = 1.5$ volts is reduced to approximately 0.25 mA.

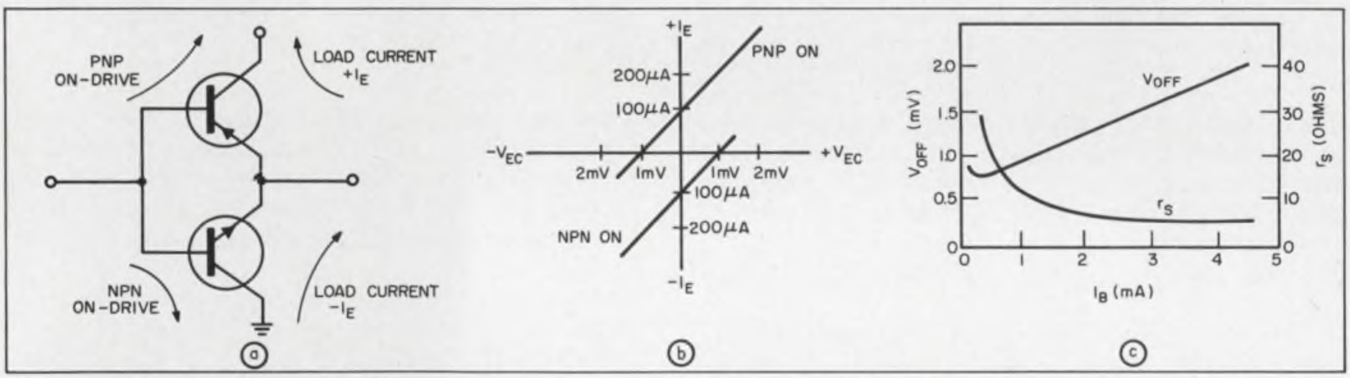
A photograph of the actual buffer circuit is shown in Fig. 2b. The four input resistors and eight output resistors are nickel-chromium (NiCr) material deposited on silicon substrates. The use of two separate chips facilitates the internal wiring and allows for greater flexibility. These particular resistors were specified with a tolerance of $\pm$ 10% and a temperature coefficient (TC) of $\pm 100$ ppm/°C. However, NiCr resistors are available with a $\pm$ 5% tolerance and a $\pm$ 50 ppm/°C TC, in resistance values from 15 ohms to 150 kilohms.




1. **Eight-bit digital-to-analog converter** uses three different types of integrated circuits: a buffer amplifier, a ladder switch and a ladder network. Note that the circled numbers refer to the pins on each individual package.




2. **The buffer amplifier (a) converts** the digital input signals to driving currents for the next stage, the ladder switch. The base resistor network is the large block at the left in the photograph (b).

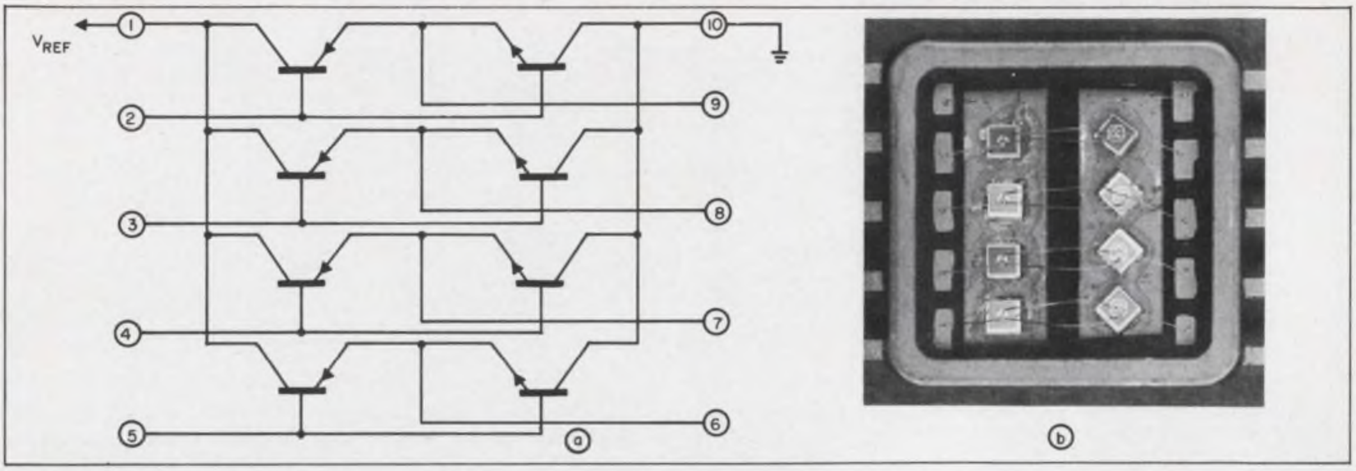



3. **Complementary transistor switch** (a) is used to provide extremely low offset voltages. With the base drive at 1 mA, both the pnp and npn transistors have an offset voltage of about 1 mV at cutoff (b). If the base current is increased (c), the offset voltage will also increase and the series resistance $r_s$ will decrease.

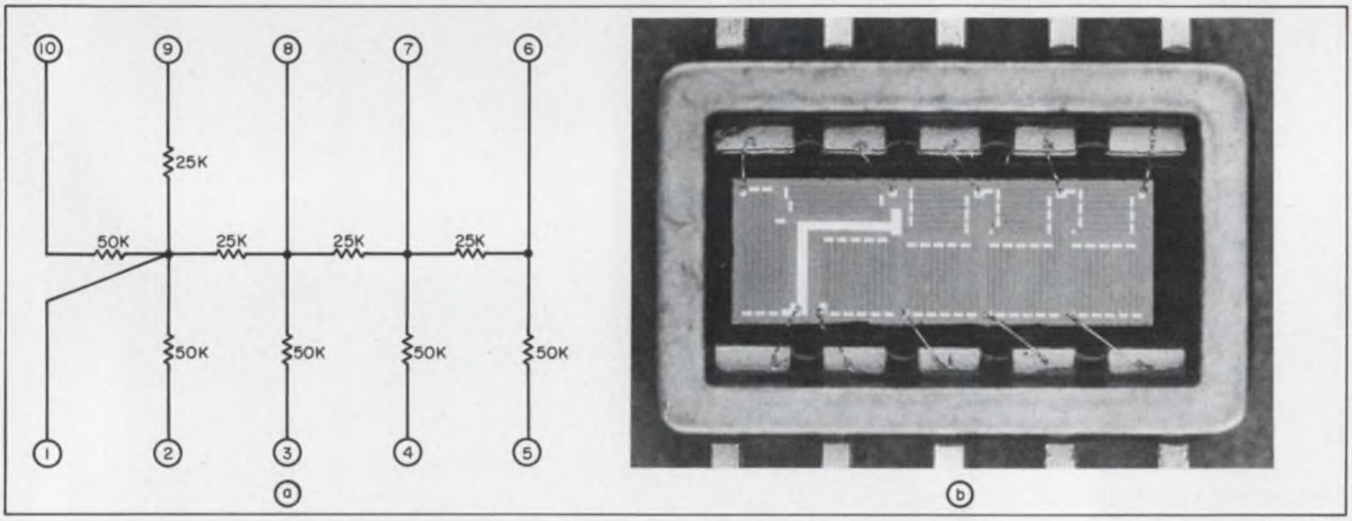
This buffer circuit was designed to accept inputs from most present digital monolithic circuits, and also to:

- Accept low level input signals as high as +0.5 volts.
- Accept a high level from 1.5 to 5 volts. Larger inputs could be tolerated but a new design would be required in order to limit power consumption.
- Require only low levels of drive current or sink current from the driving circuit.
- Supply approximately ± 1 mA of base drive to the ladder switch.

With the hybrid thin-film approach, it is easy to change either the base resistors or both collector resistors, or to change from a pnp to an npn stage. A circuit designer can make breadboard circuits with conventional discrete components knowing that the hybrid version will behave similarly.




4. **Four-bit ladder switch** uses four pairs of complementary transistors (a). The circuit is actually made up of eight individual transistor chips (b). The two sets of transistors (pnps are on the left) are each bonded to a conductive substrate to achieve a common collector connection with a low collector series resistance.




5. **Tantalum thin-film ladder network** uses highly stable and precise resistors (a). An 8-bit network is made by connecting the output of one circuit (pin 6) to pin 9 of a second circuit.

This relationship holds because the individual semiconductor chips and the tantalum and NiCr resistors do not have the parasitic capacitance problems associated with monolithic devices.

### Complementary transistors make up ladder switch

The ladder switch acts as a single-pole double-throw switch, since the ladder converter-network requires inputs which are at ground potential or at the reference voltage. The ladder switch must have negligible voltage errors in both the ON and OFF conditions. To do this a complementary transistor switch, shown in Fig. 3a, is used. The complementary transistor approach is highly desirable, since both sides of the switch can be operated in the inverted mode, thereby providing a low offset voltage. In this arrangement the voltage-drop contribution of $I_E r_s$ (where $r_s$ is the ON series resistance) is of opposite polarity to that of the offset voltage, and offset errors are minimized. The output emitter characteristics of the npn and pnp devices are shown in Fig. 3b. They each have an offset voltage of 1 mV and a series resistance of 10 ohms, which is typical for both devices when the base drive ($I_B$) is 1 mA.

Since the series resistance of the transistors varies as an inverse function of $I_B$ and the offset voltage varies as a direct function of $I_B$, it is possible to choose the optimum base drive currents to the switches in anticipation of the required load currents. The curves in Fig. 3c show the typical variations of $V_{OFF}$ and $r_s$ with $I_B$ for the transistors used. The characteristics of the npn and pnp transistors are similar enough for the curve to represent both. By adjustment of $I_B$ it is possible to restrict the error of the ladder switches to $\pm 2$ mV, which in turn holds the error at the output to less than $\pm 1$ mV. For a 12-bit converter operating from a 10-volt reference voltage, this is equivalent to $\pm$ 1/2 least significant bit (LSB), since

$$1 \text{ LSB} = \frac{1}{4096} \quad (V_{REF}).$$

A 4-bit ladder switch is schematically shown in

Fig. 4a. Figure 4b is a photograph of the actual integrated circuit. Both the pnp and the npn sets of transistors have their collectors tied in common, each set on a single land area. The common emitters and bases of the npn-pnp pairs are interconnected and then brought out of the package.

### Ladder network has well-matched resistances

The ladder network, shown in Fig. 5a, consists of five 50-KΩ and four 25-KΩ tantalum resistors deposited on a silicon substrate. Figure 5c is a photograph of the actual circuit. The network is mounted in a 0.160 in. x 0.265 in. flat pack by standard thermocompression bonding techniques. Each resistor is adjusted to a tolerance of $\pm$ 0.5% and can be matched within a 0.5% spread. As a result, the maximum analog output error, due to the resistors, is $\pm$ 0.25%. In terms of least significant bits this would be somewhat less than one LSB for an 8-bit converter. (The LSB in an 8-bit converter is 1/256, or 0.39% of the reference voltage.) This maximum error, however, occurs only when the resistor at pin 5 is high and all other resistors are low, or vice versa. In actual practice, the resistors are randomly off tolerance and the bit accuracy is much better than this worst-case situation. Bit accuracy is typically 10 to 11 bits (1/1024 to 1/2048) and results in approximately 0.05% to 0.1% error in the analog output signal. Twelve-bit accuracy devices are available on a selection basis.

Ladder networks constructed in this configuration with values as low as 10 KΩ and 5 KΩ perform nearly identically. The difference that exists is related to the temperature coefficient of the resistances. The circuit in Fig. 5 has a typical TC of −150 ppm/°C, while the 10 KΩ and 5 KΩ networks, made with thicker tantalum, have a typical TC of −20 ppm/°C. Temperature-coefficient matching for the former is guaranteed to be within a spread of 25 ppm/°C.

In actuality, the effective match of temperature coefficients for the entire circuit is much better, as in the case of resistance value matching, often reaching a few parts per million per degree centigrade; often, the steps in the output of the ladder network will vary less than 1 mV over the −55°C to +125°C temperature range for a 10 volt reference input.

The settling time of the D/A converter is approximately 4 to 5 μs. Unfortunately, since the storage time of good chopper transistors, such as the ones used in the ladder switch, is relatively long, it is difficult to construct a fast converter with low switching errors. As a result, both the npn and pnp transistors in the ladder switch will be ON at the same time for an interval of about 1 μs. During this time the switch may be at ground instead of $V_{REF}$ or vice versa, and causes spike at the output. Though these spikes are largely the result of this "storage time" error, some of this error is also due to the RC time constant of the ladder resistors and their distributed capacity. ■ ■

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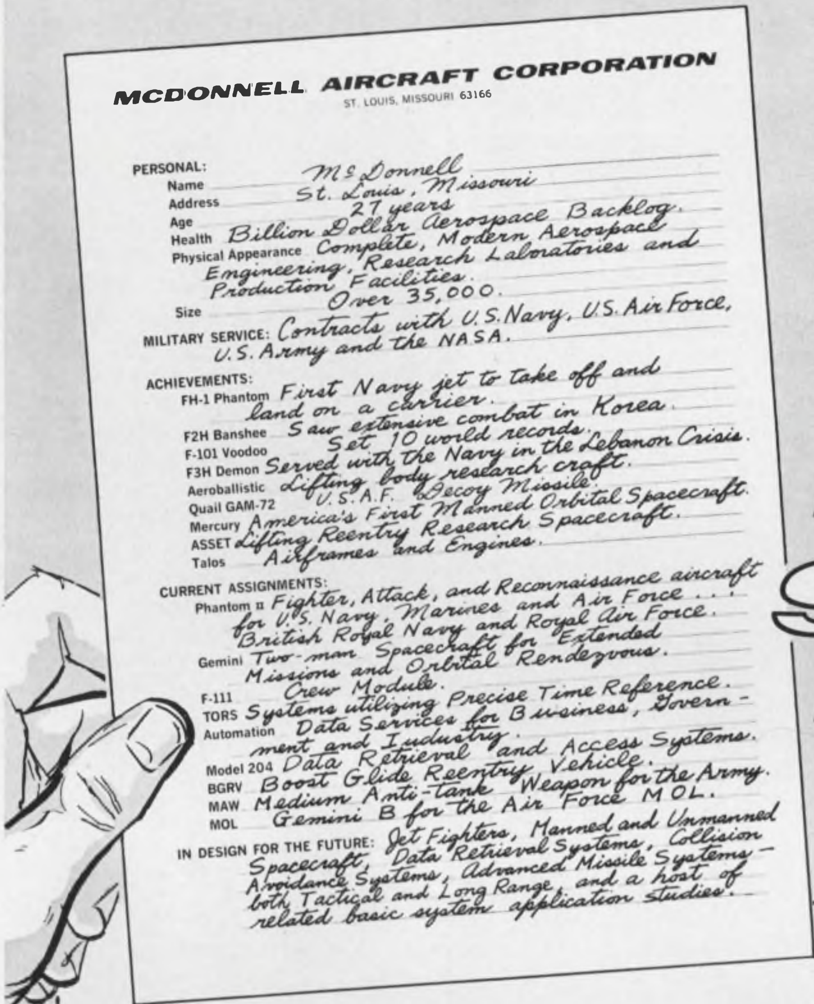


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ON CAREER-INQUIRY FORM CIRCLE 902

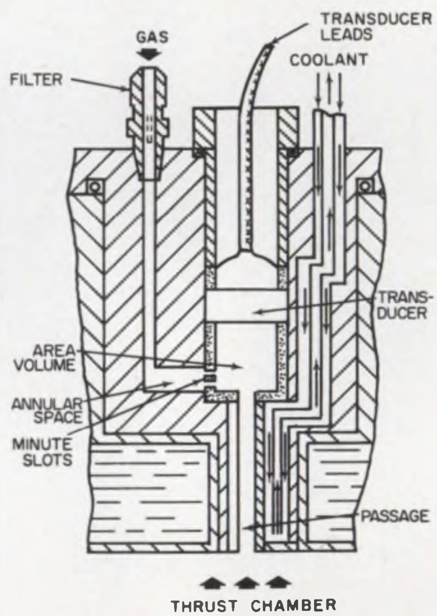
NASA Tech Brief

# Mount improves transducer accuracy

**Problem:** Measure transient pressures in a hostile environment, such as the thrust chamber of a rocket motor. Such cases require remote transducers. Complicating factors are introduced, ie., length, diameter and configuration of the passage leading to the transducer. Heat transfer to the transducer and its connecting passage and clogging by combustion products are common problems in such systems.

**Solution:** A new mount.

The transducer is mounted in a body with a sleeve designed to provide precise volume between the transducer diaphragm and a small diameter passage leading




to the chamber where pressure transients occur. A control gas is fed through a filter into an annular space that leads through four minute slots to the volume and small passage.

Thermal equilibrium is maintained by conditioning fluid circulated through an external pipe next to the transducer. Conditioning fluid exits by an internal pipe to compensate for heat passing through the chamber wall, or to obtain the chilling effect of a cryogenic regenerative coolant.

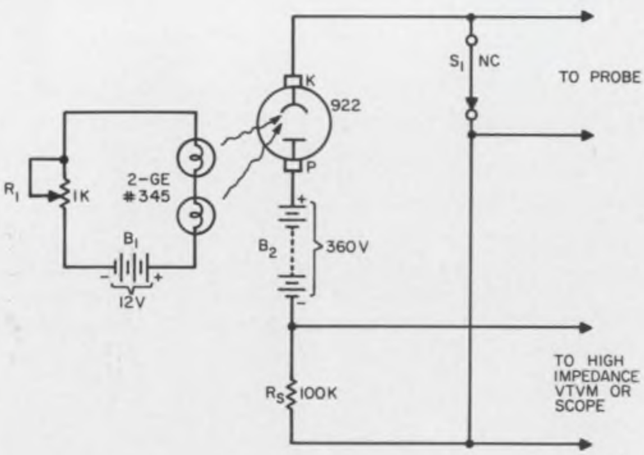
*Contact: James Preston Layton, Princeton University, P.O. Box 172, Princeton, N. J.*

# Vacuum photo-diode constitutes simple, accurate current source

A vacuum photo diode, excited by a variable-intensity light source, makes an excellent current source with almost perfect isolation between input and output. The system shows a negligible temperature coefficient.

A simple and accurate (5%) current source was needed, for a neuro-physiological application, to deliver a variable 0.1 to 3 $\mu$A dc current to a stainless steel microelectrode for plating out iron onto neural tissue. Consideration had to be given to the load impedance, which might range from 1.0 to 100 M$\Omega$ during application of the current (5 s), owing to metal-issue interface changes.

The type 922 cartridge photo-diode used in the circuit (see schematic) exhibits a plate resistance on the order of $10^9$ ohms over an anode-to-cathode voltage range of 40 to 400 volts. The unit has a maximum dark current of 0.005 $\mu$A (at 25°C) and a maximum average current rating of 5 $\mu$A. $R_S$ is a current-sensing resistor used to set the initial value of $i$ with $S_1$ (low-leakage reed switch) closed. With $S_1$ open, current $i$ is diverted into the probe. Less than a 5% change in a 2-$\mu$A current is observed when $S_1$ is opened into a 100 M$\Omega$ resistor placed across the probe terminals. Thus, no feedback system is required to achieve the accuracy desired.




**Vacuum photo-diode** is used to form a current source. Excited by lamps, the diode has a negligible temperature coefficient and features excellent isolation.

The exciting lamps (GE #345) are mounted in a light-tight box with the 922 and their intensity is controlled with series rheostat $R_1$. Battery $B_1$ is a nickel-cadmium type chosen for its flat discharge characteristic, portability and noise isolation.

Once a current-intensity calibration curve is obtained, $R_s$ may be eliminated and the entire photo-tube side of the two-port floated. Or, $R_s$ may be used in an operational amplifier circuit with the exciting lamps in the feedback loop for either precise current control or modulation.

Many optical modulation techniques can also be implemented with this photo-diode current source. The frequency response of the system is mainly limited by stray capacity rather than transit time, as far as the impedance levels discussed here are concerned.

*Julius M. J. Madey, Research Engineer, California Institute of Technology, Pasadena, Calif.*

VOTE FOR 110

## Diodes ensure start of astable multivibrator

A simple, inexpensive diode arrangement prevents an astable multivibrator from "locking-up" when starting power is applied.

It is applicable to both silicon and germanium circuits, and is far less involved than competitive logic circuitry schemes designed to detect the lock-up. The design (Fig. 1a) uses the diodes to force the multivibrator into an unstable condition.

Given a collector current level at which the astable is to work, the value of $R_E$ is chosen, so that the sum of the $V_{R_E}$ drop caused by the emitter current of one saturated transistor only and the base-to-emitter voltage of that transistor is slightly less than the forward drop of the silicon diode, $CR$, in its region of low conduction. $V_{BE}$ = 0.3 V for a 2N404 where the base current does not exceed 0.5 mA. Hence, $V_{R_E}$ is to be 0.2 to 0.25 V.

At start-up time, if both $Q_1$ and $Q_2$ were to saturate, $V_{R_E}$ would jump to 0.4 or 0.5 volt, and the base potentials of $Q_1$ and $Q_2$ above ground would be near 0.7 volts, a region where the diodes $CR$ would sustain a current of several milliamperes. Hence, the base currents of $Q_1$ and

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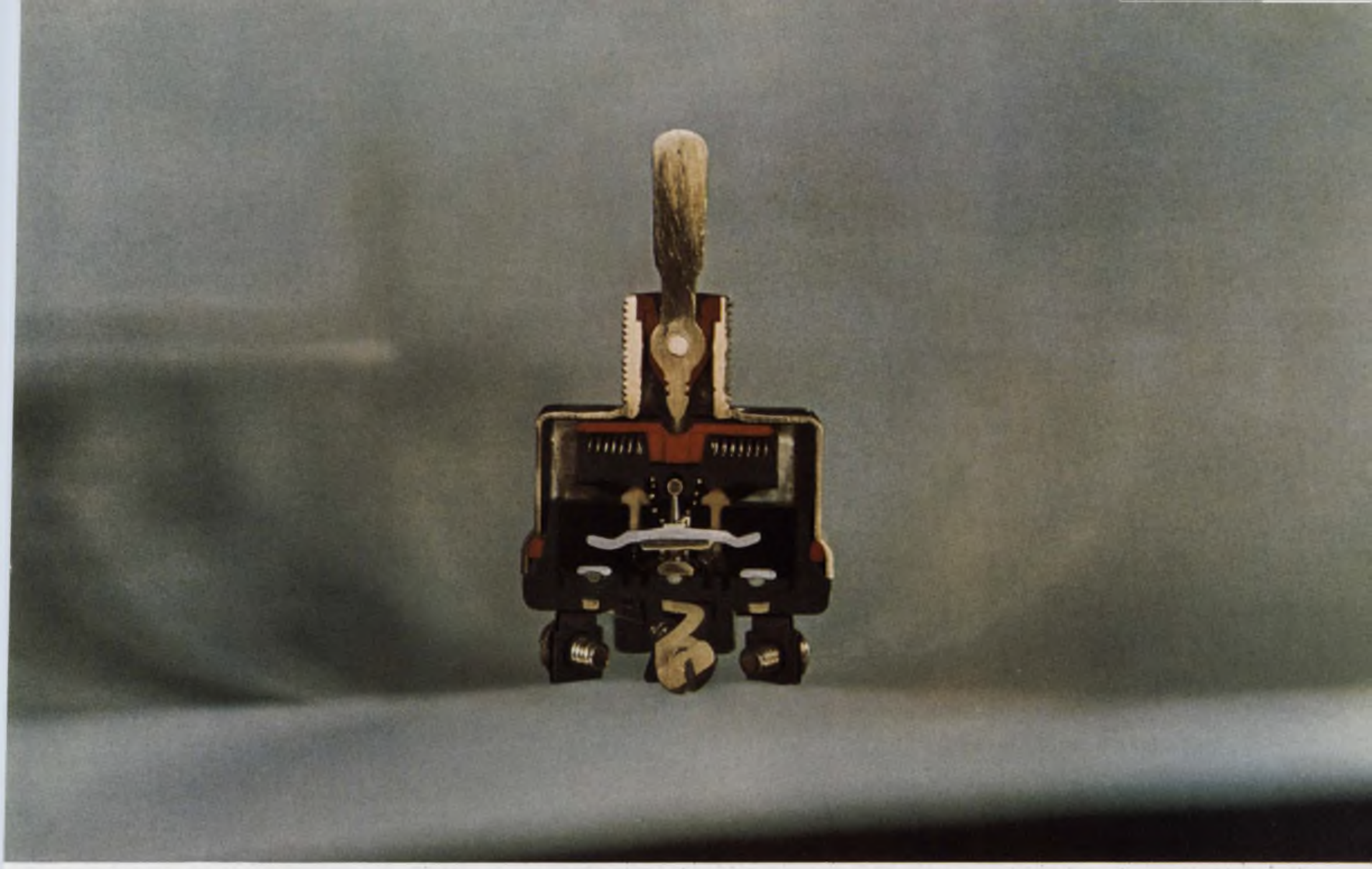

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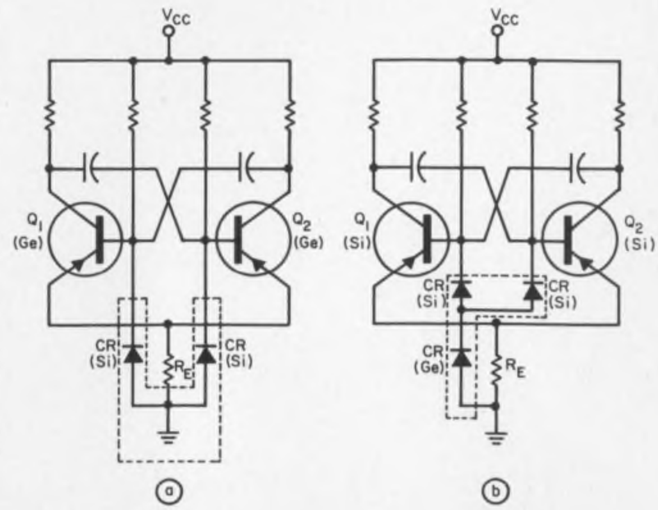
CONTROL

ON READER-SERVICE CARD CIRCLE 221




**Simple diode arrangement** prevents astable multivibrator from "locking-up." Two diodes are required for germanium circuits (a); three diodes for silicon networks (b).

$Q_2$ would be mostly diverted in the $CR$ diodes until the current contribution of $Q_1$ and $Q_2$ through $R_E$ would reduce $V_{R_E}$ to a point where an equilibrium exists between base current, $CR$ diode current and emitter current. However, this equilibrium point is out of saturation for $Q_1$ and $Q_2$, and so is unstable. Therefore, oscillations are guaranteed to start.

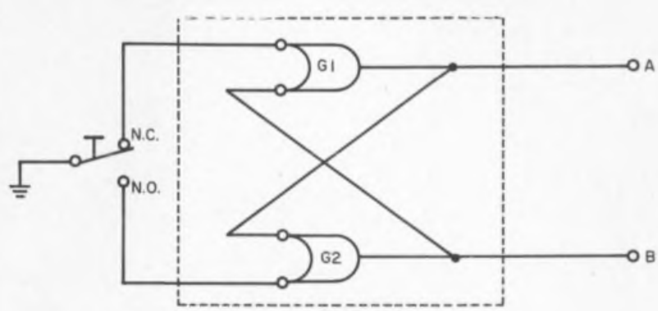
The same concept can be extended to a pair of silicon transistors by the addition of a germanium diode to compensate for the increase in $V_{BE}$ in these devices (Fig. 1b).

*R. Couturier, Senior Project Engineer, STELMA, Inc., Stamford, Conn.* VOTE FOR 111

## ICs for bounceless push-button switching

The effect of the mechanical bounce of push-button switches can be eliminated from a system through the use of a portion of a readily available, inexpensive IC. This is achieved by isolating the output from the input during the interval when bounce occurs.

Using positive logic and NAND/NOR gates (see schematic), construct a "latch" flip-flop with two 2-input gates (many IC manufacturers put four 2-input gates in a 14-lead flat pack).




**IC gates form flip-flop** to establish a bounceless, push-button switching action.

When the switch is positioned as shown, the $G_1$ input is held at ground. When the button is depressed, the $G_2$ input is held at ground, switching the flip-flop. However, when the contacts bounce from the NO position to an open-circuit condition, the flip-flop does not change state. This action provides a bounce-free switching action at either output (A or B).

*D. R. McTaggart, Consulting Engineer, D. Brown Associates, Inc., Eau Gallie, Fla.*

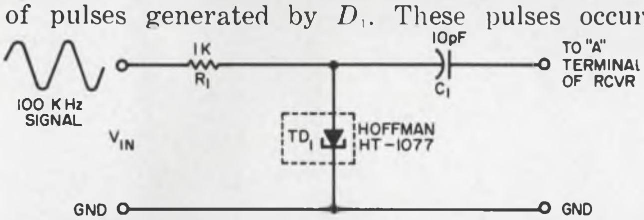
VOTE FOR 112

## Tunnel-diode generator calibrates frequency counter

A common method for calibrating frequency counters is to beat a harmonic of the 100 kHz timing-crystal output with a WWV (often at 15 MHz) carrier. A simple tunnel-diode generator circuit can be used to generate the necessary harmonics

The circuit (see schematic) generates strong harmonics to at least 30 MHz when connected to the 100-kHz output of the frequency counter. The result is much more reliable reception of easily discernible beat notes.

The harmonics are the product of a cyclic series of pulses generated by $D_1$. These pulses occur




**Tunnel diode harmonic generator** uses 100-kHz frequency counter input to produce beat-frequency notes for calibrating receivers.

once for each cycle of the input frequency as tunnel diode $D_1$ switches from a low- to a high-impedance state. The higher-frequency components of these pulses are coupled to the receiver antenna terminals through $C_1$.

Resistor $R_1$ must be small enough to allow the input current to exceed $I_{peak}$ of the tunnel diode. $R_1$ must also be large enough to prevent the continuous current rating of $D_1$ from being exceeded. $D_1$ here has an $I_{peak}$ of 0.47 mA. For this value, a $R_1$ of 1000 Ω works well for signal inputs between 0.5 and 1 volt.

Tunnel diodes with larger values of $I_{peak}$ may be used, providing the signal source can deliver pulse currents in excess of $I_{peak}$ of the diode. In most cases, the network may be left permanently attached to either the receiver or the counter.

*Kenneth G. Holmes, Chief Engineer, Magnetic Circuit Elements Inc., Montrose, Calif.*

VOTE FOR 113

**IFD Winner for March 1, 1966**

**Larry Blaser**, Senior Engineer, Fairchild Semiconductor, Mountain View, Calif.

His idea, "Dual MOS-FET simplifies FM multiplex decoder," has been voted the $50 Most Valuable of Issue Award.

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| Deflection Factor | 5 mV/div to 10 V/div | 10 mV/div to 20 V/div | 10 mV/div to 20 V/div |
| Channels | Dual | Dual | Single |
| Delay Line | Yes | Yes | No |
| Sweep Delay | Yes | No | No |
| Size Height | 7¼ | 7⅛ | 8¼ |
| Width | 12½ | 10 | 5¾ |
| Depth | 20½ | 14 | 16 |
| Weight (pounds) | 28¾ | 22 | 14 |
| Power Requirements | AC | AC, DC or Battery | AC, DC or Battery |
| Rack Mount Available | Yes (7″ Rack Height) | Yes (7″ Rack Height) | No |
| Probes and Accessories Included | Yes | Yes | Yes |
| Price | $2050 | $1400 (AC Model) *$1750 (AC/DC Model) | *$900 |

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TYPE 453

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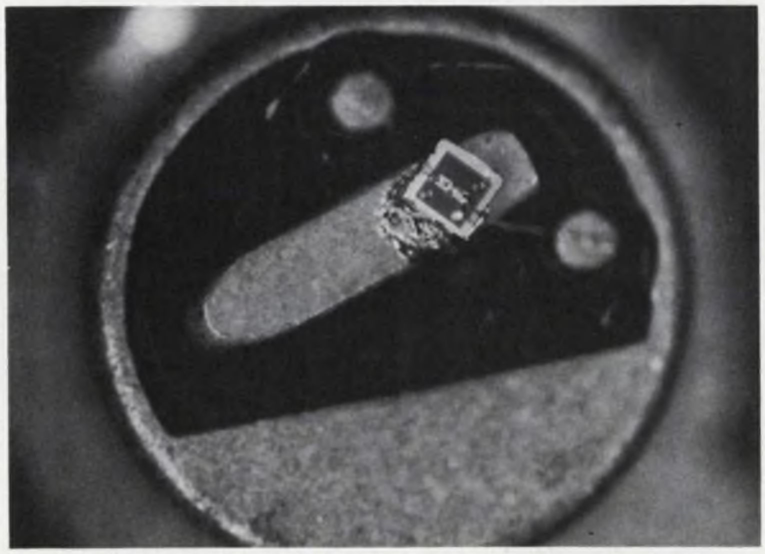
ON READER-SERVICE CARD CIRCLE 24

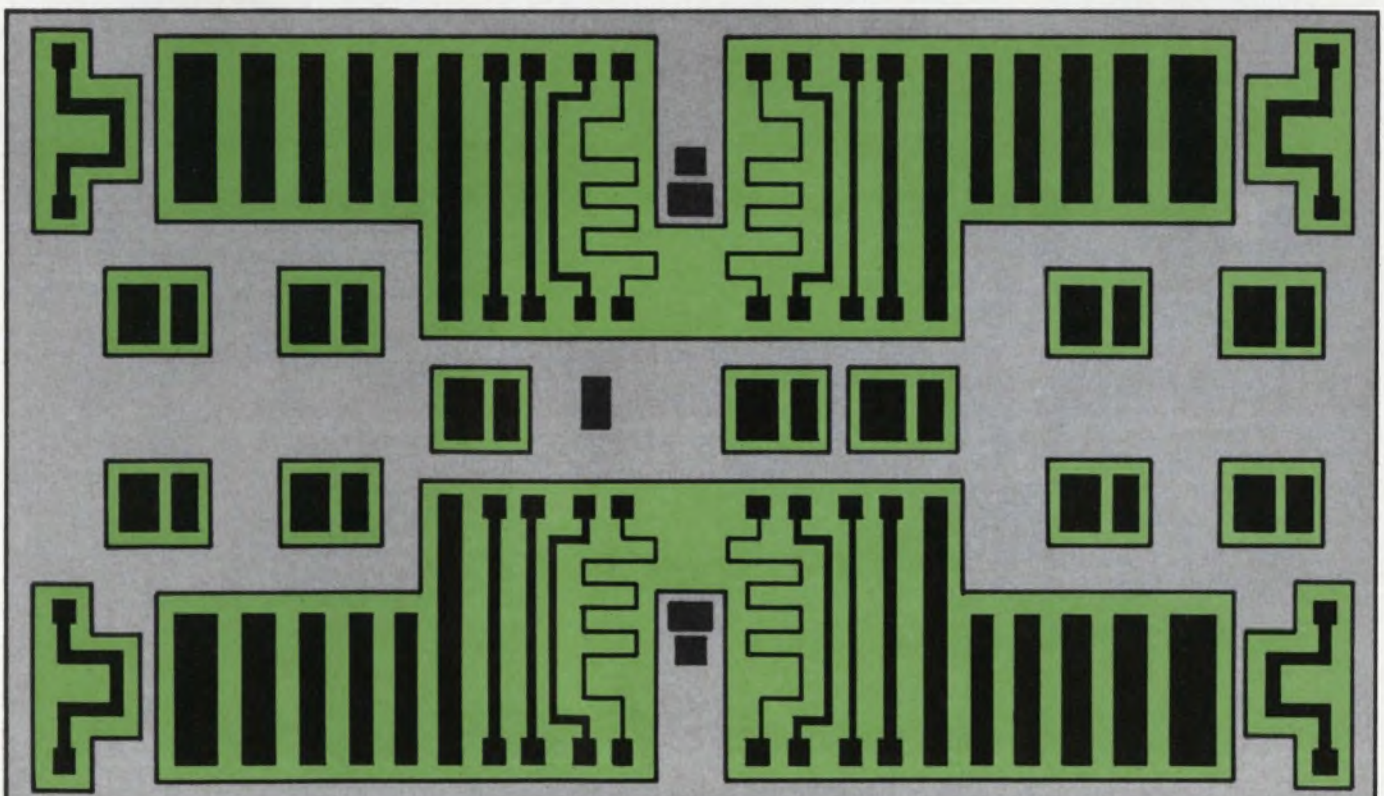
# E|D Products



One instruction, 127 increments . . . 82



Swift-switching pnp . . . 84



Instant, inexpensive ICs . . . 66

# IC breadboard allows simple bench assembly of custom circuits with the drop of a dot

Integrated circuit design and evaluation need no longer be expensive and involved. Custom or prototype units can be produced right on the bench with the WS177 Insta-Circuit. The Insta-Circuit is a monolithic 124- x 86-mil silicon die, packaged in an open 1/4- x 1/4- inch, 14-lead (TO-86) flat-pack. It contains eight planar transistors, five zener diodes and four sets of 11 diffused silicon resistors. A "road map" with keyed call-outs and values is supplied to ease component selection.

On the surface of the chip is a set of aluminum conductors and component bonding pads. This interconnection pattern has a constant 1-mil separation. A single ball or wedge bond acts as the shorting bar across appropriate pairs of conductors and components to complete the desired circuit. This technique holds jumper bonds to a minimum, thus eliminating the conventional unreliable bird's-nest wiring. The bond is made with a pigtail attached. Removal of this unwanted pigtail does not impair the bond's solidity.

All that is required in the way of capital equipment is a ball or wedge bonder. The relative economy of the bonder ($2000 and up) provides a quick, cheap technique for IC design and production.

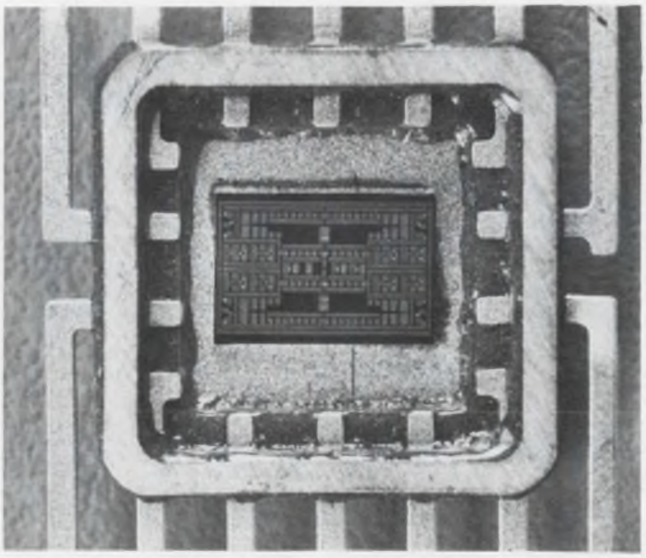
Insta-Circuits are supplied in open packages with a solder preform and lid. Lid sealing may be accomplished with a simple hot plate or soldering iron in the absence of commercial sealing equipment. For production runs, the dice should be cleaned with alcohol or similar agent, baked in an inert gas atmosphere at 200°C for eight hours and held in a desiccator until sealed.

Each set of resistors ranges from 20 Ω to 20 kΩ in a binary-coded relationship. Appropriate series connections yield any resistance value from 20 Ω to 46 kΩ in 100-Ω increments and parallel combinations provide intermediate values. Absolute values vary less than 20% and temperature coefficients are approximately 2000 ppm/°C. Tracking between two resistors over the normal temperature range is 0.2%. Capacity to substrate of the 20-kΩ resistor does not exceed 7 pF.

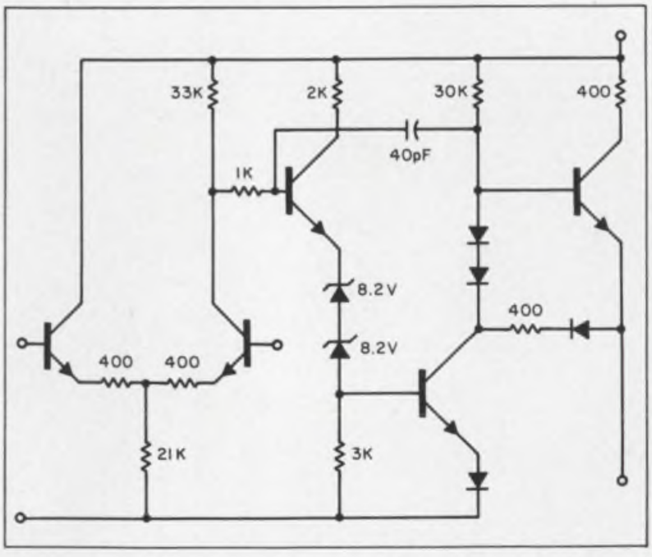
The eight transistors are non-gold doped npn epitaxial planar types. Beta is typically 40 to 120 at 25°C. Cut-off frequency exceeds 200 MHz.

The remaining components are five zener diodes. Two 5.8-V zeners are connected to the substrate, and two are floating. The fifth is a floating 8.2-V zener. All are rated less than ±5% at 25°C. The entire die dissipates no more than 250 mW.

The flexibility of the die is typified by the design of a summing amplifier circuit (see below).



**Component/conductor geometry** and design are shown on the basic Insta-Circuit die. The aluminum interconnection pattern has a constant 1-mil separation.




**The capacitor and diodes** for the summing amplifier are formed from a parallel resistor combination and transistor base-emitter junctions.

**Component characteristics (25°C)**

| | |
|---|---|
| **Resistors (±20% +5% match)** | |
| 4 · 50 Ω (tapped at 20 Ω) | |
| 4 · 100 Ω | 4 · 2000 Ω |
| 4 · 200 Ω | 4 · 4000 Ω |
| 4 · 400 Ω | 4 · 8000 Ω |
| 4 · 800 Ω | 4 · 10,000 Ω |
| 4 · 1000 Ω | 4 · 20,000 Ω |
| **Transistors** | |
| $\beta$=40 — 120 | $V_{CE\ SAT}$=0.25 V |
| $V_{CEO}$>30 V | $C_{OBO}$<3 pF |
| $V_{CBO}$>60 V | $f_T$>200 MHz |
| $V_{EBO}$=8.2 V±5% | $\beta_{pnp}$=0.05 (parasitic) |
| **Zener diodes (±5%)** | |
| 2 · 5.8 V (to substrate) | |
| 2 · 5.8 V (floating) | |
| 1 · 8.2 V (floating) | |

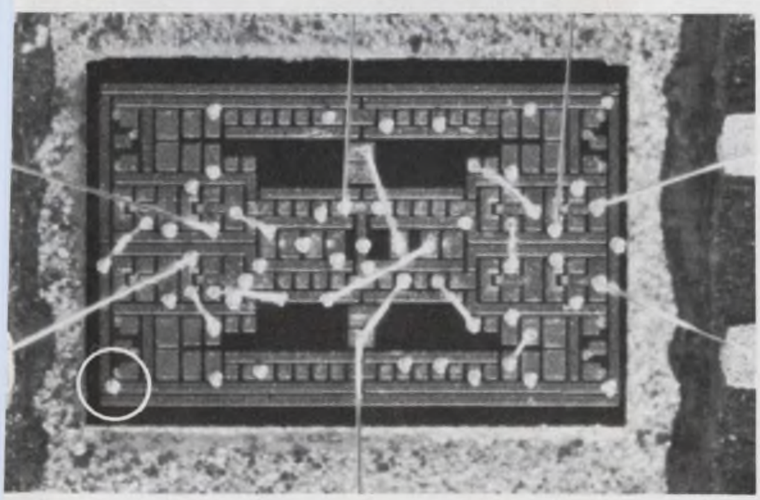
Two 8.2-V zeners are required and only one is available. A ball bond shorts the collector-to-base junction of an unused transistor and utilizes its 8.2-V emitter-to-base voltage. Signal diodes to 60 V may be obtained by the same techniques. The turn-on characteristics of every diode are the same. The designer's limits are stretched well past those seemingly imposed.

Using the Insta-Circuit, the designer may now evolve an IC from schematic to prototype in a few hours, with the inherent advantages of in-house design.

The devices are also available in a 12-pin modified TO-5 header with the same price structure.

P&A: $39.50 (1 to 9), $29 (50 to 499); stock. Westinghouse Electric Corp., Molecular Electronics Div., P. O. Box 7377, Elkridge, Md. Phone: (301) 796-3666.

*Circle No. 350*



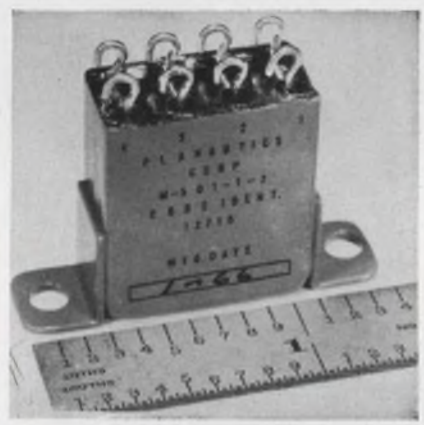
**Typical ball bond** is circled in completed amplifier. The bond may short a component and conductor or component pairs.

## Power divider

HHP-50 power hybrids handle up to 500 W cw and up to 1500 W peak envelope power. Four ports with type N connectors exhibit 25-dB min isolation between the two input arms and between the sum and difference arms. Insertion loss is 0.5 dB max, phase balance between input arms is 5° max, amplitude balance is 0.2 dB max and vswr is 1.3.

P&A: $325; stock. Adams-Russell Co., 280 Bear Hill Rd., Waltham, Mass. Phone: (617) 899-3145.

*Circle No. 262*



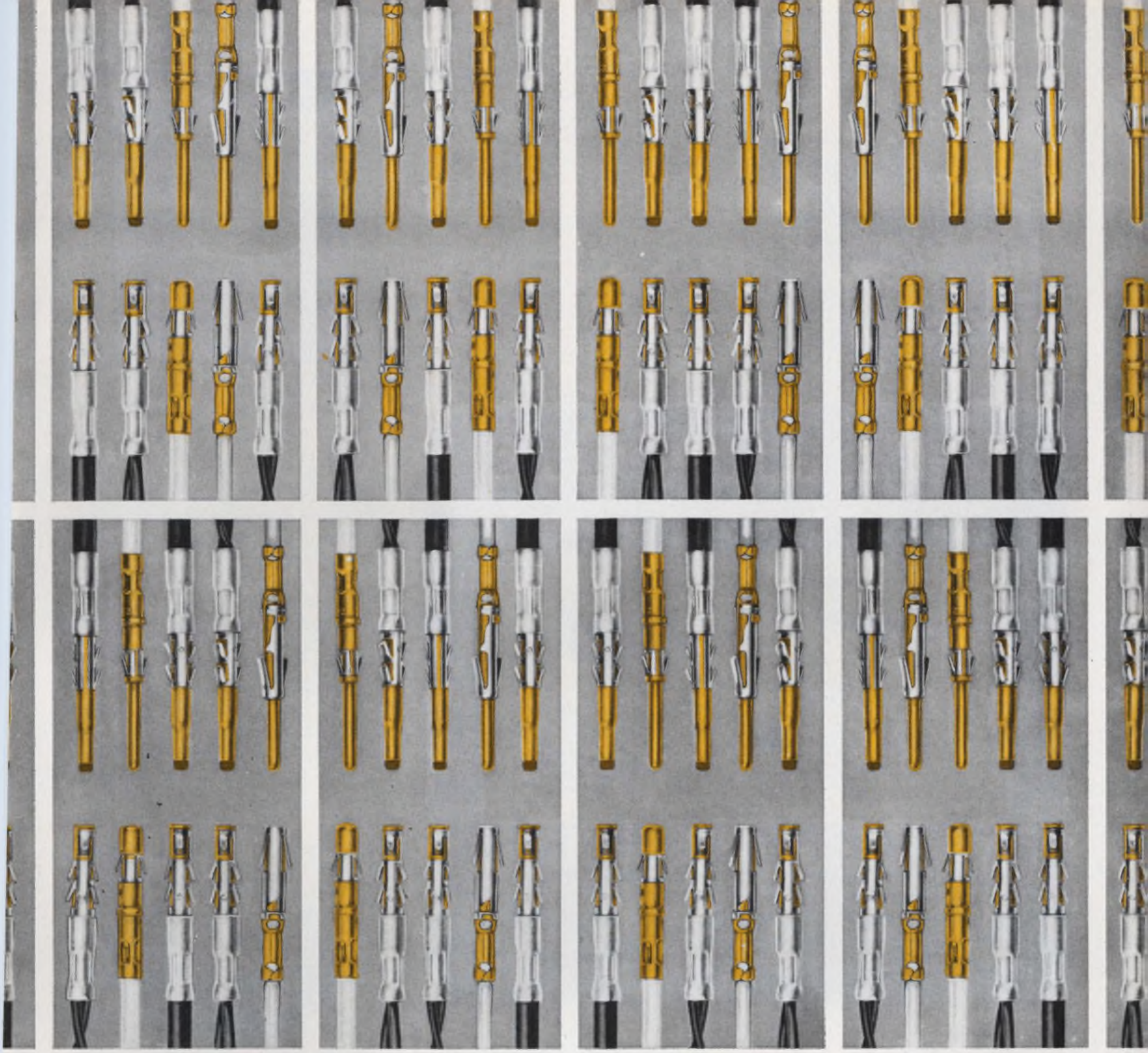
## Time-delay switch

A 2-oz, hermetically sealed time-delay switch provides 150 ms delay at 22 to 36 Vdc and up to 0.5 A. The model M-501-1-2 functions on the first event at the specified time interval.

Time interval may be modified from 0.01 to 10 s. The 2-pole device features line-transient protection and built-in suppression for inductive loads.

Planautics Corp., 410 S. Cedros Ave., Solano Beach, Calif. Phone: (714) 755-1181.

*Circle No. 263*



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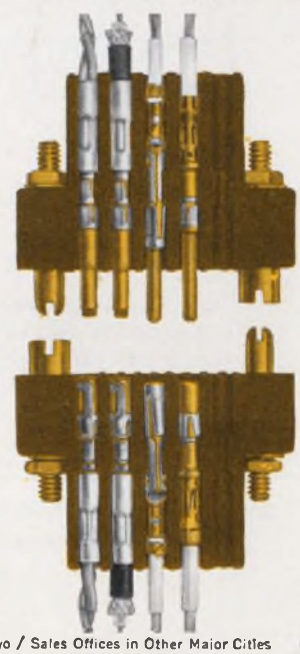

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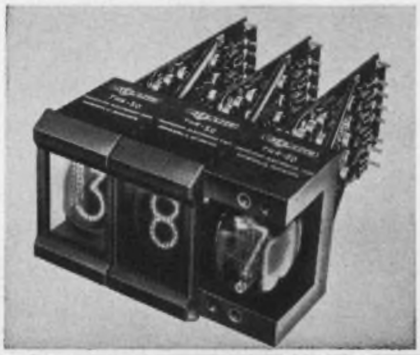
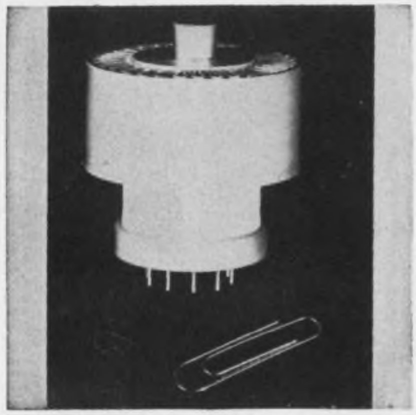
COMPONENTS

## Digital readout



Series TNR-50 digital readouts consists of 8 models handling 8-wire BCD input in 1, 2, 4, 8 code with input signals of 3.5 V. Supply voltage of 180 ±10 Vdc at 2 to 12 mA is confined to the panel areas. The transistorized decoder-driven circuitry eliminates diode decoders. Nixie tubes have a 100,000- to 200,-000-hour life expectancy. Other input codes and a variety of signal voltages are available.

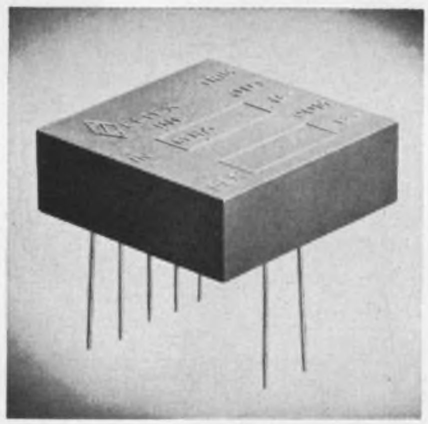
Transistor Electronics Corp., P. O. Box 6191, Minneapolis. Phone: (612) 941-1100. *Circle No. 264*



## Pentode

The PL-8582/267 ceramic beam pentode has a third-order intermodulation distortion level of at least −40 dB at 350 W useful power output. Plate dissipation rating is 300 W. The external-anode, forced-air cooled tube is 2.16-in. long by 1.75-in. in diameter and uses a vane-type suppressor grid and an oxide-coated unipotential cathode. Required filament voltage is 26.5 V at 1.0. Plate voltage is 200 V max and plate current is 350 mA max. Transconductance is 0.04 mhos.

Price: $87 (1 to 5). Machlett Labs., 312 N. Nopal St., Santa Barbara, Calif. Phone: (805) 965-4581. *Circle No. 265*



## Operational amplifier

Model 115D differential op-amp is designed as an amplifying black-box for PC cards with 0.1-in. hole spacing. Output is ±10 V at 4 mA and unity gain bandwidth is 1 MHz. Voltage drift is 25 $\mu$V/°C and current drift is 5 nA/°C. Narrow band input noise is 10 $\mu$V peak. Package is 0.8-in.$^3$ molded epoxy.

P&A: $19 (1 to 9); stock. Zeltex, Inc., 1000 Chalomar Blvd., Concord, Calif. Phone: (415) 686-6660. *Circle No. 266*

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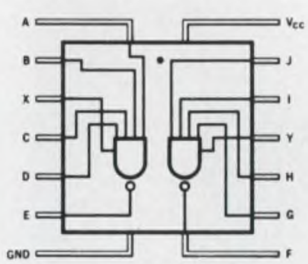
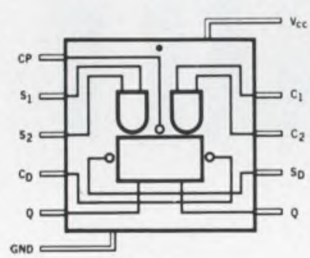
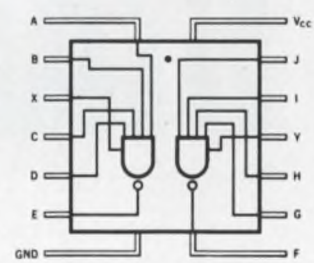


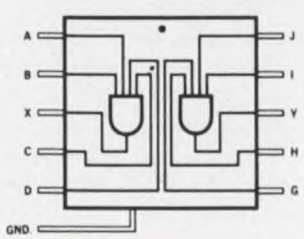
**Dual gate**
**DTμL 930, DTμL 961**



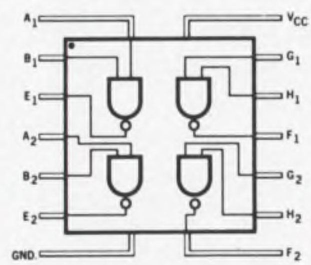
**Clocked flip-flops**
**DTμL 931, DTμL 945, DTμL 948**



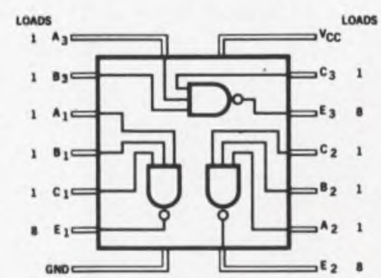
**Dual buffer — DTμL 932**
**Dual power gate — DTμL 944**



**Dual four-input extender**
**DTμL 933**



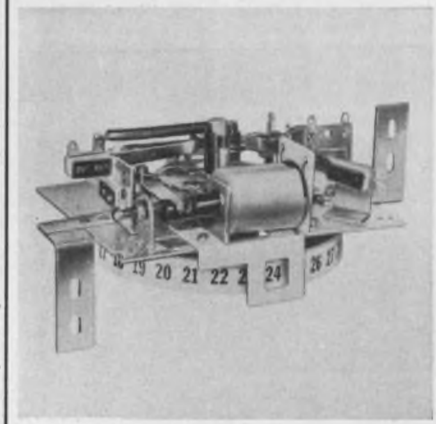
**Quad two-input gate**
**DTμL 946, DTμL 949**



**Triple three-input gate**
**DTμL 962, DTμL 963**

FAIRCHILD SEMICONDUCTOR/A Division of Fairchild Camera and Instrument Corporation ■ 313 Fairchild Drive, Mountain View, California (415) 962-5011 ■ TWX: 910-379-6435

ON READER-SERVICE CARD CIRCLE 28

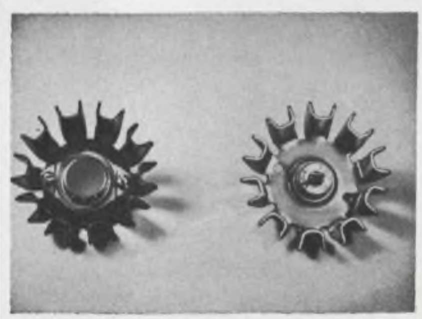



## Accumulator

A lifetime of $10^6$ cycles is claimed for this 28-position numerical accumulator. Series 130-2532 adds and subtracts by single counts from 0 to 28. Count may be stopped at any number and reset one step at a time or completely reset to zero. Pulsing rate is 350 to 400 counts/minute. Solenoid operating voltages are 12 to 115 Vac or dc.

P&A: $7.50 (1 to 9); stock to 3 wks. Chicago Dynamic Industries, 1725 Diversey Blvd., Chicago. Phone: (312) 935-4600.

*Circle No. 267*



## Heat sinks

Two series of low-profile heat dissipators accommodate press-fit diodes, rectifiers and SCRs, and transistor cans. Both feature a 10-sided, formed-fin configuration for max heat transfer. Series 606 for press-fit devices has a controlled press-fit aluminum expansion jacket. Series 600 is available with hole patterns for TO-3, TO-6, TO-8 and TO-36 cans.

P&A: From $0.42; stock. Alpha Components Corp., 4222 Glencoe, Venice, Calif. Phone: (213) 398-7773.

*Circle No. 268*



ON READER-SERVICE CARD CIRCLE 223 ➤


## ETC® has them . . . already developed . . . already de-bugged

Designing and fabricating cathode ray tubes for out-of-the-ordinary requirements is a specialty at ETC. We thrive on challenges.

Each of the different tube types that make up our "standard" line was designed to answer a specific customer need. They range from small electrostatic CRT's to a twelve-gun multiple-display model, from fibre optic screens to distortionless rear windows. And they're all deliverable, saving you the expense of prototype development and de-bugging.

The same design ingenuity that turned these custom-engineered tubes into standard items can be applied to the modification of an existing tube, or the development of an entirely new one, if a stock answer doesn't fill the bill. Whatever it takes, we've got the know-how and skills to do it . . . including over three decades of experience in multilayer phosphors, multi-gun structure, non-linear spiral bandings, hybrid deflection, shielding and potting.

Whether your needs involve data display, radar, mapping, or any other exacting application, you can be certain that an ETC tube will give you light output, deflection sensitivity and spot size criteria equaling or exceeding those available elsewhere. And you'll find our service to be prompt, efficient, courteous—no matter how simple or complex the assignment.

We can't promise you a scientific breakthrough. But we *will* provide you with the right tube for the job . . . even if we have to stretch the current art boundaries to do it. Find out why this kind of "total CRT capability" is your assurance of the greatest value in display. Write today for our latest catalog.

**GENERAL ATRONICS**
ELECTRONIC TUBE DIVISION
PHILADELPHIA • PENNSYLVANIA 19118

GENERAL ATRONICS®

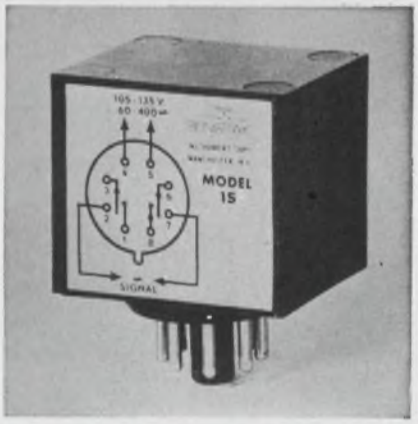
## Differential preamp

A hybrid solid-state/nuvistor preamplifier, LRA 045, has a dc to 100-kHz bandwidth. The driven common-mode circuitry in the input stage provides independence of common mode rejection from source impedance variations. Common mode rejection at 1 kHz is 140 dB and noise is less than 8 $\mu$V p-p. Input impedance is 20 M$\Omega$ and gain is 10,000.

Price: $265. Argonaut Associates, Inc., P. O. Box 273, Beaverton, Ore. Phone: (503) 292-3149.

*Circle No. 269*

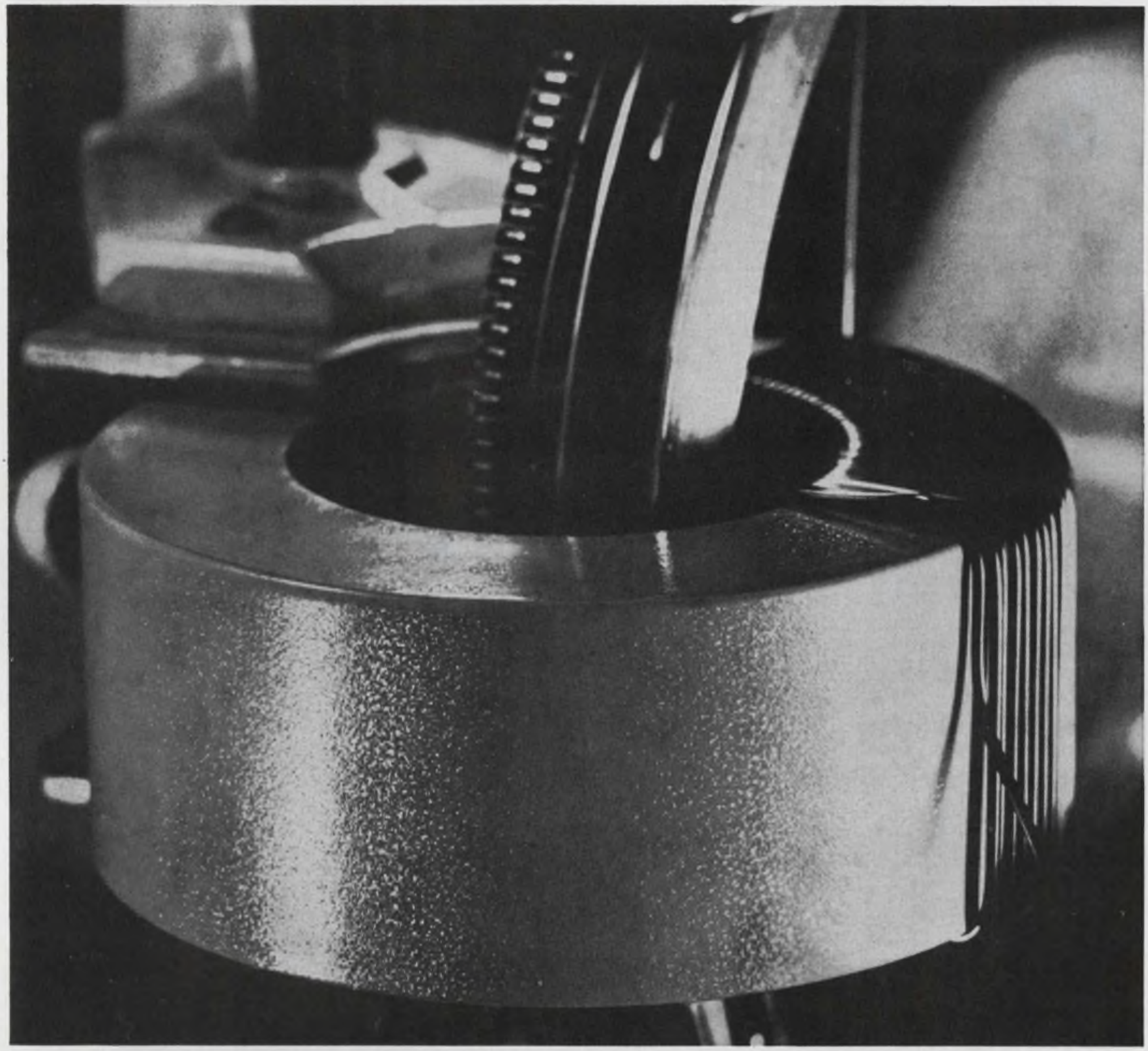
## Servo/differential relay




Model 15 servo/differential relay incorporates a high-gain silicon amplifier requiring a primary power source and a derived phase sensing signal source. The relay output consists of dry reeds with 15-W ac or dc switching capacity. Current amplification factor is $10^8$. Signal input impedance is 20 k$\Omega$.

Price: $31.95. Sensitak Instrument Corp., 531 Front St., Manchester, N. H. Phone: (603) 627-1432.

*Circle No. 270*



## Control transformers

These "Versatile" control transformers are designed for multivoltage and/or current requirements. Transformers have 117 V 50/60 Hz primary and 3 isolated 12-V secondaries, one with center tap. Four sizes are available with secondaries of 100, 150, 250 and 500 mA. Secondaries of 6, 12, 18, 20, 24 and 36 V may be obtained.

Essex Wire Corp., 3501 W. Addison St., Chicago. Phone: (312) 463-7400.

*Circle No. 271*

## Plastic pot

A conductive plastic track is integrally molded with the Model CP-36's slip rings, terminal and case for improved reliability over wirewound pots. Linearity is better than 1% with essentially infinite resolution. Standard resistance range is 500 Ω to 100 Ω. Multigang cups and servo mounts can be provided.

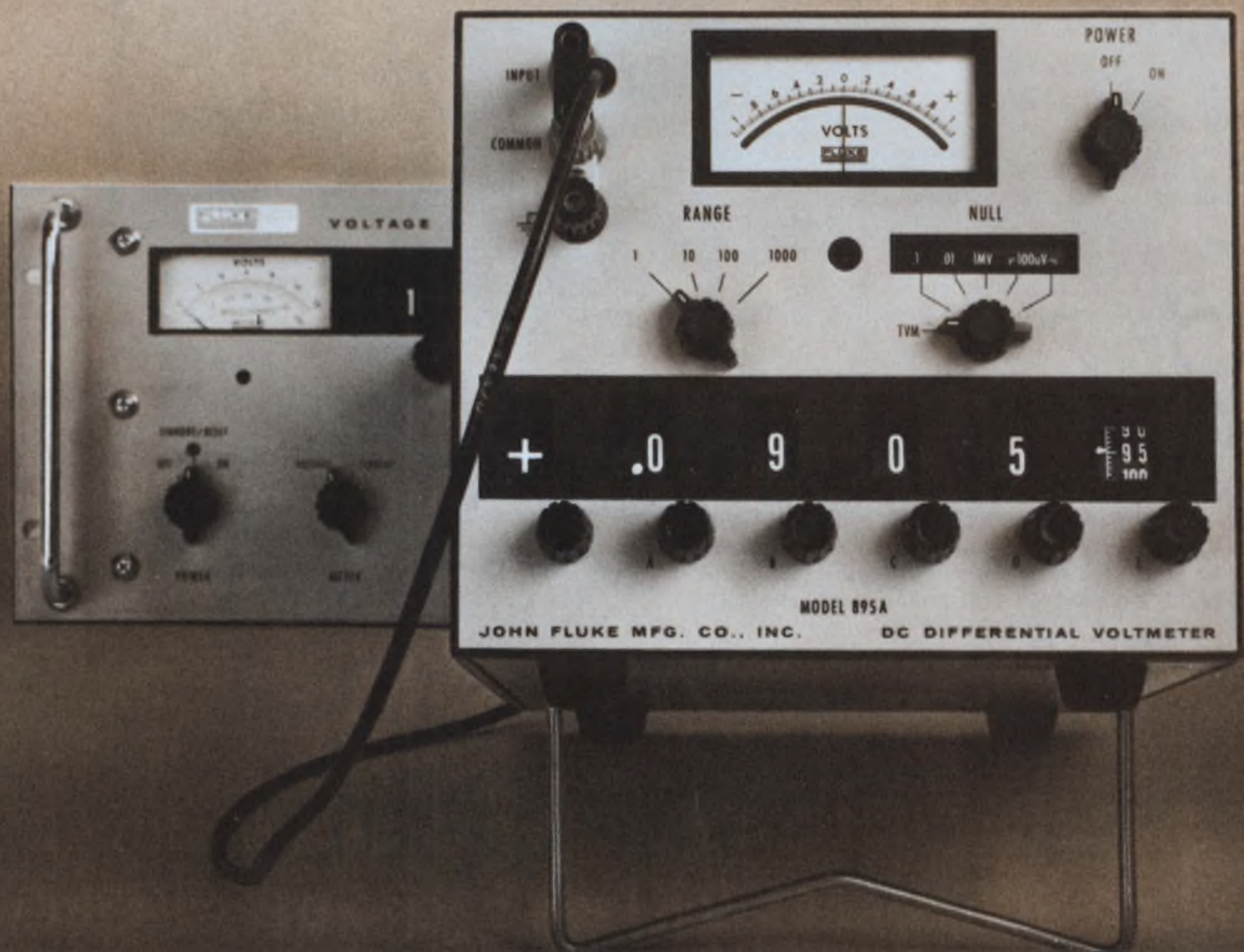
Keltron Corp., 223 Crescent St., Waltham, Mass. Phone: (617) 894-0525.

*Circle No. 272*





ON READER-SERVICE CARD CIRCLE 224 ➤


VOLTAGE
INPUT
COMMON
VOLTS
POWER
OFF
ON
RANGE
1 10 100 1000
NULL
TVM
+ .0 9 0 5
MODEL 895A
JOHN FLUKE MFG. CO., INC.
DC DIFFERENTIAL VOLTMETER

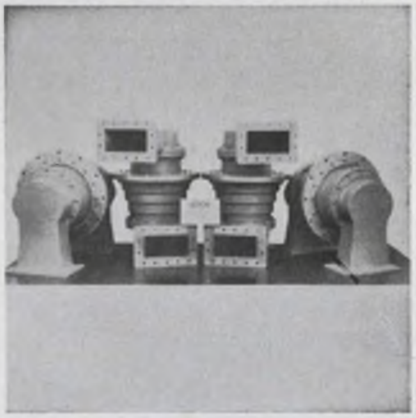
## Dual TR-limiter

The MA-3813Z combines a gas TR tube and a solid-state limiter to provide protection from spike leakage energy for crystal receivers and tunnel diode amplifiers. The device operates up to 16-to-17 GHz with a peak power of 40 kW max. Vswr is 1.3 max and insertion loss is 1.0 dB. Recovery time is 2 $\mu$s and spike leakage is less than 0.05 ergs/pulse.

Microwave Associates, Inc., South St., Burlington, Mass. Phone: (617) 272-3000.

*Circle No. 273*

## Rotary joints

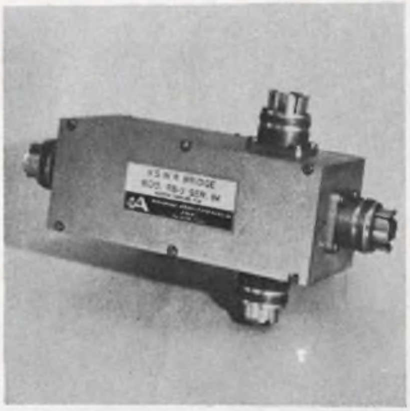


A new family of circular waveguide rotary joints is designed for L, S, C, X, Xb, Ku and Ka band operation.

The joints handle full waveguide power over a 7% band with a max vswr less than 1.15 and an insertion loss less than 0.1 dB. Typical waveguide sizes used are in the category of WR770 through RG-96/U.

Diamond Antenna & Microwave Corp., 35 River St., Winchester, Mass. Phone: (617) 729-5500.

*Circle No. 274*

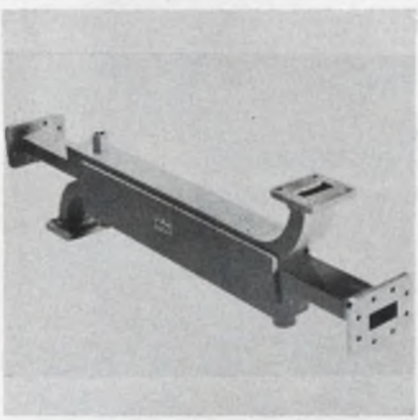


## Vswr bridges

Two bridges enable vswr and return loss measurement in fixed or swept set-ups. Model RB-1 covers 0.5 to 50 MHz and RB-3 covers 3 to 1500 MHz. Accuracy of the RB-1 is 1% for vswr to 1.5 and 2% at vswr of 2. Max vswr error of the RB-3 is 1.5% below 1 GHz, and 2.5% at 1.5 GHz for vswr up to 1.5. Both have a short-circuit termination and a table converting return loss to vswr.

P&A: $360; stock to 4 wks. Anzac Electronics Inc., Moody's Lane, Norwalk, Conn. Phone: (203) 838 8451.

*Circle No. 275*

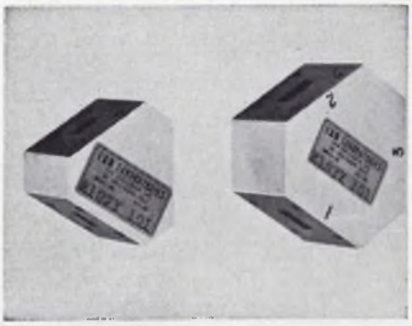


## Top wall coupler

DBH-S-879 dual top wall waveguide coupler handles 30 kW cw with a 0.05-dB insertion loss. It is designed for water-cooled operation and pressurization to 60 psig. Forward coupling is 65 dB and reverse coupling is 35 dB. Directivity is typically 35 dB across the band. Vswr is 1.05 max in the main arm and 1.03 max in the coupling arms.

P&A: $595; stock to 4 wks. DeMornay-Bernardi Div. of Datapulse, Inc., 780 S. Arroyo, Pasadena, Calif. Phone: (213) 681-7416.

*Circle No. 276*



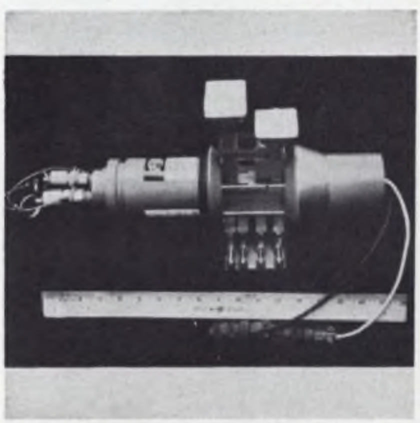
## Waveguide circulators

Waveguide circulators covering a 20.0 to 36.0 GHz range are offered in 3 models in RG-53/U and RG-96/U waveguide. Featured are 2.0 GHz bandwidths with 20 dB min isolation, 0.5 dB max insertion loss and 1.2 max vswr. The millimeter-region units are designed for duplexing and paramp systems.

They can be modified for use as low-loss terminated circulators and switches.

E & M Labs., 7419 Greenbush Ave., North Holloywood, Calif. Phone: (213) 875-1484.

*Circle No. 277*



## X-band amplifier

Series SAX-4700 X-band cw amplifier tunes over 500 MHz and has a 1-dB bandwidth of 40 MHz. The bellows-type tuners allow remote-gang tuning. The 8-kW cw unit covers 7.9 to 8.4 GHz with a gain of 45 dB. Beam voltage is 14 kV and beam current is 1.7 A. Heater voltage is 10 V and heater current is 5 A. Solenoid power required is 1.1 kW.

Electronic Tube Div. of Sperry Rand Corp., Gainsville, Fla. Phone: (305) 372-0411.

*Circle No. 278*

## Digital plotting system

The "Delta" digital incremental plotter is designed to self-program up to 100 steps from a single input command via punched cards. One command from computer or tape will also produce up to 127 incremental plotting steps. The control unit is available with IBM 360 software. Either a magnetic tape or a card reader is included.

Benson-Lehner Corp., 14761 Califa, Van Nuys, Calif. Phone: (213) 781-7100.

*Circle No. 279*

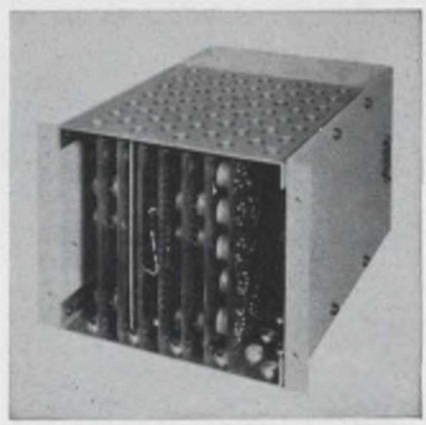


## Vhf receivers

Series 500 vhf receivers cover AM, FM and cw in the 54- to 260-MHz range and are tunable in a single band. A tape dial, a 115/230-Vac power supply and built-in BFO are standard. IF bandwidth of 10 or 300 kHz is front-panel selectable. Video bandwidth is adjustable to 1, 3, 10, 30 or 150 kHz.

P&A: $1600 to $1750; stock to 30 days. Communication Electronics Inc., 6006 Executive Blvd., Rockville, Md. Phone: (301) 933-2800.

*Circle No. 280*



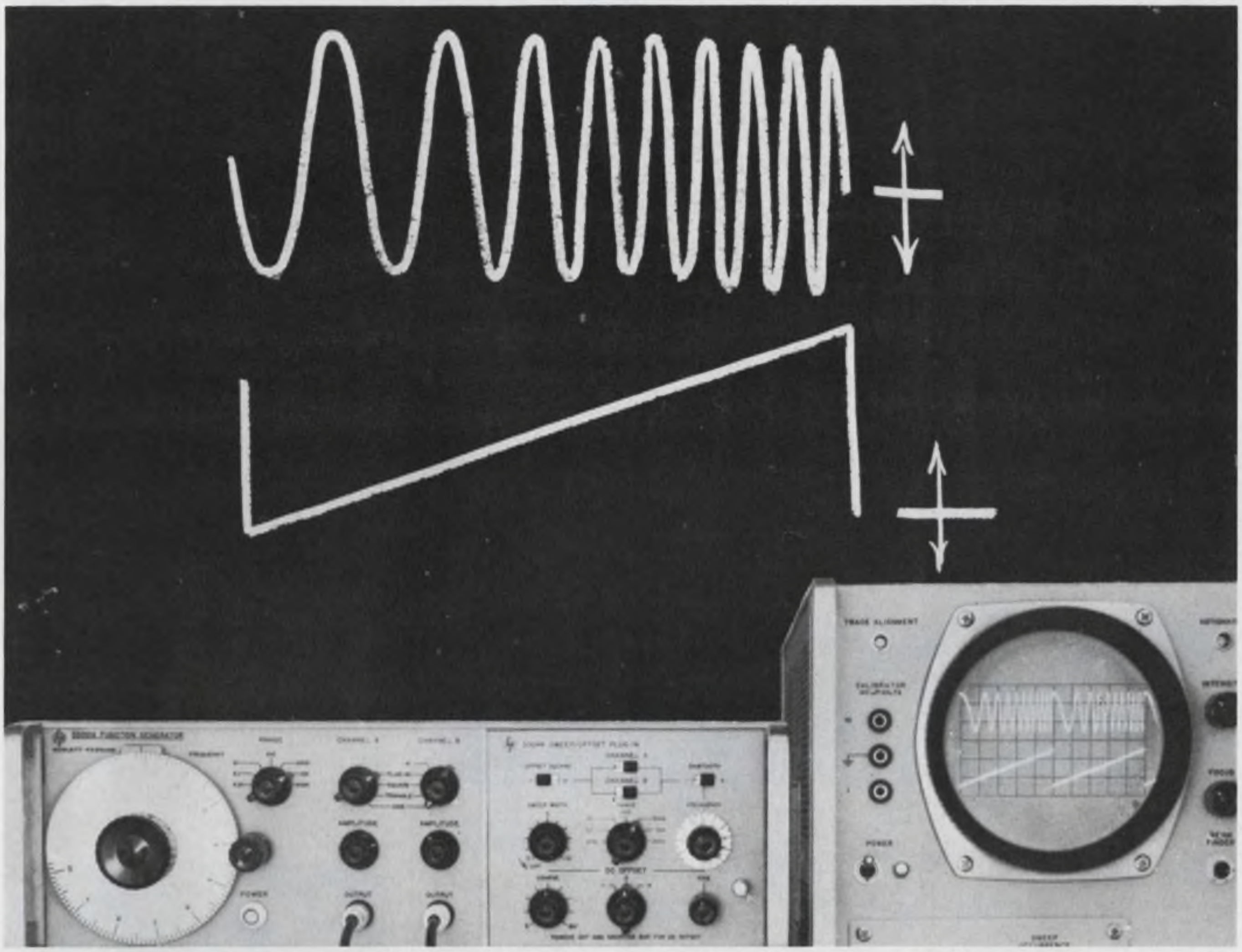
## Communications buffer

Series MCDL sequential access buffer, designed as a magnetic core delay line, has a 1386-bit capacity. The basic bit serial in/bit serial out unit contains the 1386-bit array selected on 4 coordinates by mutually prime ring counters. Each stage provides the shift and core drive function in each circuit. A bit serial in/bit parallel out model is obtained by adding a magnetic core rope card which will accommodate up to 16 parallel bits.

Di/An Controls Inc., 944 Dorchester Ave., Boston. Phone: (617) 288-7700.

*Circle No. 281*

# New value-priced sweeper...



# with a dc offset plug-in for your Hewlett-Packard 3300A Function Generator

Here's a low cost ($210) plug-in, 3304A, for the Hewlett-Packard 3300A Function Generator that provides internal sweeping, up to ±16 v of dc offset on all functions, plus sawtooth and offset square-wave outputs.

This is an instrument package you need to use on your bench . . . it provides more flexibility than words can describe. The new plug-in sweeps internally over a decade. The sweep starts at the main frame frequency setting and is controlled at the top end by the "Sweep Width" control. Any function can be offset with stability of ±50 mv over 24 hours. The 3304A plug-in sawtooth is independent of the 3300A main frame frequency and can be used for driving external systems. The offset square wave clamps the top or bottom of the waveform either to the dc offset voltage or to ground potential.

The plug-in provides the offset with coarse and vernier control, a 15 v sawtooth (adjustable) and the square wave over the same frequency range as the main frame. The main frame, the 3300A itself, is the first plug-in function generator to offer variable phase, phase-lock capability with accurate sine, square, triangular output, amplitude controlled, 0.01 Hz to 100 kHz. It offers linear voltage programmability, single-cycle, multi-cycle, free-run operation, external trigger capability. It provides isolated dual output amplifiers, plus a sync pulse output for oscilloscope or recorder.

All this for just $570, plus the cost of one of these plug-ins: 3301A Operational Plug-in, $20; 3302A Trigger/Phase-Lock Plug-in, $190; 3304A Offset Plug-in, $210.

Ask for a demonstration. Have your Hewlett-Packard field engineer turn it on and show you what this remarkably versatile instrument can give you. Or write for a special chart showing all the outputs available from this instrument and its plug-ins: Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

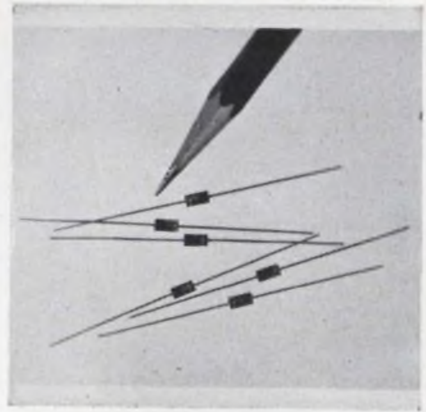
*Data subject to change without notice. Prices f.o.b. factory.*

HEWLETT hp PACKARD

*An extra measure of quality*

1369

ON READER-SERVICE CARD CIRCLE 42

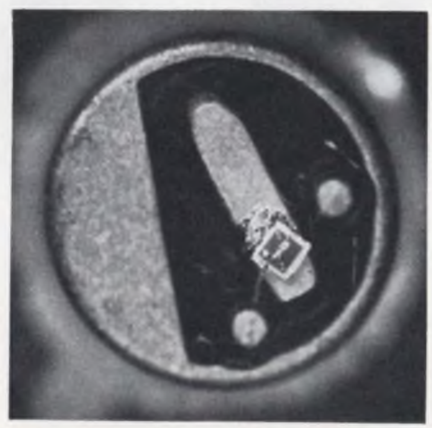


## Capacitance diodes

Ratings of 80 and 100 Vdc are combined with a 50-MHz Q as high as 300 in these voltage-variable capacitance diodes. The SV-4500 to SV-4800 and SV-5500 to SV-5700 series utilize an abrupt junction epitaxial structure to achieve minimum capacitance ratios of 5.6 and 6.4 for 80 and 100 V. Capacitance ranges from 10 to 47 pF at 4-V bias with 10% tolerance.

P&A: From $5.00; stock to 2 wks. Somerset Electronics Corp., P.O. Box 115, Manville, N. J. Phone: (201) 722-2340.

*Circle No. 282*

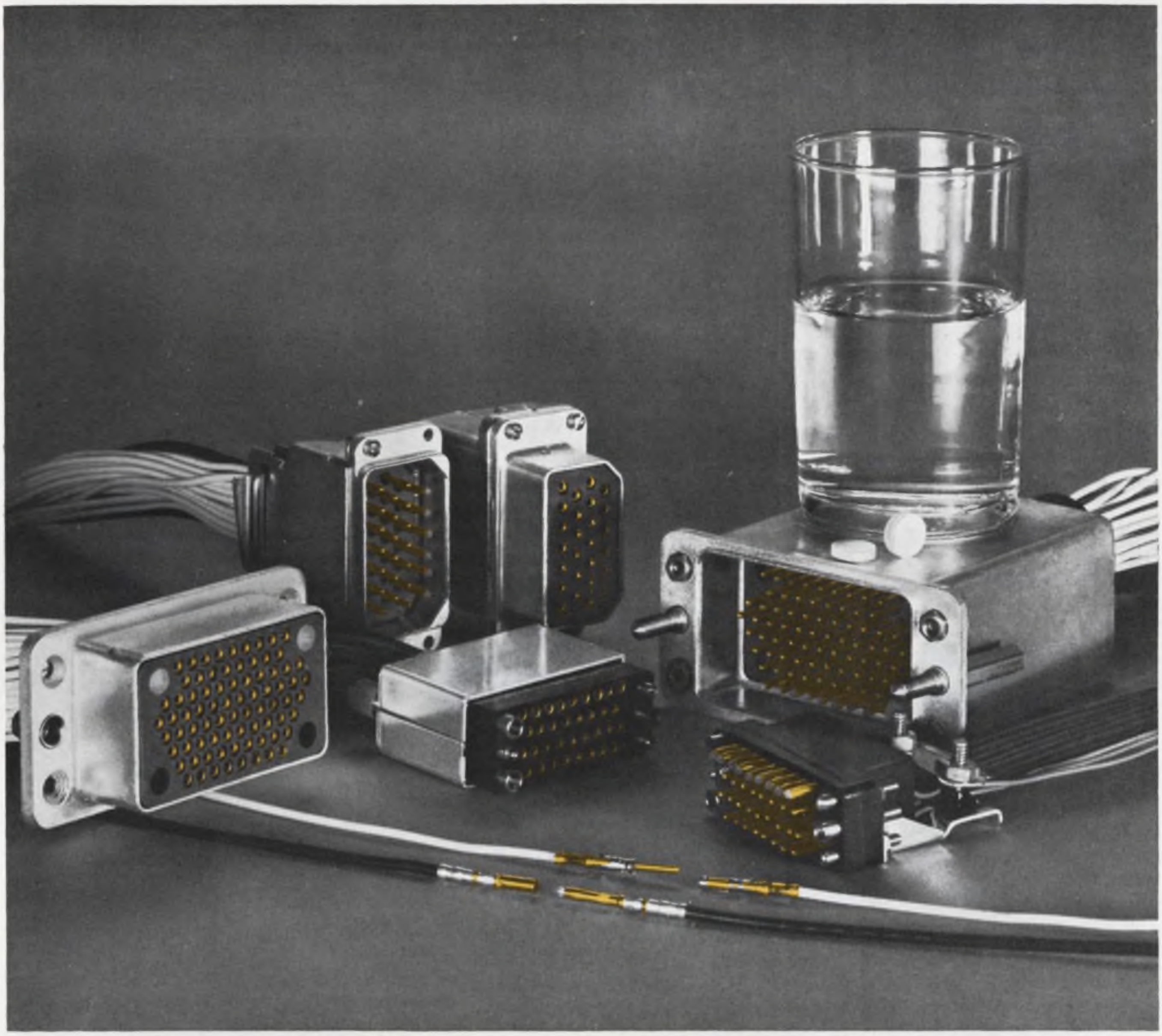


## Pnp transistor

Typical switching time of the TW-300 pnp silicon planar transistor is better than 20 $\mu$s at a collector current of 1 $\mu$A. Switching speed stems from the small geometry epitaxial base. Collector-to-base breakdown voltage of the single emitter device is 45 V and emitter-to-base breakdown voltage is 30 V. Beta is greater than 30 at 1 $\mu$A and $V_{ce}$ of 0.5 V.

P&A: $13.50 (1 to 99), stock. Sprague Electric Co., 347 Marshall St., North Adams, Mass.

*Circle No. 283*



## Silicon rectifiers


Series R plug-in silicon rectifiers are available in full- and half-wave, doubler, center-tap, open-bridge and three-phase types.

The octal socket devices contain double diffused passivated controlled avalanche junctions in a cold case configuration. Voltage ratings range from 50 to 5,000 V PIV and currents from 100 mA to 6 A.

Edal Industries, Inc., 4 Short Beach Rd., East Haven, Conn. Phone: (203) 467-2591.

*Circle No. 284*



## High-gain amplifier

The TQN-0030 transistor amplifier operates at 30 MHz with a 2-MHz bandwidth and provides a gain of 100 dB min. Actual noise figure is 2.5 dB max and quiescent current drain is 6 V at 1.5 mA. The gain characteristic has a stability of ±3 dB at an operating range of −25 to +75°C. Input and output both have 50-Ω connectors.

Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N. J. Phone: (201) 464-3000.

*Circle No. 285*

## Switching diode

A subminiature high-speed germanium gold alloy junction switching diode is 1/3 the volume of comparable units. The hermetically sealed diode is 0.07-in. in diameter and 0.16-in. in length. Characteristics include a 100-ps reverse recovery time with resistance load of 120 Ω. PIV is 1 V to − 25 V at 50 μA. Forward current is over 200 mA at 1 V.

P&A: $0.85; 2 wks. International Diode Corp., 90 Forrest St., Jersey City, N. J. Phone: (201) 432-7151.

*Circle No. 286*

## SCRs

Series 22RC of SCRs has PRV ratings from 25 to 700 V (800 V non-repetitive transient rated). Maximum current rating is 22.3 A average, 25 A rms at up to 70°C case temperature. Junction temperature capability is 150°C. The SCRs are packaged in TO-48 cans.

P&A: $10.80 to $51 (1 to 9); 2 to 4 wks. International Rectifier, 233 Kansas St., El Segundo, Calif. Phone: (213) 678-6281.

*Circle No. 287*

## Impulse noise counter

Noise pulses on voice frequency circuits are counted by the 74258-A impulse noise counter. An internal register records all pulses exceeding a pre-set amplitude between 0 and −60 dB. Counting time can be adjusted in steps up to 60 minutes with max count of 9999. All pulses separated by 125 ms or more will record. The instrument operates from dry cells or a dc supply.

Standard Telephones & Cables Ltd., Newport, Monmouthsire, England. Phone: NE: 72281.

*Circle No. 288*

## Resistance test set

Model UTS-4 takes low-range dc resistance measurements from 2-terminal or complex multi-position devices. A constant 10 or 100 mA passes through the test resistance and the drop is measured with a high-resistance volt-meter. Constant currents are regulated at ±1% over an ambient temperature range of 60° to 90°F.

Sparton Corp., P.O. Box 1784, Albuquerque, N. M. Phone: (505) 898-1150.

*Circle No. 289*

## Coulometer

The VT-1176 coulometer incorporates a 6-digit counter with manual reset and a front-panel switch. Any of four scales may be dialed with the last counter digit set to read in 0.01, 0.1, 1.0 or 10 coulombs. Accuracy of 1% ± one digit is not affected by over-ranging up to 250%. The coulometer can be adapted with appropriate transducer to measure any physical parameter which can be converted to a varying voltage.

P&A: $350; stock. Vari-Tech Co., 546 Leonard St., N.W., Grand Rapids, Mich. Phone: (616) 459-7281.

*Circle No. 290*

## Resistance system

A guarded Wheatstone resistance measuring system, model 232, has ±0.01% accuracy. The 5-dial bridge has 6-place resolution on 11 ranges from 1.2 Ω to 12,000 MΩ full scale. The null-detector has 5-μV sensitivity, 70-dB ac rejection and 5-s overload recovery. The completely guarded generator provides up to 200 V at a variable 0 to 1 W.

P&A: $1045; stock to 30 days. Electro Scientific Industries, 13900 N.W. Science Park Dr., Portland, Ore. Phone: (503) 646-4141.

*Circle No. 291*

# Application Notes

## Current integration

"Using the Electrometer Voltmeter as a Current Integrating or Charge Measuring Instrument" is a 6-page application note discussing circuit considerations for these measurements. This technique is used in measurements of capacitors, random current pulses, laser energy, ion and electron beams, current integration as a timing device and dosimetry. Circuits and equations involved in these applications are given. Two techniques are described. Keithley Instruments.

*Circle No. 292*

## Af amplifier design

A 12-page application note details design of a 4-output af amplifier. The circuit uses germanium transistors in the push-pull output stage and silicon transistors in the input and driver stages. Complete with schematics, charts and graphs, the bulletin gives power supply data and a modified battery-operated circuit. American Elite Inc.

*Circle No. 293*

## Generator calibration

A 12-page application note 19 describes the IF substitution technique for attenuation measurement as applied to calibration of signal generator controls. Procedures for calibration of cw and pulse-modulated signal generators to accuracies of ±1 dBm are given. The method of measurement, operation of the manufacturer's substitution receiver, error summation and equipment necessary to perform the measurement in a +10 to −110 dBm range are discussed. PRD Electronics.

*Circle No. 294*

## SCR motor controls

Open-chassis SCR motor controls for OEM applications are described in a 4-page bulletin. Complete specifications, configurations and dimensions are given. Also included are typical performance curves and a list of standard and optional accessories. Gerald K. Heller Co.

*Circle No. 295*

# New Literature

## Stator winder

A two-page, two-color bulletin describes the Link-Possis automatic stator winder, model ST-W-4B. Model ST-W-4B winds one to five coils per pole for 2, 4, or 6 pole stators. It winds 2, 3, or 4 poles simultaneously. Possis Machine Corp.

*Circle No. 296*


## Spark gaps

A 20-page brochure discusses almost 300 types of 2-electrode and triggered spark gaps. Drawings, curves and application notes aid in presenting operation and performance data on both types. Catalog information and mounting methods are given. Signalite Inc.

*Circle No. 297*

## Force transducer

Major features, specifications and typical applications of the "microprobe" are detailed in a new data sheet. The transducer is fully described as a force probe comprising a rigid mechanical system acting on a pair of semiconductor strain gages. Endevco Corp.

*Circle No. 298*

## Infrared detector

A 2-page bulletin covers the manufacturer's infrared detector. Test conditions, electrical characteristics, application notes, dimensions and a general description are included. Borg-Warner.

*Circle No. 299*

## Test equipment

A review of scientific and test instruments is the subject of catalog PD-602. The 20-page brochure concentrates on strain gage devices and high-speed strip chart recorders. The catalog encompasses photographs of each unit, as well as drawings, specifications, dimensions and graphs. Baldwin-Lima-Hamilton Corp.

*Circle No. 300*

## Photo-sensitive FET

A 12-page brochure explains the operation of the photo-sensitive FET. Examples of circuits using this FET as a light amplifier and as a switch are provided. Applications described include chopper, modulator, multiplexer, servo, relay, logical and computer uses. Performance data for these and other applications are supplied. Teledyne Inc, Crystalonics Div.

*Circle No. 301*

## Photo choppers

Bulletin PC-118 provides information on ac and dc drive photo choppers. Internal schematics and a typical application of a photo chopper in a modulator circuit are provided. The bulletin includes scope traces of output waveforms and dimensional drawings. Airpax Electronics Inc.

*Circle No. 302*

## Tunnel diode amplifiers

Low noise figure tunnel-diode amplifiers are listed with principal specifications in a short form catalog folder. The two-color brochure lists 68 standard models ranging from 250 MHz to 20 HGz in the uhf, L, S, C, X and K bands. Micro State Electronics.

*Circle No. 303*

## Potentiometer catalog

The 60-page potentiometer catalog P-3 provides detailed engineering information and includes 15 different resistance curves, nomenclature, test methods, attenuator circuits and attenuator calculations. Quick reference charts list seven basic pots from 0.1 to 4 W. Centralab, Div. of Globe-Union Inc.

*Circle No. 304*

### Fluidics

An explanation of fluidics technology is given in a new 12-page folder. In an applications section, the illustrated pamphlet cites such typical fluidic functions as binary logic, computing, counting, timing, digital switching, amplification, information handling, sensing and other control techniques. A page of symbols for use by designers is also contained.

Devices covered include flip-flops, an OR/NOR gate, an AND gate, single and staged binary counters, proportional amplifiers, a pneumatic timer and fluid resistors. A language section includes 39 definitions of terms, including functions, uses and operating principles of various types of fluid amplifiers. Corning Glass Works.

*Circle No. 305*

### Vibratory systems

"How to Analyze Vibratory Systems" is the title of the 4-page, 2-color design monograph No. 5. Essential information to classify and analyze linear single-degree-of-freedom system vibrations is given. Formulas with definitions, charts and graphs are used. Lord Corp.

*Circle No. 306*

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Microfilm copies of all 1961, 1962, 1963, 1964 and 1965 issues of Electronic Design are available through University Microfilms, Inc., 313 N. First Street, Ann Arbor, Mich.

# Manufacturers

*Advertisements of booklets, brochures, catalogs and data sheets. To order use Reader-Service Card*

## White Noise Loading Tests Systems


A new paper entitled "White Noise Loading of multi-channel Communications Systems" by W. Oliver is available from Marconi Instruments. Under a number of general headings, the paper deals with Noise Power Ratio measurement, measurement of intermodulation distortion and crosstalk together with other noise and distortion criteria of multi-channel systems.

**MARCONI INSTRUMENTS**
111 Cedar Lane
Englewood, New Jersey

**172**

## The Multireed Relay


This highly explicit pamphlet provides full technical data on Thermosen's Multireed Relay. The Multireed Type A has 4 to 8 contact groups controlled by a single coil; Type B has up to 3 independent DPDT relays; and Type C has up to 5 SPDT relays. True Form C switching and individual contact adjustment make this unit adaptable in a wide variety of applications. For further information write:

**Thermosen, Inc.**
375 Fairfield Avenue
Stamford, Conn.

**174**

## Complete Line of Non-Linear Resistors


This 110-page engineering guide covers the most complete line of heat-, light-, and voltage-sensitive resistors available today. Prepared by the Components Division of Amperex, the book describes physical principles, measurement techniques and the electrical and mechanical properties of the non-linear resistors in the Amperex line. These fall into four broad categories: negative temperature-coefficient thermistors, positive temperature-coefficient thermistors, voltage-dependent resistors, and light-dependent resistors. Applications data, including circuits and selection criteria, are given for each type.

**Amperex Electronic Corporation**
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Hicksville, Long Island, N. Y. 11802


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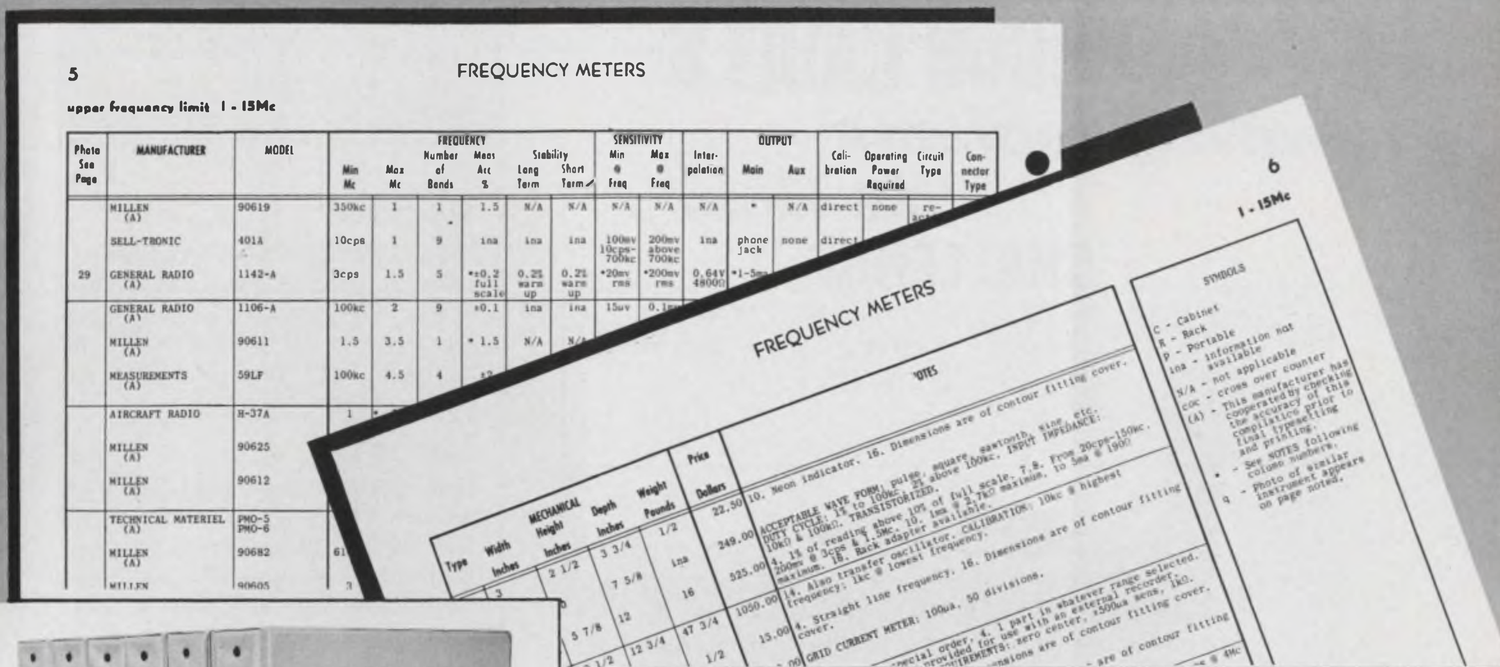


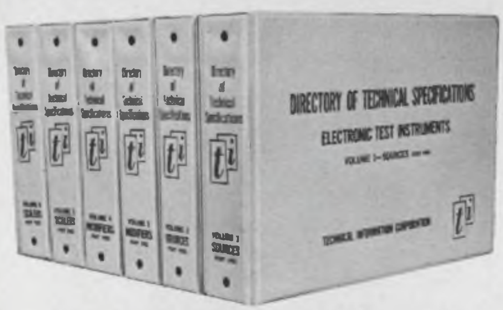


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