VOL. 15 NO. 2

# Electronic Design

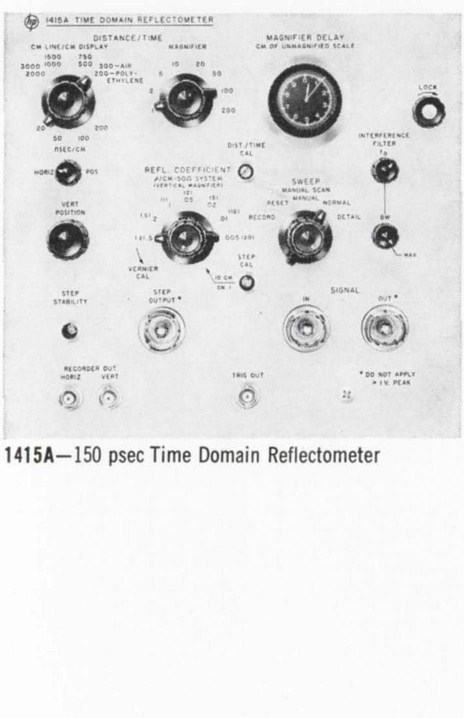
THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JAN. 18, 1967

**IC voltage regulator is adjustable** externally. It can deliver from 1.8 to 30 volts with regulation and temperature stability better than 1%. Although output current is 20 mA, addition of external power transistors extends outputs beyond 2 amps. Now you can use monolithic ICs in your next power supply design. (Page 92.)

*hp140A—The Scope System that gives you*

# BETTER PERFORMANCE


**1415A**—150 psec Time Domain Reflectometer

**SIMPLIFY DESIGN OF MICROWAVE AND PULSE CIRCUITS WITH 150 psec TDR**—The versatile hp 140A scope gives you a choice of 17 plug-ins which cover the entire spectrum of oscilloscope measurements. You can, for example, use a 1415A Time Domain Reflectometer plug-in to quickly determine the magnitude and nature of each resistive or reactive discontinuity in coaxial components such as attenuators, cables, connectors and delay lines. This 150 psec system enables you to locate each discontinuity to within an inch.

The 1415A is a completely self-contained system consisting of a fast rise pulse generator, single channel sampler, and time base. No additional vertical or horizontal amplifiers are required, eliminating introduction of additional chances of error. The vertical channel is calibrated in reflection coefficient for direct readout, with a maximum sensitivity of .005/cm for measurement of extremely small discontinuities. Full 10 cm vertical display area gives additional resolution. Distances can be read directly on the horizontal axis—air or polyethylene dielectrics. The compact control panel contains only those controls necessary for TDR measurements—making the 1415A much simpler to operate than comparable systems costing twice as much.

Accessories include Rise Time Converters which eliminate reflections beyond the bandwidth of interest, 75-ohm adapters, and a Susceptance Standard which gives direct readings of reactive discontinuities. Extensive "how-to" data is available in hp Application Notes 62, 67 and 75 and is yours for the asking.

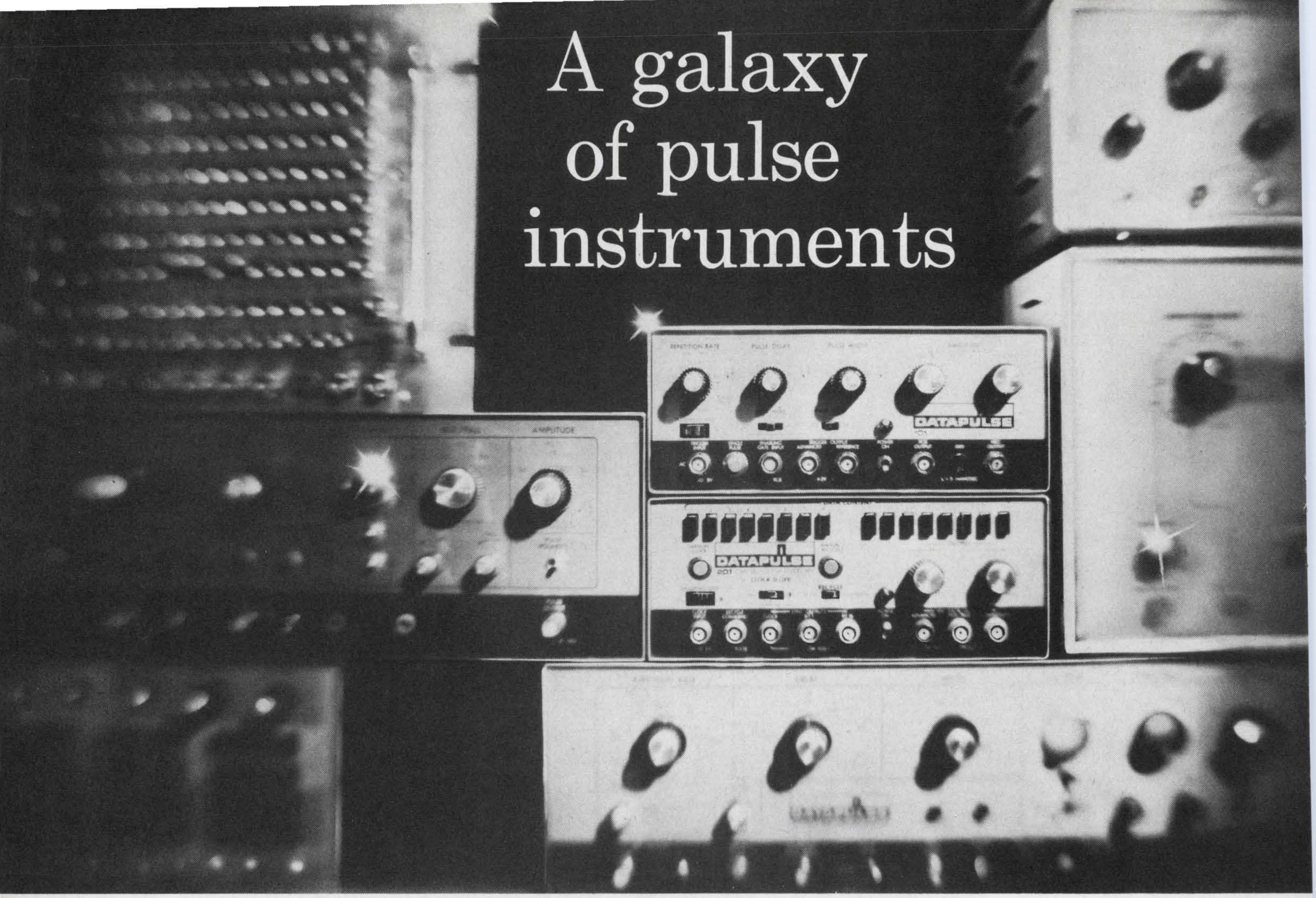
Price of the hp 1415A TDR System *with the standard hp 140A mainframe is $1645*. An alternate mainframe (141A) provides the additional advantages of variable persistence and storage. Price: $2325. Ask your hp Sales Engineer for brochure (Data Sheet 140A) with specs on the TDR system. Or, write to Hewlett-Packard, Palo Alto, California, 94304. Phone (415) 326-7000. In Europe: 54 Route des Acacias, Geneva.

hp 140A: **PERFORMANCE IN ANY DIRECTION**
20 MHz Wideband • High-Sensitivity, no drift • 150 ps TDR • 12.4 GHz Sampling • Variable Persistence and Storage

HEWLETT hp PACKARD
*An extra measure of performance*

**ON READER-SERVICE CARD CIRCLE 202**

# A galaxy of pulse instruments




— 111 Pulse Generator, 2 ns variable rise, baseline offset, 40 MHz — 101 Pulse Generator, 10 MHz, only $395.00 — 201 Data Generator, 10 MHz, 1-16 bits, only $680.00 — 203 Data Generator, 25 MHz, 1-100 bits — 208 Character Generator, 8 channels, 1-16 bits each, 5 MHz — 106A Pulse Generator, linear rise and fall to 10 ns — 110A Pulse Generator, linear rise to 4.0 ns — programmable pulse generators, etc. —

This galaxy of pulse instruments holds some bright new standards for pulse and data generators. It's an ever expanding universe of smaller, more versatile, and less expensive pulse test equipment. Now, and in the future, look to us for the solution to your pulse requirements. Start today by asking for the new Datapulse general catalog.

DATAPULSE®

**TECHNICAL SALES REPRESENTATIVES**

**Airep Electronics, Inc.**
Houston, Texas
713-774-2260
Dallas, Texas
214-824-3800
San Antonio, Texas
512-828-1488
Austin, Texas
512-EN 1795
Oklahoma City, Oklahoma
405-EN 1795
Tulsa, Oklahoma
918-EN 1795

**BCS Associates, Inc.**
Orlando, Florida
305-425-2764
Greensboro, North Carolina
919-273-1918
Huntsville, Alabama
205-534-1648
Metaire, Louisiana
504-834-6598

**Brimberg Associates, Inc.**
Silver Spring, Maryland
301-588-7790
Towson, Maryland
301-727-1444

**G. Curtis Engel & Associates**
Ridgewood, New Jersey
201-444-1400
Norristown, Pennsylvania
215-922-3270
New York, New York
212-732-0001
Long Island, New York
516-741-4621

**Hytronic Measurements**
Denver, Colorado
303-733-3701
Albuquerque, New Mexico
505-268-3941
Salt Lake City, Utah
801-466-4924

**Instrument Consultants, Inc.**
Waban, Massachusetts
617-969-9881
Hamden, Connecticut
203-248-4174

**Lee Mark Associates**
Prairie Villlage, Kansas
913-648-0124
St. Louis, Missouri
314-647-4545

**Harry Levinson Company**
Seattle, Washington
206-323-5100

**O'Halloran & Associates**
North Hollywood, California
213-877-0173
Palo Alto, California
415-326-1493
San Diego, California
714-224-2824
Phoenix, Arizona
602-EN 1200
Las Vegas, Nevada
702-361-5084

**Ridgway Associates**
Chicago, Illinois
312-282-5929
Minneapolis, Minnesota
612-866-3305
Fairview Park, Ohio
216-734-5201
Dayton, Ohio
513-298-0163

**J. D. Ryerson Assoc., Inc.**
Syracuse, New York
315-656-7419

**TECHNICAL SALES REPRESENTATIVES**

**Sample Electronics Pty. Ltd.**
Richmond El,
Victoria, Australia
42-4757
Sydney, N.S.W., Australia
69-6338
Onehunga, Auckland,
New Zealand
567-356

**Electronic Import**
Wien 1, Austria
57-93-71

**Belram Electronics**
Brussels, Belgium
35-29-58

**Atlas Instruments Corporation**
Toronto 19, Ontario, Canada
416-781-6174
Montreal, Quebec, Canada
514-489-8495
Ottawa, Ontario, Canada
614-233-9471
Vancouver, B.C., Canada
604-684-7927

**Oltronix A/S**
Gentofte, Denmark
Gentofte 8030

**Dynamco Instruments, Ltd.**
Mychett, Camberley,
Surrey, England
Farnborough Hants 44422

**Oy Findip AB**
Helsinki 25, Finland
90-49-0158

**Elofysica N.V.-Amsterdam**
Amsterdam-c, Holland
236300

**Technique et Produits**
Boulogne-S/-Seine, France
408-1400

**Neumuller & Co., GMBH**
8 Munich 13,
West Germany
299724

**Toshniwal Bros. Private Ltd.**
Bombay 1, India
246131

**Eastronics Ltd.**
Tel Aviv, Israel
446060

**Special-Ind.**
Milan, Italy
632-435

**Taiyo Shoji Company, Inc.**
Minato-ku, Tokyo, Japan
431-5634

**Datamatik**
Oslo, Norway
67-2847

**Unitronics**
Madrid 13, Spain
241-1496

**Scantele AB**
Stockholm, Sweden
245825

**Baerlocher AG**
Zurich 8021, Switzerland
051-42-9900

Datapulse welcomes technical employment inquiries.

DATAPULSE/Division of Datapulse Incorporated/509 Hindry Ave., Inglewood, California 90306/(213) 671-4334, 678-4275/TWX: 910-328-6109/ Cable DATAPULSE

DATAPULSE • NESCO INSTRUMENTS • DE MORNAY-BONARDI • KRS INSTRUMENTS

VOL. 15 NO. 2

# Electronic Design

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JAN. 18, 1967

## NEWS



## TECHNOLOGY



## PRODUCTS



Cover Photo: The new IC voltage regulator from National Semiconductor Corp. was photographed by Lee Reeves, who used an everyday egg carton and special lighting to achieve a surrealistic effect. The device, mounted in an 8 pin TO-5, is shown alone and on a PC board with a booster transistor in a regulator circuit with a finned heat sink.



## Departments



**ELECTRONIC DESIGN** is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y. 10022. James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled-circulation postage paid at Chicago, Ill., Cleveland, Ohio, and New York, N. Y. Application to mail at controlled postage rates pending at St. Louis, Mo.  61,302 copies this issue.

# DC voltage

# this 


## New Bendix modules can shrink your costs down to size, too.

These miniaturized Bendix® modules are a series of complete DC voltage regulators in TO-3, high-dome, transistor packages. Think of the space you can save over the hand-wired circuits and card-type units you're using now. It's a great way to improve your design without compromise—and cut labor costs as well as component costs in the process.

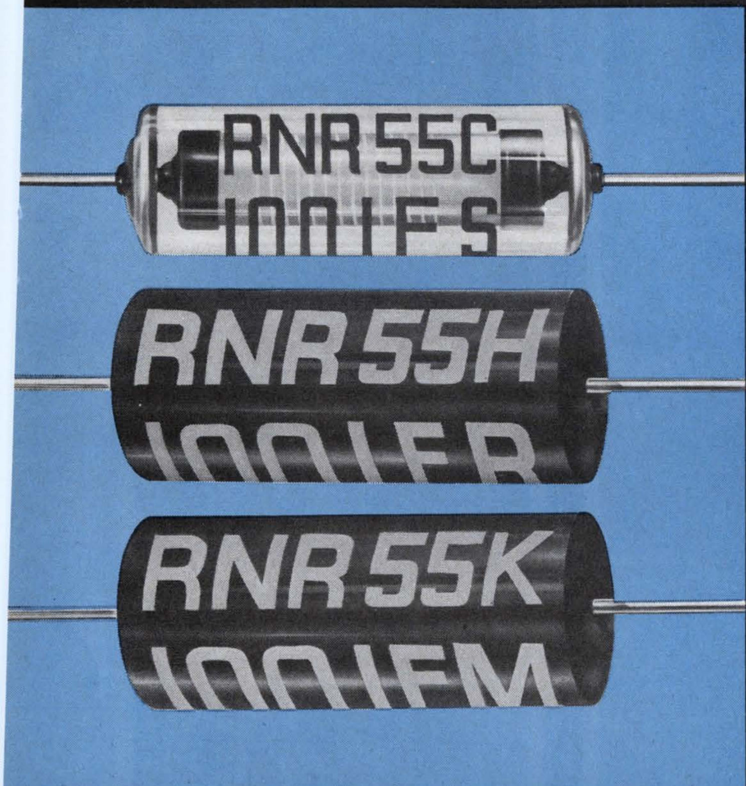
Each module contains a complete silicon, solid state, comparator amplifier assembly that weighs in at only one half ounce. These 1-amp modules come as series regulators of 5, 6, 12, 18 and 24 volts or as shunt regulators of 5, 6, 9 and 12 volts. Load regulation from no load to full load is $\pm 1\%$ with a low temperature coefficient of $0.04\%/°C$ typical. Maximum power dissipation at 25°C case is 25 watts. And that's not all. The TO-3 configuration fits all standard sockets and heat sinks.

Call your local Bendix office or Bendix Semiconductor Distributor. Just ask for more details about the incredible shrinking regulator. Or write us direct: Bendix Semiconductor Division, Holmdel, N. J.

**Baltimore (Towson), Md.**—(301) 828-6877; **Chicago**—(312) 637-6929; **Dallas**—(214) 357-1972; **Detroit**—(313) 548-2120; **Greenwich, Conn.**—(203) 869-7797; **Holmdel, N. J.**—(201) 946-9400; **Los Angeles**—(213) 776-4100; **Minneapolis**—(612) 926-4633; **Los Altos, Calif.**—W. W. Posey Co., (415) 948-7771; **Seattle**—Ray Johnston Co., Inc. (206) LA 4-5170; **Syracuse, N. Y.**—(315) 474-7531; **Waltham, Mass.**—(617) 899-0770; **Export**—Cable: "Bendixint," 605 Third Avenue, New York, (212) 973-2121; **Ottawa, Ont.**—Computing Devices of Canada, P.O. Box 508—(613) TAlbot 8-2711.

ON READER-SERVICE CARD CIRCLE 6

# Reliability and price levels for every ER application




C/S — Hermetic seal — 50 PPM
.001% Failure Rate

H/R — Molded — 50 PPM
.01% Failure Rate

K/M — Molded — 100 PPM
1.% Failure Rate

Mepco, using MIL-R-55182 rev. C as a base, now makes metal film resistors available in three reliability and cost levels to meet your specific application.

- C/S in Mepco's FH series hermetic seal metal film resistors . . . for applications requiring the highest level of reliability and absolute protection against the most stringent environmental conditions.
- H/R in Mepco's FE series molded metal film resistors . . .for use where true hermetic sealing is not critical.
- K/M in Mepco's FE series molded metal film resistors . . . where economy can be achieved for ER applications.

Let us show you how this product line can fit into your program. Write or call today for Bulletin FE.

Mepco, Inc., Columbia Road, Morristown, N.J. 07960
(201) 539-2000, TWX (201) 538-6709

MEPCO

MANUFACTURERS OF **PRECISION ELECTRONIC DEVICES**

*A Heritage of Reliability*

ON READER-SERVICE CARD CIRCLE 7

# economy as well as size and Amperex hybrid integrated circuits.

farads to 2 microfarads. Precise masking, alignment and exposure produce circuit line widths of only 2.5 microns (100 microinches), allowing us to design for extremely small circuit areas. Dissipation can be as high as 6.5 watts per square inch of film area.

The extremely successful ATF-401 operational amplifier is a typical example of an Amperex 'off-the-shelf' hybrid IC. At $29.00, in hundred lots, the ATF-401 outperforms many discrete op amps, and without exception, it outperforms every monolithic op amp available today. Since it is fully frequency-compensated internally, it requires no external circuitry which would increase its effective size.

ATF-401 OP AMP BEFORE ENCAPSULATION

Other examples, of even greater interest to today's markets can be taken from among this list of Amperex custom-designed hybrid IC's: Low-noise DC Amplifiers • Special Digital Interface Circuits • Signal Conditioners • Solid-State Commutating Switches • RF and IF Amplifiers and Limiters • Power Supply Regulators • Audio Amplifiers, Modulators and Demodulators.

The plain facts, then, lead to only one practical conclusion: If your product has reached the stage where you must begin thinking in terms of microcircuitry, it's not enough to think size and performance only . . . think costs, too! . . . think hybrid . . . think Amperex!

Ask Amperex about custom hybrid IC's for your linear applications, for impedance matching, logic transformation, current and voltage drive, low-noise amplification and any other application you can think of.

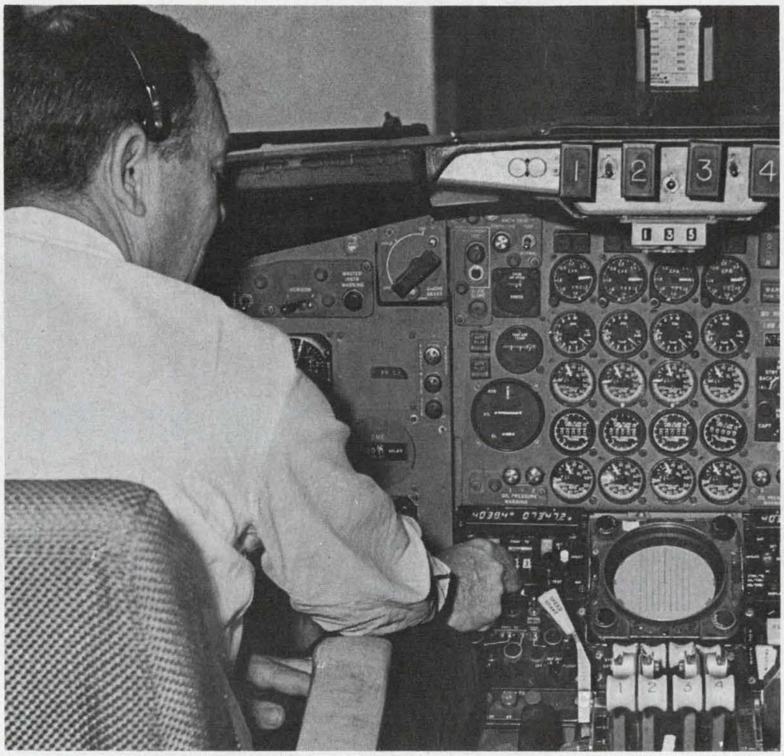
Write: Amperex Electronic Corporation, Semiconductor and Receiving Tube Division, Department 371, Slatersville, Rhode Island, 02876.

**Amperex®**

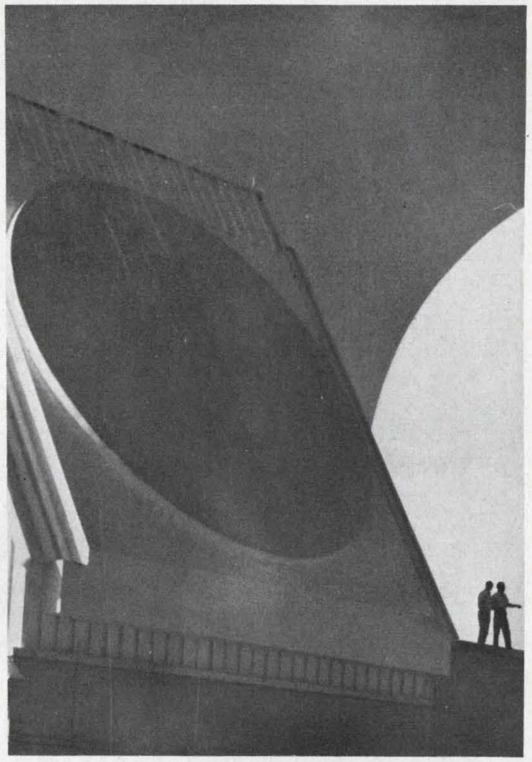
*TOMORROW'S THINKING IN TODAY'S PRODUCTS*

ON READER-SERVICE CARD CIRCLE 8

# News



**Inertial navigators are under evaluation** by commercial airlines; FAA certification is expected shortly. Page 17

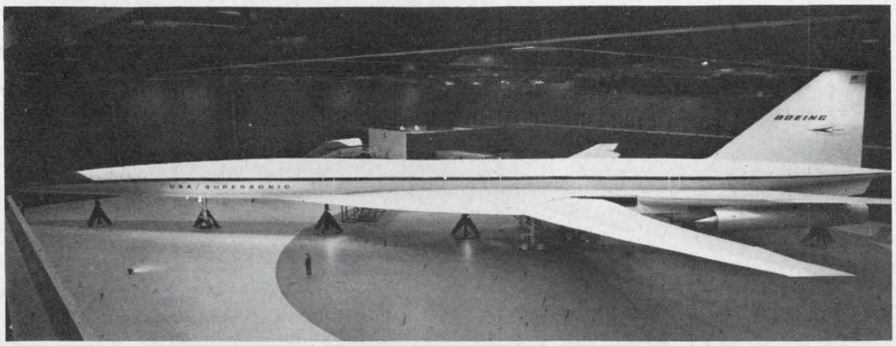


**3-story-high lens antenna tested** for use in antimissile systems. Page 36

**Modulated light beams employed** in closed-loop delay circuits may be the heart of future multipurpose computers. The light is delayed between concave spherical mirrors. Page 24

## Also in this section:

# Electronic firms await SST's economic boom



Now that the intense design competition for the supersonic transport jet has ended, the electronics industry is looking forward to a fat share of what could become a $25 billion market by the mid-1970s.

However, the hundreds of subcontractors that may eventually be involved in the program may have to wait a while yet. Though the basic size and shape of the aircraft have been settled, it is still not clear when the Administration will give the go-ahead to start on the next phase of the SST program—the construction of two prototype aircraft.

Because of the Vietnam war and other budgetary considerations, some industry spokesmen believe that Congress and the Administration may delay the SST program.

Nevertheless, the $1.5 billion that the Federal Aviation Agency has allotted to build the 338-ton superjet is expected to find its way through the prime contractors, Boeing and General Electric, to subcontractors in all 50 states.

Barring undue delays, test aircraft are slated to be airborne by 1970, and regular flights may begin by 1974. The total cost of bringing the aircraft into scheduled service, including funds raised by private manufacturers, is estimated at $4.5 billion.

An FAA spokesman estimated that 15 to 20 per cent of the $35 million cost of each SST would go on electronic equipment. He expected each aircraft to carry about 1900 pounds of such equipment. The superjet may require also advanced automatic check-out and monitoring systems. Its short-range communications equipment will be substantially the same as that of today's commercial airliners, except that there will be a steady trend toward microminiaturization.

## New search for aircraft anticollision systems

The nation's airlines are embarking on a new phase in their continuing efforts to develop a practical standard collision avoidance system.

The Air Traffic Control Committee of the Air Transport Association announced formation of a working group—composed primarily of electronics experts—that will examine proposed methods of applying time and frequency techniques to collision avoidance systems.

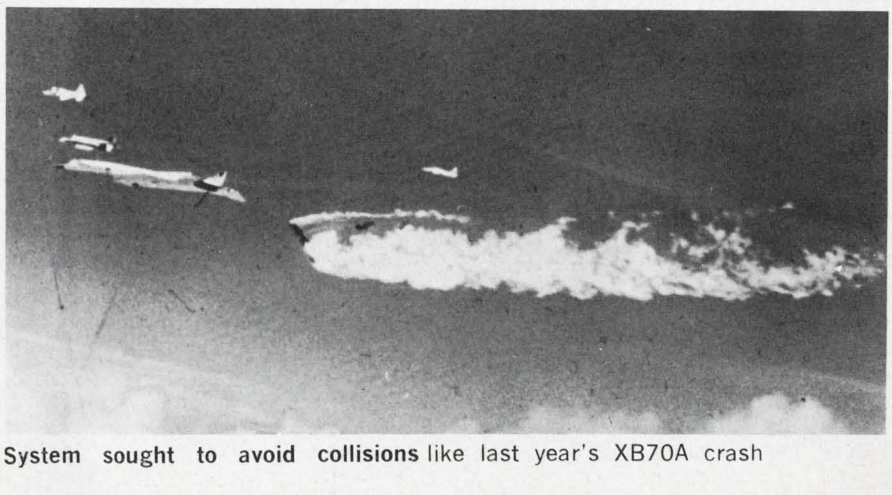
In the time-frequency technique, aircraft transmit their altitude on a common frequency at very precise times. The difference in microseconds between assigned times of a transmission and actual time of receipt by airborne computers carried onboard the aircraft determines the distance between the aircraft. The computers divide distance by rate of closure to predict "time to go until collision."

Stanley Seltzer, director of the association's air navigation and traffic control branch said: "The airline goal is to get a common system, one where airline collision avoidance equipment will work cooperatively with equipment carried by both civil and military aircraft. The airlines believe that the advent of an operational common collision avoidance system will be speeded by developing a proposed standard as quickly as possible."

The Air Traffic Control committee has already evaluated two proposed design concepts for collision avoidance systems—one by Collins Radio, the other by McDonnell Aircraft. Both of these proposals were reported to have met basic airline requirements; however, the two systems were not compatible with each other.

Chairman of the new technical working group is Howard Mehrling, director, electronics—electrical engineering for Eastern Airlines. American, Braniff, Pan American, Transworld and United have named representatives to the group.

Meanwhile, development of a time-frequency airborne collision avoidance system, that is reported



**System sought to avoid collisions** like last year's XB70A crash to be able to operate without ground-station synchronization or the expensive atomic clock required in current time-frequency systems, has recently been announced by TRG, Inc.

## U.S. sets uniform price for its R&D reports

A fixed-price system has been introduced for Government-sponsored research and development reports published by the Clearinghouse for Federal Scientific and Technical Information. Single copies of documents cost $3 on paper or 65¢ in microfiche. The new price is less than the average old price, which was based on document size.

The customer buys order coupons from the Clearinghouse and uses them as scrip to pay for the documents he wants. He merely fills in his name and address and the number of the desired document on the coupon and mails it in. No further payment is required. It is hoped that the new system, which does not apply to certain individually announced reports and multiple-copy orders, will enable the Clearinghouse to fill orders quicker.

Coupons for paper copies may be purchased singly or in books of 10, and for microfiches in books of 50, from the U.S. Dept. of Commerce, Clearinghouse for Scientific and Technical Information, Springfield, Va. 22151.

## Junior satellite tracker pierces the Iron Curtain

A British satellite tracking station, which more than once has detected Soviet space launchings before Moscow announced them publicly, uses the latest in sophisticated electronic equipment. True or false?

Answer: False. It uses a surplus World War II radio outfit, a borrowed toy globe, some paper clips and copper wire.

The makeshift monitoring post is being operated by students of the Grammar School in Kettering, England, under the direction of physics teacher G. E. Perry. A 40-foot antenna has been set up on the school's physics building.

Perry says the station tracks all satellites transmitting on frequencies up to about 20 MHz. Mainly these are capsules in the Soviet Cosmos series.

The globe, Perry explains, was borrowed from his daughter. "We use a clip and a piece of copper wire around the globe to plot the satellites," he says. "The wire represents the orbit and is attached to a curved support."

Since 1962, when the tracking began, 1700 radio observations have been made by the students, and the orbits of 75 satellites have been put on record.

## Artificial northern lights —courtesy of NASA

The National Aeronautics and Space Administration (NASA) plans to lob a small electron accelerator into the ionosphere for research into auroral phenomena. If successful, the accelerator will artificially generate an effect similar to the northern lights.

The experiment, slated for June, will involve launching the accelerator from Wallops Island, Va., to an altitude of 240 miles atop an Aerobee 350 rocket. The rocket would then turn downward so that the accelerator can direct electron beams toward the earth's atmosphere.

Dr. George F. Pieper, assistant director of NASA's Space Science Directorate, said that it was hoped to generate a series of auroral flashes at an altitude of about 60 miles. Each flash, coming at ten-second intervals, would last a couple of seconds and extend over a range of from half a mile to six miles. Red and green were expected to be the dominant colors of the multicolored spectacle, which should be visible over a wide area.

The experiment will mark the begining of further research into the little understood auroras. Dr. Pieper said that later an attempt may be made to shoot an electron beam from one hemisphere to another, so that the auroral effect would appear above the diametrically opposite side of the earth from where it originates.

## Parametric amplification achieved in infrared

Bell Laboratory scientist, Dr. C. Kumar Patel, reports having achieved the first parametric amplification of infrared light.

Dr. Patel used tellurium to achieve a 3-dB gain in intensity of laser light at a wavelength of 17.9 microns.

The scientist said that parametric amplification of far infrared light is an important means of increasing the intensity of a weak light source, and is a first step toward constructing a parametric oscillator, that is a tunable source of coherent infrared radiation.

Optical parametric amplifiers and oscillators are currently being investigated for possible use in future laser communications systems.

In optical parametric amplification, three light waves of different frequencies interact within a nonlinear material—in this case tellurium. Energy from one wave, at the "pump" frequency is transferred to two other waves: the signal wave, which is amplified, and the "idler" wave, which is generated as a byproduct of parametric amplification.

In Dr. Patel's experiment, light beams from a carbon dioxide laser and a helium-neon laser were combined and focused into a 7-mm-long tellurium crystal. The idler wave had a wavelength of 25.9 microns.

## Two devices help light the way to car safety

Two new electron safety devices for use in automobiles have been spotlighted by the Bendix Radio Corp. of Baltimore.

One is a solid-state hazard-warning and turn-signal flasher, reported to be insensitive to voltage and temperature variations. Bendix claims for it a life expectancy five times greater than that of conventional bimetal flashers.

The other device ties the car's entire external lighting system into a central indicator, which shows at a glance whether it is functioning properly. In case of a failure of a headlight, tail light, brake light, turn signal, back-up light or license-plate light, the dash-mounted indicator lights up and remains lighted until the defect has been repaired.

# NEW MICROTRANSFORMERS AND MICROINDUCTORS

## MIL-Spec Reliability, Laminated-Core Efficiency in a ¼-inch Cube!

Now — microtransformers and microinductors created especially for tight, hi-rel military/aerospace environments. The new Bourns Models 4210 and 4220 exceed the environmental requirements of MIL-T-27B and the transformer-reliability specifications of MIL-T-39013!

In performance, too, these models hit new highs. They are the only units to give you the efficiency of laminated-core construction. At 1000 cps the insertion loss is less than 3db. In high-frequency operation, the model 4210 is dramatically superior to the smallest solid-core units available. In square-wave operation, droop is as low as 5%, overshoot as low as 10% and rise time as little as 100 nanoseconds. In every performance category, Models 4210 and 4220 give you the industry's highest ratio of performance to size.

Like Bourns potentiometers, the 4210 and 4220 are subjected to the intensive testing of the exclusive Bourns Reliability Assurance Program. The big "B" on the cover means there's a full measure of reliability in the package.

We specialize in winding custom microtransformers and microinductors to meet your exact requirements, and we substantiate performance in our qualified test laboratory.

Write today for complete technical data!

**Standard Specifications, Model 4210 and 4220**

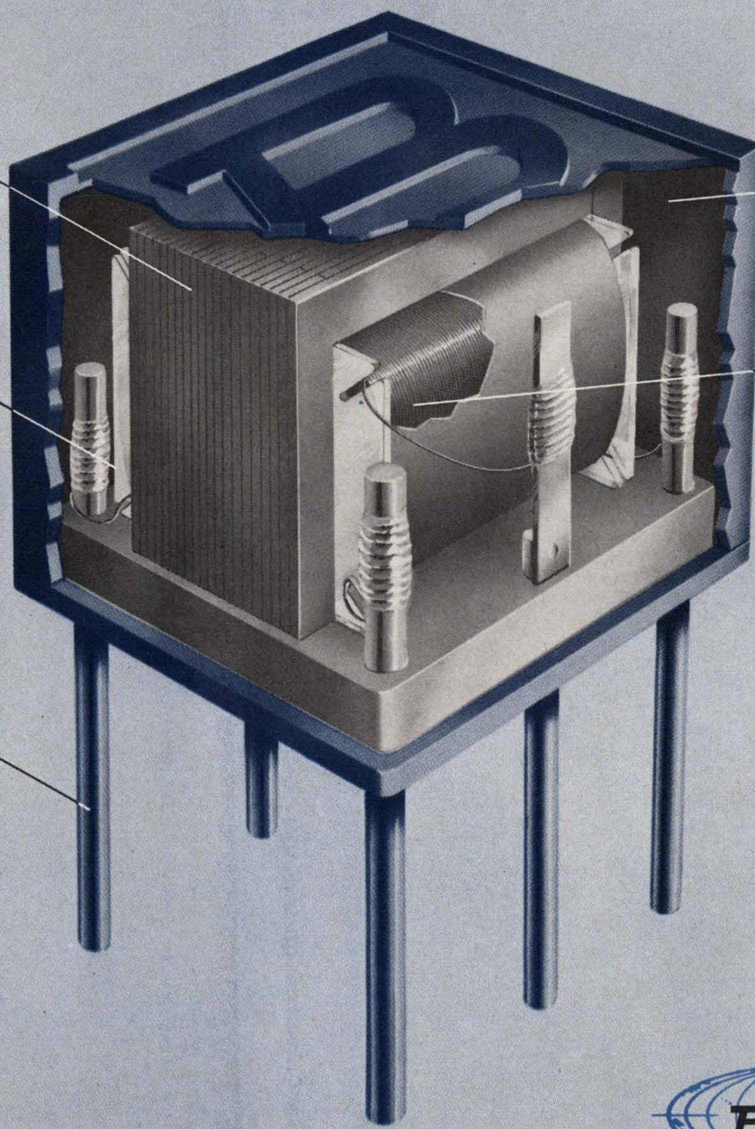
Units shown actual size

Size: .25" x .25" x .25"
Maximum operating temp.: +130°C
Frequency response: —2db, 400 cps to 250 kcps (Model 4210)
Power rating: 1 watt at 10KC (Model 4210)
Insertion loss: 3db max. (Model 4210)
Primary impedance range: 100Ω to 200KΩ; Secondary impedance range: 3.2Ω to 10KΩ (Model 4210)
Turns ratios: to 15:1 (Model 4210)
Inductance range: .08 to 66 Hy (Model 4220)
MIL-Specs: designed to exceed MIL-T-27B and MIL-T-39013

Bourns Model 4210 Microtransformer

Bourns Model 4220 Microinductor

**Standard Models available from stock!**




BOURNS INC.

BOURNS, INC., TRIMPOT DIVISION
1200 COLUMBIA AVE., RIVERSIDE, CALIF.
PHONE 684-1700 · TWX: 714-682 9582
CABLE: BOURNSINC.

TRIMPOT® AND PRECISION POTENTIOMETERS — RELAYS — MICROCOMPONENTS: TRANSFORMERS, INDUCTORS, RESISTORS AND CAPACITORS

# Commercial inertial is ready for take-off

## Airlines expecting FAA approval this year for navigation systems that could speed traffic aloft

**Ron Gechman**
West Coast Editor

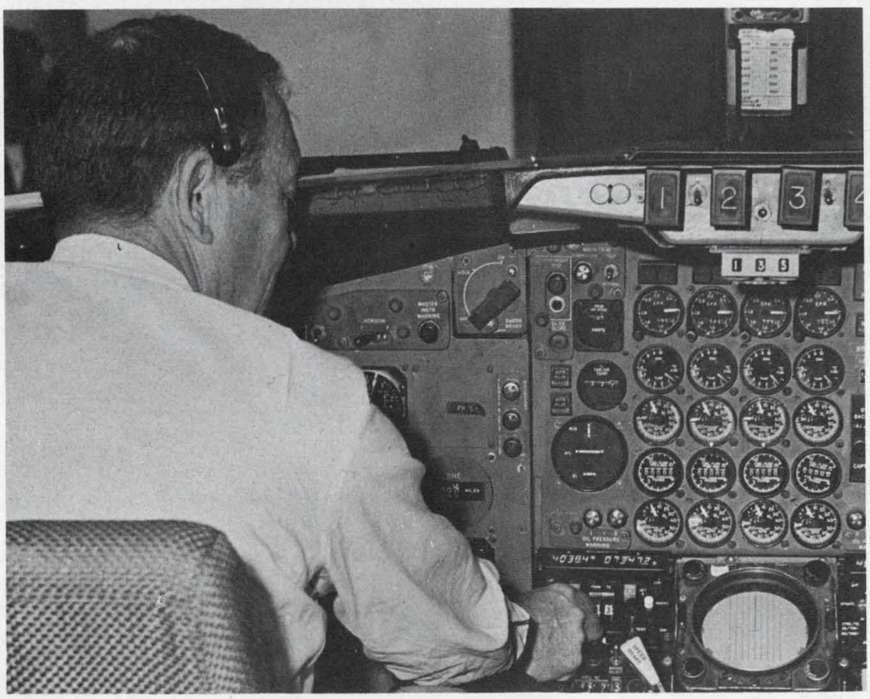
Inertial guidance—the key to accurate navigation in interplanetary flight and long undersea travel—seems destined for a less exotic but highly practical role this year: the commercial airlines hope to receive Federal Aviation Agency approval to use it as part of a giant step forward in modernizing their navigation systems.

The major problem in adapting inertial for aircraft—gyro precision in a small package—has been overcome, manufacturers say. As with many aircraft innovations, military prototypes have led the way here for commercial development. Sperry Gyroscope of Great Neck, N. Y., and the Litton Guidance and Control Group, Woodland Hills, Calif., have developed and tested commercial aircraft inertial systems over the last three years. The competition is growing. Other companies working on inertial navigators for the commercial market include AC Electronics, Bendix, General Electric, General Precision, Autonetics, Nortronics and TRW Systems.

Nor is the potential application limited to the airlines. At least one maker of private aircraft, Grumman, has designed the airframe of its forthcoming Gulfstream II twin-engine business jet so that it can be equipped with an inertial system, if the buyer prefers.

Why do the airlines want inertial navigation capability? They now can fly all over the world with the help of ground-based navigation aids and such airborne equipment as VHF radio, VOR (Visual Omni Range), DME (Distance Measuring Equipment) and Doppler radar. The main advantages of inertial guidance are these:

- Navigation is possible anywhere without external aids. This gives airline crews greater flexibility in selecting flight paths, particularly over areas where ground aids are sparse or nonexistent.
- Greater accuracy and reliability are claimed than for any other method now in use. This would permit the use of narrower air traffic lanes in congested areas—over the North Atlantic, for example—and would facilitate operations in bad weather.
- Instantaneous position reports can be obtained; the time lapse inherent with external navigation aids is eliminated. This is important as jet speeds increase. The proposed supersonic transports, for example, will be dependent on inertial navigation.
- Great-circle courses—the shortest distances between any two points on the earth—are computed automatically.
- A crew navigator is not needed; the pilot can operate the inertial system alone. The savings in eliminating one crew member, airline officials believe, could pay for the inertial systems in a few years.



**Inertial navigation equipment** is adjusted before take-off by Pan American World Airways pilot, Capt. D.L. Combs. The Sperry SGN-10 system, which is being installed on the first of 70 Pan Am airliners, is completing engineering evaluation tests. The airline hopes to receive Federal certification for the equipment this year.

### Installation begun by Pan Am

Pan American World Airways was the first airline to install experimental inertial navigation equipment on its aircraft. It began a system evaluation in 1963, when it conducted an R&D program for the FAA with a Litton platform. Two years later it completed a follow-up program, using an advanced Litton platform. Both Litton systems were military versions used in the F-104 and F-4 aircraft.

Subsequently Pan Am began evaluating a prototype of a Litton commercial system, designated the

(**inertial,** *continued*)

LTN-50. This evaluation is still under way, and Litton has declined at this time to make public technical details of the system.

Between the two earlier Litton programs, Pan Am checked an inertial system developed by Sperry—the SGN-10—and eventually it signed a contract for enough Sperry systems to equip 55 airliners, a figure that was then raised to 70.

Capt. William Moss, director of the Pan Am inertial navigation project, says the Sperry system is completing an engineering evaluation stage, and the airline hopes to get FAA certification by late spring or early summer. Over 6000 hours of flight operations have been logged with the Sperry system, Moss says, and Pan Am has started to equip its airliners—seven so far—with dual inertial systems. Dual systems permit the use of one system to check the performance of the other.

At least three other airlines plan to install inertial navigation systems this year. Alitalia, the Italian carrier, has ordered two Sperry systems for its new DC-8 jetliners, which will be delivered early this year. British Overseas Aircraft Corp. is also equipping some of its aircraft with Sperry systems and plans to test them over the next year. Lufthansa, the German airline, has purchased two such systems for installation in a Boeing 707.

The proposed jumbo jetliners, designed to carry 350 to 450 passengers, are considered sure-fire candidates for inertial navigation. Litton and AC Electronics, for example, are finalists in a competition to furnish the system for the Boeing 747, and a choice is scheduled to be made next month.

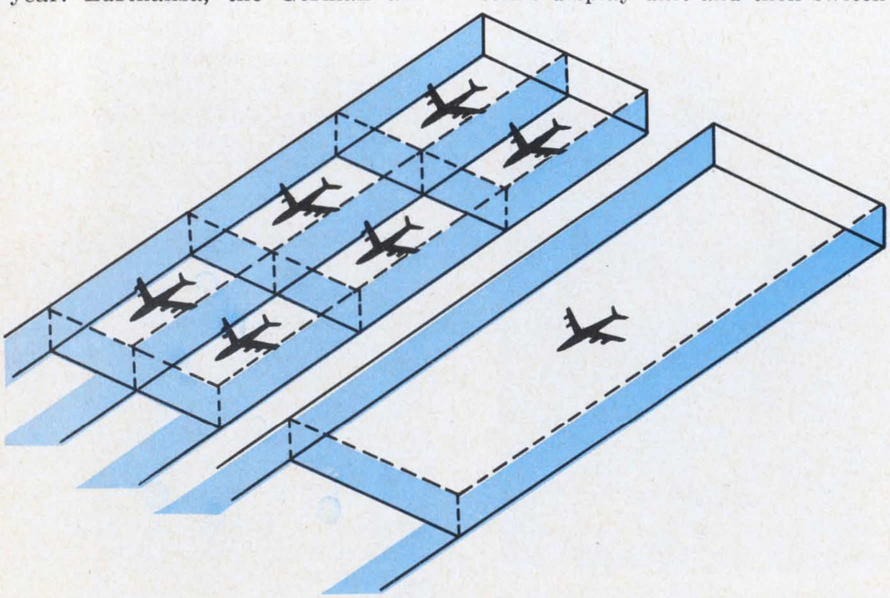
Even though a fair amount of experience is available from military aircraft inertial systems, the development of commercial units has not been easy. The problem lay in the different needs of commercial and military users. For commercial use, pure inertial systems must remain accurate during flights lasting up to 10 or 12 hours. The military systems, installed in tactical aircraft, typically do not operate for more than one or two hours at a time. Therefore the drift rate in a commercial system must be sufficiently low so that after 10 or 12 hours of operation it still works accurately.

Sperry says that the "breakthrough" for it was the "successful marriage of the easily maintained Rotorace gyro with the highly reliable, compact Mark 12 digital computer." The result was the SGN-10, which can be operated by the same person who flies the aircraft.

Before take-off the pilot merely feeds the latitude and longitude of his departure point into the system's display unit and then switches to the "align" mode. The system automatically aligns itself to the local vertical and true north, and it is ready to navigate.

"The latitude and longitude of up to nine check points, or destinations, can be entered and stored in the computer's memory unit," according to Sperry. "These check points determine the desired flight path in great-circle arcs. It is possible to change any destination at any time during the flight, and the system will instantly compute the great-circle track from the present position to the new destination."

The system's display panel gives the pilot continuous information aloft on the aircraft's ground speed; distance and time to destination; miles to the left or right of the track and track angle error (from which the speed and direction of the wind can be figured); true heading and grid heading.



**How inertial navigation could affect North Atlantic traffic:** At present one airliner occupies a "cocoon" of air (right) that is 120 nautical miles wide and the equivalent of 30 minutes of flight time long. Increased accuracy of inertial navigation systems could allow six aircraft to occupy the same space.

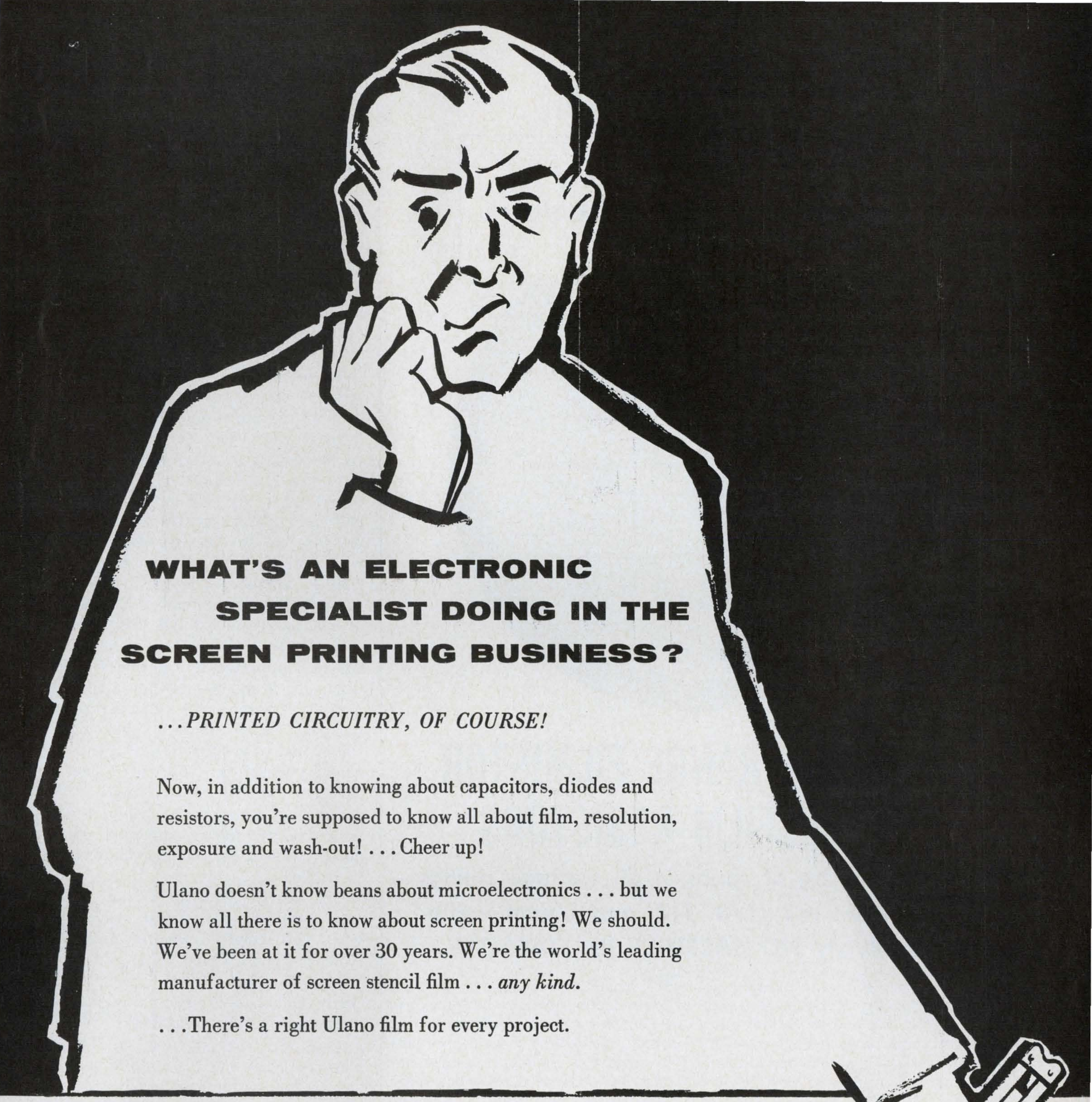
## Hands-off operation

The inertial system can be linked to the aircraft autopilot, to provide full hands-off navigation and flight. Pan Am is also investigating the feasibility of linking the navigator to a Boeing-Bendix automatic landing system. Future system modifications will probably bring about the interfacing of the autopilot, guidance and landing systems.

The computer in the Sperry system has a magnetic core memory and 5632 words of 21 bits. Ninety per cent of the memory is nondestructive read-out, and the remaining 10 per cent of destructive read-out is used for the input of latitude and longitude coordinates of check points.

The system accuracy was demonstrated last Nov. 10 when a regularly scheduled Pan Am flight, with a full load of passengers and four FAA observers, flew the polar route from London to Seattle. A dual inertial system navigated the plane during the entire 10-and-a-half-hour, 4800-nautical-mile flight, and the plane was reported never more than 12 miles off course.

Microelectronics has played a significant role in increasing the accuracy and reliability and reducing the size and weight of inertial systems. Around 1950, for example, an AC Electronics inertial system in-



(**inertial,** *continued*)

stalled in a B-52 bomber weighed 4000 pounds, and it also took 72 hours of preparation to set it up before each flight. By contrast, the system that Pan Am is evaluating weighs about 50 pounds; it is packaged in a box that is 10 inches wide, 29 inches deep and 10-5/8 inches high.

International airlines and the FAA are highly interested in inertial navigation because it can greatly ease traffic problems on over-water routes and on one route in particular—the North Atlantic. At present, traffic over the Atlantic is so dense that flights are assigned to arbitrary air corridors. In normal jet operations the corridors measure up to 120 nautical miles wide and have a 2000-foot separation in altitude. The jets proceed through these corridors as a series of moving "cocoons." The length of each cocoon is the mileage equivalent to 30 minutes' flying time. During peak flight periods an airline may be forced to fly several hundred miles off its optimum route, just to get through at a time when it wants to. This costs fuel, time and money. With improved navigation accuracy, the size of the individual corridors could be reduced, with a subsequent increase in traffic.

The North Atlantic is not the only route where inertial systems would be helpful. Pacific flights from the West Coast to Honolulu, Tahiti, the Fiji Islands, Australia, Guam and Tokyo must cover long distances with relatively few ground aids for navigating. The New York-Buenos Aires flight also poses a navigation problem, because it cuts over the heart of South America, where ground aids are scarce.

As for the future, the high-flying, high-speed SSTs appear heavily committed to inertial navigation. Ground aids like VOR, for example, are not much good above 45,000 feet. The VOR stations have been set up so that, for aircraft flying below 45,000 feet, interference does not occur between two stations operating on the same frequency. Above critical altitude, serious interference can occur. ■ ■

# New gains made in optical communications

## Bell reports 3 modulators each use only about 1.5 mW of power per megahertz of bandwidth

**Ralph Dobriner**
Chief News Editor

Three new light modulators developed by Bell Telephone Laboratories make it economically and technically feasible to put communication signals onto a laser beam, according to the company.

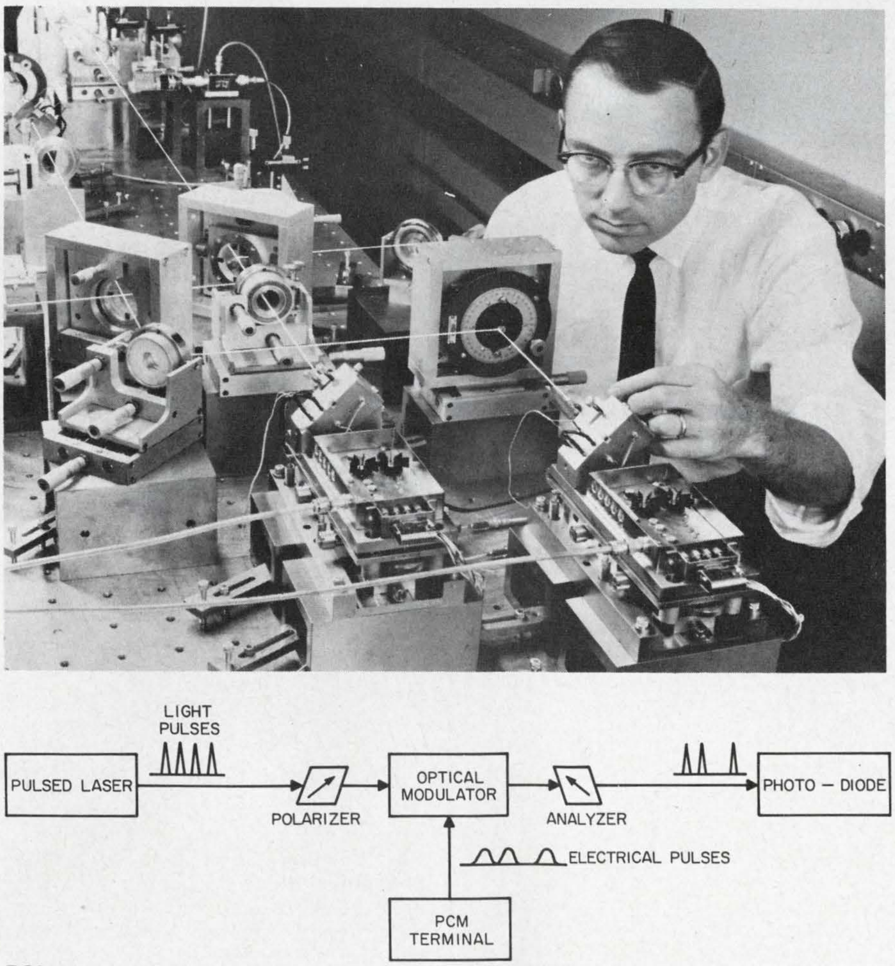
The new devices make it possible to impress broadband communications signals onto both pulsed- and cw-laser beams at modulation powers of about 1.5 mW for each megahertz of bandwidth, Bell scientists said. Most earlier modulators, using such materials as potassium dihydrogen phosphate (KDP), lithium niobate and barium titanate, required either too much power or had insufficient optical bandwidth to be practical, they said. Moreover, the physical characteristics of the materials changed fairly rapidly. (For a fuller discussion of problems, see "Electro-Optics," a special report, ED No. 22, September, 1966, pp. 50-67.)

The devices newly developed by Bell's Murray Hill, N. J., center are:

- An electro-optic modulator in which visible light passing through a lithium tantalate crystal is modulated by an electric field that is pulsed rapidly through the crystal.
- A magneto-optic modulator containing a gallium-doped yttrium iron garnet (YIG) crystal, in which near-infrared light waves are continuously modulated by varying the direction of the crystal's internal magnetic field.
- An electro-optic modulator in which a reverse bias applied to a gallium phosphide diode modulates visible or near-infrared light traveling along the plane of the diode p-n junction.

This is reported to be the first use of lithium tantalate and gallium-doped YIG materials as light modulators. The gallium phosphide modulator was first announced by Bell in 1964; however, no details were given at that time.

Bell scientists decline to predict when optical communication systems, with their enormous bandwidth-handling capabilities, might be used commercially. Present systems more than fulfill all requirements for the near future. One scientist suggested that an optical system would be needed if, say, there were a consumer demand for millions of Picturephones in large cities.




**PCM system with two lithium tantalate modulators,** is checked by R. T Denton of Bell Telephone Laboratories. A schematic of the setup is also shown. The modulators use high-speed signals to encode light pulses from a laser.

### PCM experiments pressed

The lithium tantalate electro-optic modulator, developed by R. T. Denton, T. S. Kinsel, F. S. Chen and A. A. Ballman, of the Bell scientific staff, is currently being used in an experimental system for high-speed transmission of pulse code modulation (PCM) signals.

In this system the modulator uses signals generated at 224 million bits a second to encode light pulses from a helium-neon laser.

Because the laser pulses are of considerably shorter duration than the PCM pulse repetition period, several high-speed PCM signals, converted to optical pulses, can be multiplexed onto a single laser beam.

The width of the pulses from the helium-neon laser permits four pulses to be inserted during each PCM pulse repetition period, so that the maximum potential speed of this optical PCM system is 896 megabits (million bits) per second, ac-

(**optical,** *continued*)

cording to the Bell scientists.

This bit-rate, which corresponds to a bandwidth of 1600 MHz, can be achieved by using four modulators to time-multiplex signals from four PCM terminals.

The lithium tantalate modulator, it was reported, requires only 10 mW of input power to a transistor pulse amplifier, which supplies the drive voltage for the crystal (30 volts across 5.5-pF capacitance) to produce 100 per cent modulation. Lithium tantalate needs only one-twentieth the power required by KDP, one of the most commonly used electro-optic materials.

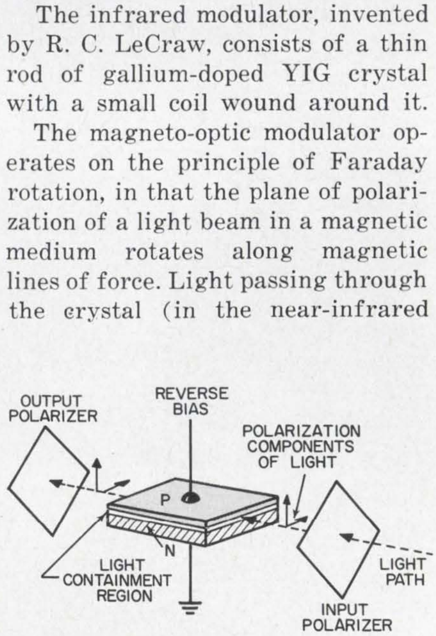
The modulator can also be used to encode a continuous light beam. In this mode, a drive power of one-fifth of a watt has produced 80-per-cent modulation over a 220-MHz bandwidth, according to Bell.

The optical characteristics of lithium tantalate are highly temperature-sensitive. A heat sink-thermistor combination stabilizes the crystal.

According to Bell, lithium tantalate is considerably easier to work with and has more stable characteristics than either KDP or lithium niobate.

The infrared modulator, invented by R. C. LeCraw, consists of a thin rod of gallium-doped YIG crystal with a small coil wound around it.

The magneto-optic modulator operates on the principle of Faraday rotation, in that the plane of polarization of a light beam in a magnetic medium rotates along magnetic lines of force. Light passing through the crystal (in the near-infrared




**Reverse bias applied to a gallium phosphide diode** focuses a polarized light beam on the diode's p-n junction region. The two polarized components of the light wave travel at different velocities along the plane of the junction, imparting phase modulation to each polarization component.

spectrum) is continuously modulated by a varying signal current applied to the coil. The strength of this signal determines the percentage of modulation at any time.

From the crystal, the light passes through an analyzer, which converts the fluctuating plane of polarization into an amplitude-modulated light wave. The wave is detected by a high-speed germanium photodiode, which demodulates the signal impressed on the light beam.

According to LeCraw, a bandwidth of 200 MHz and 40-per-cent modulation has been achieved at room temperature with a modulating power of less than one-tenth of a watt. LeCraw notes that a bandwidth of 200 MHz is sufficient to transmit about 50,000 telephone calls or 30 television programs.

### Gallium phosphide modulates

The gallium phosphide modulator was developed by A. Ashkin, M. Gershenzen, D. F. Nelson and F. K. Reinhart. It consists of a semi-conductor p-n junction with a mounting, and input and output lenses.

The diodes are basically electro-optic phase modulators, but they can be converted by conventional techniques for use as amplitude modulators, the scientists report. Large phase differences can be achieved with small modulating voltages, they said. The modulators can be operated at room temperature.

When reverse bias is applied to the diode, two polarization components of an incoming light wave travel at different velocities in the p-n junction. The change in velocity gives a phase modulation to each polarization component.

Amplitude modulation is achieved by passing the phase-modulated components through an output polarizer.

According to the scientists, this type of modulator has exhibited phase modulation corresponding to over 80-per-cent intensity-modulation of visible light (0.63 microns) when excited with 1.5 mW of power for each megahertz of modulation bandwidth.

This test of modulation efficiency was made at 51.1 MHz, but modulation can be achieved in this diode at all frequencies up to 7000 MHz, the scientists said. ■ ■

# Laser loop: New concept for optical memory

## Elimination of electronic transition permits high-speed storage of digital and analog data

**Neil Sclater**
East Coast Editor

Circulating memories that store modulated light beams may lead to multipurpose computers that will handle more data at a faster speed than existing systems.

Such optical memories have been developed by Bell Laboratories, of Murray Hill, N.J., and scientists there say that improved computers will become feasible when other components can match the higher speeds attainable with the new memories.

Bell's latest optical memory is a closed-loop gas laser, which includes a unique scheme that employs concave spherical mirrors to delay light. Another version contains the same delay scheme, with one exception: the feedback loop requires optical-electrical conversion. Both memories, Bell says, are potentially superior to existing acoustic memories.

The advantages of the optical schemes over present acoustic memories, according to Donald Herriott, a Bell physicist, are superior bandwidth capabilities and the absence of frequency dispersion—a problem with sonic units.

Herriott says that optical delay lines offer the possibility of speeding nonlinear calculations like multiplication and division in future computer systems operations. They can also be used for improved correlation of returned signals from sonar and radar systems.

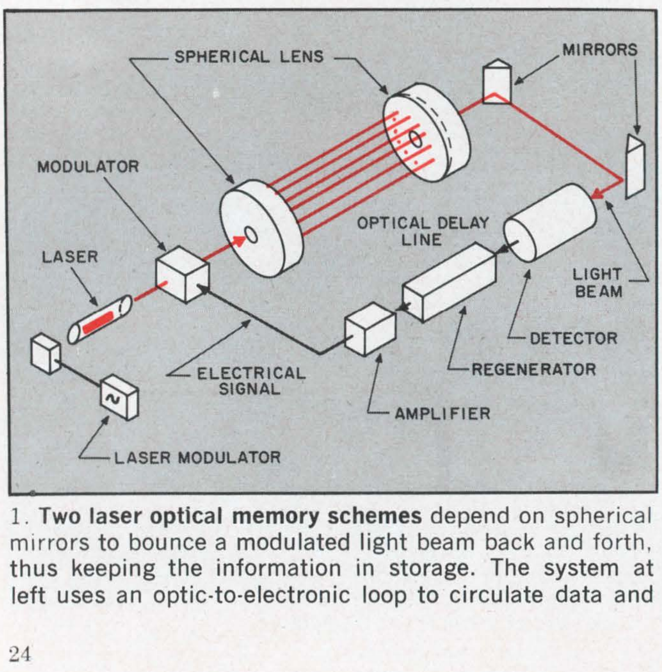
Both the all-optical and the optical-electronic memories are based on folded optical delay lines, first reported by Herriott and Dr. Harry Schulte, also a physicist, as a result of their work at Bell Laboratories in the summer of 1965. In the electronic system, light energy from a laser is converted into an electronic signal and then back to an optical beam. The all-optic scheme achieves the closed loop by using the light-amplification property of a laser.

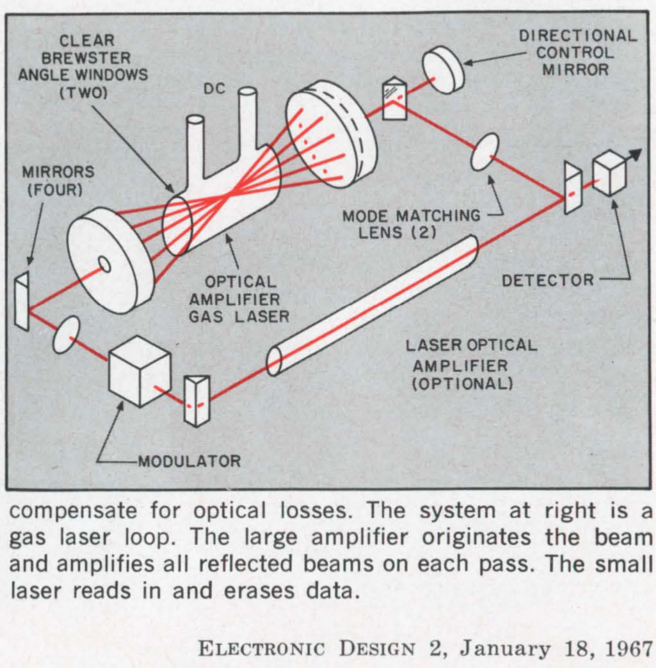
Like other memory units, both optical memories store information until it is called for in computation. A finite delay time is achieved as a light beam successively ricochets off the mirrors as many as 1000 times. The cycle of transmitting and receiving is continued until gating transfers in new information or clears the existing information.

### Light beam is folded

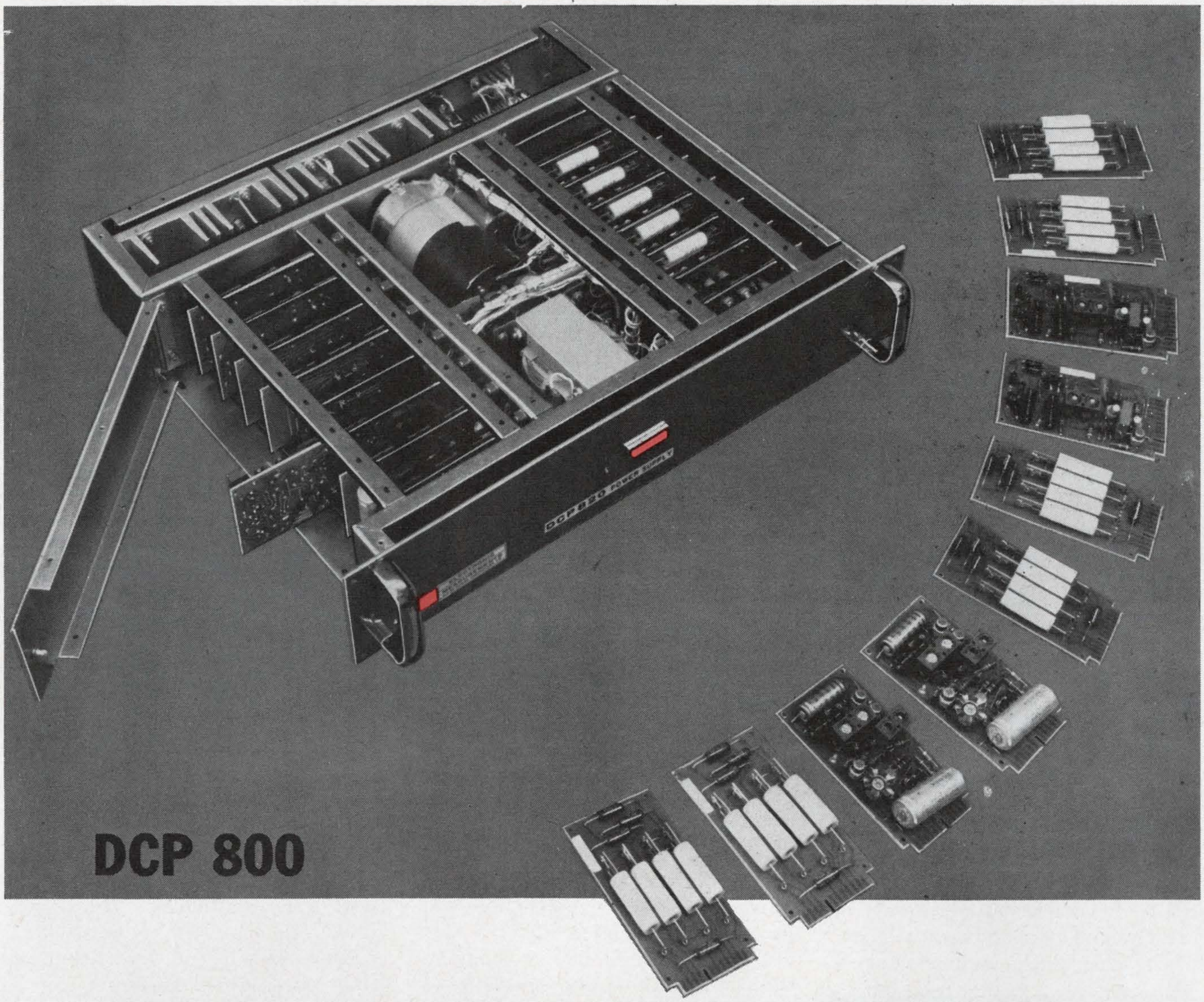
In the experimental setup, two spherical mirrors about 10 feet apart face each other. Small holes in the reflecting surface permit the coherent light beam to be injected at an angle. The geometry of the arrangement permits multiple reflections without overlap (the focal points of the mirrors must be greater than half the distance of separation). This is comparable to folding a two-mile-long laser beam into a 10-foot space. Information that is modulated into the light beam can be stored and retrieved 10 microseconds later. The delay line can store up to 10,000 bits, which can be read out serially one bit every nanosecond.

Because the light beam has no dispersion, information modulated into the laser beam is not distorted.




1. **Two laser optical memory schemes** depend on spherical mirrors to bounce a modulated light beam back and forth, thus keeping the information in storage. The system at left uses an optic-to-electronic loop to circulate data and compensate for optical losses. The system at right is a gas laser loop. The large amplifier originates the beam and amplifies all reflected beams on each pass. The small laser reads in and erases data.




The DCP 800 Power Supply is a high performance, solid state DC power supply with exceptional versatility. It is a digitally programmed unit suitable for automatic test equipment. It provides automatic crossover from regulated voltage to regulated current.

**POWER INPUT:**

105-125 Volts — 50-63 cps — single phase.

**CONTROL INPUT:**

Voltage — Binary Coded Decimal Five Digit Programming in 1 mv steps.
Current — Binary Coded Four Digit Programming in 1 ua steps with 10 to 1 and 100 to 1 range expansion. The DCP-812 only has a 10 to 1 range expansion.
Excitation — Provided by 24 Volts to Reed Relay Input Circuit.

**OUTPUT:**

| | DCP-812 | DCP-813 | DCP-814 | DCP-820 | DCP-821 |
|---|---|---|---|---|---|
| Voltage | 0-100V | 0-50V | 0-100V | 0-.50V | 0.100V |
| Current | 0-0.1A | 0-1A | 0-1A | 0-0.5A | 0-0.5A |

**ABSOLUTE VOLTAGE ACCURACY:** 0.1% or 1.5 mv. Includes:

Line regulation measured for an input voltage step change of 105-125 Volts at 50-63 cps.
Load regulation measured for a no load to full load or full load to no load change within range.
Stability for 8 hours after 30 minutes warm-up.

**ABSOLUTE CURRENT ACCURACY:** 0.35% or 0.25 uamp. Includes:

Line regulation measured for an input voltage step change of 105 to 125 Volts at 50-63 cps.
Load regulation measured for 100 Volt step change increase or decrease.
Stability for 8 hours after 30 minutes warm-up.

*Write for more information.*

THE ROWAN CONTROLLER COMPANY • ELECTRONIC MEASUREMENTS DIV.
OCEANPORT, NEW JERSEY 07757

ON READER-SERVICE CARD CIRCLE 17

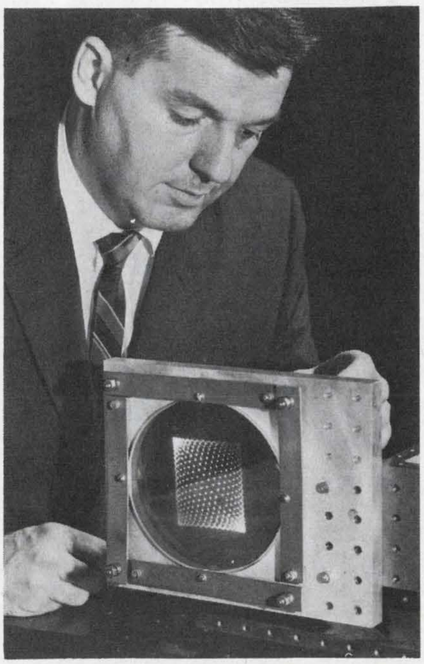
(**optical memory,** *continued*)

The periodic focusing performed by the spherical mirrors keeps the system's diffraction losses low.

The maximum number of beam reflections is limited by the area of the mirrors and their scattering loss (diffraction losses are negligible). During 1000 reflections the beam's light energy is reduced by scattering by only about 20 dB.

To make the most effective use of the mirrors, a slight cylindrical distortion is ground into both mirrors. An otherwise elliptical pattern of reflection then assumes the shape of the familiar Lissajous pattern. This lens design permits the greatest number of reflected spots in the smallest surface area. The output beam can be separated from the others by discriminating in both angle and position.

The present 10-$\mu$s storage time is, according to Herriott, very easy to obtain with acoustic delay lines. In fact, he says, time delays of 10 to 100 times this are possible with bandwidths of 100 MHz. And in the future, the bandwidth of the acoustic memories may well reach 2 GHz. Acoustic delay lines, however, are limited by dispersion at these frequencies and can handle only digital information. The optical delay lines, on the other hand, would not be limited in this manner.



2. **One of the two spherical mirrors** used to trap and reflect a laser beam is adjusted by Donald Herriott of Bell Telephone Laboratories. It is one end of an optical delay line.

Herriott says that dispersion—the change of speed of propagation with frequency—is a problem in acoustic devices, whereas diffraction—the loss of light out of a collimated beam—is the main trouble with laser transmission systems.

## Electronic link in memory

One of the Bell optical memories, using an optic-to-electronic-to-optic conversion (Fig. 1), was constructed by Schulte to demonstrate the feasibility of employing an electronic feedback loop to recirculate data to the folded optical delay line.

The optical delay makes use of two 7.5-cm-diameter spherical mirrors with slight cylindrical astigmatism (Fig. 2).

The focal lengths of the mirrors were far greater than the mirror separation distance, thus giving a beam pattern cross-section almost as large as the mirrors.

The laser used to inject the initial modulated light beam is of the helium-neon type, producing a light output of about 20 mW at 6328 Å. This beam is in the visible red region.

The detector used to convert the light beam into an electrical signal is a photomultiplier, that is fast enough to follow the modulation, and has low-noise characteristics.

The regenerator uses transistors to reshape the pulses, recognize the pulses that are received and locate their position.

The amplifier boosts power in the pulses to drive the modulator pulse amplifier. The modulator is a potassium tantalate niobate (KTN) or a lithium niobate device. (see "New gains made in optical communication," p. 21).

Present gas lasers cannot be modulated by varying the pumping power at the high frequencies required for effective storage. Time is needed—on the order of a microsecond—to decelerate the electrons through collision with atoms. Hence, a separate modulator is required for these lasers.

## Laser loop returns light

The second version of the optical memory at Bell Laboratories (Fig. 1) is actually a loop gas laser amplifier. This scheme, constructed by Willis Yocom, another Bell physicist, uses a folded optical delay line. The laser amplifier is positioned between the two mirrors and not only generates the beams but amplifies them to overcome attenuation losses.

Amplification occurs each time the beam passes through the laser amplifier, which is essentially a gas laser without end mirrors. The complete system can lase by itself.

The focal points of the spherical lenses overlap only slightly, to permit all light beams to pass through the laser amplifier.

The amplifying laser contains a helium-neon gas mixture and achieves only enough amplification to cancel losses in the delay line.

The all-optical memory eliminates some of the problems encountered with the optical-electrical loop. It can operate with both analog and digital signals and may ultimately operate at higher frequencies. The choice of system would depend on engineering applications.

The loop laser system can be modulated with both light and dark pulses. A light pulse occurs when a light beam is injected from a separate laser; a dark pulse occurs when light is canceled for a short period by the modulator.

The system needs no separate laser source to oscillate. A separate laser can be used to erase dark pulses—that is, to eliminate light canceled from the system.

The second optical laser (marked optional in Fig. 1) is unnecessary for oscillation but compensates for the additional loss caused by high-speed modulators.

## Optical memories at work

Optical delay lines may make higher frequencies possible in the relatively long-term future, Herriott says. They allow information to be stored with repeat rates that can be slighly different, so that one set of stored information can be shifted with respect to another in a manner that allows cross correlation to be done between sets of information.

Herriott explains that optical memories can be used to correlate radar signals or equivalent sound. It can be used for shifting digital information, so that digital nonlinear processes can be carried out more rapidly. These applications depend on reports, high modulation rates and analog storage. ■ ■

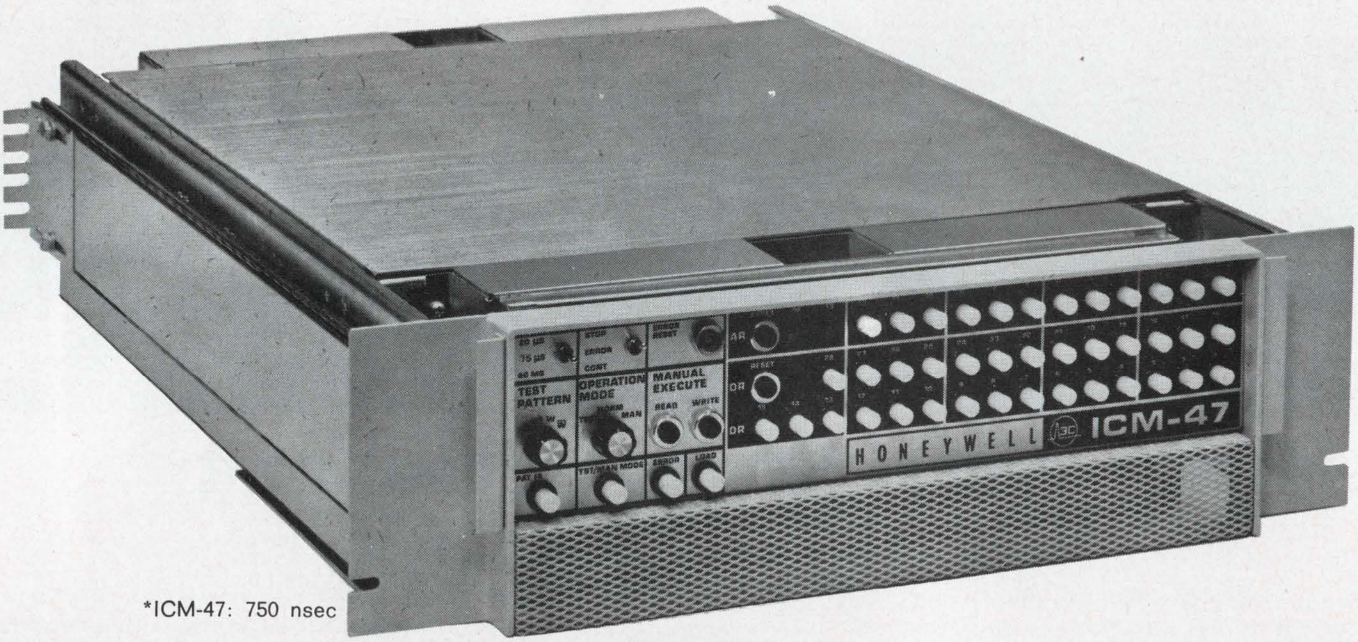
## Only Honeywell Offers A Family of Compatible High Speed* I/C Core Memories

μ-STORE ICM core memories are fast, reliable, and able to store more words in less space than any other core memories on the market. They are field-proven and in high volume production . . . yet offer a flexible design which meets a wide range of system requirements.

ICM-47 — 750 nanoseconds full cycle time; capacities from 4K to 32K words in a single 5¼″ high module (like the one shown below). ICM-40 — 1 microsecond full cycle time; capacities from 4K to 32K words. In addition, multiple module capability allows ICM's to be expanded to larger capacities. Both models feature high noise protection, data retention in case of power failure and maximum use of integrated circuits to achieve high reliability. In brief, you'll find the ICM-40 and ICM-47 designed to perform comfortably in a wide variety of operating environments and to fit easily into almost any system requirement.

Because ICM's come from Honeywell, Computer Control Division, you know they're backed by more than eight years' experience in the design and production of standard core memories . . . and by some pretty intensive special purpose memory systems experience as well. Add to this our I/C capabilities, logic module capabilities, and digital computer capabilities, and you can be sure of dependable support in solving your core memory applications and systems design problems.

Write today! Ask for our μ-STORE summary brochure. Honeywell, Computer Control Division, Old Connecticut Path, Framingham, Massachusetts 01701.




*ICM-47: 750 nsec

**Honeywell**

COMPUTER CONTROL DIVISION

ON READER-SERVICE CARD CIRCLE 19

The goal: research that yields hardware

# Washington Report

S. DAVID PURSGLOVE, WASHINGTON EDITOR

## Pentagon to rein in basic research

The Pentagon is going to pull much of its research back into Government laboratories and insist that research have a more definite military orientation. This is what the office of the Director of Defense Research and Engineering foresees as the outcome of a recently released report on the directorate's little known but controversial "Project Hindsight." The project is an evaluation of weapons systems, particularly of those that are already complete.

Chief among the tentative conclusions of the study which began two and a half years ago are the following:

▪ The contributions to military systems made by basic and applied research over the past 20 years have been greatest when the research was specifically oriented toward military needs, rather than supported merely in the hope that one day some of it might be applicable to some system.

▪ Scientific and technical information that could be used in weapons systems was produced more efficiently when the research programs were funded and managed by the Defense Dept. or the military contracting industry for defense purposes than when funded and managed by the nonmilitary sector of industry or government with no specific concern for military requirements.

▪ The productivity of Defense Dept. in-house laboratories has been comparable to that of laboratories in the defense industry.

The studies also pointed up that the technology that was needed for the successful development of weapons systems now in use was already at hand even at the time when the initial engineering thinking on the system began. This is considered by some directorate officials to be a body blow to Government support of general basic research on the campuses.

Relentless use is expected to be made of the report by members of the Congressional Armed Services and Appropriations Committee, who have long opposed Defense Dept. support of general research. It will probably also be cited by Defense Secretary Robert S. McNamara when he makes his anticipated announcement of cuts in Pentagon-supported research in line with new budget guidelines.

## Probe into communications likely

A sweeping probe into the technology of communications in the U. S. seems more and more likely during 1967. The only questions that remain appear to be who will make the study and how binding will its results be on whom.

First there was a report of the Commerce Dept. Technical Advisory Board on overcrowding of the electromagnetic spectrum, a situation that the panel terms "the silent crisis." Then came the contention of Commissioner Nicholas Johnson of the Federal Communications Commission that the commission must make deeper studies of communications technology. Then Chairman George P. Miller (D-Calif.) of the House Science and Astronautics Committee and his subcommittee chairman for science, research and development, Emilio Q. Daddario (D-Conn.) began to indicate that the House may take up the "silent crisis" as a cause. Commissioner Johnson, the young and controversial Maritime Commissioner for a brief term, wants the FCC to receive a budget increase to conduct the study. Capitol Hill observers, however, believe that such a study is likely to be carried out by some sector of the Commerce Dept., probably the National Bureau of Standards. This being the case, observers predict a struggle between Commerce and the FCC. Since the FCC is so independent-minded, such a wrangle would have been likely even without the outspoken and tenacious Johnson.

A call to battle, which is likely to be big and bitter, is the Commerce Dept. Technical

Advisory Panel's recommendation that the Federal Government should set up a research and development agency, "which has as its primary objective the improvement of the over-all effectiveness of utilization of the electromagnetic spectrum." Although the panel concedes that such an agency would serve the FCC, it would also be responsive to the Director of Telecommunications Management (a White House office), the State Dept. and myriad other Federal bodies that either use the electromagnetic spectrum heavily or are charged with allocating its use and watching out for U.S. interests in worldwide allocations.

In addition to monitoring the increasing use of the electromagnetic spectrum and sounding the alarm whenever it sees overcrowding, the proposed agency would also seek areas where research and development programs on the spectrum's better utilization, or even on totally new means of communication, might be conducted.

These are precisely the areas that old hands at the FCC have been trying to have assigned to the commission and that Commissioner Johnson is now loudly demanding. He has pointed out that all but $2 million of the FCC's $17 million budget has gone on salaries. He believes that the Federal Government should at least equal industry in its ability to perform communications research and development. And it is at this point that Capitol Hill observers believe that Johnson kills his argument.

Johnson points to Bell Laboratories which employs 15,000 scientists and claims that the Government should have at least as great a facility. Congressional technology committee staff say that there is slim chance that the Government would deliberately set out to create such an agency, and absolutely no chance at all at this juncture. This is why they believe that the probe would be handed over to a few extra staff taken on by the Government's already huge and well-equipped National Bureau of Standards.

## NBS studies remote access

A National Bureau of Standards study is to take the use of computers and ADP systems a step further into the fields of scientific communication and library organization and administration. The NBS Office of Standard Reference Data is using the Project MAC computer at MIT in an effort to promote the bureau's expertise in remote on-line access to computers with the aim of standardizing citation indexing and bibliographic coupling in retrieval systems.

NBS hopes that references in more recent papers to earlier papers would be able to lead researchers back through all previous relevant citations at high speed by means of computers. This is already possible in some libraries, but the researcher must be on the premises, must be using that library's catalog system and must be content with only that library's catalog of references. What NBS hopes to realize is a system whereby a researcher may query any major library's catalog and receive a full list of references, whether or not they are filed in the library where he is actually working. The technology already exists, officials point out, but there remains the mammoth task of bringing all the major libraries' systems together.

## Antennas integrated with ship's design

Officers of the U.S. Navy's Ship Systems Command believe that they may be on top of the problem of incorporating the multitude of shipboard antennas that are necessary now into the basic hull design and structure of the next generation of ships. Problems have included interference and the difficulty of separating whole critical sections of hulls and superstructures by nonconductive seals.

The command has just given the green light to DECO Electronics, Inc., of Washington, D. C., which has been working on the problem, to move into the second phase of its study.

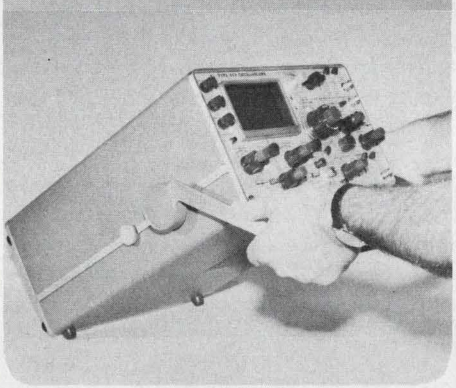
At the same time the Navy has been circulating a request to firms with "secret" clearance to begin applying what DECO had already learned during the first phase of its research. An unspecified Navy agency—presumably a West Coast unit of the Ship Systems Command—gave a number of firms until early this month to turn in rough sketches and brief descriptions of a matching antenna and transmitter network that could be made an integral part of a small, experimental craft. The chosen company will have either to have experience in both electronics and small-boat-building or to be a joint venture set up to handle the project. The Navy wants it to design, develop and build the antenna system and then integrate it into the basic design and structure of an actual boat. Says one command officer: "The antenna system has got to work and the boat's got to float."

# Tektronix Type 453 oscilloscope has

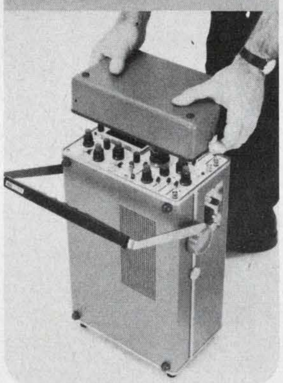
- 50 MHz Performance
- Dual Trace ● Delayed Sweep
- Easy-to-Use Triggering


# and-----it's designed to be carried!

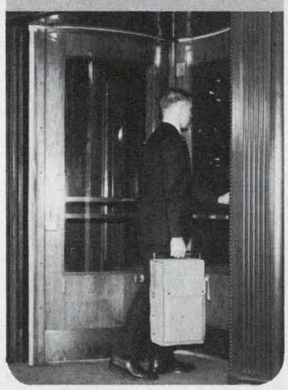
Pick it up and be convinced. The Type 453 weighs 28¾ pounds and is built to go when and where you go.



Don't worry about damaging the front panel and knobs—they're protected by a cover that also carries the accessories.



Take the Type 453 through tight places easily . . . the vertical carrying position increases portability.



Take it anywhere. The rain/dust cover is a standard accessory and carries the complete manual and optional viewing hood.

The Type 453 is a portable instrument with the built-in high performance and environmental capabilities normally found only in multiple plug-in instruments.

The vertical amplifier is specified at the probe tip and provides Dual Trace, DC to 50 MHz with 7 ns risetime at 20 mV/div. (DC to 40 MHz, 8.75 ns $T_r$ at 5 mV/div.) Full sensitivity X-Y and 1 mV/div measurements may be easily made.

The Type 453 trigger system takes the guesswork out of triggering. Pushing all the lever switches up provides a sweep and the most often used trigger logic. The sweep triggered light gives the operator a positive indication of a triggered sweep and the automatic triggering provides greater usability.

You can operate the delayed sweep with ease. Lever control to the right and HORIZ DISPLAY switch to A INTEN DURING B gives delayed sweep operation. Setting the B TIME/DIV and the DELAY-TIME MULTIPLIER to meet your requirements and switching to DELAYED SWEEP allows complete measurements to be made.

The Type 453 is a continuation of the Tektronix tradition of quality workmanship. Its design and layout make it easy to maintain and calibrate. Transistors plug in and are easily removed for out-of-circuit testing. An accurate time (0.5%) and amplitude (±1%) calibrator permits quick field calibration.

The front panel protection cover carries all the accessories with the complete manual carried in the rain and dust cover. The Type C-30 Camera and a viewing hood that fits in the rain cover also are available.

| | |
|---|---|
| Type 453 (complete with probe and accessories) | $2050.00 |
| Type C-30 Camera | $ 350.00 |
| Collapsible Viewing Hood | $ 7.50 |

U.S. Sales Prices, FOB Beaverton, Oregon

**Tektronix, Inc.**

For complete information, contact your nearby Tektronix field engineer or write: Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

ON READER-SERVICE CARD CIRCLE 20

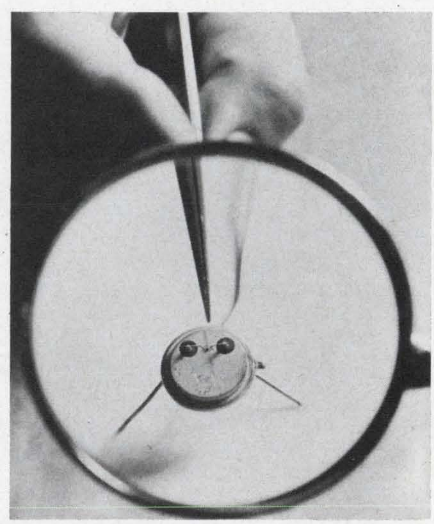
## Three-terminal diode is FM transmitter

A three-terminal, gallium arsenide junction diode that combines both Gunn-effect and field-effect phenomena in a single device has been used as a miniature FM "transmitter."

The experimental oscillator-modulator combination was developed by the Radio Corp. of America, Princeton, N. J. It is simply a two-terminal, conventional gallium arsenide diode in which a channel has been sawed through the top of the n-side to a point just above the junction. Another terminal was added to one side of this channel; the p-side terminal remains intact.

By carefully controlling the voltages applied to these three contacts, RCA scientists report that they have been able to generate, frequency-modulate and tune the microwave output of the device. The two n-side contacts are used to generate the carrier frequency, while the bottom, or p-side, contact is used to modulate the carrier.

According to Dr. Leon Nergaard, RCA director of microwave research, the gallium arsenide "transmitter" has generated carrier frequencies from 60 MHz to 2.5 GHz, and, by using field-effect modulation, has transmitted high-quality voice and music. ■ ■



**Three-terminal gallium arsenide junction diode** that generates and modulates microwave frequencies can be used to transmit voice and sound.

## Thin film measures 'star dust' speed

A thin-film sandwich six-millionths of an inch thick has been developed to measure the speed and direction of micrometeoroids streaking through outer space.

The device is said to be capable of measuring particle speeds of 150 thousand miles an hour without slowing the 'star dust' particles or diverting them from their course.

Developed by the Union Carbide Corp.'s Electronics Div., the detector consists of a film of parylene, an organic polymer, some four-millionths of an inch thick, with an aluminum film about one-millionth of an inch thick vapor-deposited on each side. The polymer has high dielectric characteristics and resistance to radiation.

When a micrometeoroid particle, which may weigh as little as a millionth of a milligram, strikes the dual surface of the device, the aluminum films are short-circuited and a pulse is recorded. The elapsed time as the particle punctures first one and then the other indicates its speed, and the relative points of puncture on the two units indicate the direction of travel.

The polymer used in the "parylene pellicle," a company official says, was selected for its almost negligible resistance to the passage of meteoroid particles, which, if fragmented in passage, would give misleading results.

The particle detector was designed for experiments on satellite sounding rockets and could be designed into large-area arrays for proposed spacecraft, according to Union Carbide.

The parylene material has a variety of other applications, the company said. It could, for example, be used as a window in an orbiting spectrometer which would be transparent to electrons but opaque to infrared radiations. It could also be used as a specimen support for an electron microscope. Acting as a "zero-mass" substrate, it would make possible an extremely fast-response thermometer. The material can also be used in optical applications such as polarizing, beam-splitting and filtering. ■ ■

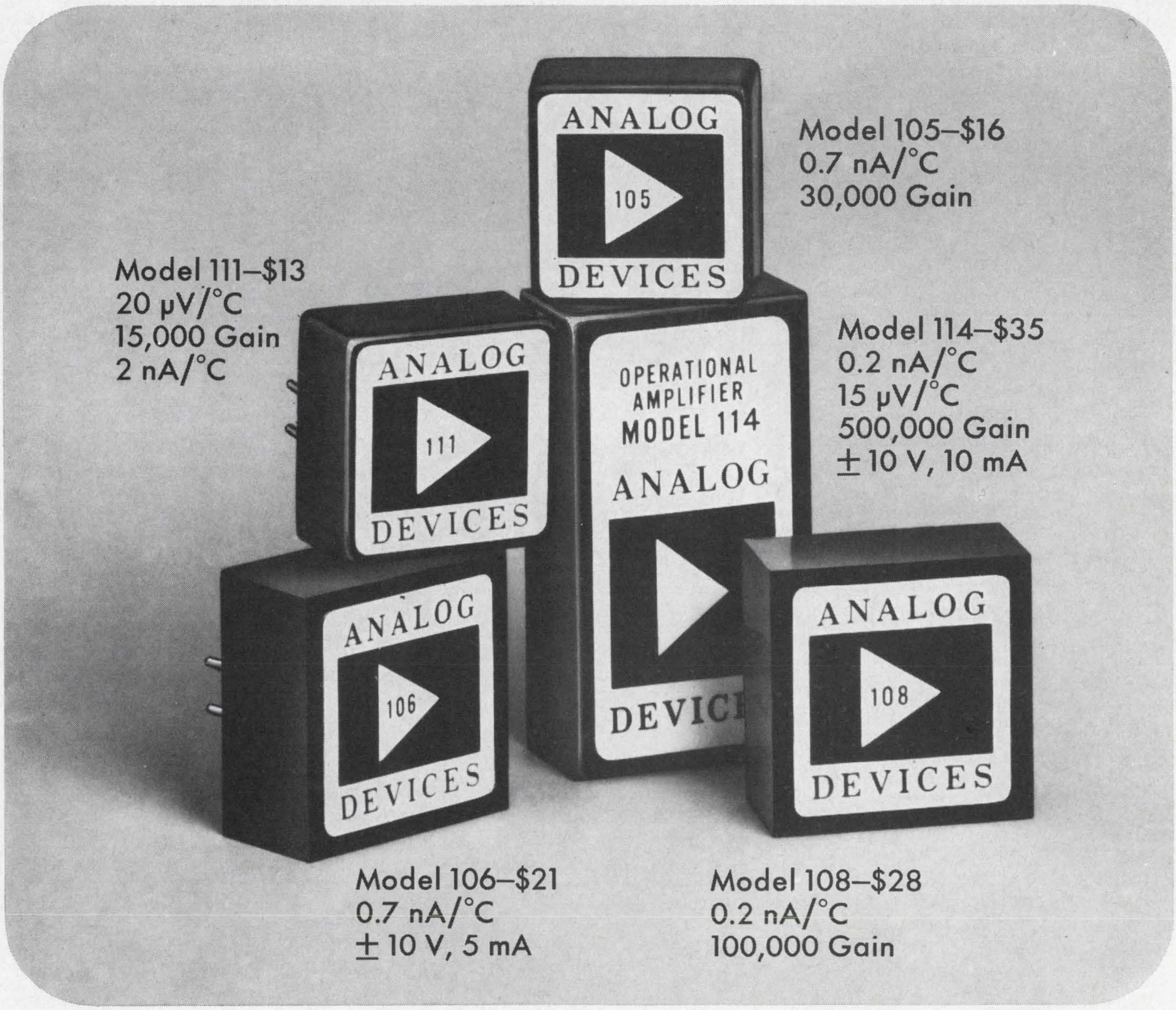
# Best Op Amp

## Prices Dropped, Specs Raised on 5 Economy Models.

### New Model 111 Is $9.75 in 1,000 Lots

Did you view Analog Devices as innovator of industry's most advanced units? You're right. But we also offer best price and performance for economy amplifiers.

Don't take our word for it. Shop around and see for yourself. And look into ICs while you're at it. Then contact us for a sample to evaluate in your own circuit.



# Values Ever!

**Max. drift and min. gain values for –25°C to +85°C range contrast with "typical" values given by many op amp manufacturers. Selection of 10 µV/°C and 5 µV/°C drift offered in B & C models.**

| Parameter | Model 111 | Model 105 | Model 106 | Model 108 | Model 114 |
|---|---|---|---|---|---|
| **Open-Loop Gain—min.** | 15,000 | 30,000 | 250,000 | 100,000 | 500,000 |
| **Rated Output—min.** | 10 V, 2.5 mA | 10 V, 2.5 mA | 10 V, 5 mA | 10 V, 2.5 mA | 10 V, 10 mA |
| **Bias Current—max.** | 200 nA | 50 nA | 50 nA | 2 nA | 2 nA |
| **vs. temp.—max.** | 2 nA/°C | 0.7 nA/°C | 0.7 nA/°C | 0.2 nA/°C | 0.2 nA/°C |
| **Offset Current—max.** | 20 nA | 5 nA | 5 nA | 2 nA | 2 nA |
| **vs. temp.—max.** | 1 nA/°C | 0.2 nA/°C | 0.2 nA/°C | 0.05 nA/°C | 0.05 nA/°C |
| **Input Impedance** | | | | | |
| **differential** | 200 kΩ | 1 mΩ | 1 mΩ | 4 mΩ | 4 mΩ |
| **common mode** | 50 mΩ | 100 mΩ | 100 mΩ | 500 mΩ | 500 mΩ |
| **Bandwith** | 1.5 mHz | 2 mHz | 2 mHz | 0.5 mHz | 0.5 mHz |
| **Voltage Drift—max.** | | | | | |
| **Model A** | 20 µV/°C | 20 µV/°C | 20 µV/°C | 20 µV/°C | 20 µV/°C |
| **Model B** | — | 10 µV/°C | 10 µV/°C | 10 µV/°C | 10 µV/°C |
| **Model C** | — | 5 µV/°C | 5 µV/°C | 5 µV/°C | 5 µV/°C |
| **Price (1–9)** | $13 | A B C<br>$16 $21 $26 | A B C<br>$21 $26 $31 | A B C<br>$28 $33 $38 | A B C<br>$35 $40 $45 |

**Price Performance Breakthrough** — Analog Devices has introduced a step-function improvement in price-performance ratio for low-cost op amps . . . not just a token advance over present-day standards.

**Consider** — Who else offers an op amp with Model 111's specs at $9.75 in 1,000 quantities? Who else has a unit (Model 105) with bias current drift below 0.7 nA/°C for only $16? Where could you get a $21 amplifier (Model 106) with 250,000 gain and 5 mA output? Or an amplifier (Model 108) with 0.2 nA/°C maximum bias current drift and 100,000 gain for only $28?

**Versus ICs** — The new price-performance standards set by Analog Devices economy line clearly resolves the controversy between discrete-component and integrated-circuit operational amplifiers (except where size is the critical factor). Today, and for the foreseeable future, ICs just can't match the current-drift, gain, and input impedance values achieved by these new amplifiers. Model 111, at $9.75 in 1,000-lots, shows that they can't compare in price for a given performance, either.

**No Excuses** — No longer can you justify a *make* rather than a *buy* decision, even when production runs into thousands of units. Now you can use op amps where they would have been uneconomical only last month.

**Catalog** — Mark bingo-card to get Economy Line Catalog with full details on these 5 units.

Catalog also gives specs on 6 further economy amplifiers. We'll send you a short-form catalog on our advanced units too.

**Sample** — Contact Don Belanger, Applications Engineer, for a unit to try out in your own circuit.


ANALOG DEVICES

221 FIFTH STREET
CAMBRIDGE,
MASS. 02142
617/491-1650


ON READER-SERVICE CARD CIRCLE 23

# Antimissile lens antenna tested

## Three-story-high radar array, suitable for hard silo, is fed by one transmitter

A microwave lens antenna the size of a billboard is testing the feasibility of using a single transmitter in antimissile phased-array systems. Such systems could be adapted to hardened silos that would protect the radar array from nuclear attack.

Other phased-array systems use individual transmitters to feed each antenna-radiating element, and many require separate transmitting and receiving elements.

The tests are being conducted by the Army with a Sperry Hard Point Demonstration Array Radar (Hapdar). The radar transmits an electronically scanned pencil beam in two dimensions (see "Phased arrays break the inertia barrier," ED 16, July 5, 1966, pp. 20-23).

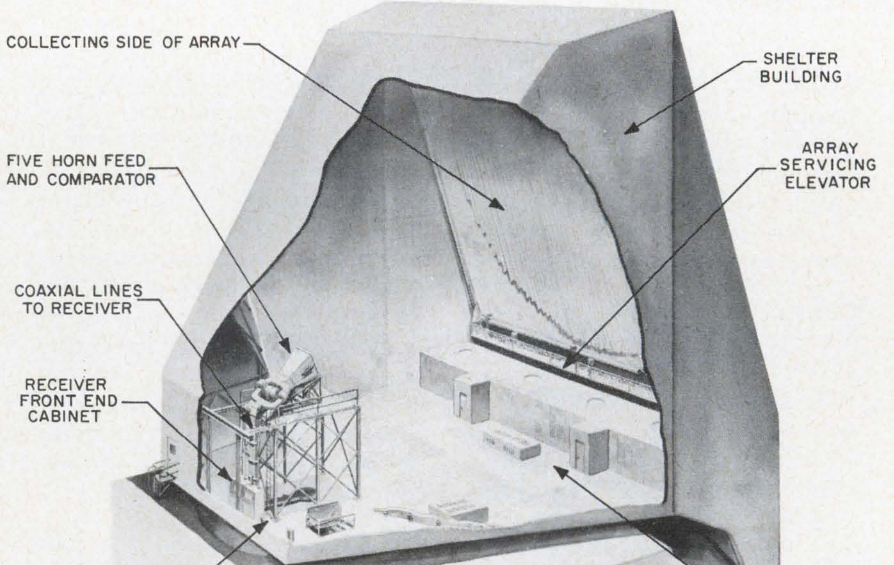
A single klystron illuminates the three-story-high lens from inside a sheltering enclosure with a five-horn monopulse feed. Phase-shifting elements of the lens collimate the incident spherical-wave front to a plane wave and steer the pencil beam that is formed.

Sperry's Great Neck, N. Y., Gyroscope Div. built the planar microwave lens radar for the Army Missile Command at the White Sands Missile Range, N. M.

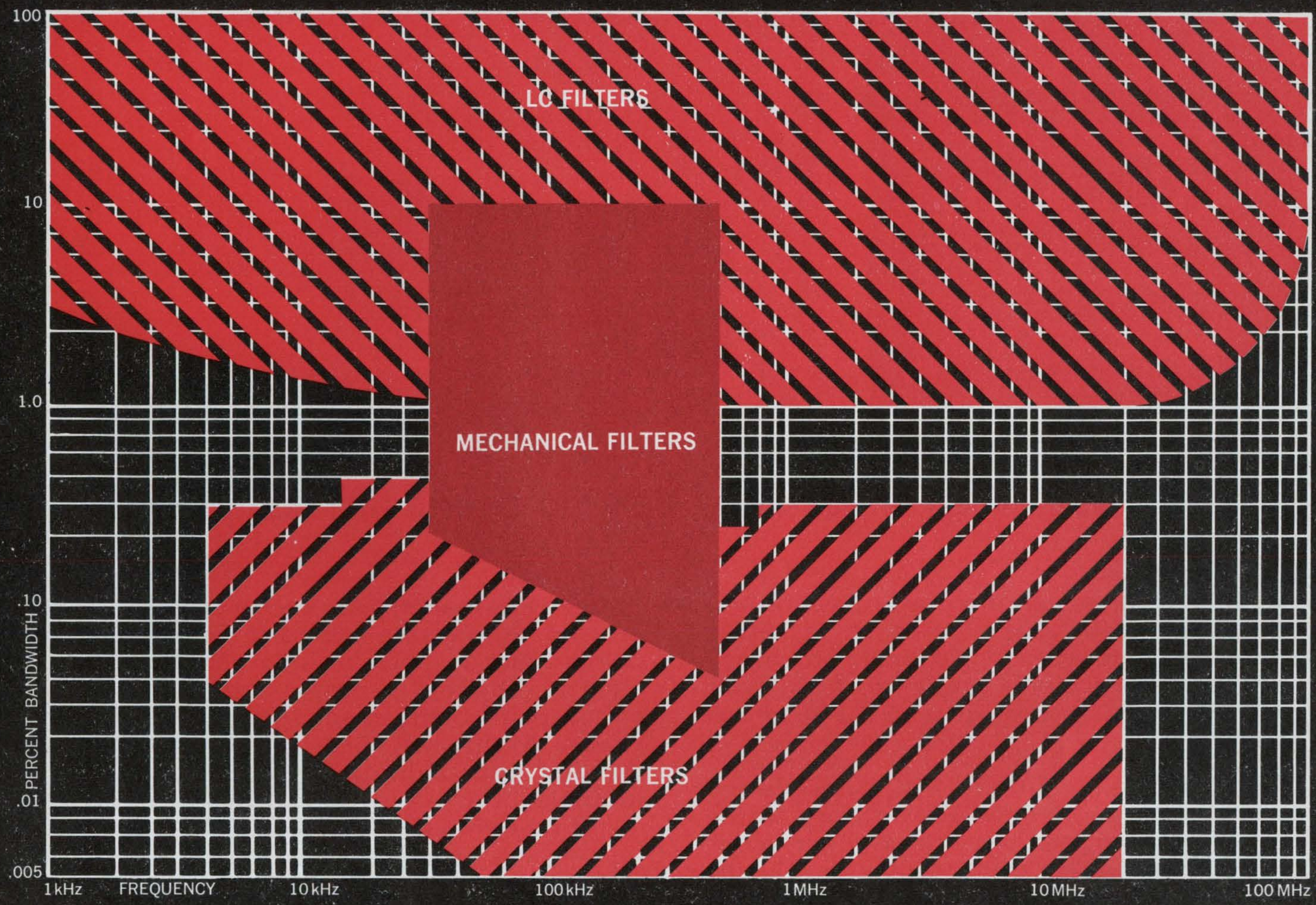
The lens array consists of radiating elements driven by three-bit digital phase shifters. All phase shifters are diode-controlled by the beam-steering unit. The beam-steering unit translates computer commands into the proper logic for actuating each individual phase shifter driver. The drivers set the on-off state of the corresponding diodes of the phase shifters to form the antenna beam in the desired direction.

The elements of the lens are printed dipole collectors, connect-

*(continued on p. 40)*




**A planar microwave lens antenna** collimates and steers the beam of Sperry's Hard Point Demonstration Array Radar. The system has but one transmitter, and its beam scans in two directions under computer command. Diode phase shifters permit both sending and receiving with the same antenna.



100
10
1.0
.10
.01
.005
PERCENT BANDWIDTH
LC FILTERS
MECHANICAL FILTERS
CRYSTAL FILTERS
1kHz
FREQUENCY
10kHz
100kHz
1MHz
10MHz
100MHz

# HOWELL H160 SERIES SOLID-STATE DIGITAL INDICATORS


## ...will measure linear or non-linear signals...or both with multiple input!

The H160 Series will monitor, measure and display . . . with digital readout in direct engineering terms . . . physical processes such as temperature, pressure, flow, voltage, etc., with an accuracy of 0.1% of full scale.

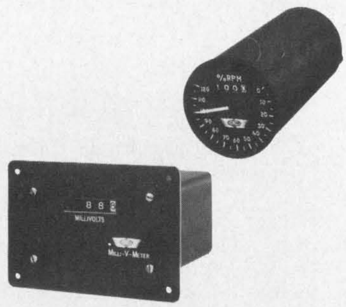
The instruments utilize the null-balance potentiometric principle to measure transducer output signals which are either linear or non-linear. The units follow non-linear functions with multiple, precisely calibrated, straight-line approximations. Non-linear curves of thermocouples, strain gauges or most any other transducer can be accurately followed.

The easy-to-read display sector may include: polarity; numerical readout with decimal point; function such as degrees C, inches Hg, PSI, etc.; out-of-range; and the number of the point being measured. Used with a Howell Multipoint Scanner, input signals may be mixed (linear or non-linear). An example of the Indicator-Scanner System might be a 40-point Scanner with 20 inputs for pressure and 20 inputs for temperature with a single Indicator displaying both sets of data. The data can also be made available in binary-coded decimal or ten-line parallel decimal form at a connector for input to a computer, printer or tape punch.

***Write for detailed brochures.***

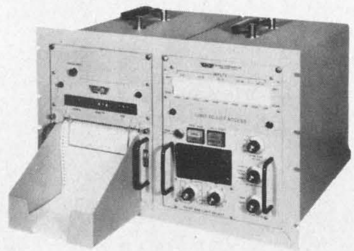
**HOWELL INSTRUMENTS ALSO OFFERS SERVO-DIGITAL INDICATORS, DIGITAL DATA SYSTEMS, AND A WIDE VARIETY OF OTHER INSTRUMENTS ...CUSTOMIZED FOR MANY APPLICATIONS.**

**BH100 and BH186/BH187 Series**




The servo-digital indicators shown above are null-balance instruments utilizing the TA'POT® slidewire. The units are available in various ranges and various direct readouts.

**BH103 Digital Data System**



The BH103 incorporates a 100-point Scanner with direct digital readout and prints the data on folded paper. i.e., EVENTS, TEMP °F, TIME.

**HOWELL INSTRUMENTS, INC.**

3479 West Vickery Blvd.

Area Code 817 336-7411 • Fort Worth, Texas 76017

*ENGINEERING AND SALES OFFICES IN PRINCIPAL CITIES IN THE UNITED STATES, CANADA, ENGLAND, AUSTRALIA, AND JAPAN*

ON READER-SERVICE CARD CIRCLE 26

## University surveys indicate:

# STARTING SALARIES OF ENGINEERS ARE DECEPTIVELY HIGH

**By James M. Jenks**

TWO SEPARATE STUDIES of the salaries made by college graduates appear to contradict the commonly held belief that engineers today make out better financially than their classmates who major in non-technical subjects.

Both surveys were conducted by large universities. The first polled graduate engineers; the second, company executives. And both resulted in identical findings! That is, the average engineer today – despite a deceptively high starting salary–climbs fast but not far.

The need for technically trained men in recent years has exceeded the supply to such an extent that companies have been forced to bid for their services–to actually set-up "recruiting" offices on college campuses all over the country. Thus, starting salaries have gone up and up. But the income ceiling for these technically-trained men is lower than that for managerial personnel.

*Despite the substantial head start engineers have, the differential in money earned over a ten-year period averages out at $7,000 more for the management man.*

And from the tenth year on, the administrator's salary obviously outstrips that of the engineer by a wider and wider margin.

This, of course, is not to say that engineering students would be wise to shift to the study of business administration–or that working engineers face a bleak future. Quite to the contrary, the continuing growth of technology means that men with technical backgrounds are as ideally qualified for the highest rewards industry has to offer–*if they also have a knowledge of the underlying principles of business.*

**FREE..."FORGING AHEAD IN BUSINESS"**

If you want to avoid the thorny barriers to success – if you're ambitious, determined to move up fast – send today for the Institute's 32-page descriptive booklet, "Forging Ahead in Business."

It explains what a man must know today to make $20,000 or more a year . . . what he must do to accumulate this knowledge. It tells why men of equal ability fare so differently in the race for better jobs and bigger salaries. It analyzes the causes of failure . . . the reasons for success. And it outlines an executive-training program which is so complete and so scientific that each day subscribers are brought a little closer to a mastery of business procedures.

There's no charge for "Forging Ahead in Business." And no obligation . . . other than the obligation to read it thoughtfully, and decide for yourself whether the training it describes is meant for you. To obtain your complimentary copy, simply fill out and return the coupon. It will be mailed to you promptly.

**ALEXANDER HAMILTON INSTITUTE**

**235 East 42nd Street, New York, New York 10017**

**ALEXANDER HAMILTON INSTITUTE**
**Dept. 829 235 East 42nd Street**
**New York, New York 10017**

Please mail me, without cost or obligation, your 32-page book, "Forging Ahead in Business."

Name . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Firm Name . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Business Address . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Position . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Home Address . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Zip Code

ON READER-SERVICE CARD CIRCLE 27

*(continued from p. 36)*
ed to strip-line, three-bit digital phase shifters. The phase shifter connects to a probe that is coupled to the radiating horn's interior.

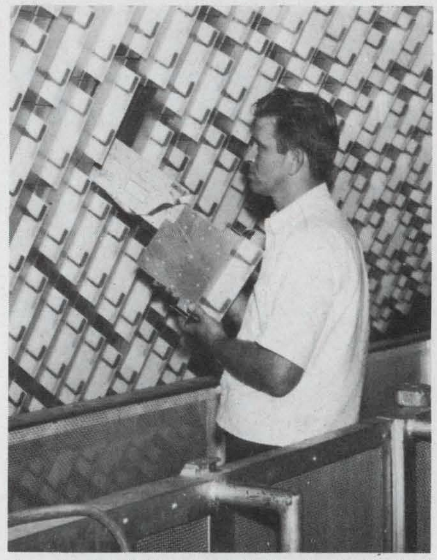
About 4000 dipoles collect energy on the receiving side of the lens for transfer to the radiation side.

The radiator side of the lens contains 3750 elements, of which 2165 are active horn radiators connected to phase shifters. According to Sperry engineers, their method of connecting collectors and radiators creates a space-tapered array on the radiating side of the lens.

The engineers say that the lens has a directive gain of 39.5 dB, with total losses of 3.6 dB. The average side-lobe level is 40 dB.

The radar system has completed most of its acceptance tests, including the simultaneous tracking of several aircraft going in different directions.

While the lens is presently positioned 30 degrees from the vertical, Sperry engineers say it could be set horizontally, flush with the ground, in a hardened silo. ■ ■



**A phase-shifter module** is installed in the collecting side of the large microwave lens in the new radar.

## 2500-MHz TV links medical facilities

A 2500-MHz broadcast television system—reported to be the largest educational TV setup in the medical field—will link five medical facilities in Atlanta, Ga.

This spring, the Radio Corporation of America will install television transmitters for broadcasting medical training programs in Grady Memorial Hospital and the Public Health Service Audiovisual facility (U.S. Dept. of Health, Education and Welfare). These two, and the Veterans' Administration Hospital, Emory University School of Medicine and Hospital, and the Georgia State Department of Health, will have receiving systems.

Roof-top antennas and "down converters" will change the 2500-MHz signals into standard TV frequencies to receive the programs.

According to A. M. Miller, vice president of RCA's Instructional Electronics Dept., 2500-MHz television is ideally suited for linking the five medical facilities since no location is more than 7.2 miles from a transmitter.

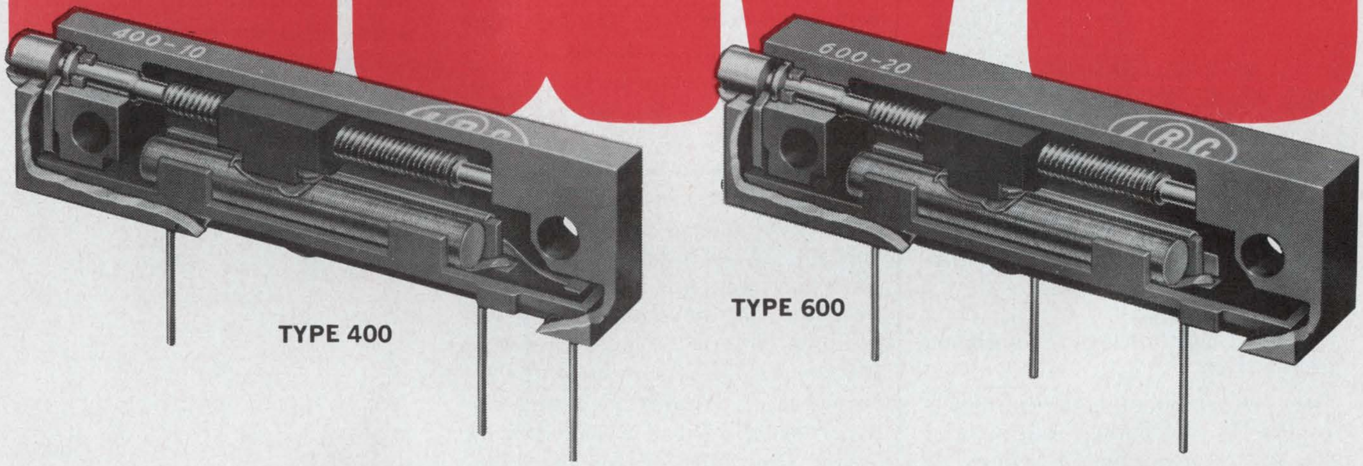
This, he said, is well within the limited broadcasting range of Instruction Television Fixed Station Service—the formal designation of 2500-MHz television established in 1963 when the Federal Communications Commission set aside 31 channels in that frequency band for educational use.

Two TK-60 TV cameras will be supplied to Grady Memorial Hospital. These will be mounted on a specially designed console that can be moved about the hospital to laboratories, auditoriums and elsewhere for broadcasting purposes.

Since the TV system is designed for two-channel operation, transmitters at Grady and the Public Health facility can each be broadcasting a different program simultaneously, or they can go on the air separately.

Last May, RCA installed a 2500-MHz educational TV system linking several hundred Catholic schools in the New York archdiocese. ■ ■

# save




# Military quality at industrial prices

## IRC wirewound rectangular trimmers save space and dollars

IRC's CIRCUITRIM potentiometers offer MIL characteristics at the same price as industrial types. Benefit by upgraded performance and reliability for your industrial needs and impressive savings for your MIL applications.

Both series are designed to perform under environmental requirements of MIL-R-27208. Molded diallyl phthalate cases are rugged, light and practical for use in any military or high grade industrial application. A one-piece, corrosion-resistant shaft and specially designed wiper block system isolate electrical elements and assure "set-and-forget" stability.

The 600 series is designed to MIL-Style RT-11 and is offered with staggered P.C. pins or teflon insulated leads. The 400 series is designed to MIL-Style RT-12 with P.C. pins in-line or teflon insulated leads. It is also available in a thin-line version of RT-11 (Type 400-20) with staggered P.C. pins which offer 30% space savings and complete interchangeability on pre-printed boards.

These low-cost MIL-type units are the result of IRC's years of experience in building high-quality trimmers. Samples available from local sales offices. For prices and data, write: IRC, Inc., 401 N. Broad St., Philadelphia, Pa. 19108.

**ONLY IRC OFFERS ALL 4 POPULAR STYLES**

Wirewound or infinite resolution elements

**CAPSULE SPECIFICATIONS**

| | TYPE 400 | TYPE 600 |
|---|---|---|
| MIL STYLE | RT-12* | RT-11 |
| POWER | 1 W @ 70°C | 1 W @ 70°C |
| TOLERANCE | ±5% | ±5% |
| RESISTANCE | 10Ω to 50KΩ | 10Ω to 50KΩ |
| TEMPERATURE | —55°C to 150°C | —55°C to 150°C |

*Plus thin-line version of RT-11 (Staggered P.C. pins)

IRC®

ON READER-SERVICE CARD CIRCLE 31

# Letters

## Vectors are better kept as vectors

Sir:

The nomograph given by R. L. Peters ["Simplify vector analysis," ED 26, Nov. 22, 1966, pp. 82-84] for the purpose of adding vectors is certainly a clever one, and I should not wish to say anything against it. I think, though, that something should be said against its use in the way suggested: ". . . the first step is to reduce them (the vectors) to the coordinate components. . . ."

In fact, if you do that, have you not just given up using vectors? There is much to be said for keeping the vectors as vectors in the problem as long as possible, and not rushing to introduce **i**, **j** and **k**. This is the way that Newton worked; you will not find a coordinate in the whole *Principia Mathematica*. Unfortunately, the direct use of vectors died out for many years, until it was revived by Gibbs, Heaviside, Chapman, Milne and others about the beginning of this century.

Anyone interested in seeing what can be done by using vectors as vectors might consult E. A. Milne, *Vectorial Mechanics* (London: Methuen & Co., 1948 and 1957) and G. Nadeau, *Introduction to Elasticity* (New York: Rinehart & Winston, Inc., 1964).

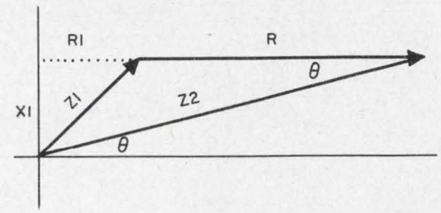
H. L. Armstrong
Queen's University
Kingston, Ont.
Canada

## Equation is as easy as working with a diagram

Sir:

Regarding J. L. Earl's Idea for Design ["Impedance diagram simplifies complex load characterization," ED 24, Oct. 25, 1966, p. 104], this is a useful technique for determining the reactive and resistive components of an impedance when one has limited measuring equipment at hand. However, I might suggest that calculation of the resistance and reactance is equally easy, if one does not want to bother with the drafting tools for the graphical solution.

The necessary equation can be derived as follows:




Given a measured impedance $|Z1|$ to which is added in series a known resistor $R$, resulting in a new measured impedance $|Z2|$, find the resistive ($R1$) and reactive ($X1$) components of $|Z1|$:

$$|Z1|^2 = R^2 + |Z2|^2 - 2R|Z2| \cos\theta \quad (1)$$

$$|Z2| \cos\theta = R1 + R. \quad (2)$$

Substituting Eq. 2 into Eq. 1 and solving for $R1$ give:

$$\begin{aligned} |Z1|^2 &= R^2 + |Z2|^2 - 2R(R1+R) \\ &= R^2 + |Z2|^2 - 2R\,R1 - 2R^2 \\ &= |Z2|^2 - R^2 - 2R\,R1; \\ R1 &= (|Z2|^2 - |Z1|^2 - R^2)/2R; \quad (3) \\ X1 &= (|Z1|^2 - R1^2)^{1/2}. \quad (4) \end{aligned}$$

A. T. Snyder
Senior Group Engineer
Missile & Information Systems Div.
The Boeing Co.
Seattle, Wash.

## The author replies

Sir:

I was pleased to read A. T. Snyder's comments on my Idea for Design. His derivations of the mathematical formulas for $R1$ and $X1$ are entirely correct, and may be used if one can remember the law of cosines or has a table of identities at hand. Most of us in the profession these days use mathematics so little it is surprising that we remember our "times tables."

Another derivation of the equations is as follows:

$$|Z1|^2 = R1^2 + |X1|^2, \quad (1)$$

$$|Z2|^2 = (R1+R)^2 + |X1|^2. \quad (2)$$

If $|X1|^2$ of Eq. 2 is replaced with its equivalent from Eq. 1, then:

$$|Z2|^2 = (R1+R)^2 + |Z1|^2 - R1^2.$$

Solving for $R1$ yields:

*(continued on p. 46)*

$$R1 = (|Z2|^2-|Z1|^2-R^2)/2R; \quad (3)$$

and from Eq. 1:

$$X1 = (|Z1|^2-R1^2)^{1/2}. \quad (4)$$

Equations 3 and 4 are the same as those of Mr. Snyder.

If one has access to a calculator, the values of *R1* and *X1* can be found fairly quickly and accurately. To grind out the solutions in longhand would be too tedious for most of us. A table of logarithms would reduce the work somewhat, but most likely one would decide to accept slide-rule accuracy. Tabulated below are the values of *R1* and *X1* calculated by three different methods:

| | Longhand | Slide rule | Impedance diagram |
|---|---|---|---|
| R1 | 13.6 | 13.8 | 13.5 |
| X1 | 73.3 | 74.2 | 73.5 |

In submitting my idea to ELECTRONIC DESIGN, it was my intention to show that one can return to fundamentals for the solution to a particular problem when the $500 impedance bridge is, for some reason, not available. The method of solution for many of our problems is a matter of personal preference. For some it may be as difficult to find a compass and a sheet of graph paper as it is for others to lay hands on a table of trigonometric identities and logarithms. More than half the engineers I know would have to borrow the slide rule to work out that good enough solution, and only a very few would grind it out the long way.

It was enjoyable, finally, to review some elementary mathematics.

J. L. Earl
Sr. Instrumentation Engr.
Lockheed Missiles & Space Co.
Santa Clara, Calif.

## Silicon FET found to operate at 77°K

Sir:

It was quite interesting to read the article in which you compared germanium and silicon field-effect transistors [ED 22, Sept. 27, 1966, p. 81]. I agree that the Ge FET lends itself to higher-frequency operation than a Si device. I feel that it is the user of the FET who must decide between advantages and disadvantages when he selects the specific device. Essentially time will tell what the outcome of the Ge FET will be.

However, I must fully disagree that a Si FET will not operate below −50°C. Back in 1964 we performed experiments, which we repeated in 1965, with Si FETs at 77°K, or liquid-nitrogen temperature, and we found that if proper $V_p$ is selected, nothing in the world stops the Si FET from operating at that temperature. We even built a two-stage amplifier which, when immersed in liquid nitrogen, operated as well as in free air.

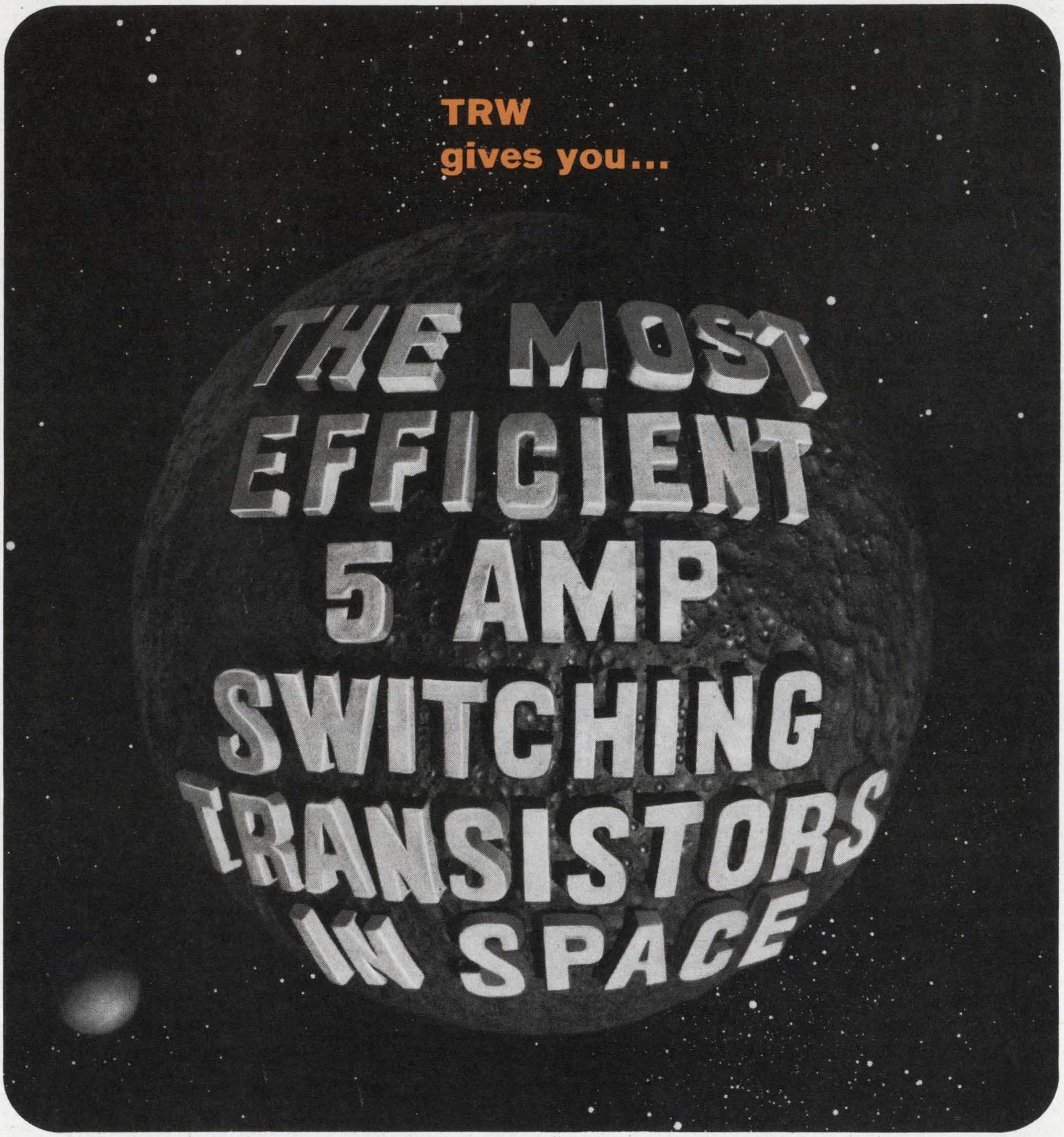
Geza Csanky
Engineering Manager
Special Devices
Dickson Electronics Corp.
Scottsdale, Ariz.

## Accuracy is our policy

In "FET amplifier and relay in a TO-5 can operates directly off low-level microcircuitry" (not microcuitry, as printed), the product cover feature in ED 28, Dec. 6, 1966, pp. 118 and 120, the contact resistance is wrongly stated. The end of the second paragraph on p. 120 should read: "Initial contact resistance is 0.1 Ω, increasing to a maximum of 0.2 Ω" (not 1 Ω and 2 Ω, respectively, as printed). The values in the table of specs on p. 120 are correct.

In "Signal generators 1.62-420 MHz" list, ED 27 (Signal Generator Reference Issue), Nov. 29, 1966, p. 26, Marconi Instruments points out that its model 2002 (listed in section SG-2) has an output of 1 volt, not 0.08 volt as printed.

In "Sweep generators 950-4000 MHz" list, ED 27 (Signal Generator Reference Issue), Nov. 29, 1966, p. 40, Jerrold Electronics' model 900-C (listed in section SW-14) is shown as having a sweep width of 10 kHz to 1 MHz. This is, in fact, only the narrow-band capability. The unit also has a 500-kHz-to-400-MHz wide-band capability.




8-18

**SPEED: 80MHz  GAIN: $50h_{FE}$ @ 1A  SATURATION: 1V @ 5A**

Every characteristic the designer needs for top performance airborne inverters and switching regulators are combined in the new TRW 2N4305—2N4312 power transistors...high frequency...high gain...low collector saturation voltage.

Another plus factor in this outstanding new series is operating voltage characteristics as high as 120V.

Available in TO-5 packages. Available in Low Profile Isolated Stud packages. Available NOW from authorized distributors everywhere!

For detailed technical information write TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif. 90260. Phone: 679-4561. TWX: 910-325-6206. Cable TRWSEMICONS / Telex: 67-7148.

**TRW SEMICONDUCTORS**

ON READER-SERVICE CARD CIRCLE 36

EDITORIAL

# War is hell — and let's face it: it costs like it, too

As the war in Vietnam heats up, more and more is heard about the low reliability of much military electronic equipment. Statements are made by Government advisers and others about the need to keep large numbers of manufacturers' representatives there to maintain and repair the equipment. This is hard to reconcile with our universally recognized advanced electronic technology, our achievements in space, and the impressive variety of reliable electronic and electrical consumer products that U.S. industry turns out.

Before an official hunt for scapegoats is begun, and before the design engineer (with no lobby to defend him) is blamed, investigators would do well to examine Government production procurement policies.

Production orders are commonly placed through IFBs (Invitations For Bids). The IFB awards are made on the basis of many factors, of which technical excellence and a contractor's reputation frequently are comparatively minor points. Right at the start, qualified firms may be precluded from bidding through so-called set asides. These stem from the Government's practice of setting aside parts of some orders for labor-surplus areas or for small-business encouragement. The social goal is admirable, but there is no guarantee that the final equipment will be the best. And, of course, in all IFBs the lowest bidder wins—even though the way he cuts corners may be dubious.

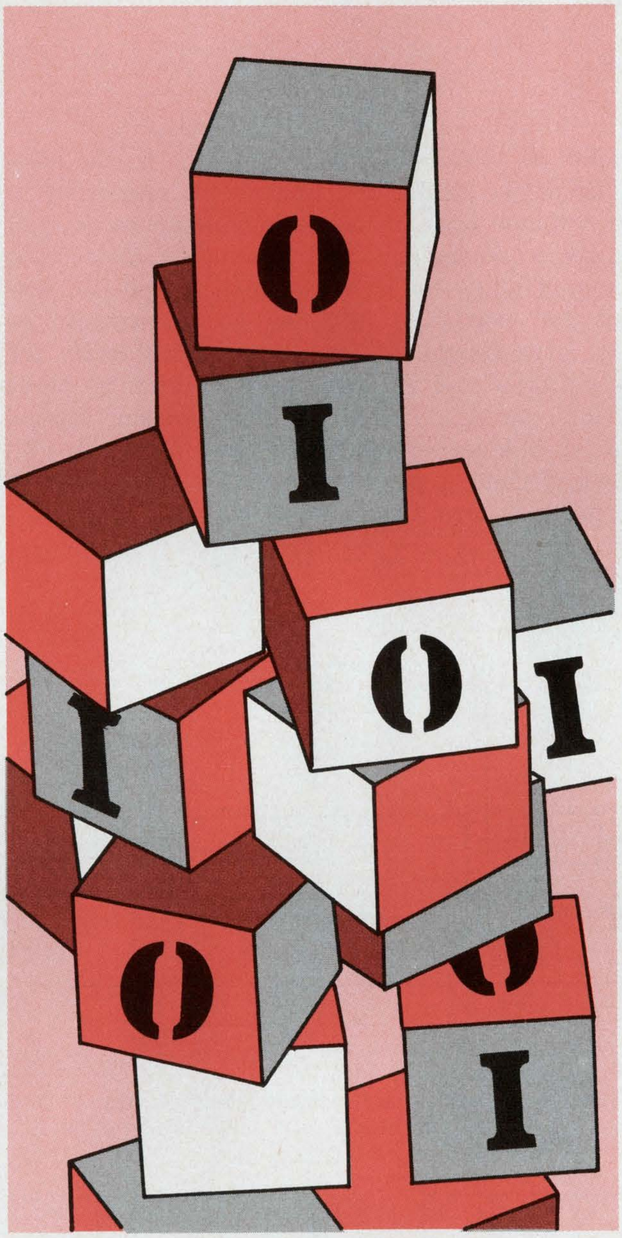
The same specifications can be interpreted differently by two contractors—and 100 per cent legally correctly in each case, too! A conscientious contractor, accustomed to manufacturing quality products, will naturally interpret the specifications as the minimum requirement. A "cost-saving" contractor will be looking for loopholes to enable him to squeak by. As a result, equipment that "meets the specifications" sometime fails the acid test on the battlefield.

The old saying, "You get what you pay for," is still valid. Here's an actual case: Not too long ago the Government called for bids to modify the circuitry of an alarm box, designed to alert troops to chemical-warfare attack. The IFB also called for an insulated container, so the alarm could be used in the winter. A small, marginally equipped company won, with a bid 50 per cent below that of the next bidder. The delivered equipment featured phenolic peg boards (radio-amateur variety) instead of glass-epoxy PC cards, cotton cocoons instead of double-wall, epoxy-filled insulating foam. Yet it was all "in spec."

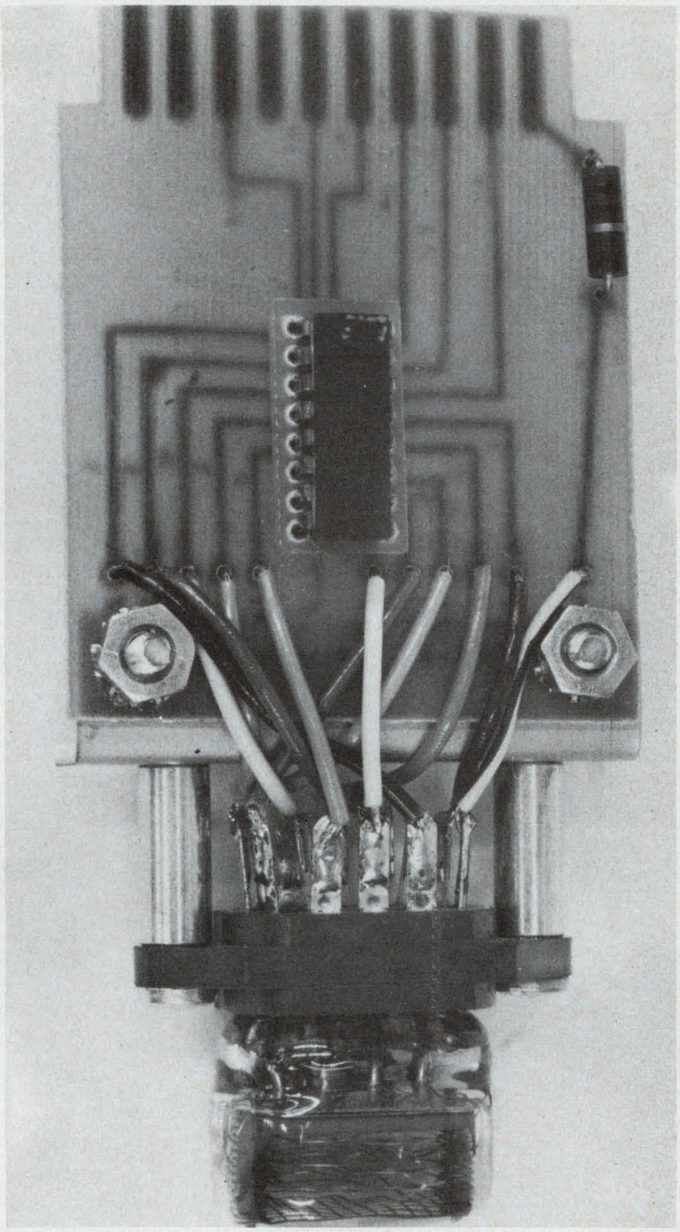
If the Government wants the best equipment, its first and only loyalty must be to our fighting men—not to an arbitrary set of procurement rules. It's time we repaired the rules instead of the equipment.

PETER N. BUDZILOVICH

# Technology




**Tunnel-diode building blocks pave road** to high-speed digital systems. Page 74



**Bidirectional decade counters excel** wherever totals need addition and subtraction. Page 58

## Also in this section:

# Simplify feedback amplifier design

with this set of straightforward equations that can be applied to a wide variety of circuits.

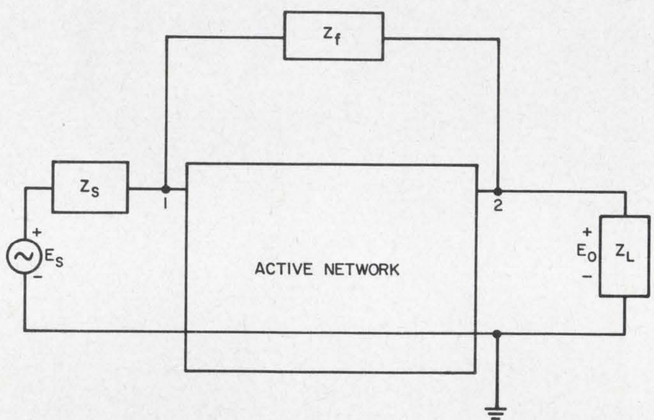
Most existing information on feedback amplifier design and analysis treats these useful circuits in a general sense. That is, signal flow or block diagram techniques are employed to investigate the effects of feedback on impedance levels, gain, sensitivity of circuit characteristics with respect to active-element parameter changes, stability, and the like. Even though these general techniques succeed in adapting basic feedback concepts to the problem of feedback amplifier design, an attempt to design a specific feedback network can be overcomplicated, particularly because of the relatively complex analysis involved.

Fortunately, there is another way—a straightforward set of design equations for a specific, widely used class of small-signal feedback amplifiers that employ an impedance element in the feedback path between the output and input terminals (Fig. 1). Although a single-stage transistor amplifier will be used to develop these equations, the approach can also be applied to any three-terminal, small-signal, multistage amplifier with a phase shift that is an odd multiple of 180 degrees. Unlike many existing design approaches, this one includes consideration of the effects of biasing resistances. Finally, a design example will be presented to demonstrate how the derived equation can be put into practice.

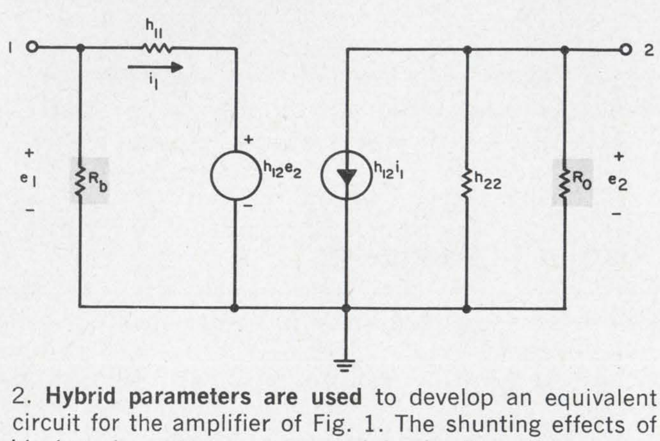
To start, consider a three-terminal active circuit in "black box" form (Fig. 1) that drives a load of impedance $Z_L$ from a source of internal impedance $Z_s$. A two-terminal impedance element, $Z_f$, is connected between input terminal 1 and output terminal 2. If the active network is presumed to be linear, it can be represented by any one of a number of commonly used two-port equivalent circuits.[1] In this case, hybrid parameters will be used. Shunting of the input and output ports by the biasing resistors of the active network is accounted for by resistances $R_b$ and $R_o$, respectively, as shown in Fig. 2.

Hybrid parameter $h_{12}$ is a measure of the amount of voltage feedback inherent in the electronic device itself. For transistors operating in the common-base or common-emitter mode and for the grounded-grid and grounded-cathode-tube configurations, $h_{12}$ is very small (typically less than $10^{-3}$ volt/volt) and can be assumed to be zero. Even though $h_{12}$ is approximately unity for the emitter- and cathode-follower circuits, these circuits can be excluded from the present discussion, since a connection such as that shown in Fig. 1 would yield a positive feedback system. With $h_{12}$ taken as zero, the input impedance is:

$$Z_i = h_{11} R_b/(h_{11}+R_b), \qquad (1)$$




1. **Design equations are derived** through use of this block diagram representation of a feedback amplifier.




2. **Hybrid parameters are used** to develop an equivalent circuit for the amplifier of Fig. 1. The shunting effects of biasing elements are accounted for by $R_b$ and $R_o$.

**John Choma, Jr.,** Instructor, Dept. of Electrical Engineering, University of Pittsburgh, Pittsburgh.

and the output impedance is:

$$Z_o = R_0/(1+h_{22}R_0). \qquad (2)$$

The voltage gain, $G_0$, is:

$$G_0 = e_2/e_1$$
$$= -h_{21}Z_o/h_{11}. \qquad (3)$$

Consequently, Eqs. 1, 2, and 3 can be used to derive a second equivalent circuit for the active network of Fig. 1. This circuit appears in Fig. 3a; Fig. 3b depicts the entire feedback amplifier using the equivalent representation of Fig. 3a.

Voltage gain for the network of Fig. 3b is determined by writing nodal equations for terminals 1 and 2:

$$e_1/Z_i+(e_1-E_s)/Z_s+(e_1-E_o)Z_f=0; \qquad (4a)$$

$$E_o/Z_L+(E_o-G_0\,e_1)/Z_o+(E_o-e_1)/Z_f=0. \qquad (4b)$$

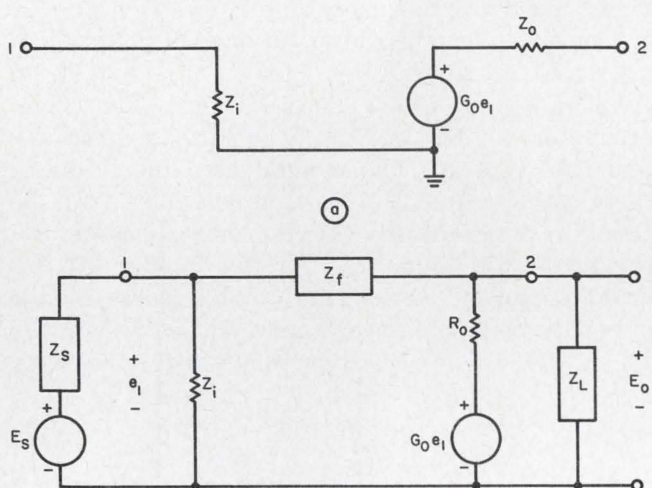
Solving for the transfer function gives:

$$E_o\,E_s = \frac{[Z_i/(Z_i+Z_s)]\,[G'+(Z_o\|Z_L)/Z_f]}{1+Z_o\|Z_L/Z_f+(1-G')Z_i\|Z_s/Z_f}, \qquad (4c)$$

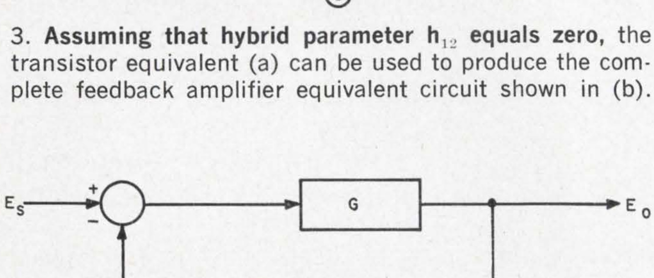
where

$$G' = G_0\,Z_L/(Z_o+Z_L). \qquad (4d)$$

Equation 4c gives the expression for the voltage gain of the feedback amplifier of Fig. 1 in terms of source, input, output, load, and feedback impedances, and the parameter $G'$. In Fig. 3b, note




3. **Assuming that hybrid parameter $h_{12}$ equals zero,** the transistor equivalent (a) can be used to produce the complete feedback amplifier equivalent circuit shown in (b).




4. **Reducing a feedback amplifier into block diagram form** allows the application of stability, sensitivity and other important concepts to the design of the amplifier.

that $G'$ is simply the open loop-voltage gain of the loaded amplifier.

Because $G'$ is directly related to the gain of the active element, for high-beta transistors ($\beta \geqq 50$), pentodes, and high-mu triodes ($\mu \geqq 20$), $|G'|>>1$ and $|G'|>>(Z_o\|Z_L)/Z_f$. With this assumption, and letting $F(s) = E_o/E_s$, Eq. 4c becomes:

$$F(s)=\left[\frac{Z_i}{Z_i+Z_s}\right]\left\{\frac{G'}{1+G'\left[\dfrac{Z_o-G_0\,(Z_i\|Z_s)}{G_0\,Z_f}\right]}\right\} \qquad (5a)$$

This can be rewritten in the simple form:

$$F(s) = G/(1+GH), \qquad (5b)$$

where

$$G=G'\,Z_i/(Z_i+Z_s), \qquad (5c)$$

$$H=[(Z_i+Z_s)/Z_i]\{[Z_o-G_0(Z_o\|Z_s)]/G_0\,Z_f\}. \qquad (5d)$$

Equation 5b can be recognized as the "standard form" feedback gain, which can be derived by employing block diagram techniques for the system depicted in Fig. 4.

In effect, therefore, the general feedback configuration of Fig. 1 has been reduced to the standard-form block diagram of Fig. 4. The advantage of this manipulation is that theories of stability, sensitivity, and other important concepts, which have been extensively developed in the systems literature, can be applied to the feedback amplifier considered here.[2,3] However, care must be exercised when employing these theories, since the literature generally presumes that $G$ and $H$ are independent functions. Inspection of Eqs. 5c and 5d shows that only when $Z_i >> Z_s$ and $G_0 >> (Z_o/Z_i\|Z_s)$ are $G$ and $H$ approximately independent of one another. For pentode amplifiers, these two approximations are valid; for some triode and transistor networks, they are too restrictive, and this must be considered during design. This interdependence complicates the gain sensitivity expression for the amplifier.

A major purpose of employing feedback around a given open-loop amplifier is to reduce the dependence of over-all amplifier gain on active-device parameters. The circuit designer may often focus his attention on variations of system gain with respect to fluctuations in the active parameter $h_{21}$. A measure of the amount of dependence of gain on $h_{21}$ is the so-called sensitivity factor, $S$, which may be defined as:

$$S = (dF/F)/(dh_{21}/h_{21})=(h_{21}/F)(dF/dh_{21}). \qquad (6)$$

Equation 6 may be expressed in terms of the circuit of Fig. 1 by separately evaluating both terms on the right-hand side. Using Eq. 5:

$$h_{21}/F = (1+GH)h_{21}/G, \qquad (7a)$$

and

$$dF/dh_{21}=[(dG/dh_{21})-(G^2dH/dh_{21})]/(1+GH)^2. \qquad (7b)$$

Substituting Eqs. 3, 4d and 5c into Eq. 7a yields:

$$h_{21}/F = -(1+GH)(h_{11}/Z_o)[(Z_i+Z_s)/Z_i][(Z_o+Z_L)/Z_L]; \quad (7c)$$

hence, using Eqs. 7b and 7c, Eq. 6 becomes:

$$S = [1/(1+GH)](h_{11}/Z_o)[(Z_i+Z_s)/Z_i][(Z_o+Z_L)/Z_L][G^2(dH/dh_{21})-(dG/dh_{21})]. \quad (7d)$$

To put Eq. 7d into more useful form, we can evaluate the two derivatives in the last bracketed term. Using Eqs. 3, 4d and 5c gives:

$$dG/dh_{21} = -[Z_i(Z_i+Z_s)][Z_L(Z_L+Z_o)](Z_o/h_{11}). \quad (8a)$$

Substituting Eq. 3 into Eq. 5d leads to an expression for $G^2\, dH/dh_{21}$:

$$H = -[(Z_i+Z_s)/Z_i][(h_{11}/Z_f\, h_{21}) - (Z_i||Z_s)/Z_f];$$

$$dH/dh_{21} = [(Z_i+Z_s)/Z_i](h_{11}/Z_f)(1/h_{21}{}^2);$$

$$G^2dH/dh_{21} = [(Z_i+Z_s)/Z_i](h_{11}/Z_f)[Z_i/(Z_i+Z_s)]^2[Z_L/(Z_L+Z_o)]^2(Z_o/h_{11})^2. \quad (8b)$$

After algebraic manipulation, Eqs. 8a and 8b substituted into Eq. 7d give the desired result:

$$S = [1/(1+GH)]\{(Z_o/Z_f)[Z_L/(Z_L+Z_o)][(Z_i+Z_s)/Z_i][Z_i/(Z_i+Z_s)]+1\}. \quad (8c)$$

$$= [1/(1+GH)]\{GHZ_o/[Z_o-G_0(Z_i||Z_s)]+1\}.$$

Eq. 8c can be further simplified if note is taken of the fact that product $GH$ is the return ratio, $T$, for the feedback amplifier.[4] Therefore, letting:

$$T = GH, \quad (8d)$$

Eq. 8c becomes:

$$S = [1/(1+T)]\{1+T/[1-G_0(\overline{Z_i||Z_s}/Z_o)]\}. \quad (8e)$$

In a given design, sensitivity factor $S$ is usually given, or its value is dictated, by the requirements imposed on the feedback amplifier. It will therefore be convenient to have return ratio $T$ expressed as a function of $S$. Manipulation of Eq. 8e yields:

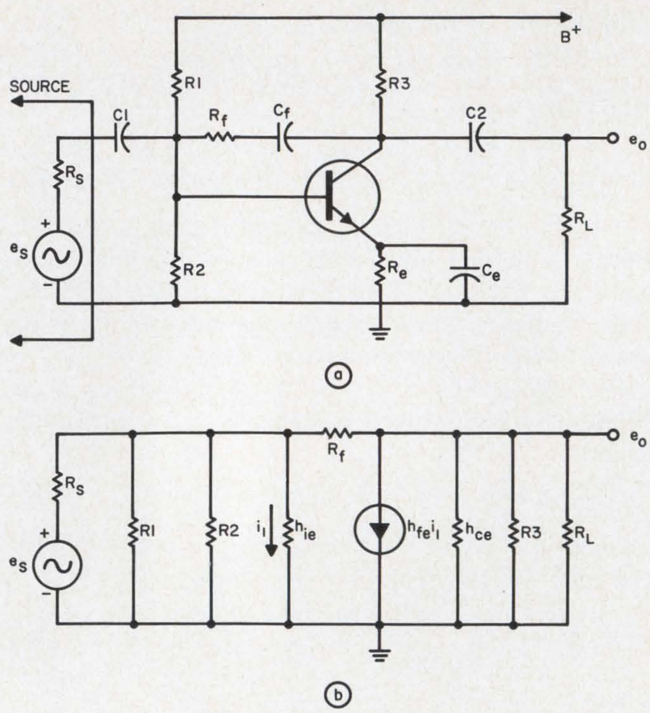
$$T = (1-S)/\{S-[1/(1-G_0\, Z_i||Z_s/Z_o)]\}. \quad (8f)$$

Everything on the right hand side of Eq. 8f is known and thus the return ratio necessary to fulfill sensitivity specifications can be calculated.

### Sample design illustrates method

To indicate the simplicity with which all of the previously developed equations can be employed in a practical design, consider the amplifier of Fig. 5a, together with its mid-frequency small-signal equivalent circuit, shown in Fig. 5b.

In Fig. 5a, $R_1$, $R_2$, $R_3$, and $R_e$ serve to bias the transistor at the desired quiescent operating point. Capacitors $C_1$, $C_2$, and $C_e$ are chosen to provide the desired response at low frequencies, while $C_f$ is employed to ensure that feedback resistance $R_f$ does not affect the quiescent operating point. Capacitor $C_f$ should appear as an ac short in comparison with $R_f$ at the signal frequencies of interest. Of course, if $R_f$ is large enough, $C_f$ may be omitted.




**5. Straightforward design equations developed in the text** can be used to obtain parameter values for this feedback amplifier (a) whose equivalent circuit (b) is developed with the assumption that $h_{re}$ equals zero.

The example will show the calculations which are necessary to arrive at values for $R_f$ and $R_L$ to fulfill a given set of specifications. Therefore, assume $R1 = 180$ kΩ, $R2 = 39$ kΩ, $R3 = 12$ kΩ, and $R_e = 3.3$ kΩ. The method used in obtaining these values, and also capacitor values, can be found in the literature.[5] Furthermore, assume, for the transistor employed, that $h_{ie} = 3.5$ kΩ, $h_{oe} = 11$ μmho, $h_{fe} = 300$, and that a voltage gain of $-50$ is to be obtained from a source resistance, $R_s$, of 100 Ω. The sensitivity of voltage gain with respect to perturbations in $h_{fe}$ is specified as 20%.

STEP 1: Comparison of Fig. 5b with Fig. 2 reveals that $R_b = R1||R2 = (39)(180)/(219) = 32$ kΩ, and $R_0 = R3 = 12$ kΩ.

STEP 2: Eq. 1 gives $Z_i = h_{11}||R_b = h_{ie}||R_b = (3.5)(32)/(35.5) = 3.16$ kΩ, while Eq. 2 yields $Z_o = R_0/(1+h_{22}R_0) = R_0/(1+h_{oe}R_0) = (12)/(1.132) = 10.6$ kΩ.

STEP 3: Eq. 3 is used to calculate $G_0 = -h_{21}Z_o/h_{11} = -h_{fe}Z_o/h_{ie} = -(300)(10.6)/(3.5) = -917$. This is the open-circuit voltage gain with no feedback element connected.

STEP 4: The required return ratio can be calculated from Eq. 8f by first noting that $Z_i||Z_s = Z_i||R_s = (3.16)(0.1)/(3.26) = 0.097$ kΩ. Then, from Eq. 8f:
$T = (1-0.2)/\{0.2-1/[1+(917)(0.097/10.6)]\} = 8.52.$

STEP 5: The required closed-circuit voltage gain without feedback, from Eq. 5b, is: $G = (1+GH)F = (1+T)F = (9.52)(-50) = -476$. Consequently, $H = T/G = (8.52)/(-476) = -0.0179$.

STEP 6: Equation 5c shows that $G' = (Z_i+Z_s)G/Z_i = (3.26)(-476)/(3.16) = -491$; whence, from Eq. 4d: $Z_L = Z_o/[(G_0/G')-1] = 10.6/[(917/491)-1] = 12.2$ kΩ.

STEP 7: The value of $R_f$ (or $Z_f$) can now be computed from Eq. 5d: $R_f = Z_f = [(Z_i+Z_s)/Z_i]\{[Z_o-G_0(Z_i \| Z_s)]/HG_0\} = (3.26/3.16)[10.6+(917)(0.097)/(0.0179)(917)] = 6.26$ kΩ. Either a 5.6-kΩ or a 6.8-kΩ, 10%-tolerant resistance can be effectively employed for $Z_f$ in this design. The design of the circuit at mid-frequencies is now complete.

Although the synthesis of a particular transistor amplifier was considered, the procedure developed is applicable to a large class of $N$-stage amplifiers, having a net phase shift of 180 ($N$) degrees, where $N$ is an odd integer. In fact, the design procedure is applicable to any amplifier which can be represented by the equivalent circuit of Fig. 3.

The primary advantage in representing the amplifier in block diagram form is the resultant simplicity of the design equations. Furthermore, although only a mid-frequency design was discussed, the fact that the amplifier can be represented in system form as in Fig. 4 implies that Bode, root locus, root contour, and Nyquist techniques can be effectively implemented in a more complex design, where feedback impedance $Z_f$ must be chosen to fulfill not only sensitivity specifications but also special frequency-response requirements. Finally, besides voltage gain and sensitivity, other circuit characteristics can be expressed in terms of the easily manipulated block diagram variables, $G$ and $H$. For example, application of circuit theory to Fig. 3 will easily show that the impedance seen by the source is very nearly the parallel combination of $Z_i$ and $Z_f/(1-G)$. ■ ■

**References:**

1. Paul M. Chirlian, *Analysis and Design of Electronic Circuits* (New York: McGraw-Hill Book Co., 1965), pp. 84-91.

2. John J. D'Azzo and Constantine H. Houpis, *Feedback Control System Analysis and Synthesis* (New York: McGraw-Hill Book Co., 1960).

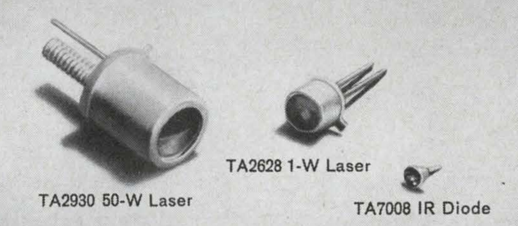
3. John G. Truxal, *Automatic Feedback Control System Analysis* (New York: McGraw-Hill Book Co., 1955).

4. *Multistage Transistor Circuits* (Semiconductor Electronics Education Committee, Vol. V [New York: John Wiley & Sons, Inc., 1965]), p. 89.

5. Maurice V. Joyce and Kenneth K. Clarke, *Transistor Circuit Analysis* (Reading, Mass.: Addison-Wesley Pub. Co., Inc., 1961), chaps. 3 and 4.

ON READER-SERVICE CARD CIRCLE 41 ➤

# Introducing... RCA Solid-State GaAs Optical Devices




- Injection Lasers with 1- to 50-W outputs at *room temperature* and threshold currents *below 15A*
- Miniature IR Diode Emitter with focused light output

| | TA2628 laser | TA2930 laser | TA7008 IR diode |
|---|---|---|---|
| Peak Power Output (min) @ 27°C | 1 W @ 30 A | 50 W @ 30 A | 0.6 mW @ 0.1 A |
| Threshold Current | 15 A | 15 A | 120 mA |
| Output Wavelength | 9050 Å ±50 | 9050 Å ±50 | 9100 Å ±50 |
| Line Width | 5—10 Å | 60—100 Å | 600 Å ±50 |
| Operating Temp. | –196 to 50°C | –196 to 50°C | –73 to 85°C |
| Pulse Width/ Repetition Rate | 0.2 μs/1000 pps | 0.2 μs/1000 pps | CW |

RCA Electronic Components and Devices

**The Most Trusted Name in Electronics**

RCA's wealth of semiconductor experience introduces a new dimension of practicality to solid-state lasers and light diodes. Available now in sampling quantities, each of these optical devices represents an important new tool for the field of electro-optics.

Check these performance benefits of RCA's TA2628 and TA2930*laser diodes:

*Practical Power Outputs*—conservative peak power rating from 1 to 50 W at room temperature.

*Practical Pulse Current*—lasing action begins with threshold currents below 15 A.

*Practical Circuit Usage*—Inexpensive semiconductor pulse circuits can be used without cryogenic hardware.

*Practical Size*—hermetically sealed in modified TO-5 and TO-46 packages.

RCA's new laser diodes are ready now for your evaluation in applications such as secure communications, intrusion alarms, traffic control, instrumentation, ranging and field illumination.

And RCA's new TA7008 IR emitter is equally exciting. Featuring a miniature but highly efficient parabolic reflection system, this tiny device provides a new source of focused light for applications such as card-reading.

Call your RCA representative today for more information on RCA's new family of developmental optical devices. For data sheets and application note on laser power supplies, write RCA Commercial Engineering, Section IG1-3, Harrison, N.J.

*The availability of the TA2930 laser array is presently limited to qualified defense contractors.

# IC bidirectional counters cost less

than two unidirectional counters. Here are three that can be designed with RT micrologic.

Bidirectional decade counters—counters that count either up or down—are extremely useful for keeping track of totals wherever digits are both added and subtracted. Far more convenient and cheaper than two unidirectional counters, they are perfectly suited for such applications as pulse summing (as in maintaining the correct slack in a loop of magnetic tape), position indicating (as in locating nuclear-reactor control rods), and measuring (as in counting fringes in an optical interferometer). Decade up-down counters display these results in decimal form rather than in binary.

Here are three designs for such counters—a Modulo 10 shift decade, a binary-quinary decade, and a 1-2-4-8 binary-coded decimal (BCD) decade. All three can be constructed with an industrial line of integrated circuit flip-flops and resistor-transistor logic.[1] RTL gates are available in an epoxy package. RTL is also the least expensive integrated logic on the market.

All three counters offer equal performance. The Modulo 10 is easiest to design, because there are no redundant codes. Since it is a shift register with five flip-flops, it returns to zero from nine without the need for a complex feedback loop to direct it to do so. Although its code is not as popular as the 1-2-4-8 code, the Modulo 10 decade counter is fine for counting, dividing and multiplying when its output need not interface with other equipment.

Since the two other counters can count past 10, some sort of feedback must be included in the design.

### Modulo 10 shift decade counter uses J-K flip-flops

A Modulo 10 shift counter[2] uses five J-K flip-flops,[3] which produce the states shown in Table 1.

**Kay D. Smith**, Senior design engineer, General Instrument Corporation*, Microelectronic Division, Hicksville, N. Y.
*Formerly with Phillips Petroleum Company

The logic levels for Table 1 and subsequent tables are 0 volts for the logical *1* and +0.9 volt for the logical *0*. $Q$ outputs refer to the *1* output of the J-K flip-flop.

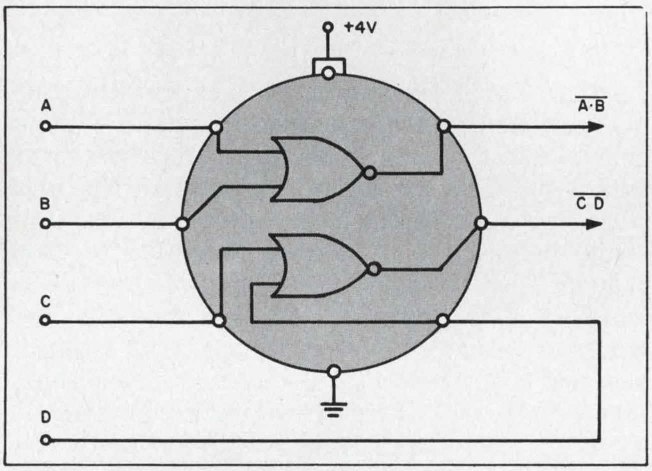
The use of the J-K truth table in Table 1 makes it possible to fill in the values for the various set and clear inputs to the J-Ks.

For example, the set and clear inputs for forward direction to the $Q_1$ flip-flop are illustrated as columns $Q_{1S}$ and $Q_{1C}$. It is assumed that the Modulo 10 shift decade starts out in the reset state, where all $Q$ outputs are *1*s. Thus, in the forward direction, it is necessary to change $Q_1$ from a *1* to a *0* on application of the first trigger command. By use of the J-K truth table, it is seen that applying either a *0-1* or a *1-1* to the set-clear inputs of $Q_1$, produces a *0* output (that is, an $\overline{X}_n$ output). Since the set input ($Q_{1S}$) can be in either state (*0* or *1*), it is a $\phi$ symbol (don't-care state) in Table 1. However, the clear input ($Q_{1C}$) must be in the *1* state to produce the correct output. This analysis produces the $\phi$-*1* state for the $Q_{1S}$-$Q_{1C}$ inputs for the reset state of the forward direction. Other values of the $Q_{1S}$-$Q_{1C}$ column are derived in a similar manner. Columns for $Q_{2S}$ through $Q_{5S}$ and $Q_{2C}$ through $Q_{5C}$ are also derived by a similar technique.

It is now possible to write the switching function for each set and clear input. Since the unit is to be a shift counter, the trigger input ($T$) to the J-Ks will be tied to the counter input: no switching function is required for the $T$ inputs.

To determine the switching function, weights of $Q_1 = 1$, $Q_2 = 2$, $Q_3 = 4$, $Q_4 = 8$, and $Q_5 = 16$ are assigned to the J-K outputs. A decimal equivalent number can now be assigned to each state of the counter, as shown in Table 1. These numbers are equal to the sum of the weights of the $Q$ columns which have logical *1*s in their rows.

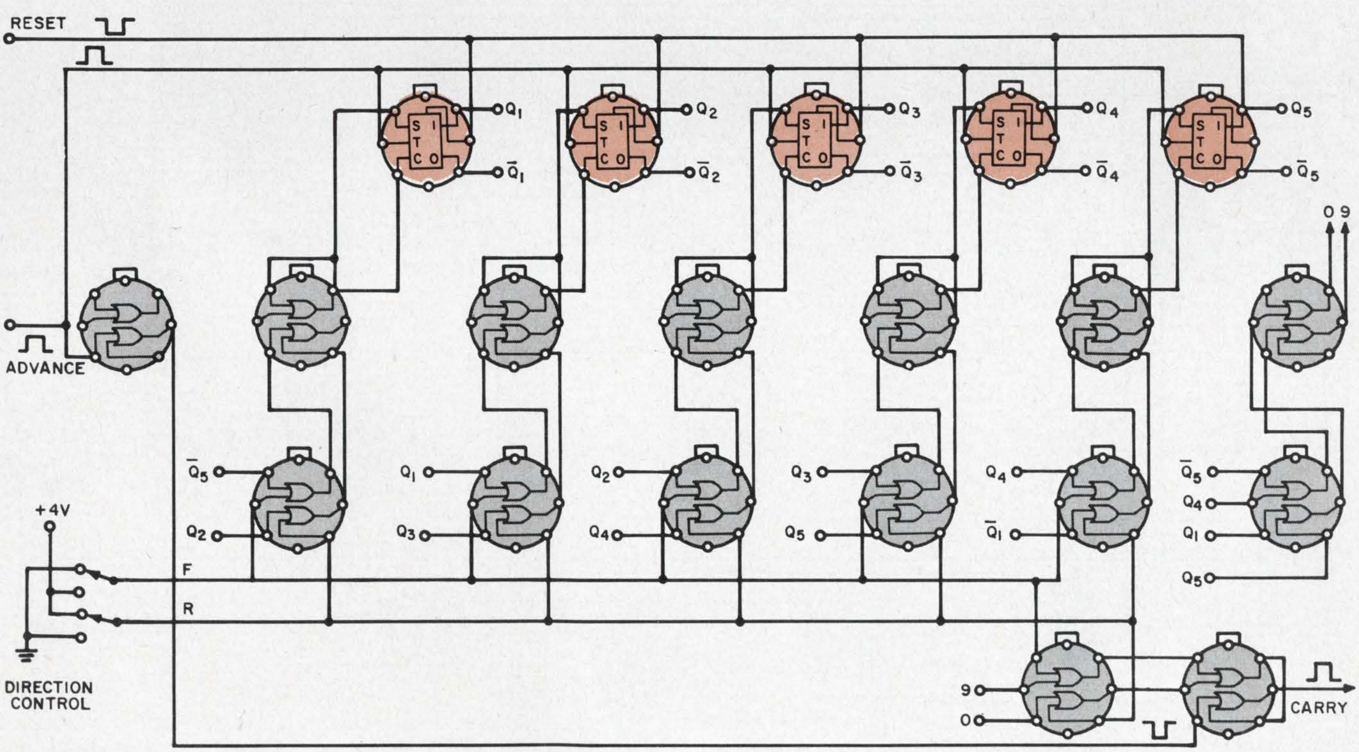
The switching functions are arrived at by summing the decimal equivalent values for the desired input. In this process the $\Sigma_1$ notation denotes that the switching function has the value *1* at that particular set of decimal values. Similarly the $\Sigma_0$




1. **The logic symbol for an RTL gate.** Available in epoxy, resistor-transistor logic is inexpensive.

## Table 1. Code for Modulo 10

| Decimal output | Decimal equiva-lent | J-K flip-flop output 1 2 4 8 16 $Q_1$ $Q_2$ $Q_3$ $Q_4$ $Q_5$ | Forward $Q_{1S}$ | Forward $Q_{1C}$ | Reverse $Q_{1S}$ | Reverse $Q_{1C}$ |
|---|---|---|---|---|---|---|
| 0 | 31 | 1 1 1 1 1 | $\phi$ | 1 | $\phi$ | 0 |
| 1 | 30 | 0 1 1 1 1 | 0 | $\phi$ | 1 | $\phi$ |
| 2 | 28 | 0 0 1 1 1 | 0 | $\phi$ | 0 | $\phi$ |
| 3 | 24 | 0 0 0 1 1 | 0 | $\phi$ | 0 | $\phi$ |
| 4 | 16 | 0 0 0 0 1 | 0 | $\phi$ | 0 | $\phi$ |
| 5 | 0 | 0 0 0 0 0 | 1 | $\phi$ | 0 | $\phi$ |
| 6 | 1 | 1 0 0 0 0 | $\phi$ | 0 | $\phi$ | 1 |
| 7 | 3 | 1 1 0 0 0 | $\phi$ | 0 | $\phi$ | 0 |
| 8 | 7 | 1 1 1 0 0 | $\phi$ | 0 | $\phi$ | 0 |
| 9 | 15 | 1 1 1 1 0 | $\phi$ | 0 | $\phi$ | 0 |




2. **The Modulo 10 shift decade is the easiest to design** because it requires no feedback loop to return it to zero after it reaches nine: its code has precisely ten positions. But it is hard to interface with accessories.

notation denotes that the switching function has the value *0* at the given set of decimal values. All other decimal values are don't-care values.

Using $F$ = forward direction and $R$ = reverse direction, the switching functions for $Q_{1S}$ and $Q_{1C}$ become:

$$Q_{1S} = F \cdot [\Sigma_1(0) + \Sigma_0(16, 24, 28, 30)] + \mathrm{R} \cdot [\Sigma_1(30) + \Sigma_0(0, 16, 24, 28)],$$
$$Q_{1C} = F \cdot [\Sigma_1(31) + \Sigma_0(1, 3, 7, 15)] + \mathrm{R} \cdot [\Sigma_1(1) + \Sigma_0(3, 7, 15, 31)].$$

Switching functions $Q_{2S}$ through $Q_{5S}$ and $Q_{2C}$ through $Q_{5C}$ are derived in an identical manner.

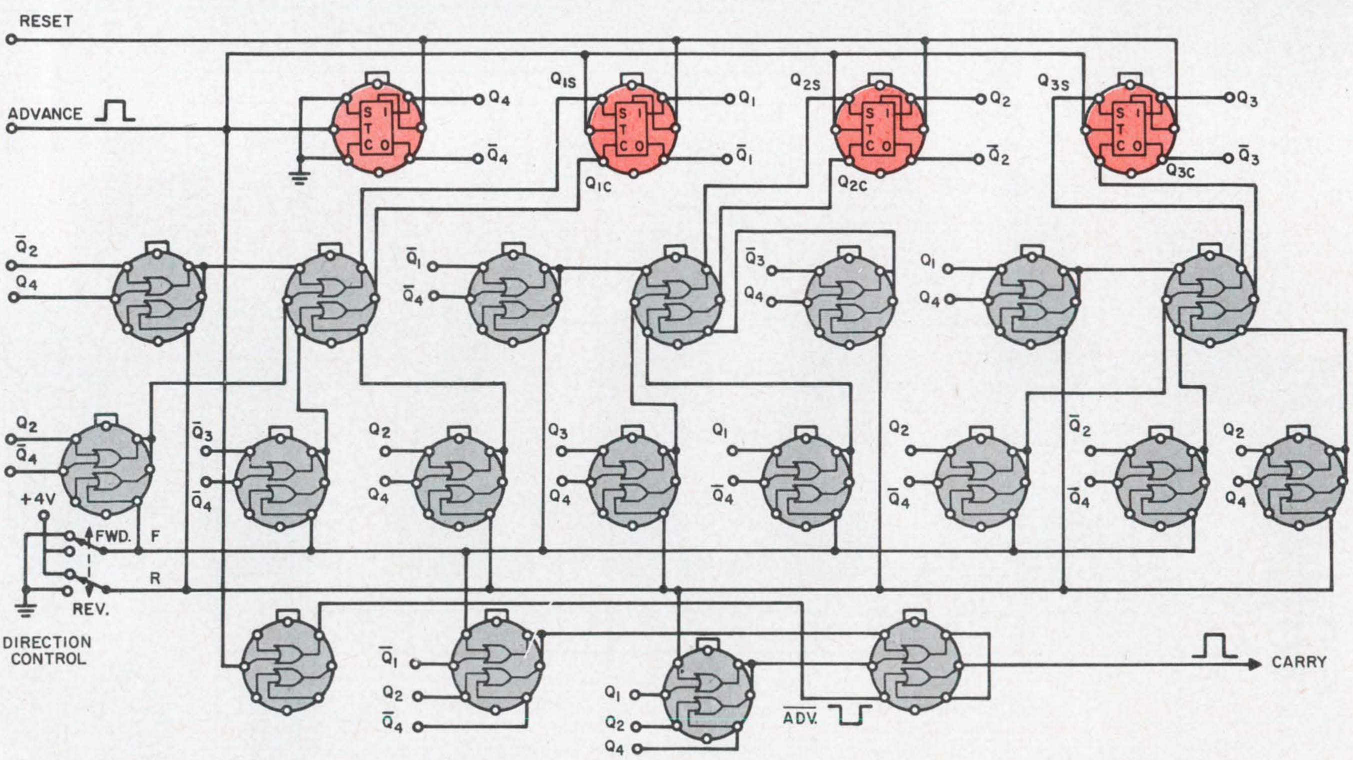
Any one of a number of minimization techniques, such as the Quine-McCluskey method,[5] will reduce the switching functions to the following form:

$$Q_{1S} = F \cdot \overline{Q_5} + R \cdot Q_2,\ Q_{1C} = \overline{Q_{1S}}$$
$$Q_{2S} = F \cdot Q_1 + R \cdot Q_3,\ Q_{2C} = \overline{Q_{2S}}$$
$$Q_{3S} = F \cdot Q_2 + R \cdot Q_4,\ Q_{3C} = \overline{Q_{3S}}$$
$$Q_{4S} = F \cdot Q_3 + R \cdot Q_5,\ Q_{4C} = \overline{Q_{4S}}$$
$$Q_{5S} = F \cdot Q_4 + R \cdot \overline{Q_1},\ Q_{5C} = \overline{Q_{5S}}$$

The carry output from the counter is derived in a manner similar to the derivation of the set and clear inputs to the J-Ks. However, there is one major difference and this concerns the use of the forward ($F$) and reverse ($R$) commands. To explain this, it is necessary to note that the J-K flip-flop will change states only on application of a trigger input command. The set and clear inputs may change state in between counts without a change in the state of the J-K. Since the carry output provides the input command to the next stage, it cannot change states between counts, as would happen in a normal direction control change. Therefore the carry output of the decade, which is a function of the $F$ and $R$ commands, must be a function of a command that is static between counts. Such a command is the count input (*Advance*) itself. Using this command in the carry output logic provides the logical carry given below:

## Table 2. Code for binary-quinary

| Decimal output | Decimal equivalent | J-K flip-flop output 1 2 4 8 $Q_1$ $Q_2$ $Q_3$ $Q_4$ | Forward $Q_{1S}$ | Forward $Q_{1C}$ | Reverse $Q_{1S}$ | Reverse $Q_{1C}$ |
|---|---|---|---|---|---|---|
| 0 | 15 | 1 1 1 1 | $\phi$ | 0 | $\phi$ | 1 |
| 1 | 7 | 1 1 1 0 | $\phi$ | 0 | $\phi$ | 0 |
| 2 | 13 | 1 0 1 1 | $\phi$ | 0 | $\phi$ | 0 |
| 3 | 5 | 1 0 1 0 | $\phi$ | 0 | $\phi$ | 0 |
| 4 | 9 | 0 0 0 1 | $\phi$ | 0 | $\phi$ | 0 |
| 5 | 1 | 1 0 0 0 | $\phi$ | 1 | $\phi$ | 0 |
| 6 | 8 | 0 0 0 1 | 0 | $\phi$ | 1 | $\phi$ |
| 7 | 0 | 0 0 0 0 | 0 | $\phi$ | 0 | $\phi$ |
| 8 | 10 | 0 1 0 1 | 0 | $\phi$ | 0 | $\phi$ |
| 9 | 2 | 0 1 0 0 | 1 | $\phi$ | 0 | $\phi$ |




3. **The binary-quinary decade's logic schematic** uses only four J-K flip-flops, but it uses 19 RTL gates: four more than either of the other two codes. Its output is not a very popular code.

## Table 3. Code for 1-2-4-8 BCD decade

| Decimal output | Decimal equiva-lent | J-K flip-flop output 1 2 4 8 $Q_1$ $Q_2$ $Q_3$ $Q_4$ | Forward $Q_{2S}$ $Q_{2C}$ $Q_{2T}$ | Reverse $Q_{2S}$ $Q_{2C}$ $Q_{2T}$ |
|---|---|---|---|---|
| 0 | 15 | 1 1 1 1 | $\phi$ $\phi$ 0 | $\phi$ 0 1 |
| 1 | 14 | 0 1 1 1 | $\phi$ 1 1 | $\phi$ $\phi$ 0 |
| 2 | 13 | 1 0 1 1 | $\phi$ $\phi$ 0 | 1 $\phi$ 1 |
| 3 | 12 | 0 0 1 1 | 1 $\phi$ 1 | $\phi$ $\phi$ 0 |
| 4 | 11 | 1 1 0 1 | $\phi$ $\phi$ 0 | $\phi$ 1 1 |
| 5 | 10 | 0 1 0 1 | $\phi$ 1 1 | $\phi$ $\phi$ 0 |
| 6 | 9 | 1 0 0 1 | $\phi$ $\phi$ 0 | 1 $\phi$ 1 |
| 7 | 8 | 0 0 0 1 | 1 $\phi$ 1 | $\phi$ $\phi$ 0 |
| 8 | 7 | 1 1 1 0 | $\phi$ $\phi$ 0 | $\phi$ 1 1 |
| 9 | 6 | 0 1 1 0 | $\phi$ 0 1 | $\phi$ $\phi$ 0 |

$$C = \overline{[F \cdot Q_4 \cdot \overline{Q_5} + R \cdot Q_1 \cdot Q_5]\ \overline{Advance}}.$$

The logical functions required of the counter are synthesized with the RTL gate[6] circuit shown in Fig. 1.

The logical diagram for the Modulo 10 shift decade is shown in Fig. 2.

### Binary circuit drives quinary

An up-down decade can be made with a binary and a quinary circuit to produce the truth table of Table 2. The binary circuit is used to drive the quinary circuit. The binary circuit is illustrated by the $Q_4$ output and the quinary by $Q_1$ through $Q_3$ outputs of Table 2. Using the same weighting for the $Q$ outputs as for the Modulo 10 shift decade, the decimal equivalent column is produced. With the J-K truth table, the $Q_{1S}$ and $Q_{1C}$ columns can be filled in for both directions, as illustrated in Table 2.

Since the $Q_4$ flip-flop operates as a binary, its set and clear inputs may be held at ground potential (logical *1*) while toggling is performed by a trigger from the input to be counted.

Other set and clear inputs, the quinary shift and the carry output codes are derived in a similar manner. The code of Table 2 produces the following switching functions:

$$\begin{aligned} Q_{1S} &= F \cdot [\Sigma_1(2) + \Sigma_0(0, 8, 10)] \\ &\quad + R \cdot [\Sigma_1(8) + \Sigma_0(0, 2, 10)], \\ Q_{1C} &= F \cdot [\Sigma_1(1) + \Sigma_0(5, 7, 9, 13, 15)] \\ &\quad + R \cdot [\Sigma_1(15) + \Sigma_0(1, 5, 7, 9, 13)]. \end{aligned}$$

These switching functions are derived in a manner identical to those of the Modulo 10 shift decade. Switching functions for $Q_{2S}$ through $Q_{4S}$ and $Q_{2C}$ through $Q_{4C}$ are similarly derived.

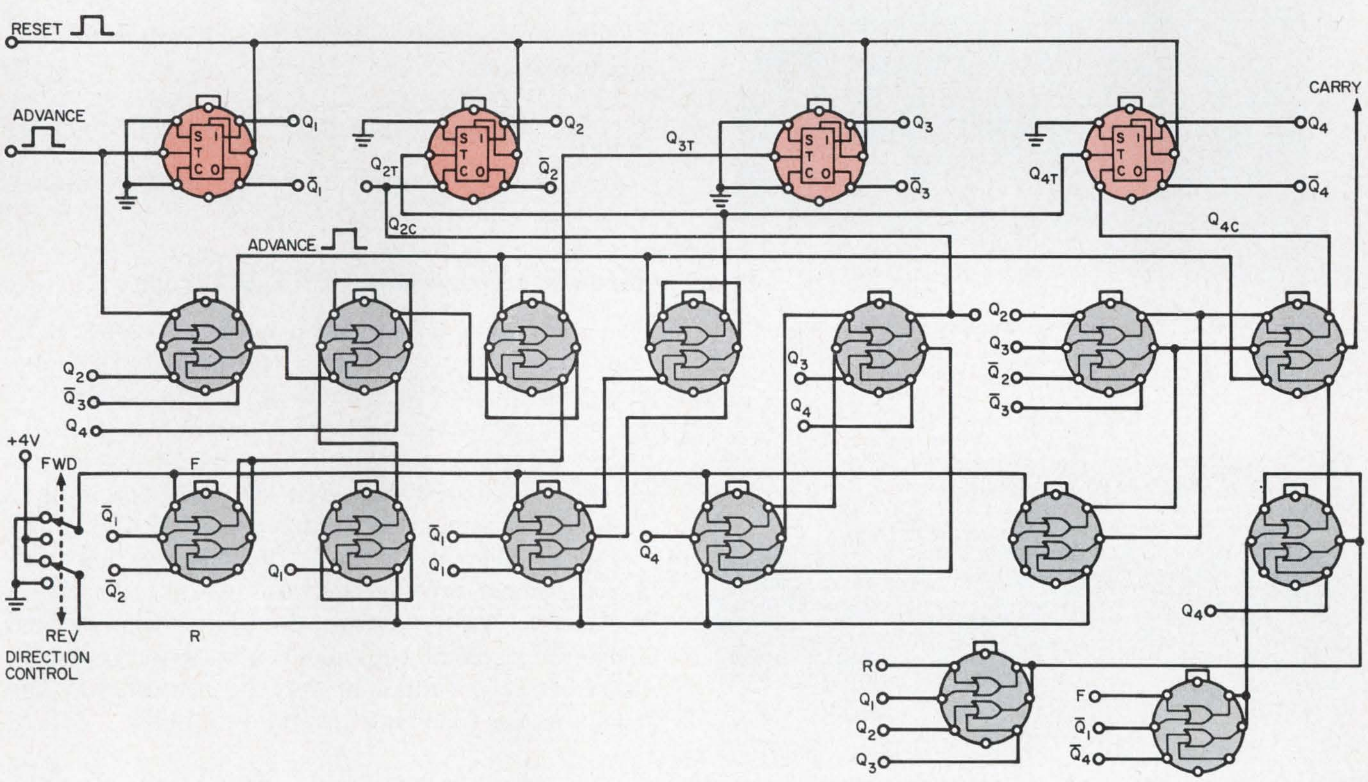
Following minimization of the switching functions, the results are:

$$Q_{1S} = F(Q_2 \cdot \overline{Q_4}) + R(\overline{Q_2} \cdot Q_4)$$

$$Q_{1C} = F(\overline{Q_3} \cdot \overline{Q_4}) + R(Q_2 \cdot Q_4)$$

$$Q_{2S} = F(Q_1 \cdot \overline{Q_4}) + R(\overline{Q_3} \cdot Q_4)$$

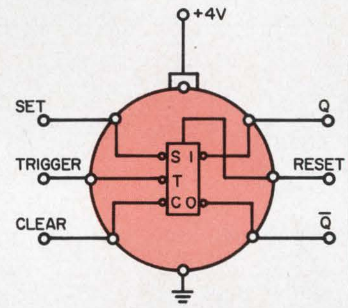
$$Q_{2C} = F(Q_1 \cdot \overline{Q_4}) + R(Q_3 \cdot Q_4)$$




4. **The 1-2-4-8 binary coded decimal decade** uses only four flip-flops and 15 gates. Its code is the most popular of the three, and an inexpensive decoder-driver-display is available. It interfaces easily with other equipment.

## The J-K flip-flop: how it works

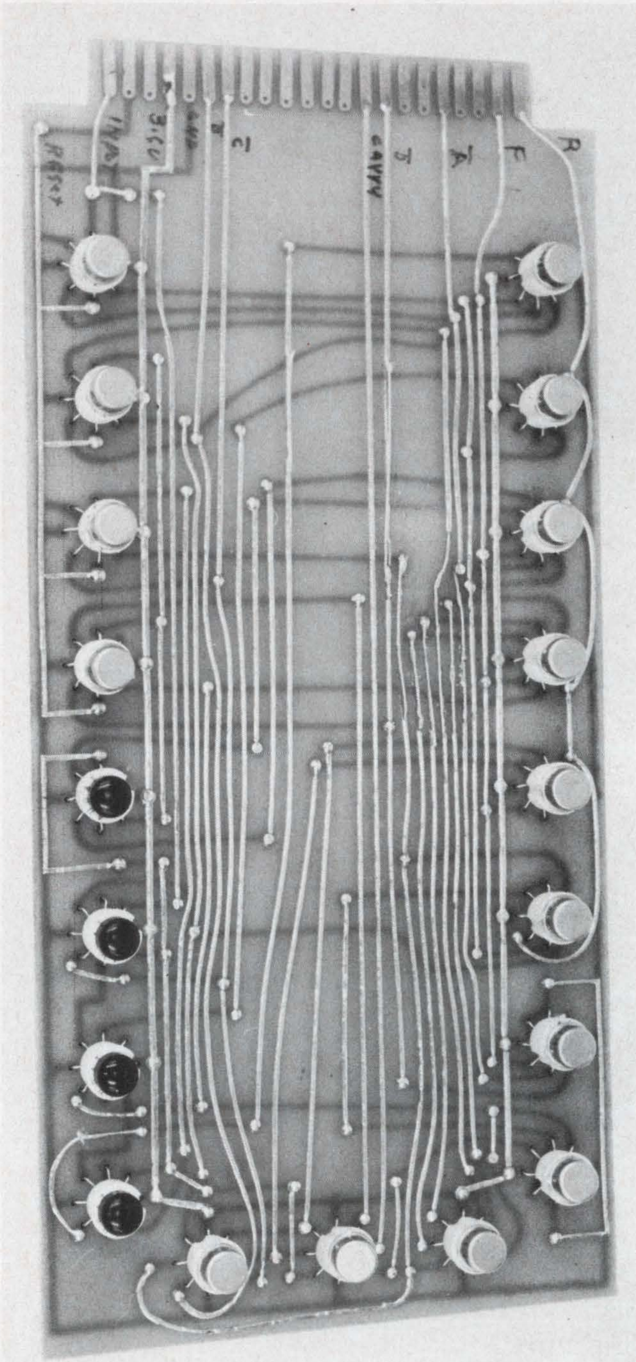
The J-K flip-flop is a sequential circuit, and its output depends on the state of the previous inputs (see illustration below). This is indicated in the accompanying truth table where the previous input is t = n and the present output is t = n + 1. Application of a trigger command, with the set and clear inputs at logical 0 (Row a), will not produce any output change. Application of a trigger command, with the set and clear inputs at logical 1 (Row d), will produce a change of state in the output. A 0-1 input on the set-clear terminals (Row b) will always produce a 0 output. A 1-0 input (Row c) will always produce a 1 output, on application of a trigger command.



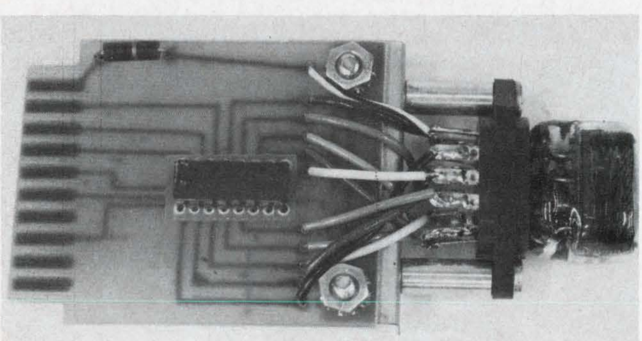

LOGIC SYMBOL

| ROW | SET (t = n) | CLEAR (t = n) | Q (t = n+1) |
|---|---|---|---|
| a | 0 | 0 | $x^n$ |
| b | 0 | 1 | 0 |
| c | 1 | 0 | 1 |
| d | 1 | 1 | $\overline{x^n}$ |

TRUTH TABLE



5. **The 1-2-4-8- BCD decade counter can be constructed** on a single printed-circuit board. The four flip-flops are located on the lower portion of the left edge.



6. **This small unit contains the decoder, driver and nixie** tube for the 1-2-4-8 decade counter.

$$Q_{3S} = F(Q_2 \cdot Q_4) + R(Q_1 \cdot Q_4)$$

$$Q_{3C} = F(\overline{Q_2} \cdot \overline{Q_4}) + R(Q_2 \cdot Q_4)$$

The carry output is derived in a similar manner, producing:

$$C = \overline{[F \cdot \overline{(\overline{Q_1} \cdot Q_2 \cdot \overline{Q_4})} + R(Q_1 \cdot Q_2 \cdot Q_4)]\ \overline{Advance}}.$$

The logical diagram for the binary-quinary decade is shown in Fig. 3.

### Up-down decade yields 1-2-4-8 BCD code

An up-down decade can produce a 1-2-4-8 BCD code (see Table 3). Using the J-K truth table, the code for the set and clear inputs to the J-K flip-flops is determined. This results in the $Q_{2S}$ and $Q_{2C}$ columns for both forward and reverse direction of Table 3. Since the $Q_1$ code is a binary code, its set and clear inputs are held at ground potential (logical *1*). $Q_{2T}$ is the J-K flip-flop trigger command for the $Q_2$ state.

After the switching equations have been written from the decimal equivalent number, as already described, the functions may be minimized. The result is the following logical functions:

$$Q_{1S} = Q_{2S} = Q_{3S} = Q_{4S} = Q_{1C} = Q_{3C} = 1$$

$$Q_{1T} = Advance$$

## Table 4. Comparison of logic elements

| Decade | Number of Logic Elements | | Decoder | |
|---|---|---|---|---|
| | J-K Flip-Flop | RTL Gates | RTL Gates | Transistors |
| Modulo 10 | 5 | 15 | 5 | 10 |
| Bi-Quinary | 4 | 19 | 10 | 10 |
| 1-2-4-8 BCD | 4 | 15 | 9 | 10 |

$$Q_{2T} = \overline{[F\cdot\overline{Q}_1+R\cdot Q_1]\overline{Advance}}=Q_{4T}$$

$$Q_{3T} = \overline{[F(\overline{Q}_1\cdot\overline{Q}_2)+R(Q_1)(\overline{Q}_4+\overline{Q_2\cdot Q_3})]Advance}$$

$$Q_{3C} = F\cdot Q_4+R(\overline{Q}_3+\overline{Q}_4)$$

$$Q_{4C} = F\cdot(\overline{Q}_2\cdot\overline{Q}_3)+R(Q_2\cdot Q_3)$$

The carry output is derived in a similar manner:

$$C = \overline{[F(\overline{Q}_1\cdot\overline{Q}_4)+R(Q_1\cdot Q_2\cdot Q_3\cdot Q_4)]Advance}.$$

The trigger inputs to the J-Ks are conditioned by the input pulse to be counted (*Advance*); the set and clear commands do not need this conditioning. The logical diagram for the 1-2-4-8 BCD decade is shown in Fig. 4.

### The decades compared with each other

The total number of logical elements in both the counter and decoder for each of the three decade codes is presented in Table 4.

The table shows that the 1-2-4-8 BCD decade uses fewest logic elements of the three counters; of the decoders, that of the Modulo 10 requires fewest logic elements. The choice of code may be influenced by the input code of the equipment with which the counter will interface. For example, an inexpensive integrated decoder-driver accepts only the 1-2-4-8 BCD code. The 1-2-4-8 BCD code is, in fact, the most popular of the three codes.

Figure 5 shows the printed-circuit board of the 1-2-4-8 BCD decade; it contains four J-K flip-flops and 15 dual RTL gate elements. The commercially available decoder driver with a suitable Nixie tube appears in Fig. 6. ■ ■


**References:**

1. *Fairchild Planar Epitaxial Micrologic, Preliminary Specifications* (Mountain View, Calif.: Fairchild Semiconductor, October, 1964).

2. R. E. Miller, *Switching Theory* (New York: John Wiley & Sons, 1965), pp. 4-8.

3. *μL 923 J-K Flip-Flop, Data Sheet* (Mountain View, Calif.: Fairchild Semiconductor, May, 1964).

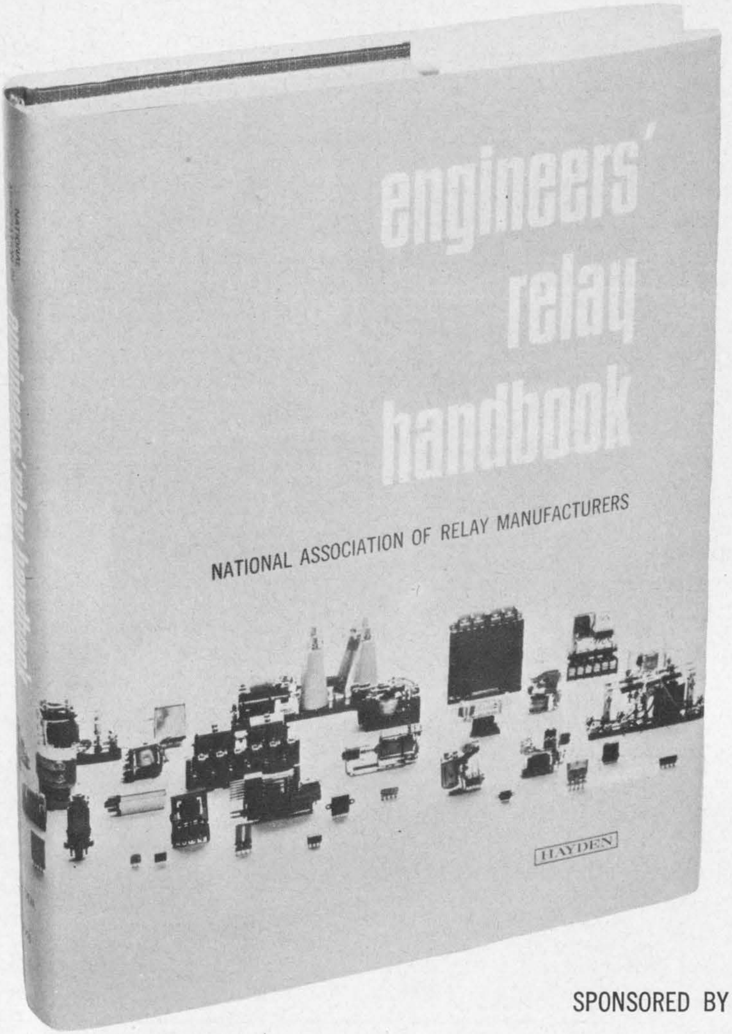
4. S. W. Caldwell, *Switching Circuits and Logical Design* (New York: John Wiley & Sons, 1959).

5. *Ibid.*

6. *Fairchild Planar Epitaxial Micrologic, 914 Dual Two-Input Gate Elements* (Mountain View, Calif.: Fairchild Semiconductor, April, 1964).

7. *Fairchild CμL 990 Decimal Decoder-Driver, Data Sheet* (Mountain View, Calif.: Fairchild Semiconductor, July, 1965).

# "a relay handbook to rely on"




That's how *Product Engineering* described the *Engineers' Relay Handbook*, just published by Hayden. And with good reason. It was sponsored and produced by the National Association of Relay Manufacturers to provide the relay user with a complete guide to all aspects of relay technology. This is a book the design or systems engineer can't afford to miss. Whether you seek information on the types, reliability, economics, or government specifications of relays, the answer is clearly and thoroughly presented in this invaluable reference.

## engineers' relay handbook

SPONSORED BY THE NATIONAL ASSOCIATION OF RELAY MANUFACTURERS

☐ the first complete roundup of objective relay information ☐ specifically prepared for the relay user ☐ detailed coverage of specification parameters ☐ clarification of performance terminology ☐ practical emphasis maintained throughout ☐ complete bibliography of relay literature

☐ 300 pages, Fully illustrated, Clothbound, $11.95.

CONTENTS

Relay Terminology • Classes of Service • Relay Classification • Principles of Relay Operation • Relay Application Considerations • Relay Reliability • How to Specify a Relay • Testing Procedures • Government Specifications • Appendices • Bibliography

## SEND FOR YOUR 10-DAY FREE EXAMINATION COPY NOW!

Dept. ED-28, Hayden Book Company, Inc., 116 W. 14 St., New York, N.Y. 10011

Send me the "Engineers' Relay Handbook" for a free examination. At the end of ten days, I will either remit $11.95 plus postage or return the book with no further obligation.

Name__________ Title__________

Company__________

Address__________

City__________ State__________ Zip__________

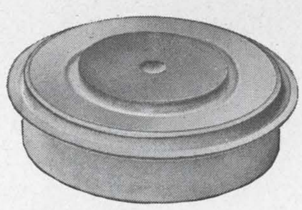
☐ **Check here if payment enclosed. Publisher pays postage with same return guarantee. (Foreign orders, except Canada, must include payment in $ U.S.)**

ELECTRONIC

# INNOVATIONS IN POWER SEMICONDUCTORS

## PRESS PAK SCR's—another packaging innovation from General Electric

Now you can get an SCR that delivers far more continuous current than comparable stud mounted devices. It's the new General Electric PRESS PAK.



**Actual size G-E PRESS PAK SCR rated up to 1300 volts**

A typical current capability increase of about 60% stems from PRESS PAK's externally applied pressure contact package. The new package allows double-sided cooling of the SCR, drastically reducing thermal resistance. Result: you get more average amps per total dollar.

Right now PRESS PAK SCR's are available rated up to 1300 volts, 110 or 240 amps *average* (equivalent to 172 amps and 377 amps RMS *respectively* on stud-mounted types). Soon, other kinds of semiconductor devices, as well as other SCR's will also be available in the PRESS PAK.

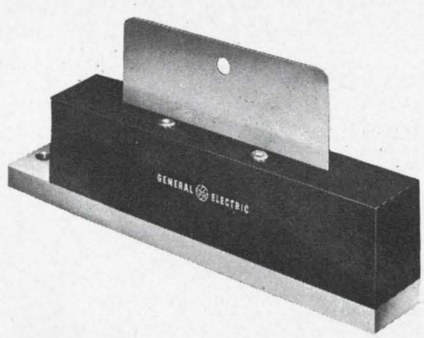
Try PRESS PAK SCR's for heavy industrial, motor drive, electro-plating, and other high line voltage applications.

## ■ NOW AVAILABLE FOR HIGHER POWER AT HIGHER FREQUENCIES: G-E POWER SCR'S

For computer power supplies, G-E C14040 power SCR's give you high frequency switching at current levels up to 80 amps peak at 25 kHz, or 310 amps peak at 5 kHz.

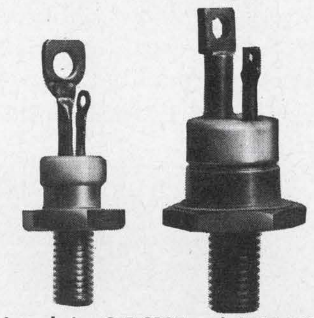
Unique matching capability allows common anode and common cathode terminations, making G-E power thyristors convenient and economical performers as inverters, choppers, cycloconverters, and regulated power supplies.

G-E C14040 line SCR's are also ideal for ultrasonic generators, high frequency lighting, sonar transmitters, induction heaters, and radio transmitters.




**G-E C14040 power SCR for high power/high frequency applications**

## ■ PRESENTING: HIGH VOLTAGE IN A MEDIUM CURRENT PACKAGE—G-E C137 AND C145 SCR'S



**Actual size G-E C137 and C145 SCR's**

Get 1200 volt capability for 480-volt a-c operation of industrial equipments.

G.E.'s C137 SCR is a compact 35 amp device with a di/dt rating of 150 amps/μsec. when switching from 1200 volts or 300 amps/μsec. when switching from 600 volts. And the 100 volts/μsec. minimum dv/dt rating eliminates the need for many protective components . . . reduces the cost of your circuits.

For high current transformer primary phase control, the 55 amp C145 puts the squeeze on cost and size, but delivers 1200-volt capability. Maximum di/dt rating is 100 amps/μsec., when switching from 1200 volts or 200 amps/μsec. when switching from 600 volts. The minimum dv/dt rating is a money-saving 200 volts/μsec.

Typical C137 or C145 SCR applications include motor speed control, power supply regulation, pulse modulation, a-c static switching, and transformer primary phase control applications.

For further information on these and other items in G.E.'s leadership line of SCR's and rectifiers see your G-E engineer/salesman or distributor and get the full story of G.E.'s total electronic capability.

**Or write to Section 220-43. General Electric Company, Schenectady, N.Y. In Canada: Canadian G.E., 189 Dufferin St., Toronto, Ont. Export: Electronic Components Sales I.G.E. Export Division, 159 Madison Ave., New York, N.Y.**

**GENERAL ELECTRIC**

ON READER-SERVICE CARD CIRCLE 42

# Put operational amplifiers to work

## in four applications unusual and useful enough to win top honors in an industry-wide contest.

New and unusual applications for operational amplifiers are constantly being found by designers. Here are four that were considered so unusual and useful that they received top honors in a design contest.

The four ideas were entered in last spring's Fairchild Operational Amplifier Contest, which focused on applications for the Fairchild A00-9 and A00-10 operational amplifiers. (See page 70 for specs.) Although they apply to a specific device, each of these blue-ribbon entries is readily adaptable to operational amplifiers in general:

- *Double-integration circuit,* submitted by Gordon J. Hansen, Sandia Corp., Albuquerque, N. M.
- *Multipurpose oscillator,* submitted by D. F. Palmer, Research Triangle Institute, Durham, N. C.
- *Dual-limit comparator,* submitted by Richard D. Wood, Sunnyvale, Calif.
- *Wheel-slippage prevention system,* submitted by L. J. Lawson, Lear Siegler, Inc., Cleveland.

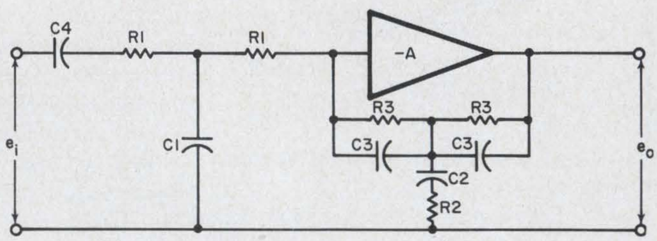
### On-line double integration

The stabilized operational amplifier can be used to perform real-time, on-line double integration for displacement vs time data systems. It dispenses with the need for computer processing during data reduction and the accompanying delay, expense and loss of accuracy.

The need for double integration is apparent in system response or earth-motion measurements involving accelerometer instrumentation. Until recently, to obtain the change in distance as a function of elapsed-time information, one on-line integration was performed, and then down-time data reduction by computer was called for. Double integration in the field (on-line) was virtually impossible because of the limitations imposed by operational amplifier drift and zero shifting.

The new breed of operational amplifiers with built-in stability and minimal drift makes on-line double integration easy. Moreover, it is now possible to make accurate measurements even when hours pass between the moment of final adjustment and the beginning of test operation.

Besides the operational amplifier, all that is needed in the way of additional circuitry is resistive and capacitive components that satisfy the mathematical requirements of the double-integration function. These are connected in the input and feedback circuits of the amplifier (Fig. 1).




1. **Double integration is performed on-line** when appropriate resistive and capacitive components are added to the input and feedback loop of a stable operational amplifier.

The Laplace transformations for the input and feedback networks of the subsystem are:

$$Z_i(s) = \frac{R1^2\,C1}{s}\left[s^2 + \frac{2C4 + C1}{R1C1C4} + \frac{1}{R1^2C1C4}\right], \quad (1)$$

$$Z_f(s) = \frac{2}{C3}\left\{\frac{s^2 + \dfrac{4R2+R3}{2R2R3C3} + \dfrac{1}{R2R3C2C3}}{[s + (1/R3C3)]^2[s + (1/R2C2)]}\right\} \quad (2)$$

Making $C4 >> C1$ and $R3 >> R2$ has the following effect:

$$Z_i(s) = \frac{R1^2\,C1}{s}\left(s + \frac{2}{R1\,C1}\right)\left(s + \frac{1}{2\,R1\,C4}\right), \quad (3)$$

## Oscillator building block

An operational amplifier as a key stage in an oscillator network secures subsystem versatility. The relatively simple subsystem blocks produced in this manner can be used for programing, multiplexing or demodulating.

The use of operational amplifiers in oscillator circuits is neither well-known nor widespread, but the combination yields:

- A stable audio oscillator (dc to 500 kHz) variable by programing or manual means.
- An oscillator with a linear FM characteristic that can be frequency-multiplexed or phase-locked for demodulation, and thus serve as a versatile laboratory instrument.

The basic unit is an RC phase-shift oscillator that has an operational amplifier as the active component (Fig. 2). Design equations for the common oscillator configurations are available in many handbooks, but operational amplifiers can be used over a much wider range than these equations imply. Their phase shift decreases from 180° at higher frequencies, and so requires less phase shift, and yields less attenuation, in the RC network. Figure 3 depicts a simple RC lag network used in the basic oscillator.

A typical oscillator, designed to operate at 100 kHz, appears in Fig. 4. Its frequency variation with RC, 1/RC, and amplifier gain, $A$, is shown in Fig. 5. These curves demonstrate that the frequency can be varied manually or remotely to provide a laboratory oscillator (13 kHz to 300 kHz) with a nearly linear characteristic over a wide range.

The open-loop gain of the oscillator (Fig. 4) never exceeds approximately 2.2. Component nonlinearities therefore stabilize the amplitude of oscillation. In other cases it may be desirable to replace some of the linear components with varactors, or thyrite, thermite or soft-kneed Zener diodes. These same nonlinear components make remote operation possible.

The ability to angle-modulate this oscillator broadens its use for instrumentation; its operating frequency range is suited for hard-wire links in underground, underwater, or other remote

$$Z_f(s) = \frac{2}{C3}\left\{\frac{[s + (1/2\,R2\,C3)][s + (2/R3\,C2)]}{[s + (1/R3\,C3)]^2\,[s + (1/R2C2)]}\right\}. \quad (4)$$

Component values are chosen such that $R1\,C1 = 4\,R2\,C3$; $R3\,C2 = 4\,R1\,C4$, and $R2\,C2 = R3\,C3 = T_c$. Therefore:

$$E_o(s)/E_i(s) = Z_f(s)/Z_i(s), \text{ and}$$

$$\frac{Z_f(s)}{Z_i(s)} = \frac{2}{R1^2\,C1\,C3}\left\{\frac{s}{[s + (1/R3\,C3)]^3}\right\}$$

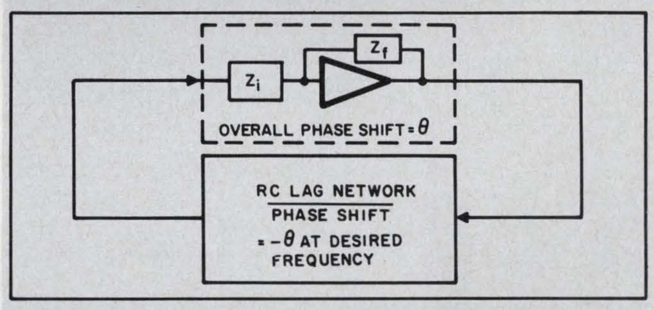
$$= \frac{2\,C4}{T_c^2\,C3}\left\{\frac{s}{[s + (1/T_c)]^3}\right\}. \quad (5)$$

Taking the inverse transformation for a unit-step input for Eq. 5 produces:

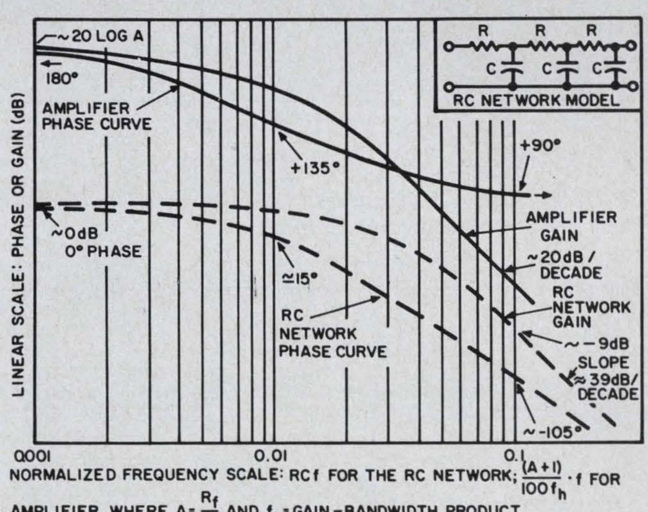
$$e_o(t) = -(C4/T_c^2\,C3)t^2\,\epsilon^{-t/T_c}. \quad (6)$$

Note that Eq. 6 is the form which performs short-term double integration (via the $t^2$ term) with long-term stability (shown by exponential).

This circuit can be constructed with components of only 10% tolerances; polystyrene or similar precision capacitors are not necessary. The circuit will hold a zero indefinitely without the need for shorting relays. It will perform accurate double integrations over periods of several seconds.




2. **Versatility is increased** in an RC phase-shift oscillator when an operational amplifier is used as the active element.




3. **Simple RC lag network yields good performance** from operational amplifier oscillator.

*(continued on p. 68)*

*(continued from p. 67)*

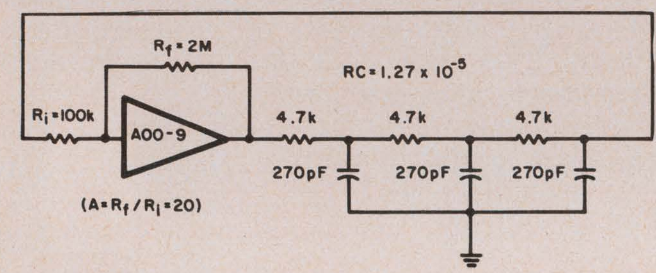
experiments. It is in such applications that it is especially important to have a very stable, low-drift operational amplifier.

**Feedback element sets modulation mode E**

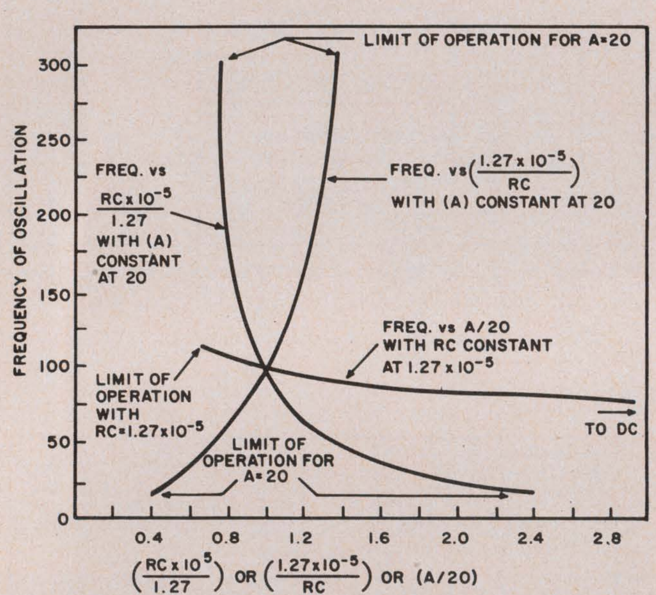
The simplest way to achieve modulation is to replace feedback resistor $R_f$ with a soft-kneed Zener diode and a series linear resistor. A proper choice of resistance values would then allow gain $A$ to vary nearly linearly with input voltage. A bias, then, is needed for bipolar signals.

The circuit of Fig. 6 is the final configuration of the basic oscillator. Modulation voltages can be applied to the input as shown. The resultant frequency change is predictable, as Fig. 5 demonstrates.

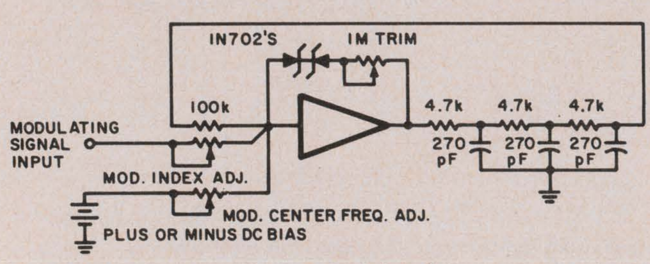
Frequency multiplexing is also a simple matter because a number of control voltages can be applied with good isolation. Application of a signal with a component at the basic oscillator frequency will cause mixing in the nonlinear $R_f$. All mixing components (except the low-frequency one) will be attenuated, since they occur beyond twice the oscillator's frequency. This low-frequency component will be amplified and modulate $R_f$. The result is phase locking and tracking of the incoming signal by the oscillator.




4. **Open-loop gain never exceeds 2.2** in this oscillator designed to operate at 100 kHz.




5. **Curves show nearly linear characteristic** of oscillator over wide frequency range.



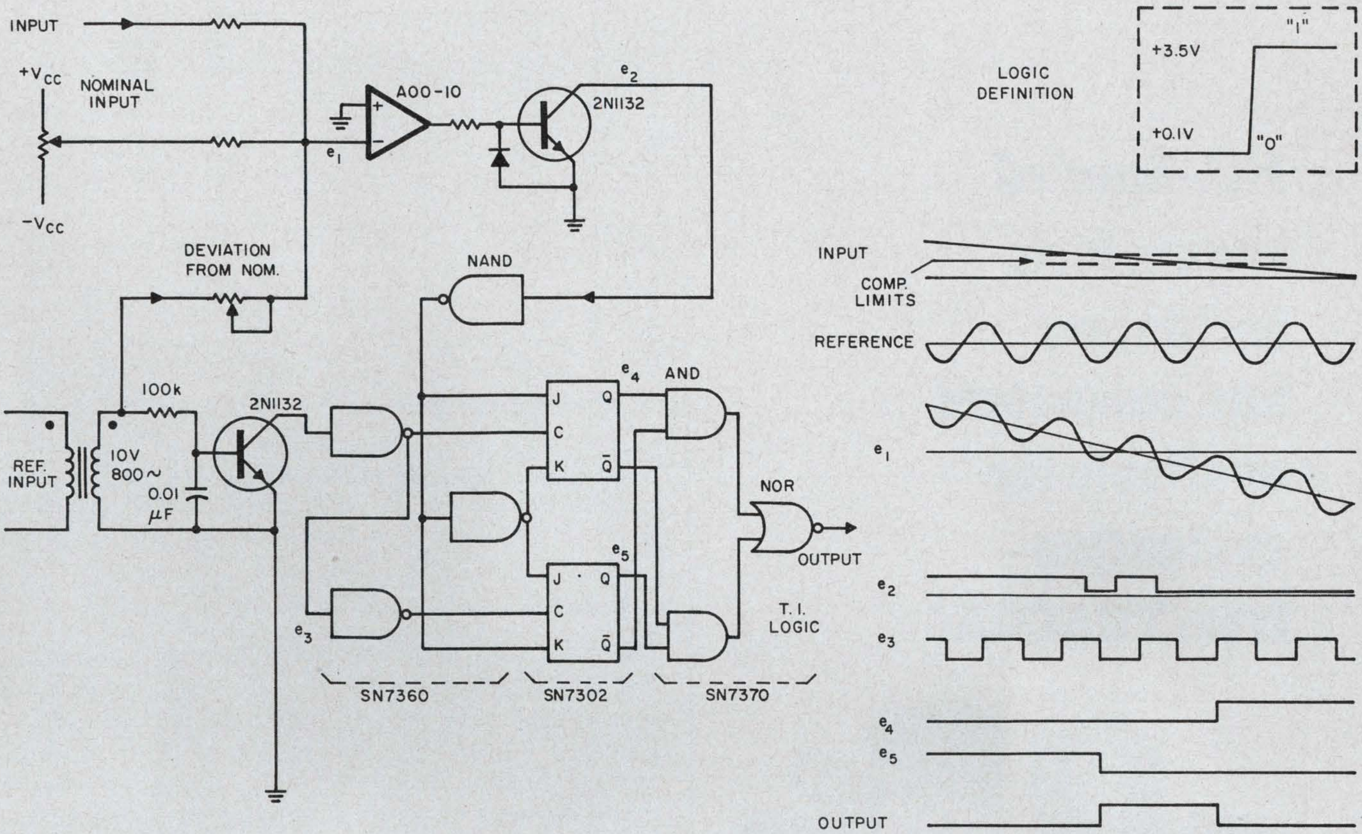

6. **Oscillator can easily be modulated** by external signal. Frequency multiplexing as well as phase locking to an external signal are also possible.

## Dual-limit comparator

A comparator with two limits can be constructed from a stable operational amplifier with a few integrated gates and J-K flip-flops.

Two controls are shown on the circuit diagram (Fig. 7): the first sets the nominal input; the second controls the deviation from this nominal value. The reference input shown is an ac signal, the frequency of which must be considerably higher than the input voltage that is being compared.

The low-drift operational amplifier acts as a dc comparator operating about the zero input level. This is illustrated by waveform $e_1$; the $e_2$ output voltage represents the operational amplifier input signal in binary form. The reference signal is delayed somewhat less than 90° and is applied as a square wave to the J-K flip-flops. The flip-flops respond to a rising clock pulse signal only, and are not affected by a steady-state voltage in any manner. As illustrated by the logic and the waveforms, the flip-flops monitor the comparator voltage serially. If the comparator signal alternates while being sampled, the exclusive-OR gate generates a logical *1* output. Thus, only one operational amplifier forms a dual-limit comparator.



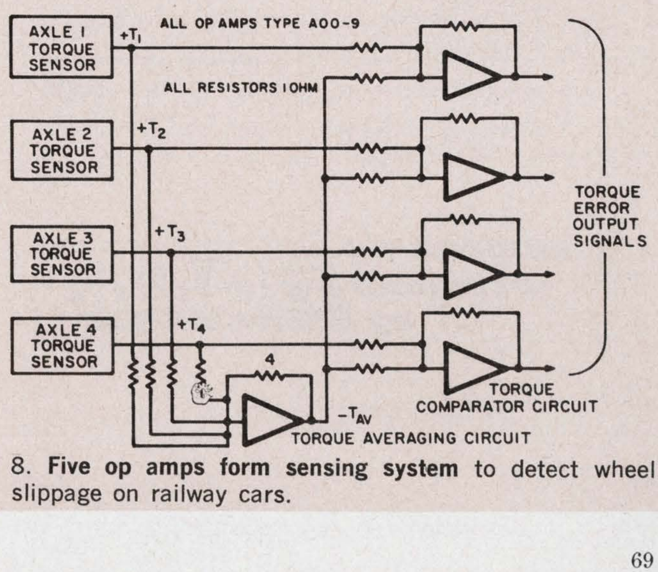

7. **Op amp functions as dc comparator** operating about the zero input level.

## Wheel slippage sensors

The common, disturbing and even disastrous problem of wheel slippage in railway drive systems can be completely eliminated by a unique application of highly-stable operational amplifiers. The system senses the tendency toward slippage before it occurs, and initiates corrective action.

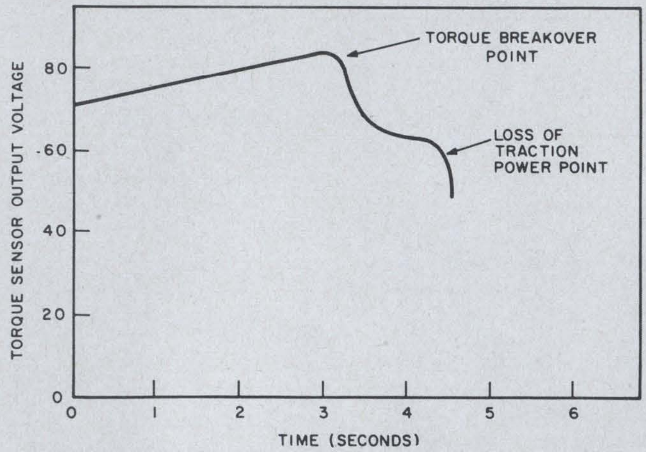
A block diagram of the slippage prevention system is shown in Fig. 8. The dc input signals to the system are obtained from Lear Siegler torque sensors. These ac inductive-type transducer-demodulators produce a dc output voltage which is proportional to the actual torque delivered to each axle (tractive force to the rail). The sensor out-

*(continued on p. 70)*




8. **Five op amps form sensing system** to detect wheel slippage on railway cars.

*(continued from p. 69)*




9. **Slippage is preceded by torque breakover point,** which can be detected by the system before actual slippage occurs.

put-voltage profile of an axle going into a slippage condition is shown in Fig. 9. The sharp change in sensor output is seen to occur at the instant a tendency toward loss of wheel traction begins (torque breakover point). This torque variation gives warning of an eventual loss of wheel traction that will occur if no preventive action is taken.

In operation (Fig. 8), the outputs of all four axle torque sensors are coupled to the torque averaging circuit where they are summed and divided by four. The resulting output signal is proportional to the negative average axle torque. This average torque term is then individually summed with each axle torque signal at the torque comparator circuit, which has one operational amplifier for each axle. An error signal at the comparator circuit output above a preset threshold will immediately initiate remedial action to prevent wheel slippage. What corrective use is made of the comparator output signals depends on the driving configuration of the locomotive or multiple-unit car. In certain cases, tractive power can be reduced at the offending axle; in others, power to the four axles must be reduced until the tendency toward slippage has been eliminated. ■ ■

## A00-9 and A00-10 specifications

| | A00-9 | A00-10 |
|---|---|---|
| DC gain | 4 x $10^7$ (min) | 5 x $10^7$ (min) |
| Drift | $<1\ \mu V/°C$ | $<0.5\ \mu V/°C$ |
| Long-term drift | 2 V/100 hrs. | 1 V/100 hrs. |
| Output | 40 mA at ±100 V; 10 mA at ±140 V | 5 mA at ±25 V |

evaluating semiconductors?

# use one of these Tektronix transistor curve tracers to meet your needs

**The performance range of the Type 575 enables you to evaluate the dynamic characteristics of most semiconductor devices.**

Several transistor characteristic curves may be displayed including the collector family of NPN or PNP devices in a common base or a common emitter configuration with forward or reverse biasing. The Type 575 features collector sweep supply ranges continuously variable from 0 to 20 V at 10 A, or 0-200 V at 1 A. A base or emitter step generator, operating at either 2 or 4 times the line frequency, provides 4 to 12 steps per family of characteristic curves in single or repetitive display modes. The step generator provides voltage increments from .01 V/step to 0.2 V/step or current increments from .001 mA/step to 200 mA/step.

**Choose the Type 575 MOD 122C transistor curve tracer for evaluating higher voltage devices.**

The Type 575 MOD 122C has the same features of the Type 575 plus the capability of diode breakdown test voltage variable from 0 to 1500 V at 1 mA and a much higher collector supply voltage of up to 400 V at 0.5 A.

**For evaluating high current semiconductors, add the Type 175 High Current Adapter to either of these curve tracers.**

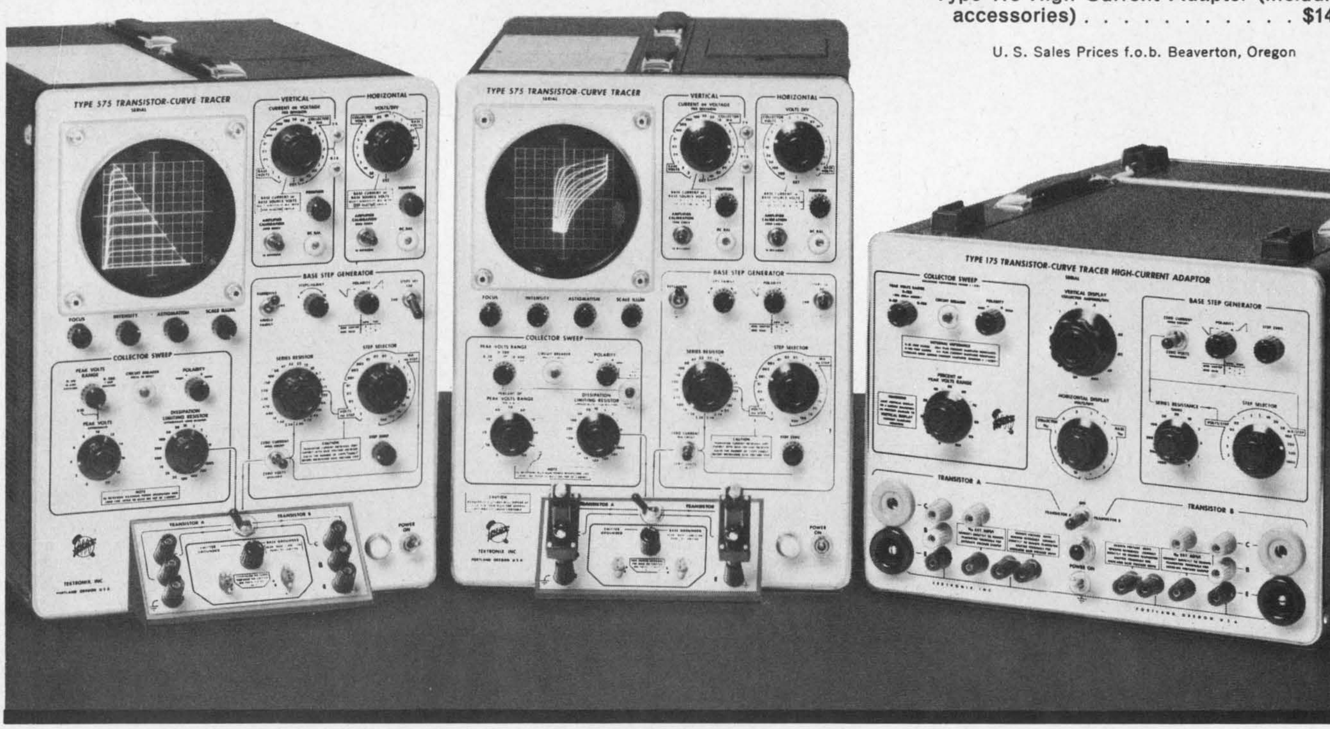
The Type 175 features collector sweep supply ranges of 0-200 A at 0-20 V and 0-40 A at 0-100 V. The Type 175 step generator provides current ranges from 1 mA/step to 1000 mA/step and voltage steps from 0.5 to 10 V/step with driving resistance selectable from 11 values ranging from 0.5 ohms to 1 k ohm. Other resistance values may be added externally.

Type 575 Transistor Curve Tracer (including accessories) . . . . . . . . . . $1075

Type 575 Transistor Curve Tracer MOD 122C (including accessories . . . . . . $1325

Type 175 High Current Adapter (including accessories) . . . . . . . . . . . . $1475

U. S. Sales Prices f.o.b. Beaverton, Oregon

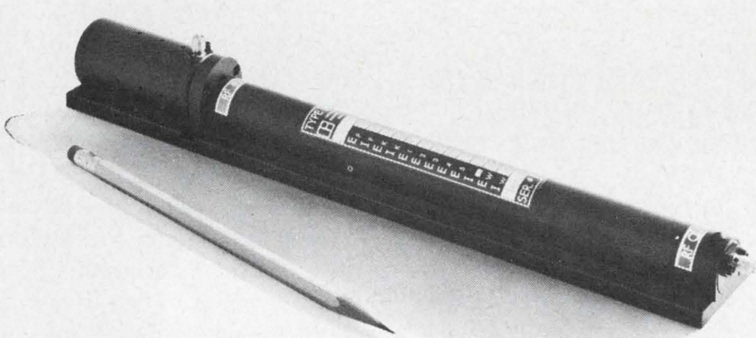



**Tektronix, Inc.**

For complete information, contact your nearby Tektronix field engineer or write:
Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

ON READER-SERVICE CARD CIRCLE 45

# In designing a low-noise TWT, the real problem is keeping it small and light.



## Our new L-5088 weighs only 1.8 pounds.

Small, light and rugged, it's ideal for airborne applications. Noise figure is less than 10 db across most of the band (conservatively rated at 12 db maximum between 2.0 and 4.0 Gc). Construction is metal/ceramic to MIL-E-5400; focus is by PPM Alnico magnets. Minimum saturation power output is 7dbm; minimum small signal gain is 33 db. Conservative cathode design assures long life.

Something else to think about. Our new L-5088 comes as a compatible package, if you like—TWT plus matching integral solid state power supply. Find out more about Litton's lightweight TWT. Send for Data Package. Electron Tube Division, 960 Industrial Road, San Carlos, Calif. 94070. (415) 591-8411.

**LITTON INDUSTRIES**
ELECTRON TUBE DIVISION

ON READER-SERVICE CARD CIRCLE 46

# Tunnel-diode circuits pave the way

## to the ultra-high-speed digital circuits required for wide-band, high-resolution communication systems.

Future communication systems will require higher-speed digital circuits in order to provide high-resolution intelligence, coding capability and multiplexing features, and to employ available RF bandwidths efficiently. An investigation of high-speed digital circuits showed that the most promising means of obtaining logic at uhf rates was a three-phase, clocked, tunnel-diode circuit. To obtain some indication of system performance, feasibility models of a shift register generator and comparator generator were built and error rate measurements taken.

The problems encountered—capacitive coupling, ground-plane noise, and coaxial-cable coupling—are not peculiar to this specific system, but are general difficulties that have to be overcome if any high-speed digital system is to be operated successfully. The error data are indicative of the error rates that can be achieved in the present state of the art.

High-speed logic systems such as the one described are likely to find application in:

- Data links for the transmission of wide-band sensor data.
- Economical data links for the transmission of many TV, voice and data channels on one link.
- Communications equipment on deep space probes.

The first logical step in developing this uhf digital equipment is to set up techniques and circuits from which standard logic blocks such as flip-flops, gates, and inverters may be evolved. These blocks should, in turn, be compatible with each other and be capable of implementing different types of system operation.

### Shift register is system's foundation

A system (Fig. 1) developed at Fairchild Hiller consisted of two seven-stage, psuedorandom code generators which were synchronized and whose outputs were fed into a comparator to generate error pulses if the outputs of the two code generators differed. These error pulses were fed into a string of five binary dividers to reduce the maximum error rate to one that could be measured with readily available commercial counters.

With the exception of the lower-speed binary dividers, the entire system was built from the standard block shown in Fig. 2.

The basic building block is a shift register-generator module which can also perform as a flip-flop, binary divider, AND gate, OR gate, NAND gate, NOR gate, and modulo-two adder for two inputs. The schematic of this module is shown in Fig. 3. It uses a three-phase sinusoidal clock, to obtain isolation between input and output of the block, and diode coupling between phases.

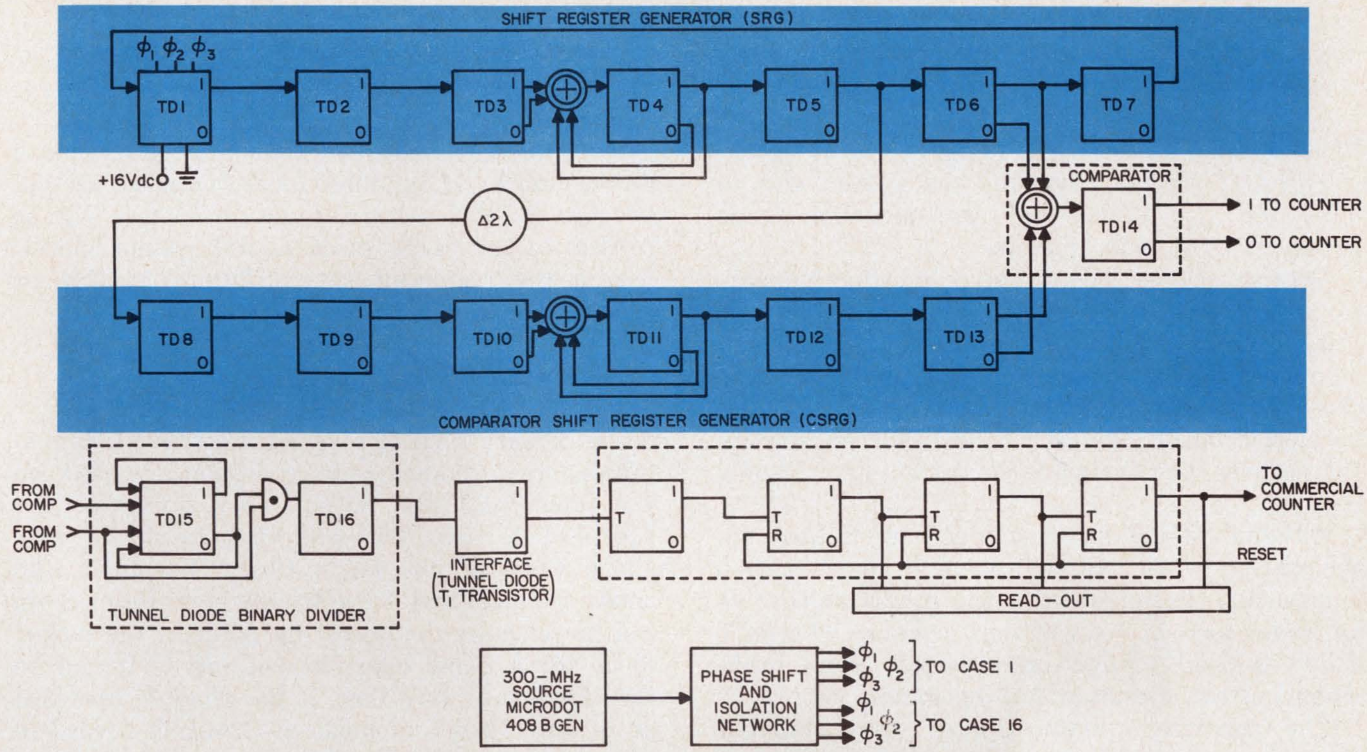
Prior to the final design of the circuit, an extensive study had shown that the tunnel diode was the only element available that would give successful ultra-high-speed operation. The study also showed that a tunnel-diode, stored-charge diode circuit should be capable of operation near 1 GHz, with a fan-out of 3. Laboratory models of the circuit, however, were capable of only limited logic-function operation (i.e., AND, OR, etc.) at that frequency. The root of the problem was capacitive coupling between components and the ground-plane structure and series lead inductance.

Meanwhile, system operation at several hundred hertz was possible with the circuit shown in Fig. 3, a basic three-phase clocked circuit with AND and OR functions determined by setting the bias currents to the single-phase stages used. Final card layout of the circuit was the result of a trade-off in spreading components apart to avoid coupling and yet keeping them close enough together to avoid excessive phase shift. Ground-plane construction was a necessity.

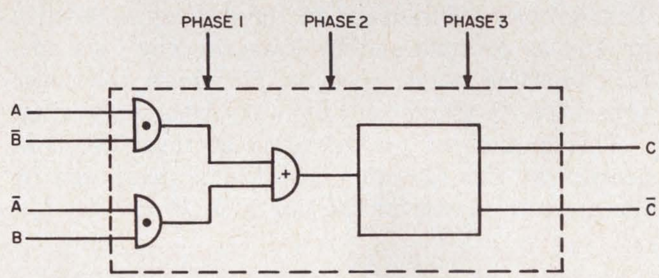
Two basic modules connected as a binary divider and their input and output waveforms are shown in Fig. 4a. Figure 4b shows them in a four-stage pseudorandom code generator and the code output waveform. Waveforms were photographed from a Tektronix 661 sampling oscilloscope.

Figure 5 shows how the three-phase clock was derived. Two criteria for the power divider network were good clock source voltage stability and clock outputs to each card with a 25-dB minimum

**James A. Walker**, Senior engineer, Fairchild Hiller Corp., Germantown, Md.

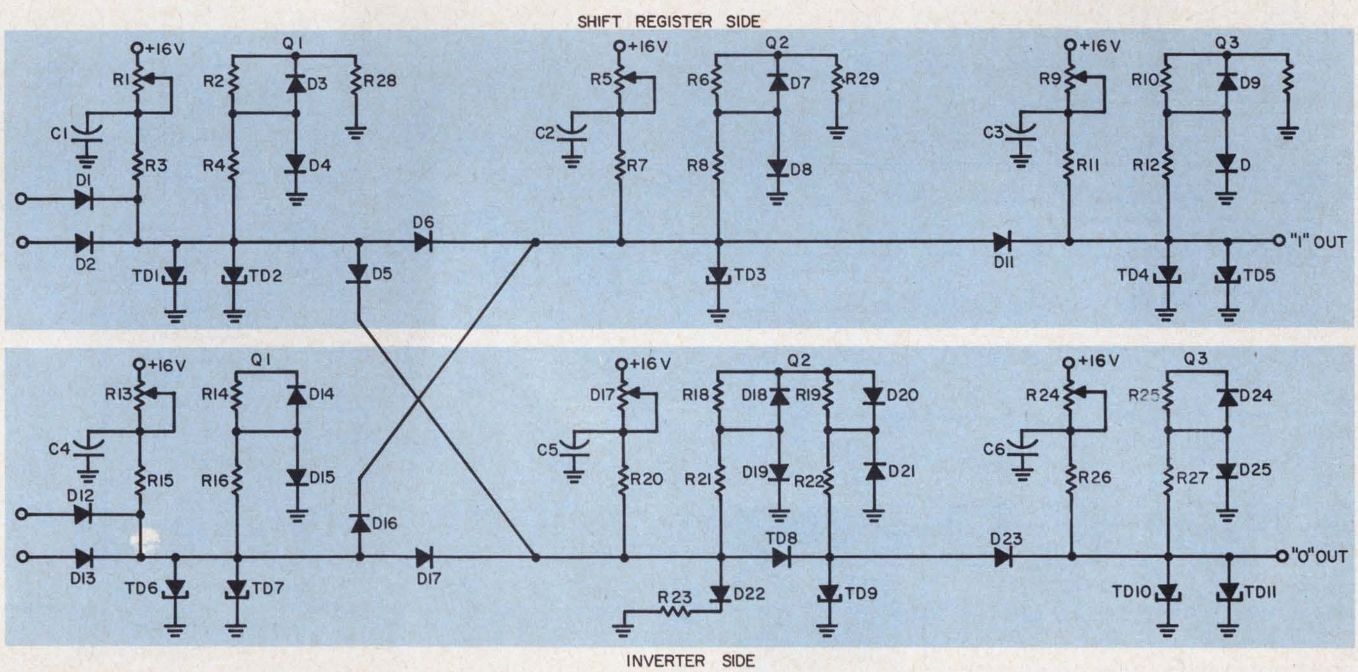



1. **Uhf logic forms the basis of a high-speed communication system.** Code generator outputs are fed to a comparator which generates output error pulses if the code generator outputs differ.




2. **Shift register generator module is the basic building block** for the uhf logic system. This block can perform the functions of a flip-flop, binary divider and various gates.

3. **Circuit details for the block diagram of Fig. 2.** A three-phase sinusoidal clock is used to obtain isolation between input and output.




R1, R5, R9, R13, R24 —— BOURNS TRIMPOT 2k 271-1-202 650 2AA
R2, R4, R10, R12, R14, R16, R25, R27 —— 300Ω
R11, R26, —— 750Ω
R20 —— 2.4k
R23 —— 68Ω
D1 THROUGH D25 —— SYLVANIA 1N4121
TD2, TD5, TD7, TD9, TD11, TD3 —— G.E. 253B
ALL RESISTORS 1/4 WATT

R3, R7, R15 —— 1k
R6, R8 —— 430Ω
R17 —— BOURNS TRIMPOT 5k 271-1-502 6450A
R19, R22 —— 510Ω
R18, R21 —— 820Ω
TD1, TD4, TD6, TD8, TD10 —— G.E. 252A
C1, C2, C3, C4, C5, C6 —— 470 pF

isolation between clock outputs at $f_c$ (clock frequency). The phase delays were generated with coaxial-line phase shifters.

**Reliable code generators needed**

The first step in operating the system was to have the two seven-stage pseudorandom code generators function reliably.

Detailed connections of the seven-stage generator and its coded output waveform are shown in Fig. 6. After the first generator was set up and operating, its output was connected to the input of the second generator. Reliable operation then became increasingly difficult, and even more so as the outputs were compared and the errors counted.

Although stable operation was hard to keep up, the system would run stably for an hour or so—long enough to make error rate measurements as an indication of system performance. Table 1 shows several typical measurement runs made when system operation was optimum.

The percentage errors figure was computed according to the formula:

$$\% \ errors = N_e/N_b \times 100.$$

The number of errors, $N_e$, is the count registered on the commercial counter at time $T$ multiplied by 32, which is the count of the five-stage system counter. The number of bits ($N_b$) is the bit rate multiplied by $T$.

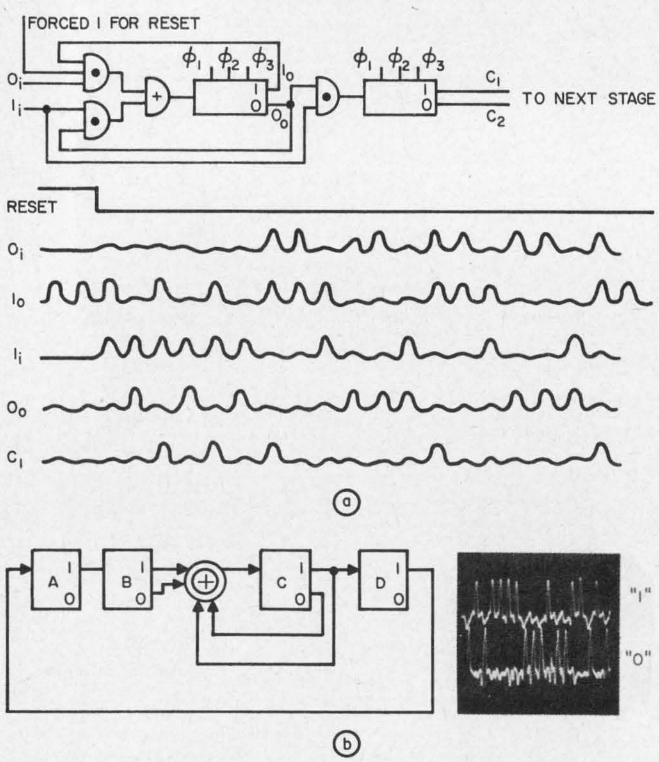
During operation, errors did not occur randomly, several errors at a time, but tended to occur in groups ranging in size from 100 to 300 errors per group. Table 2 shows figures for a group error rate measurement.

The reasons for the drop in operating reliability as the number of building blocks increased are not peculiar to this system. Such problems will be present in any tunnel-diode digital system operating in the region of several hundred MHz or higher. The problems encountered were:

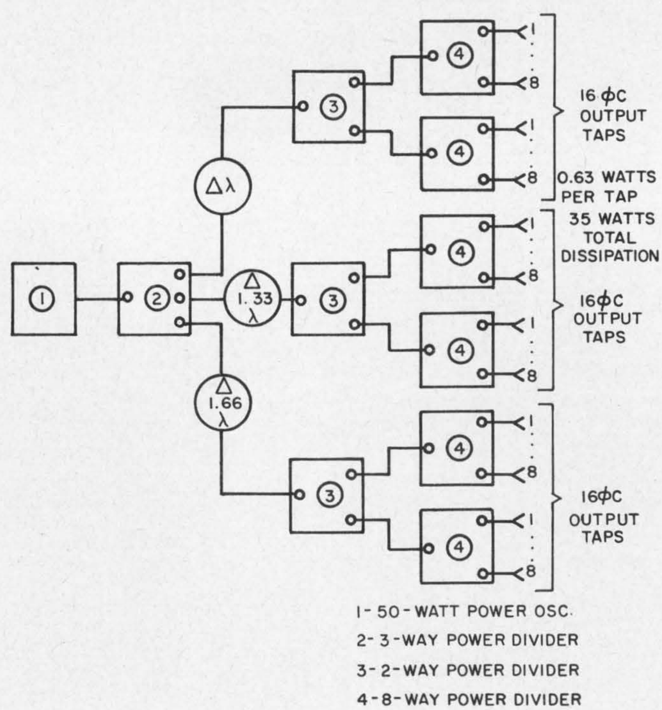
- Noise
- Capacitive Coupling
- Reflected Signals

*Noise*: Figure 7 shows a curve of a typical 15-mA-peak-current tunnel-diode combination used on the input ($\phi_1$) and output ($\phi_3$) stages of the tunnel-diode cards. Two load lines are shown: *LL1* shows the load line for a 13-mA bias and *LL2* shows the load line for a 10-mA bias. Point *A* on the curve shows the operating point of the tunnel diode for a 2-mA data current input. It can be seen from the curve that, if the diode is operated at *A*, only 50 mV of noise at 2 mA is needed to trigger the tunnel diode falsely into its high state. This problem is reduced by providing as good a ground as possible and by lowering the bias current to some point, such as *B*, where the noise present, $I_n$, is insufficient to cause false triggering.

This method of providing noise immunity has drawbacks, for fan-out capability is decreased by the amount shown on the curve in Fig. 7 ($I_c$-$I_d$).




4. **Two basic shift-generator modules are connected to form a binary divider** (a). These two modules can also be connected to form a four-stage pseudorandom code generator (b).




5. **Three-phase clock signals are derived and distributed** with this circuit. Phase delays are generated with coaxial-line phase shifters. Clock voltage stability and isolation between clock outputs were important design criteria.

First, ground noise and induced noise, $I_n$, lower fan-out. Then, since the operating point is lower in bias current, more data current is required at the input, and thus the fan-outs of the modules driving this stage are effectively reduced further because more of their total output current is required per card.

*Capacitive coupling*: Two types of capacitive coupling were encountered: parasitic capacitive coupling between components, and capacitive coupling between points on either side of the printed board, with G10 board material acting as a dielectric.

Although the basic frequency involved is the clock, the fast rising edge of the tunnel-diode output (0.4 ns) contains frequency components much higher than the clock frequency. The 0.4-ns edge measured by the sampling scope corresponds approximately to a 1-GHz signal. At 1 GHz the impedance of the 1-pF capacitor is:

$$Z = 1/2\pi fC = 106\ \Omega. \tag{1}$$

The tunnel-diode voltage change of 0.5 volt is capable of coupling considerable current through this impedance. Equation 2 shows the coupling current through 1 pF to be 3 mA:

$$I_c = 0.5\ \mathrm{V}/160\ \Omega = 3\ \mathrm{mA}. \tag{2}$$

Actual measurement shows this to be somewhat less than predicted, but only in the order of milliamperes. Thus we can see that this current is capable of introducing false errors if bias levels are not reduced to eliminate the problem. But again, lowering the bias lowers fan-out and increases input drive requirements.

Values of parasitic capacitance between components were difficult to determine but experimentation showed them to be small with the packaging configuration used. Capacitance between points on opposite sides of the printed board such as the *0* output and the *1* output showed capacitances of 0.5-1.5 pF until the boards were modified to decrease the coupling. The modification consisted of spreading the points farther apart by insertion of another piece of glass board. This same modification was used on the input pads on the cards.

The parasitic capacitance between components does put some limitations on packaging. An attempt to increase the packaging density resulted in an increase in parasitic capacitance to such an extent that the circuit would only operate at a much lower frequency.

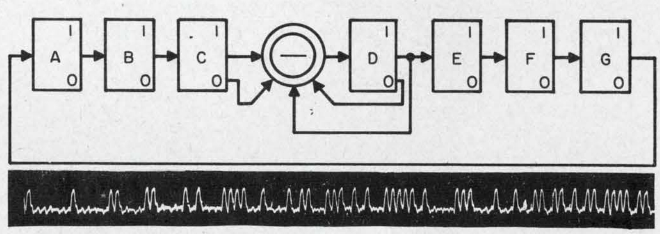
*Reflected signals*: Ideally the length of the connections, $l$, between cards should be as short as possible ($l << \lambda$), as on the code generator trays. Several places on the system, however, require the use of coaxial lines for signal routing, such as the connection between the two generator trays and between the generator inputs and the comparator. Where the length of the connection would be less than one clock wavelength, a longer connection, which must be some multiple of a wavelength,

**Table 1. Single error percentages.**

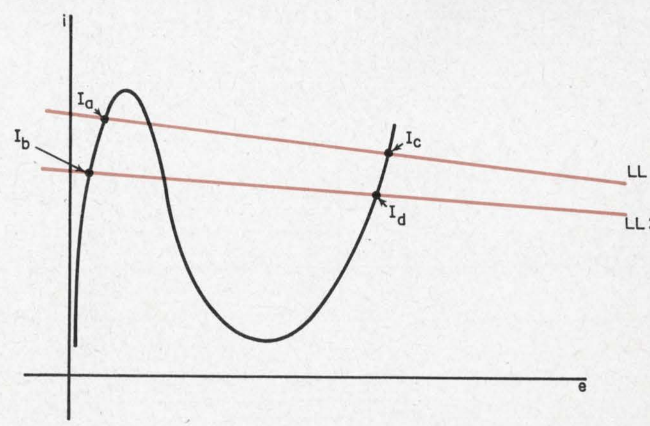
| Run | Time (min) | % errors |
|---|---|---|
| 1 | 3<br>7<br>11 | 0.0013<br>0.0011<br>0.0009 |
| 2 | 5<br>10<br>15 | 0.0003<br>0.0004<br>0.0005 |
| 3 | 5<br>10<br>15<br>25 | 0.00062<br>0.00057<br>0.00058<br>0.00053 |

**Table 2. Group error percentages.**

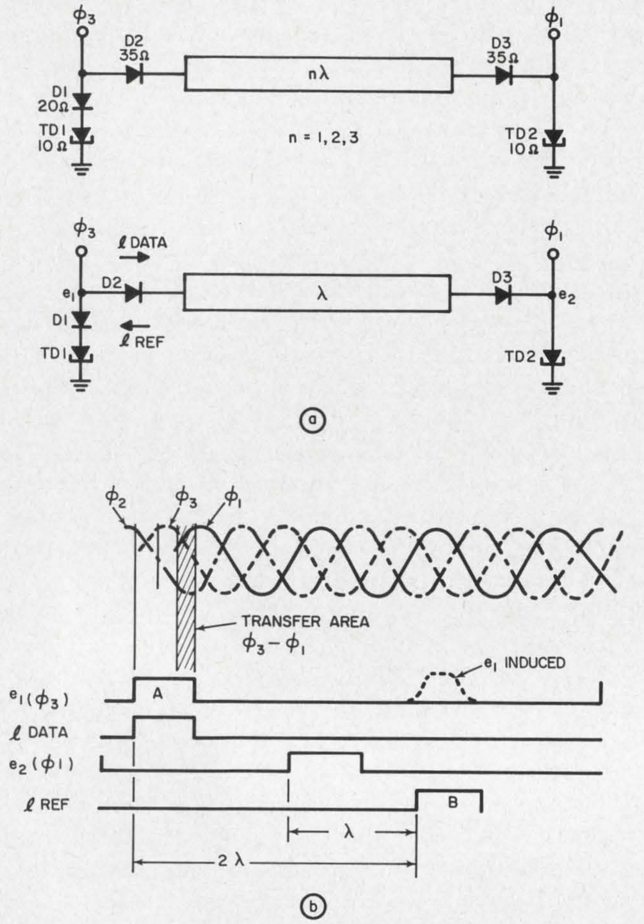
| Time (min) | % group errors |
|---|---|
| 2 | $5.5 \times 15^{-6}$ |
| 4 | $5.5 \times 10^{-6}$ |



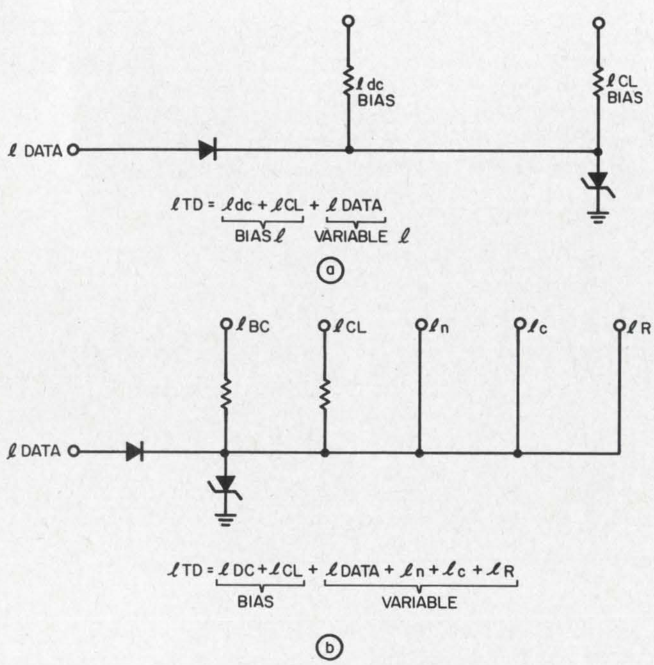

6. **Shift register modules are connected to form a seven-stage** pseudorandom code generator (top). Two of these generators are used in the system. The coded output waveform of one generator is shown at the bottom.




7. **Effects of bias levels on tunnel-diode operation are shown** by the load lines plotted on the characteristic curve for a 15-mA-peak tunnel diode. LL1 represents a bias current of 13 mA while LL2 is for a 10-mA bias.




8. **Coaxial coupling is used between system stages** (a). Diodes D2 and D3 are needed for isolation while diode D1 provides the level shift necessary for the output of tunnel diode TD1 to overcome the combined threshold of diodes D2 and D3. Part (b) shows the effect of reflected signals if the bias of D1 is not low enough.




9. **An ideal tunnel diode is shown in (a)** together with its bias and data currents. Actual tunnel diode is shown in (b).

must be used.

The problem encountered in these coaxial connections is one of reflected signals. It stems from the difficulty of connecting two nonlinear, low-impedance devices through a properly terminated coaxial cable. Figure 8a shows the method of coupling that was used. The resistance values shown were selected for the bias conditions at which the various diodes operate. Diodes *D2* and *D3* are both needed for isolation. Because the *1* output level of tunnel diode *TD1* is insufficient (0.6 V) to overcome the combined threshold of diodes *D2* and *D3* (0.8 V), diode *D1* was inserted to provide the level shift needed (0.5 V).

Although the diode resistances approximate the 50-ohm termination needed for the coaxial cable, and isolation diodes *D2* and *D3* minimize the reflections that are introduced, some reflected signal ($I_r$) can still be coupled back into *TD1* unless the bias of *TD1* is reduced below the level of the reflected signal.

Figure 8 shows the effect of reflected signals if the bias of *D1* is not reduced enough. A data bit *A* is shifted into *TD1* and one wavelength or bit-time later the data are shifted into *TD2*. At the instant *TD2* is switched to its high-voltage state, the line is abruptly terminated in a high impedance instead of 50 ohms because *D2* and *D3* are suddenly reverse-biased. The result is that a reflected current bit, *B*, is sent back down the coaxial line two bit-times later than the original data pulse and coupled into *TD1*. The way to avoid this problem was again to reduce the bias, which, as in the case of noise, further reduced the fan-out.

Figure 9 illustrates the effect of the major problems in system operation: Fig. 9a shows the ideal tunnel diode with its bias and data currents; Fig. 9b shows the practicable case. As system complexity increases, the signals on the ground planes and the number of interconnections increase, and—predictably—system operation becomes more unstable.

Two of the problems discussed—capacitive coupling and noise—are directly related to frequency. As frequency increases, the impedance of the coupling decreases:

$$Z_c = 1/\omega C. \qquad (3)$$

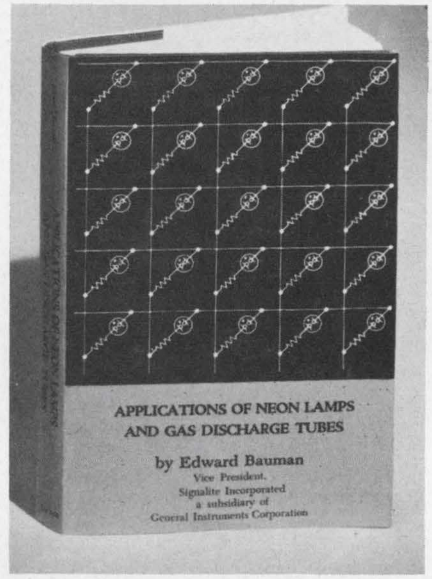
The noise problem and signals on the ground are due primarily to the series inductance in the ground plane which causes it to deviate from an ideal ground. From:

$$Z_L = \omega L, \qquad (4)$$

it can be seen that the series impedance of the ground increases with frequency also.

As would be expected, when operation at higher frequencies was attempted, the problems were too great to allow the system to perform, even though individual logic functions could be made to operate at a considerably higher speed. ■ ■

# Book Reviews




## A glut of gaslights for every design need

*Applications of Neon Lamps and Gas Discharge Tubes,* Edward Bauman (Carlton Press, New York), 160 pp. $2.95.

Here is a book full of circuits, display devices, memory elements, etc., all using neon glow lamps and gas discharge tubes. Its 160 pages are packed with practical examples of oscillators, timers, switches, and voltage regulators. The book should be useful to any electronic engineer, i.e., circuit and equipment designers, production and test engineers, systems engineers. It is written in simple language and the material is arranged in order of increasing complexity to aid understanding.

While most of the lamps discussed in the book are manufactured by Signalite, Inc., understanding the operation of each circuit should make it possible to use other lamps in similar applications. In this sense, the book is fairly objective and it can very well serve as a general reference on applications of neon glow lamps and gas discharge tubes.

*—Peter N. Budzilovich*

# CAREER INQUIRY – confidential

Respond to the career opportunities advertised in this issue. Fill out and send us this handy resume. **Electronic Design** will do the rest – neatly typed copies of this form will be mailed to the companies of your choice, indicated by the circled Career Inquiry Numbers at the bottom of this page.

**2**

| **Name** | | | **Home Phone** | |
|---|---|---|---|---|
| **Home Address** (Street) | | City | State | ZIP Code |
| **Age** | **U.S. Citizen** ☐ Yes ☐ No | **Security Clearance** | | |

| Prime Experience | Secondary Experience |
|---|---|
| | |
| | |
| | |
| | |
| | |

| **Desired Salary** | **Availability Date** |
|---|---|
| | |

**Employment History** – present and previous employers

| | | | |
|---|---|---|---|
| Company | | | |
| City, State | | | |
| Dates | to | to | to |
| Title | | | |
| Specialty | | | |

**Education** – indicate major if degree is not self-explanatory

| | | | |
|---|---|---|---|
| Degree | | | |
| College | | | |
| City, State | | | |
| Dates | to | to | to |

**Additional Training** – non-degree, industry, military, etc.

**Professional Societies**

**Published Articles**

**Career Inquiry Numbers:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 |
| 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 |

**ELECTRONIC DESIGN**
850 Third Avenue
New York, New York 10022

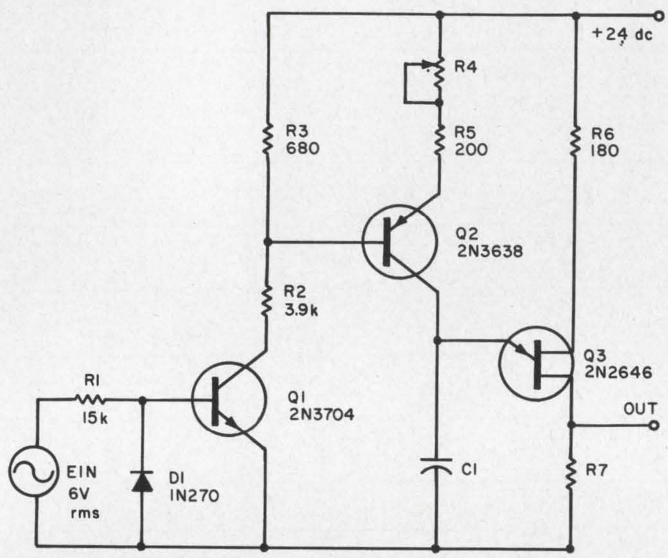
# UJT and ac current source used to divide frequency

This circuit will divide an input sine-wave frequency by 2 to 20 depending on the setting of *R4*. With appropriate circuit values, the input sine-wave frequency may be from 10 to 100 kHz. The maximum output pulse frequency will be in the vicinity of 50 kHz.

The value of *R1* is such as to allow the generator, $E_{IN}$, to drive *Q1* into cutoff or saturation. When *Q1* is saturated, a voltage drop will be developed across *R3*, which will be matched by the sum of $V_{BE}$ of *Q2* and the voltage drop across *R4* and *R5* created by *Q2* emitter current. Virtually all *Q2* emitter current becomes *Q2* collector current, which will charge *C1*. The magnitude of *Q2* emitter or collector current will be determined by the setting of *R4*. When *Q1* is cut off, *Q2* is also cut off, and *C1* can discharge only by means of negligible leakage current through *Q2*, *Q3*, or its own internal resistance.

Then, for each cycle of sine-wave input, one pulse of constant amplitude current will charge *C1*.

The circuit can be proportioned so that the capacitance of *C1*, the magnitude of the current pulse as established by *R4*, and the frequency of current pulses as established by the $E_{IN}$ generator, will be sufficient periodically to charge *C1*, in steps, to a voltage level equal to the peak point of unijunction transistor *Q3*. At that point, *C1* will discharge through *Q3* and *R7* to the valley point of *Q3*. The period of the charge and discharge of *C1* can be made any exact multiple of the period of $E_{IN}$ by proper adjustment of *R4*. The discharge of *C1* through *R7* will create an output voltage pulse across *R7*, which will be a predetermined submultiple of the frequency of $E_{IN}$.




1. **Switching current source** Q2 charges C1 in steps up to the "firing" of Q3. The number of steps depends on R4, R5, and C1.

**VOTE!** Circle the Reader-Service-Card number corresponding to what you think is the best Idea-for-Design in this issue.

**SEND US YOUR IDEAS FOR DESIGN.** Submit your IFD describing a new or important circuit or design technique, the clever use of a new component, or a cost-saving design tip to our Ideas-for-Design editor. If your idea is published, you will receive $20 and become eligible for an additional $30 (awarded for the best-of-issue Idea) and the grand prize of $1000 for the Idea of the Year.

## Effects of temperature and R4 variations

| Input frequency ($f_{IN}$) | Dividing multiple (N) | Temp (°C) | R7 (ohms) | Range of R4 to hold given N (ohms*) |
|---|---|---|---|---|
| 60 Hz | 5 | 30 | 120 | 315 to 440 |
| 60 Hz | 20 | 30 | 120 | 2270 to 2390 |
| 60 Hz | 5 | 50 | 120 | 310 to 440 |
| 60 Hz | 20 | 50 | 120 | 2250 to 2380 |
| 100 kHz | 5 | 30 | 56 | 205 to 250 |
| 100 kHz | 20 | 30 | 56 | 1745 to 1795 |
| 100 kHz | 5 | 45 | 56 | 205 to 250 |
| 100 kHz | 20 | 45 | 56 | 1762 to 1820 |

To ensure maximum stability of the circuit's performance as a frequency divider, the time constant ($C1$ and $R7$) should be such that the pulse width across $R7$, when $Q3$ fires, will be roughly equal to half the period of $E_{IN}$. This time constant will permit unijunction transistor $Q3$ to sink all of the remaining portion of the current pulse from $Q2$ collector; the sinking of this current is what finally causes $C1$ to fire $Q3$.

Circuit capability was investigated at different frequencies, temperatures, and dividing multiples. Circuit values valid for all conditions appear in the schematic. Missing values are given in the table above. These values are related to the input frequency and dividing multiple.

An idea of circuit stability is given in the table by the range of $R4$ values, where the dividing multiple, $N$, remained constant. For example, at 60 hertz in a divide-by-five circuit, the mean value of $R4$ is 380 ohms. This value could be varied ±15% with no change in the dividing multiple. The tabulation shows only minor changes in the $R4$ range with temperature changes of 20°C. Also, a ±10% change in the power supply voltage had no more effect on the range of $R4$ than a 20°C temperature change.

*J. C. Rich, Engineer, Test Equipment Engineering Quality Control, General Electric, St. Petersburg, Fla.* VOTE FOR 110

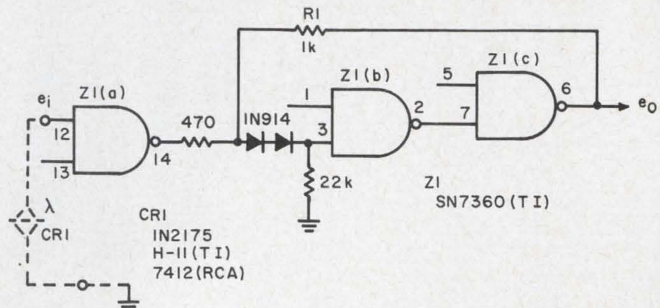
## Photocell output squared with IC digital systems

Entering photoelectric data into an integrated-circuit digital system often requires the design of special circuits using conventional components and requiring additional power supply voltages.

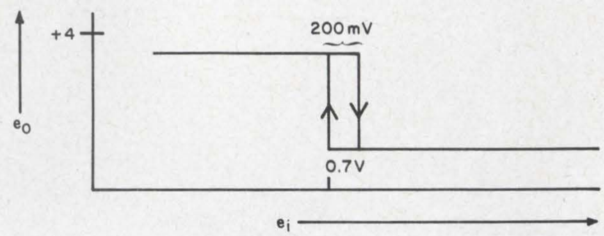
The circuit described here accomplishes this with a standard IC logic network and a few passive components. This approach will work with most optical shuttering applications that involve a nearby source of light, such as a punched-tape reader or code wheel.

With the IC used, the open-circuit voltage at the input of $Z1(a)$ is near 4 volts (Fig. 1). The current flowing from the input of $Z1(a)$ through the photoconductor to ground is sufficient to sense the impedance variation; no other bias is required.

With the photoconductor illuminated, the impedance is low enough to cause the output of $Z1(a)$ to change state. Resistor $R1$ provides positive feedback to the input of $Z1(b)$ through a diode level converter. Thus the circuit operates as a Schmitt trigger, and when the illumination reaches a threshold level, the output of $Z1$ ($c$) will rapidly change state.




1. **Photoelectric data** is entered into IC logic with a minimum number of discrete components.




2. **Any slowly varying voltages** can be squared with the circuit of Fig. 1, provided that such voltages do not exceed the limitations of the logic. The notation of Fig. 1. is used.

The output rise and fall time is 50 ns, regardless of the rate of change of the illumination level. The small amount of inherent hysteresis prevents ambiguities due to irregular shutter motion and fluctuations in the light source.

The circuit may also be used to square up any slowly varying voltage as long as the input voltage limitations of the logics are not exceeded. With the values shown, the threshold voltage is about 0.7 volt with a 200-mV hysteresis (Fig. 2).

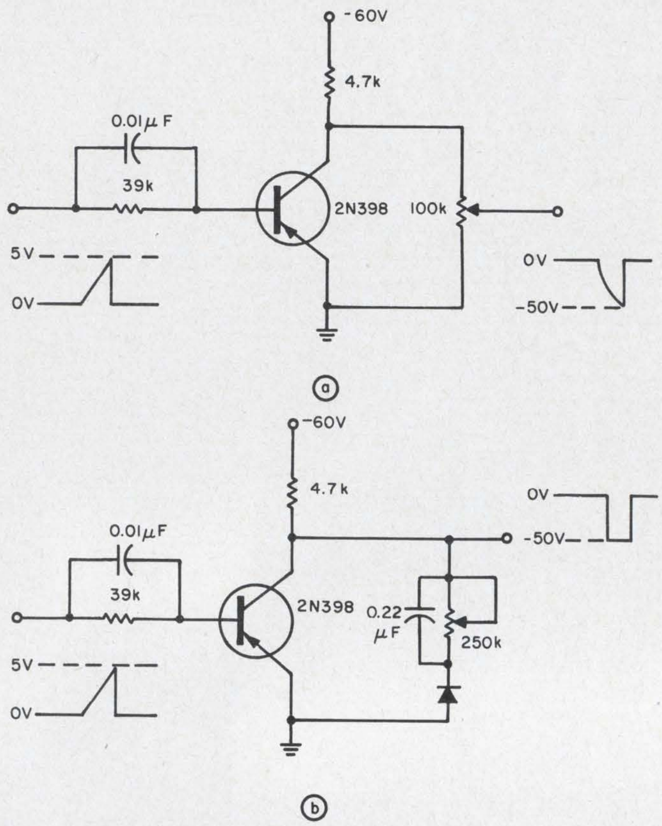
*Harold E. Clupper, Senior Staff Engineer, ITT Federal Laboratories, Fort Wayne, Ind.*

VOTE FOR 111

## "Diode follower" provides undistorted variable pulse

Proper design of collector load can make the output of a saturating pulse amplifier variable without distortion. Rectangularity of the pulse is greatly affected by the position of the wiper arm in the basic circuit (Fig. 1a). The fall time of the output pulse is proportional to the resistance between the wiper arm and the collector.

The circuit of Fig. 1b has the transfer characteristics of an emitter-follower. The capacitor-diode combination provides a low-impedance path for turning off the saturated transistor without affecting turn-on time. The variable dc impedance




**Pulse amplitude** can be varied over a wide range without affecting its rectangularity (b), by the addition of a diode and a capacitor to a commonly used circuit (a).

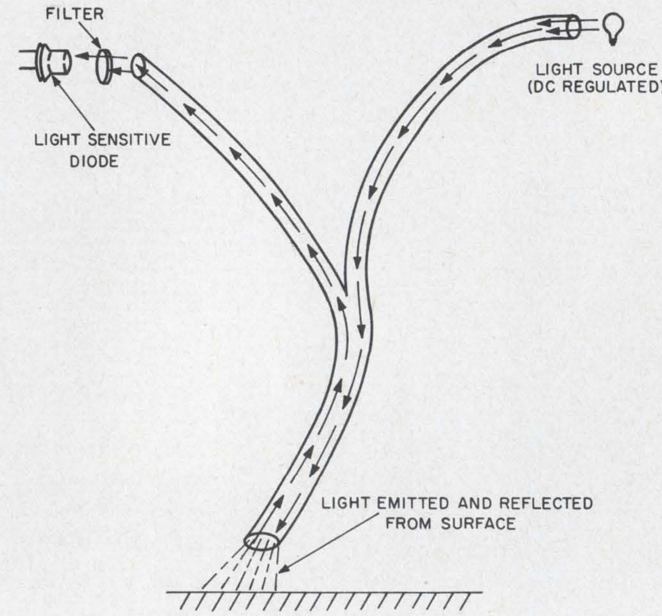
of the circuit allows the collector quiescent point to be shifted, while the zero reference level is established by saturation of the transistor during conduction. These features provide a rectangular pulse of an amplitude that is variable over the full range of the potentiometer.

*William Staewen, Electronics Engineer, Sinai Hospital, Baltimore.* VOTE FOR 112

# Fiberoptics sense water level

This technique meets the unique requirements for measuring the depth of flow on a water table used to develop fluid-logic elements. These requirements are accuracy ($\pm 0.005$ in.), no disturbance of water flow, and provision for simultaneous readings in many places.

The heart of the system is a fiberoptic light pipe in the form of a Y (see diagram). Light is directed into one arm of the Y, emitted through 50 per cent of the fibers at the common end (base of Y), and reflected back from the water surface through the remaining fibers to the opposite arm of the Y. This light is filtered so that a narrow




1. **Distance** between the input-output end of the fiber-optic light pipe and the water surface is read out by the photocell.

band of infrared frequencies impinges on an EG&G SD100 photodiode. Resistance change in the diode due to a change in reflected infrared rays is read on a digital voltmeter. Multiple channels can be recorded on a strip-chart recorder.

This system is linear over a range of half an inch. The reflected light density is an exponential function of distance, but the geometry of the system compensates as distance increases, and an acceptable linear operational range results.

A power supply is required for the prefocused projector-type lamp to avoid 60-Hz noise. A condensing lens is used to increase the amount of light entering the light pipe. The infrared filter eliminates interference from ambient light, so the system may be used in a normally lighted laboratory.

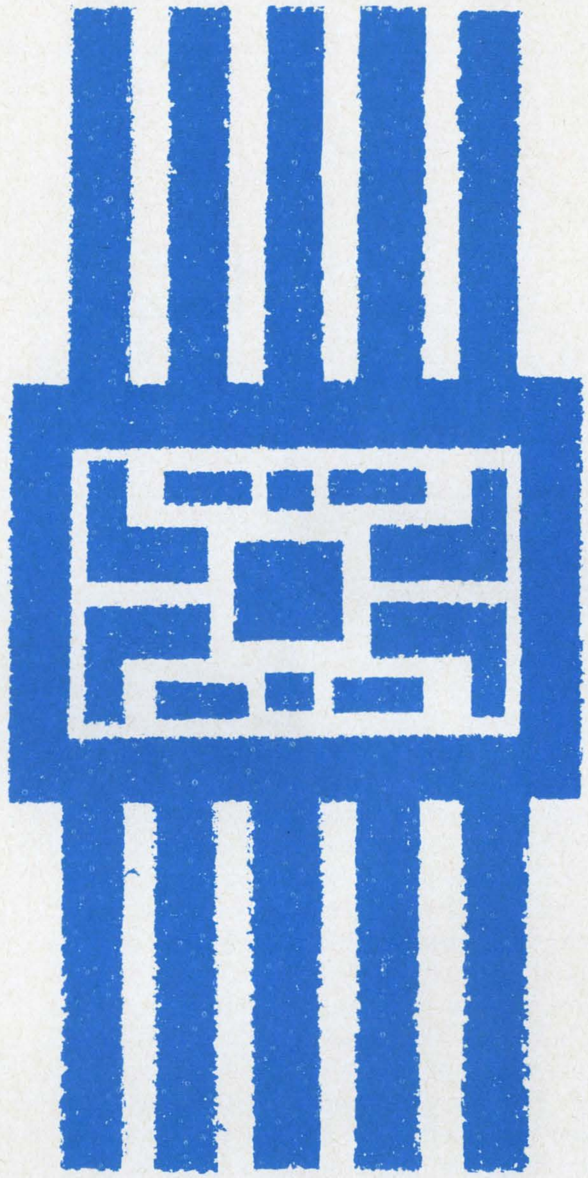
*J. M. Phillips and J. K. Shane, Component Test Equipment Development Div., Sandia Corp., Albuquerque, N. M.* VOTE FOR 113

# Pulse-width discriminator eliminates delay line

This pulse-width discriminator (see Fig. 1a) is useful in discriminating against pulses of less than a specified time duration. The discrimination pulse-width is continuously variable from 1 µs to 3.5 ms.

Pulse-width discrimination is usually accomplished with a delay line and AND gate. Delay

# Almost every engineer who uses our IC bandpass amplifier says it's better than a discrete amplifier.



# (Charlie Wisgard says it's just as good.)

But, at the price, we know that you won't be able to get a discrete or IC bandpass amplifier that can out-perform the PA 7601.

Look at the performance. It has a gain control circuit which provides 12 db of gain reduction with typically less than 10% variation in output terminal impedance. In broadband applications, gain control from 0 to 12 db produces negligible effect on bandwidth over a frequency range of 30 to 150 MHz.

Our PA 7601 is your best solution to high-frequency phase and amplitude distortion problems. For narrowband applications, you can use a bandpass filter or selective feedback components.

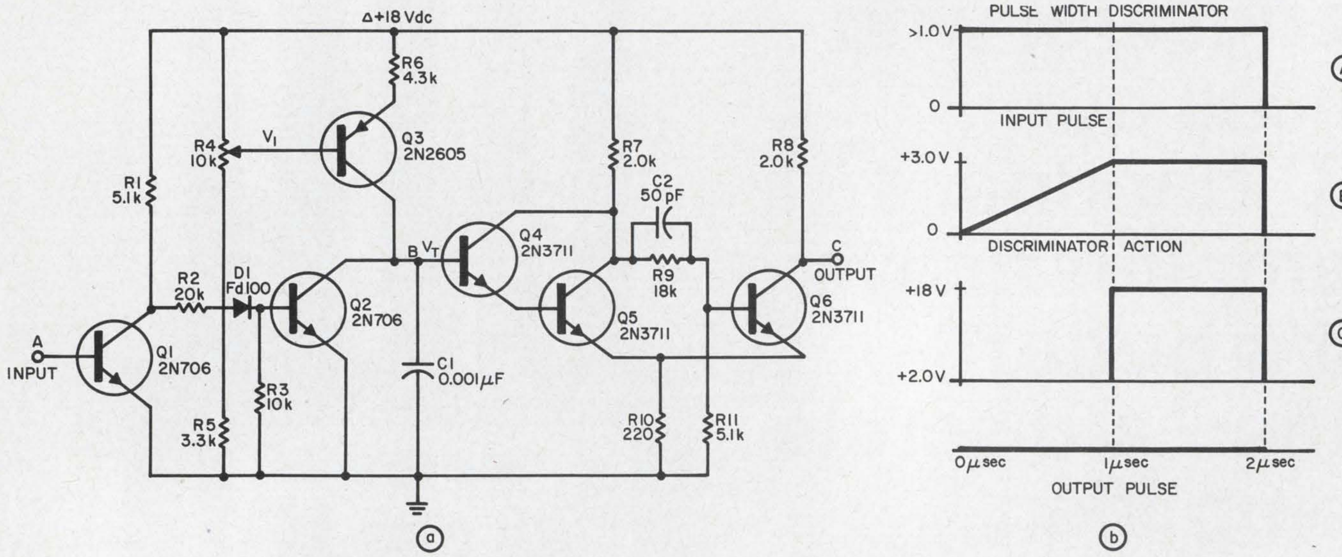
Don't take our word for it. Try the PA 7601 for yourself. It's available in 10-lead flat pack or TO-5 can. Temperature range: −55°C to 100°C.

Call or write: **Philco-Ford Corporation Microelectronics Division Sales Offices:** 2920 San Ysidro Way, Santa Clara, California (408-245-2966) / 999 North Sepulveda, El Segundo, California (213-772-6226) / Northwest Industrial Park, Second Ave., Burlington, Mass. (617-272-1600) / Benson Manor, Suite 114B, Washington Lane, Jenkintown, Pa. (215-885-0430) / 1215 Drew Street, Clearwater, Florida (813-446-0124) / 815 Connecticut Avenue, N. W., Washington, D. C. (202-298-7810) / Suite 208, 700-108th St., N. E., Bellevue, Wash. (206-454-5061) / New York, N. Y. (212-244-1373).

PHILCO Ford

PHILCO-FORD CORPORATION
Microelectronics Division
Santa Clara, California • 95051

ON READER-SERVICE CARD CIRCLE 51




**1. Current source Q3,** switched by the amplifier Q1 and Q2, and capacitor C1 determine the discriminator timing.

lines, however, are generally quite large and of only a few microseconds' delay. The wide discrimination range of this circuit cannot be obtained with a variable delay line.

With no pulse applied, transistor *Q1* is OFF; *Q2* is saturated and shunts current source *Q3* to ground. The base of *Q4* is thus at approximately ground potential. Transistors *Q4*, *Q5* and *Q6* comprise a Schmitt trigger with a trigger level at the base of *Q4* of approximately 3 volts.

Therefore, with no pulse applied, triggering voltage $V_T$ is below the Schmitt-trigger level. When a positive pulse is applied, *Q1* switches ON and *Q2* turns OFF. The current from current source *Q3* is now applied to capacitor *C1*, and the voltage to the Schmitt trigger begins to increase linearly at a rate given by:

$$\Delta V/\Delta t = i/c = [V_{cc} - (V_1 + V_{be3})]/R6\ C1, \quad (1)$$

where $V_1$ is the voltage at the base of *Q3* set by potentiometer *R4*.

The time required for the voltage to reach the 3-volt Schmitt-trigger level is therefore given by:

$$\Delta t = \Delta V\ R6\ C1/[V_{cc} - (V_1 + V_{be3})]. \quad (2)$$

If the input pulse duration is greater than discrimination time $\Delta t$, the voltage across *C1* will reach the Schmitt-trigger level and fire the Schmitt. When the input pulse returns to zero, *Q2* is again switched ON and discharges *C1* to approximately zero volts. This resets the Schmitt trigger; thus an output pulse of approximately 16.0 volts' amplitude will be generated at the output. The time duration is given by:

$$\textit{output pulse time} = \textit{input pulse time} - \Delta t. \quad (3)$$

Since the output pulse time must be zero or a positive quantity, it can be seen from Eq. 3 that, if the input pulse time is less than $\Delta t$, no output pulse will be generated.

Voltage $V_1$ can be varied from +4.4 volts to +18.0 volts. From Eq. 2 this gives a continuously variable discrimination time range of 1 μs to infinity. The upper discrimination time, however, is limited owing to the requirement that the Darlington configuration, *Q4* and *Q5*, must saturate. Therefore, the minimum current from current source *Q3* must be sufficient to keep *Q4*, *Q5* saturated. This current is given by:

$$I_{3mW} = V_{cc}/[(R7+R10)\beta_4\beta_5] \approx 18/(2200)10^4 = 8.2\times10^{-7}\ \text{A}, \quad (4)$$

assuming $\beta_4 = \beta_5 = 100$.

This gives a maximum discrimination time from Eq. 2 of:

$$\Delta t = \Delta V(c/i) = (3\times10^{-9})/(8.2\times10^{-7}) = 3.65\ \text{ms}. \quad (5)$$

Changing *R6* and choosing good switching transistors makes it possible to lower the minimum discrimination time to 200 ns or better.

*R5* limits the minimum value of $V_1$ to 4.4 volts in order to ensure the proper bias at *Q3* collector-base junction at all times.

*C. P. Pittman, Advanced Technology Operations, Beckman Instruments, Inc., Scientific and Process Instruments Div., Fullerton, Calif.*

VOTE FOR 114

**IFD Winner for Oct. 11, 1966**

**Gottfried Irminger,** Design Engineer, Wettingen, Switzerland.

His Idea, "Diode bridge saves wires in motor-reversing systems," has been voted the $50 Most Valuable of Issue Award.

**Cast Your Vote for the Best Idea in this Issue.**

# The wire that's specially-made for feeding automated wiring systems:

## Brand-Rex Turbowrap™

Turbowrap runs like silk in automatic and semi-automatic wiring machines and tools, because it's *unusually uniform.* Foot by foot, and lot by lot — consistent quality in electricals, physicals and mechanicals reduces the chance of jammed or erratic feeding, nicks, strains, cuts or shorts.

And Turbowrap, in a broad choice of insulations and sizes, gives you almost unlimited design freedom. Standard insulations include semi-rigid PVC and PVC/nylon, Teflon FEP and FEP/nylon, Teflon TFE, Kynar and Polysulfone. Sizes as small as #30 AWG, and walls as thin as .004", help you put more wire in less space.

Various Turbowrap types have been expressly engineered for the world's leading manufacturers of computers and business machines. They're one reason why Brand-Rex has chalked up more UL approvals for business machine wire than any other company.

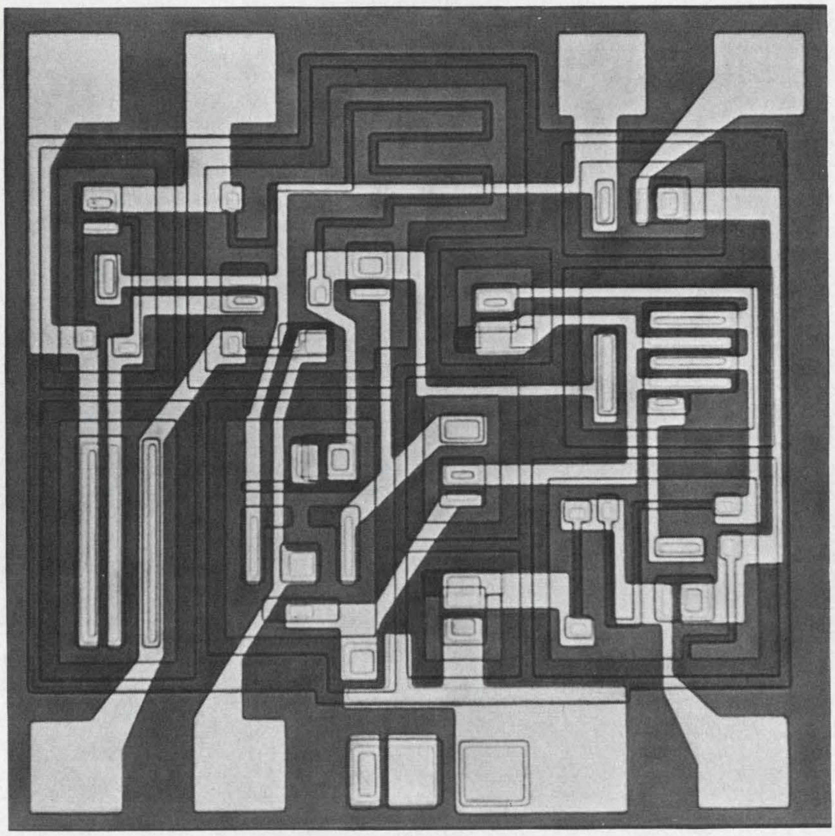
Want to get more out of automated, high-density wiring? Write us for details on Turbowrap.

**AMERICAN ENKA CORPORATION**
**BRAND-REX DIVISION**
WILLIMANTIC, CONNECTICUT 06226
PHONE 203 423-7771

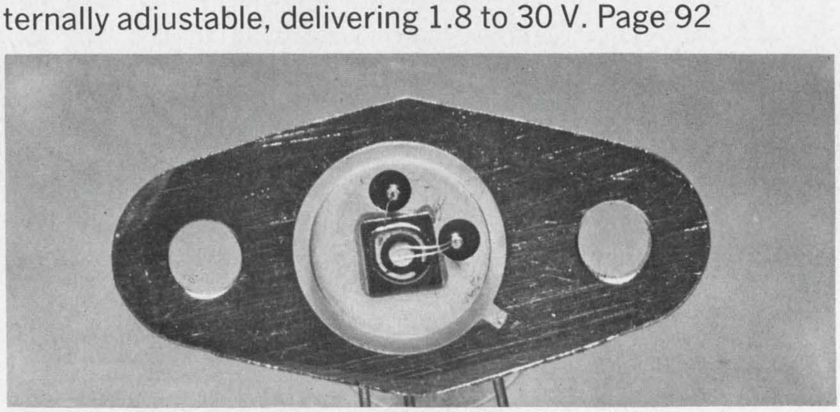
BRAND REX

ON READER-SERVICE CARD CIRCLE 52

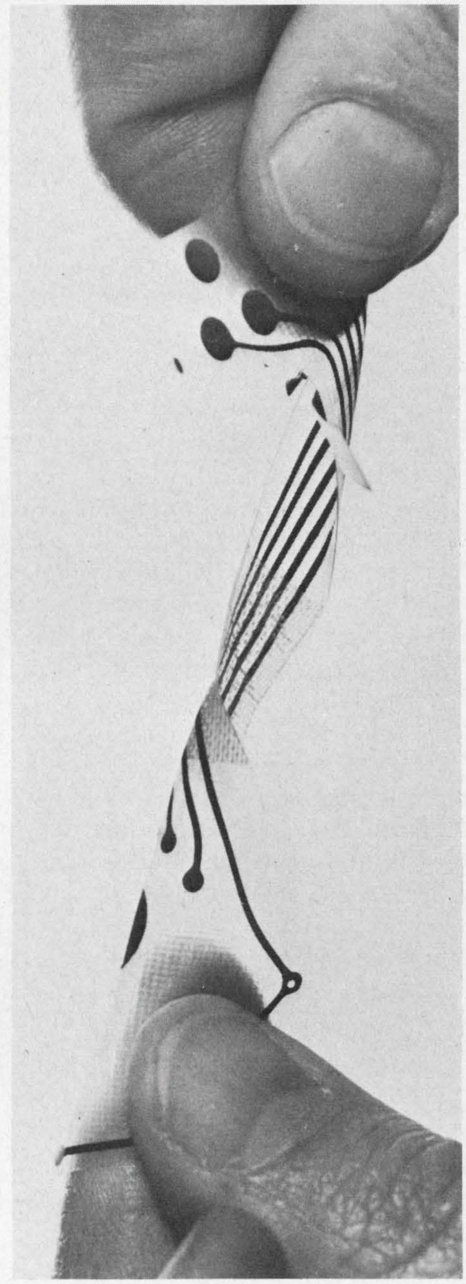
# Products



**A single chip prevents voltage dip.** This monolithic IC is externally adjustable, delivering 1.8 to 30 V. Page 92



**Silicon npn transistor has 1000-V breakdown** and 40-MHz gain-bandwidth product. Great for driving CRTs. Page 112



**More give to the inch** in this thermoset laminate. Page 120

## Also in this section:

**Silicon power transistors** available in low-profile flat-packs. Page 113

**Ordinary scopes become microwave receivers** with YIG-tuned plug-ins. Page 116

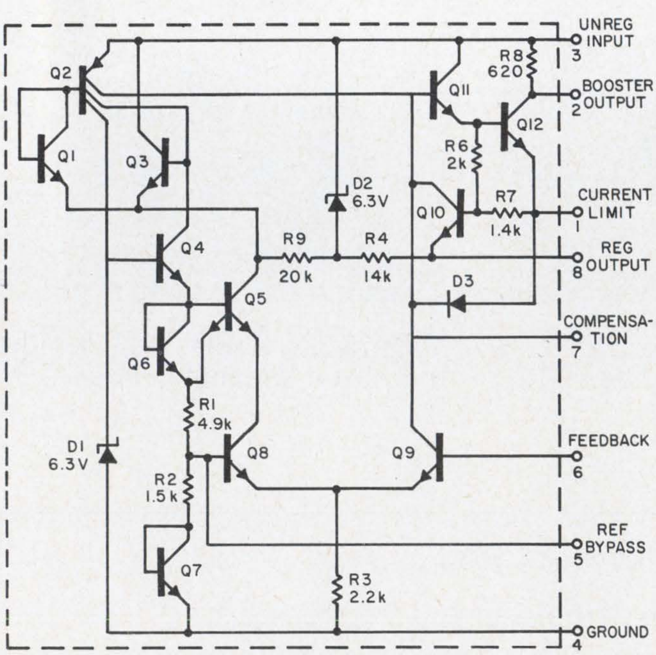
**Open-air cryogenics** without frost problems. Page 122

# IC voltage regulator is externally adjustable. Booster transistors give 2-A outputs.

*National Semiconductor Corp., Microcircuits Div., 2950 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-4320. P&A: $60; stock to 2 wks.*

A single 35-mil square monolithic integrated circuit delivers regulated voltage, externally adjustable from less than 2 to more than 30 volts. Operating as a linear, dissipating or a high-efficiency switching regulator, National Semiconductor Corporation's LM100 voltage regulator delivers up to 20 mA. An external transistor can be added for currents to 250 mA. A second external power transistor gives the regulator 2-A capabilities.

Regulation is better than 1% for varying load and line conditions. The 8-pin TO-5 device features 1% temperature stability over the full MIL range, external resistor-adjustable short-circuit current limiting, fast transient responses and a 10- to 100-mW standby dissipation. Typical performance specs are given in the Table.

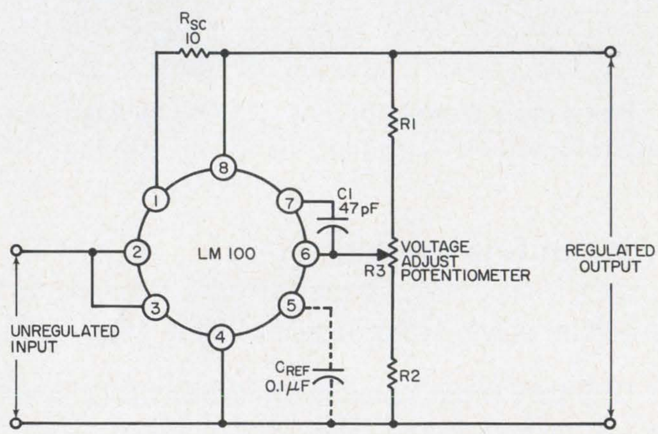



1. **Basically a single-stage diff-amp** with Darlington emitter-follower output, the regulator permits addition of pnp at Q12 for higher currents.

A schematic of the IC is shown in Fig. 1. Basically it is a single-stage differential amplifier with a Darlington emitter-follower output. The use of a pnp, Q2, as a collector load ensures high gain and good supply voltage regulation. Connecting a small external capacitor from the collector to the base of the amplifier and isolating the load in the Darlington emitter-follower keeps the regulator from oscillating with any resistive or reactive load. Excellent transient response is also provided.

The collector of output transistor Q12, brought out separately, and 620-Ω emitter-base resistor R8 permit addition of an external pnp transistor for higher currents. This resistor is shorted out when the regulator is used without the external transistor.

The value of output current limit is determined by an external resistor between the current limit and regulated output terminals. The negative temperature coefficient of the emitter-base voltage of Q10 and the temperature coefficient differential between Q12 and Q10 cause the current limit to halve as chip temperature increases from 25 to 150°C. The regulator delivers maximum current




2. **Output of basic regulator circuit** is set by R1 and R2 with potentiometer R3 providing fine adjustment. Reference capacitor cuts output noise.

at room temperature. It is still protected when the output is shorted and the dissipation increases: the current will decrease as the chip heats, holding dissipation to a safe level. This current-limiting scheme works only when the two transistors are in close thermal contact, as in this monolithic IC.

The regulator is stable without bypass capacitance on the output (if external booster transistors are not used), so it is possible to obtain extremely rapid current limiting for sensitive transistor loads. If current limiting is not needed, load regulation can be improved by shorting together the current limit terminals ($R_{sc}=0$). Short-circuit protection is obtained by connecting a resistor between the current limit terminals.

The output impedance at high frequencies can be reduced somewhat by addition of a low-inductance (solid tantalum) capacitor. A 0.1-$\mu$F capacitor on the reference bypass terminal will cut noise inherent in the reference diode.

A basic regulator circuit it shown in Fig. 2. The output voltage is set by R1 and R2 with fine adjustment provided by potentiometer R3. The resistance seen by the feedback terminal should be approximately 2.2 k$\Omega$ to minimize bias current drift.

Higher output currents and better load regulation can be obtained by adding external "booster" transistors. Output currents are then limited only by the power-dissipating and current-handling capabilities of the boosters. Use of these transistors as the series pass elements also reduces internal dissipation and prevents temperature drift due to heating of the internal reference.

One circuit capable of up to 200 mA load current with 1% regulation is shown in Fig. 3. When external transistors (such as this 2N2905A) are used, it is necessary to bypass the output terminals close to the IC to suppress oscillations in the minor feedback loop around the external transistor and the output transistor. If even greater output currents are required, it is necessary to add a second booster to provide more current gain. The pnp Q1 then drives the npn power transistor Q2 (2N3055 in Fig. 3). Here both the input and output terminals must be bypassed with low-inductance capacitors.

## Typical performance

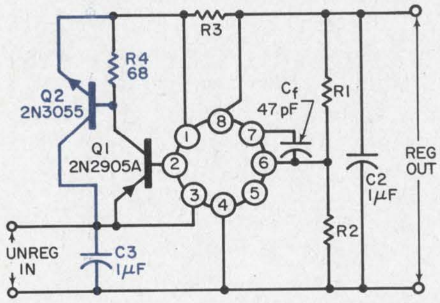
| | |
|---|---|
| Input voltage range | 7.5-40 V |
| Output voltage range | 1.8-30 V |
| Output-input voltage differential | 2.5-30 V |
| Load regulation ($R_{SC}=0$, $I_o<15$ mA) | 0.1% |
| Line regulation | 0.03%/V |
| Output voltage TC | 0.003%/°C |
| Output noise voltage | 0.005% |
| Long-term stability | 0.1% |
| Standby current drain | 1 mA |
| Minimum load current | 1.5 mA |

A switching regulator is shown in Fig. 4. It is designed for an application where an 18-Vdc source supplies a 5-V, 1-A digital system. Conversion efficiency is better than 80% at full load. Regulation, load and line, exceeds 1%. The overshoot for a 0.2-A load transient is 0.15 V; recovery time is 0.36 ms. The output ripple is 40 mV at a 5-kHz switching frequency. Dissipation is 0.3 W in the series-pass transistor Q1 and 0.5 W in the current-return diode D1.

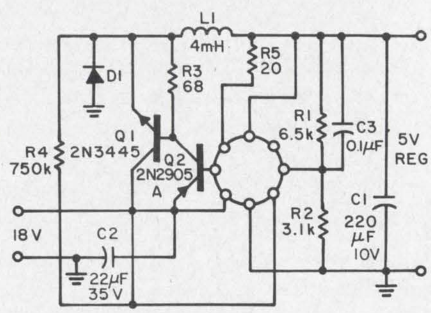
An external npn and pnp are cascaded to handle the output current. This regulated output is fed back through a resistive divider that determines the output voltage. The regulator is made to oscillate by applying positive feedback to the reference terminal through R4.

In applications such as integrated logic circuitry, performance can be improved if the regulator output changes with temperature such as to operate the load at its optimum voltage. Optimum performance can be realized by powering the devices with a voltage that decreases with increasing temperature. The circuit is shown in Fig. 5. Silicon diodes are used in the feedback divider to give the required negative temperature coefficient. Diode-connected transistors (base shorted to collector) can be used for greater accuracy.

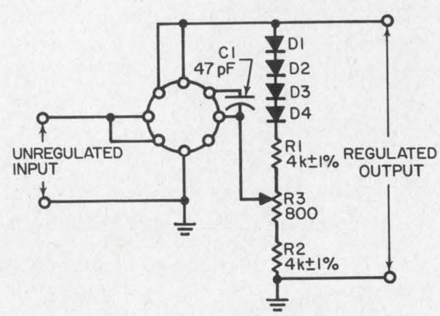
CIRCLE NO. 211




3. **Booster transistor Q1** brings outputs to 200 mA. Addition of Q2, C3 and R4 (color) gives 2-A output. Tantalum bypass capacitors C2 and C3 prevent oscillations.

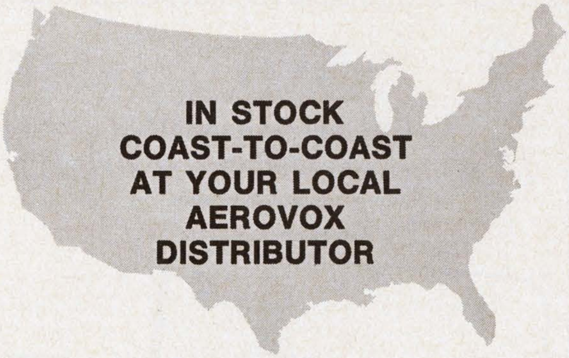



4. **Switching regulator** supplies 5 V, 1 A from an 18-Vdc source at 80% efficiency. When Q1 and Q2 are off, inductor L1 supplies the load with D1 as a return path.




5. **Temperature compensating regulator** has 5.5-V output at −55°C, decreasing to 4 V at 125°C. Diode-connected transistors rather than silicon diodes will increase accuracy.

## if you're developing prototype hybrid circuits you need this...




# CHIP CAPACITOR ENGINEERING KIT


AEROVOX Hi-Q ATTACK INDIVIDUAL MISTAKES AIM ZERO DEFECTS PROGRAM

AEROVOX—the industry's leading supplier of ceramic chip capacitors offers this Engineering Kit to facilitate your prototype development of hybrid circuits. The kit contains 125 chip capacitors in values from 1 pf to 100,000 pf in three basic temperature characteristics (stable, semi-stable and Hi-K) to permit the user to select the smallest chip for any given temperature and capacitance requirement.

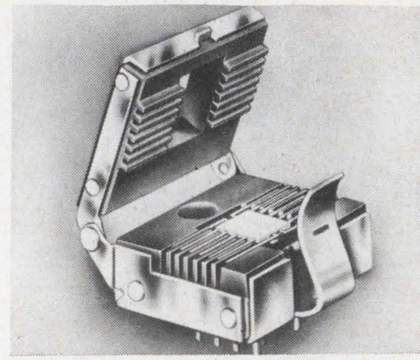
The CERALAM capacitor featured in this kit is a rugged, monolithic block of ceramic dielectric and noble metal plate laminated into an extremely dense unit. Because of their unique structure, these units are impervious to moisture and organic solvents. They can be soldered or welded directly into the circuitry. The high ratio of capacity-to-volume inherent with Ceralam capacitors permits significantly smaller sizes suited to hybrid circuitry.

The Chip Capacitor Engineering Kit is available from your local Aerovox Distributor at $59.95. For the name of your nearest distributor or further information write or call. . . .

AEROVOX Hi-Q®

**AEROVOX**
CORPORATION
OLEAN, NEW YORK

ON READER-SERVICE CARD CIRCLE 55

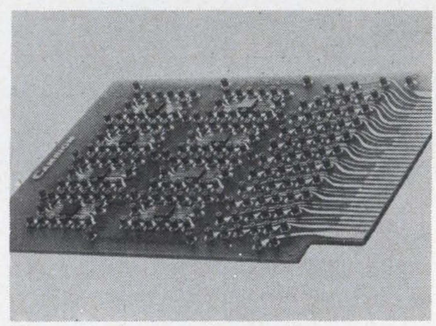


## Flip-top IC sockets offered in polysulfone

*Barnes Development Co., Lansdowne, Pa. Phone: (215) 622-1525.*

Series MD-80 "flip-top" sockets for flat-pack integrated circuits are manufactured of polysulfone. The material allows an operating temperature range of −65 to 150°C. They accept flat-packs with as many as 14 leads on 0.05-in. centers in all commonly used sizes and configurations. Like other units of the manufacturer's line, automatic positioning and lead isolation is a standard feature.

**CIRCLE NO. 212**

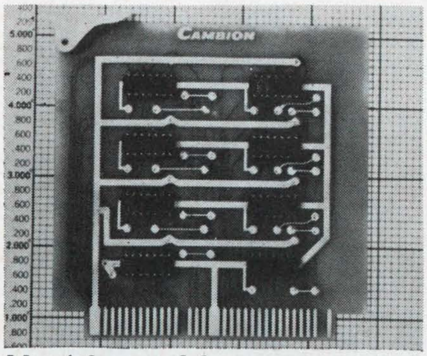


## Patch-board cards for IC flat-packs

*Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. Phone: (617) 876-2800. P&A: $21.40 (10-49); stock.*

The same hardware system can be used from breadboard to production with these versatile flat-pack cards. Interconnection between microelectronic circuits can be made permanently or with 0.04-in. diameter patch-cord plugs. Jacks are connected by PC buses to a 70-pin connector for power and ground connections. Cards come in either 8 or 16 flat-pack locations. Terminal connections are available for final circuit wiring.

**CIRCLE NO. 213**

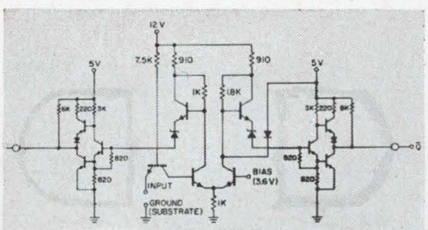



## Up/down binary counter is 4-stage flip-flop

*Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. Phone: (617) 876-2800. P&A: $49 (10 to 49); stock.*

This up/down binary counter is a 4-stage J-K flip-flop card assembly that can count in either direction. The counter can preset to any desired number. Any word length that is an increment of 4 bits may be assembled by properly cascading the logic card assemblies. High speed and excellent noise immunity are featured.

**CIRCLE NO. 214**

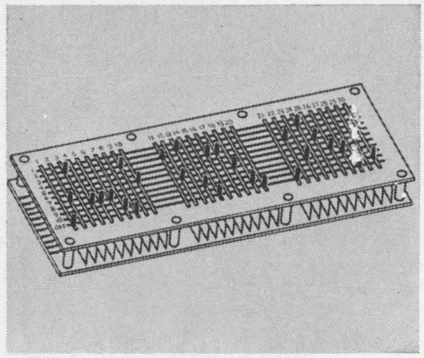



## Digital line receiver has high noise immunity

*Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. Phone: (408) 245-1000. Price: $31.80 (military), $23.80 (commercial), (100).*

This digital line receiver is applicable in military and industrial logic applications requiring high noise immunity. Designed primarily as a signal discriminator at the end of a coax transmission line in digital data systems, the circuit is also useful as a voltage comparator. Consisting of two gates driven by a differential amplifier, the unit has a TTL input and complementary outputs compatible with DTL and TTL logic. Input threshold is set by the differential amplifier reference voltage which may be adjusted over a 3- to 4.5-volt range.

**CIRCLE NO. 215**

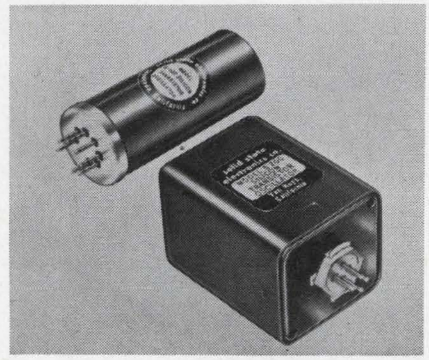


## Crossbar selector replaces 30 wafers

*Cherry Electrical Products Corp., 1650 Old Deerfield Rd., Highland Park, Ill. Phone: (312) 432-8182. Price: $43.*

Thirty 10-position wafer switches are said to be replaced by the C10-43A crossbar selector switch. With 300 crosspoints, the C10-43A mounts on 41 in.$^2$ of panel space and requires no soldering. The manufacturer estimates that use of the switch results in a 50% panel space saving over rotaries.

**CIRCLE NO. 216**

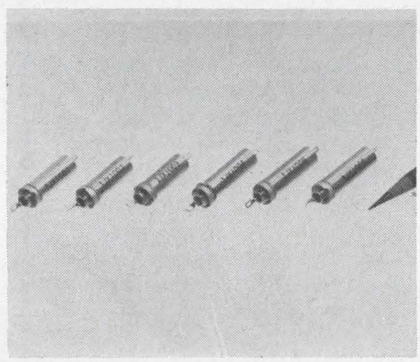


## Transistor oscillator generates sine waves

*Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. Phone: (213) 785-4473. P&A: $185; 1 wk.*

The Models S-100 and S-200 silicon transistor oscillators are epoxy-encapsulated units designed to create a sine wave signal. Both are plug-in modules; S-100 is a tubular design while S-200 is rectangular. Temperature rating is −20 to +85°C. Due to the ruggedized design, applications are seen in missiles and airborne areas.

**CIRCLE NO. 218**

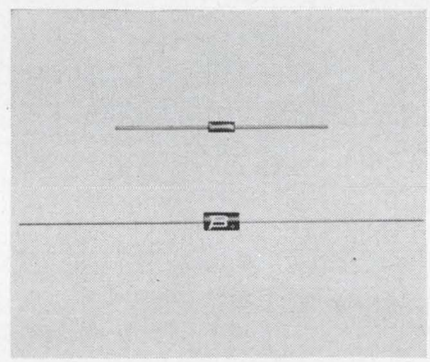


## Submin EMI filters have low insertion loss

*Sprague Electric Co., 347 Marshall St., North Adams, Mass.*

Designed for use on low-voltage power and control lines, these filters offer low dc resistance and are available in six circuit configurations. L and pi designs are rated at 0.5 A; T and double-L at 0.4 A. All units are rated at 50 Vdc for continuous operation from −55 to 85°C. The frequency range is 20 kHz to 100 MHz. The units are hermetically sealed with glass-to-metal seals in corrosion-resistant metal cases.

**CIRCLE NO. 217**

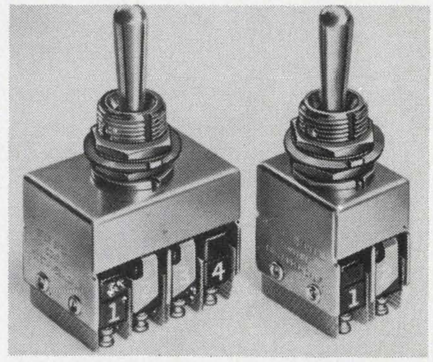


## Micromin cap meets environmental specs

*Bourns, Inc., Trimpot Div., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 686-7404.*

This capacitor, encased in a high temperature plastic, molded body of only 0.1 x 20-in. has a terminal strength of 5 pounds. In addition, it meets all the applicable environmental conditions of MIL-C-11015C for voltage temperature limits, life, vibration, temperature cycling, moisture resistance and immersion. Its gold-plated nickel leads are weldable and solderable.

**CIRCLE NO. 219**

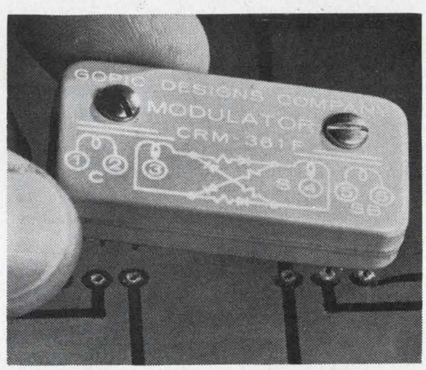


## Three-position toggle provides quick transfer

*Master Specialties Co., 1640 Monrovia, Costa Mesa, Calif. Phone: (213) 642-2427.*

A detenting action allows quick and positive transfer in the Series 21 three-position toggles. A choice of three actions is offered in the line: momentary-maintain-momentary, maintain-maintain-maintain, maintain-maintain-momentary. The switching mechanism transfers contacts to within 1° of the toggle lever's 34° travel arc.

**CIRCLE NO. 220**



## Modulator-demodulator for PC mounting

*Gopic Designs Co., 2166 Chatsworth Blvd., San Diego, Calif. Phone: (714) 222-6948. P&A: $34 (1 to 9); stock.*

One of a new series of ring modulator-demodulators is designed for mounting directly on closely-spaced PC cards. Precisely balanced transformers and carefully selected carbon film resistors and silicon diodes ensure adequate carrier suppression for most communications and frequency translation circuits. Carriers may range from 2.5 to 1000 kHz and beyond while the signal frequency may be as low as zero.

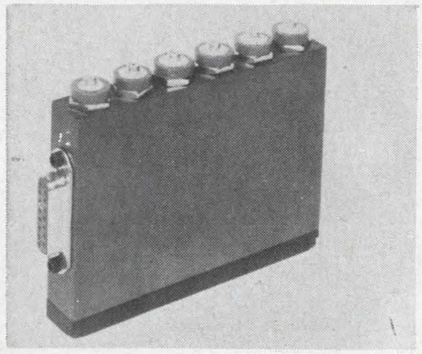
**CIRCLE NO. 221**


## Analog multiplier has 10-MHz upper limit

*Optical Electronics Inc., P.O. Box 11140, Tucson, Ariz. Phone: (602) 624-3605. P&A: $140 (1 to 9); 30 days.*

This single-quadrant multiplier, with a 10-MHz upper frequency limit, claims the hiqhest frequency response available. Featuring all solid-state circuitry, the multiplier has matched inputs and an adjustable equation coefficient. Nominal transfer equation is $E_o = \pm 0.05$ XY, where X and Y are inputs. Maximum error is 1% of full scale.

**CIRCLE NO. 222**

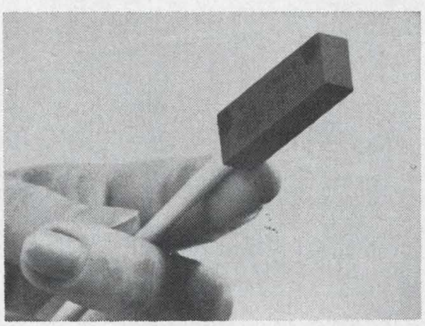


## Modular coax switch has isolated points

*Matrix Co., 9119 Desoto Ave., Chatsworth, Calif. Price: approx. $45 per point.*

This coax switch, in a modular construction, is single-throw, 5-point, and switches both center conductor and shield. It is available in 1-by-2 and 1-by-20 formats. Each switch is completely isolated from the case and from all other switch points. Designed for airborne use, it meets MIL and RFI specs.

**CIRCLE NO. 224**

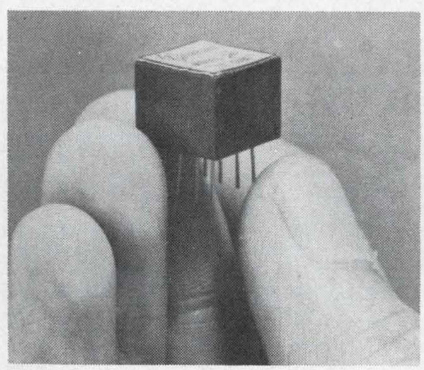


## Ac-dc magnetic switch has long operating life

*Electro-Tec Corp., P. O Box 667, Ormond Beach, Fla. P&A: $4.20 each; stock.*

This ac-dc permanent-magnet proximity switch, designed for counting and positioning of moving devices, can be installed behind any non-ferrous shield. Its electrical life is in the hundreds of millions of operations. It can detect the presence of a specific magnetic body at a predetermined distance from a reference point. Available in NC and NO positions, it will withstand shock and vibration up to 50 G.

**CIRCLE NO. 223**

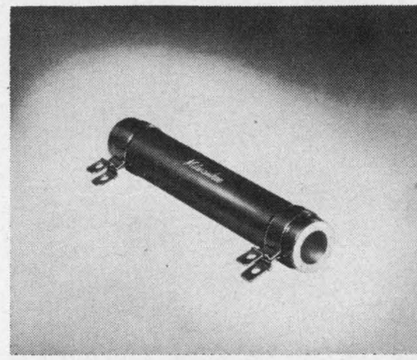


## Differential amplifier based on hybrid ICs

*Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. Phone: (415) 686-6660. Price: $47 in 100 lots.*

Hybrid integrated circuitry is cited as the key to stability for the model 161 differential amplifier. Key specifications of the unit are a 25 $\mu$V/°C drift, a gain of 80,000, an output of $\pm$10 V at 4 mA, a 150-nA input offset and an input impedance of 20 M$\Omega$. Model 161 is packaged as an epoxy cube measuring 0.5 x 0.5 x 0.4-in. It mounts flush to the board without lead spraying.

**CIRCLE NO. 225**



## Quick terminals now on wirewounds

*Milwaukee Resistor Co., 700 W. Virginia St., Milwaukee. Phone: (414) 271-9900.*

A line of resistors is offered with double connectors at each end and at any taps. Two lead wires can be connected onto each terminal without auxiliary hardware. The terminals have a pair of 1/4-in. male connectors which are formed from the terminal band itself.

**CIRCLE NO. 226**

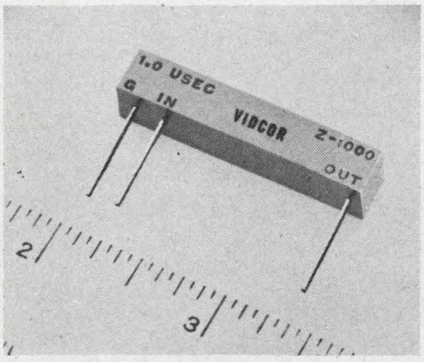



## FM microtransmitters for vhf band

*Vector Div., United Aircraft, 723 Street Rd., Southampton, Pa. Phone: (215) 355-2700.*

A line of vhf-FM microtransmitters offering up to 3-W output in the 215- to 260-MHz range, come in sizes from 2.5 to 3 in.$^3$. Integrated circuits and discrete components are combined to provide a densely packaged unit. The units require a 28- to 32-volt source, accept modulation signals from dc to 100 kHz, and operate with a nonlinear distortion of less than 2%. A center frequency stability of 1 part in $10^4$ is provided by a crystal-controlled oscillator.

**CIRCLE NO. 227**

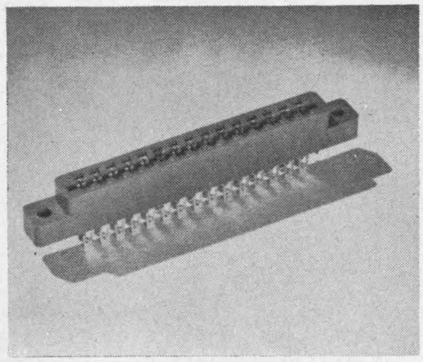



## Delay line claims 60% smaller size

*Vidcor Corp., 730 Centinela Ave., Inglewood, Calif. Phone: (213) 678-4024.*

This 1-μs delay line claims to be 60% smaller than its competitors. In a 1.5 x 0.3 x 0.3-in. thermosetting resin case, it operates at 105°C, and has an impedance of 1 kΩ. The dielectric withstands 300 Vdc. Leads are of tinned Dumet and are spaced for standard 0.1-in. circuit board grids.

**CIRCLE NO. 228**

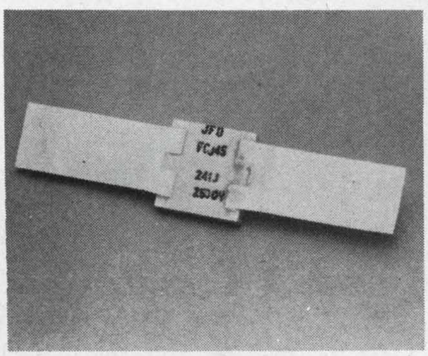


## PC connectors have "bellows" contacts

*Viking Industries, Inc., 21001 Nordhoff St., Chatsworth, Calif.*

A commercial-grade series of PC connectors comes in all standard contact configurations from 6 to 22, single and double row. The contacts are of the "bellows" design, copper alloy with gold flash. The insulator material is filled alkyd. Pierced or dip-solder terminations are optional. The connector is available in three mounting styles.

**CIRCLE NO. 230**

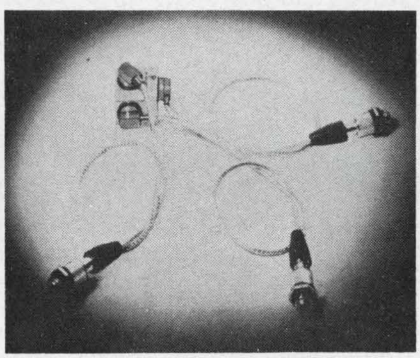


## Miniature RF capacitors take high voltage

*JFD Electronics Co., Components Div., 15th Ave. at 62nd St., Bklyn., N. Y. Phone: (212) 331-1000.*

Miniature glass-encapsulated RF capacitors, designed for use in airborne, spaceborne and mobile transmitters, are available in values from 20 pF, or lower, to 3000 pF. Typical is the 1000-pF unit rated at 2500 Vdc, 1/2-in.² and 1/8 to 1/16-in. thick. Standard tolerances from 1 to 20% are furnished. The units meet MIL-Std 202. The dielectric can withstand temperatures from −55 to 125°C.

**CIRCLE NO. 229**

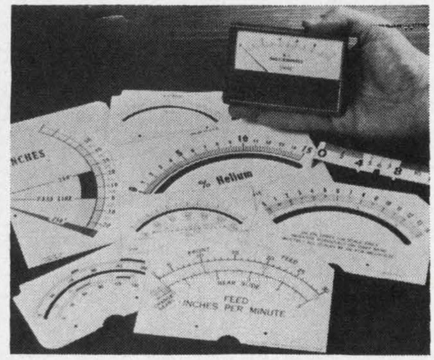


## Triax accelerometer weighs only 8 grams

*Columbia Research Labs., Inc., MacDade Blvd. & Bullens Lane, Woodlyn, Pa. Phone: (215) 532-9464.*

Capable of measuring simultaneous acceleration in three axes, the model 612 accelerometer is described as the world's smallest. The unit measures 0.5 x 0.5 x 0.33-in. and weighs 8 grams. A second feature of the unit is its use of detachable cable allowing easy replacement of cables on site. Sensitivity of the model 612TX for each of its three axes is 5 pk mV/pk G and charge sensitivity is 1.5 pC/G.

**CIRCLE NO. 231**

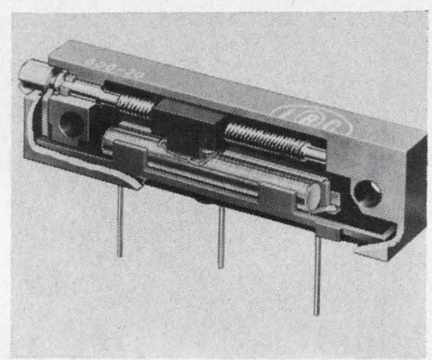


## Custom meter scales read your way

*Triplett Electrical Instrument Co., Bluffton, Ohio. Phone: (419) 351-4912. Availability: 2 to 6 wks.*

Meters which read exactly what the designer wants read are available through a custom meter-scale service. A drawing of the required meter-face is made to the designer's specifications, photographed and printed on a white-faced aluminum plate shaped to mate the specified meter. Various color codings and sizes are available.

**CIRCLE NO. 232**

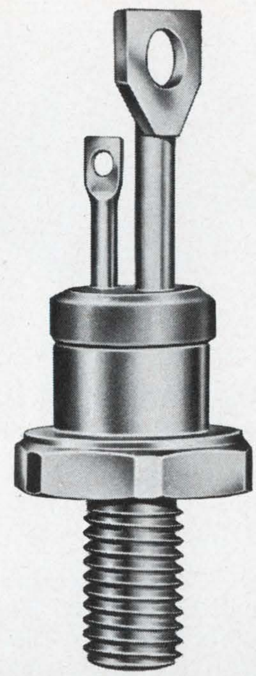


## Wirewound trimmer has isolated elements

*IRC, Inc., 401 N. Broad St., Philadelphia. Phone: (215) 922-8900. P&A: $3.56 (100); 4 weeks.*

In addition to its line of precision rectangular wirewound trimmers, IRC's type 600 is designed to perform under environmental requirements of MIL-R-27208. A specially designed wiper block system effectively isolates electrical elements. The unit is housed in a rugged diallyl phthalate case and is offered with either PC pins or teflon-insulated leads. Resistance values of 10 Ω to 50 kΩ ±5% are available. The units are rated at 1 W at 70°C.

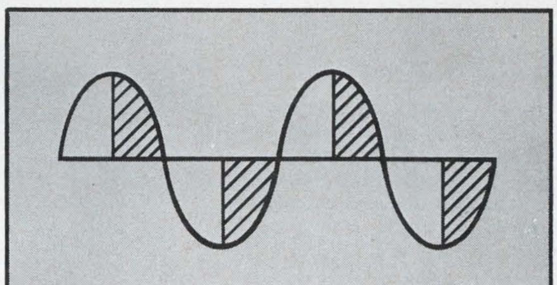
**CIRCLE NO. 233**



# one good reason

***You should buy Syntron Avalanche Silicon Controlled Rectifiers is for their inherent transient protection provided by the avalanche characteristics.***

**SCR AC Phase control at 90° is easy but L $\frac{di}{dt}$ transients can cause indiscriminate failures. Can you afford to be without the additional reliability provided by Syntron Avalanche SCR's?**



90° AC Phase Control

SYNTRON

**SYNTRON COMPANY**

283 LEXINGTON AVENUE • HOMER CITY, PA. 15748
TELEPHONE 412—479-8011
Sales Representatives Coast-to-Coast

Please send complete information on
Avalanche Silicon Controlled Rectifiers

Name & Title____________________

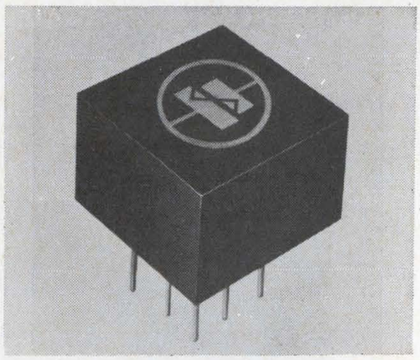
Company____________________

Address____________________

City & State____________________ Zip__________

67R1

ON READER-SERVICE CARD CIRCLE 67

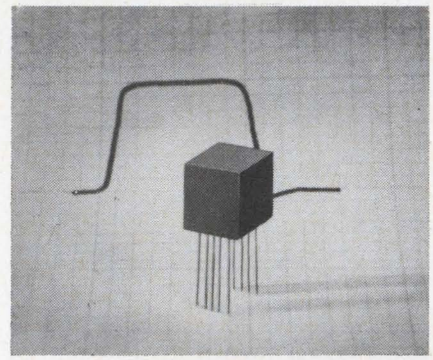


## Analog multiplier has no hysteresis error

*Transmagnetics, Inc., 134-08 36th Road, Flushing, N. Y. Phone: (212) 539-2750. P&A: $150; 4 to 6 wks.*

Model 365 four-quadrant analog multiplier has a 3-dB bandwidth from 200 to 50,000 Hz. The 1/3 in.$^3$ component generates the product of a dc and an ac input. Inherently resistive, the unit's features include complete absence of hysteresis errors and military-range temperature specifications. Applications are in fire control, radars and automatic flight directors.

**CIRCLE NO. 234**

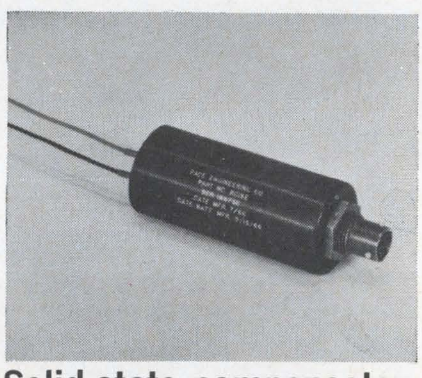


## Pulse transformers for PC applications

*Fugle-Miller Laboratories, Inc., 301 Central Ave., Clark, N. J. Phone: (201) 381-2727.*

A line of pulse transformers are miniaturized for printed-circuit applications. Sizes range from 0.2-in. diameter by 0.2-in. high to 0.5-in. by 0.5-in. Pulse characteristics include less than 20-ns rise and fall and pulse widths range to 20 $\mu$s. Either Dumet or nickel terminals are provided.

**CIRCLE NO. 236**

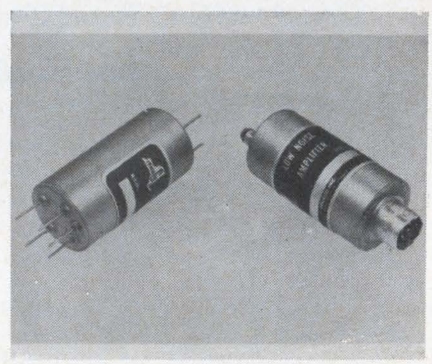


## Solid-state compensator completely self-powered

*Whittaker Corp., 12838 Saticoy St., North Hollywood, Calif. Phone: (213) 781-8950.*

With a reference accuracy of $\pm 0.5°$ F, the RC19 reference junction compensator is completely self-powered. The solid-state component is intended for such applications as aircraft and missiles and it is solidly encapsulated in epoxy for ruggedness. Allowable ambient range is $-15$ to 200°F. It will withstand linear acceleration beyond 10 G and vibration up to 15 G at 2 kHz.

**CIRCLE NO. 235**

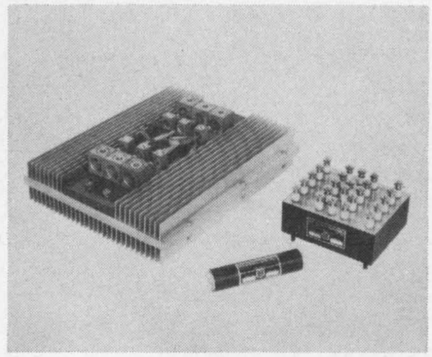


## Remote-switched gain in low-noise preamp

*Ithaco, Inc., 413 Taughannock Blvd., Ithaca, N. Y. Phone: (607) 272-7640.*

Remotely switchable gain is the leading feature of the model 155 low-noise preamplifier. The amplifier is designed for remote applications where widely varying signal amplitudes are encountered. The two switchable gain-states are 20 and 40 dB with a stability of 1%. Passband is 0.5 Hz to 200 kHz. Noise, referred to input, is 3 $\mu$V max and an internal divider net permits injection of a calibration signal.

**CIRCLE NO. 237**

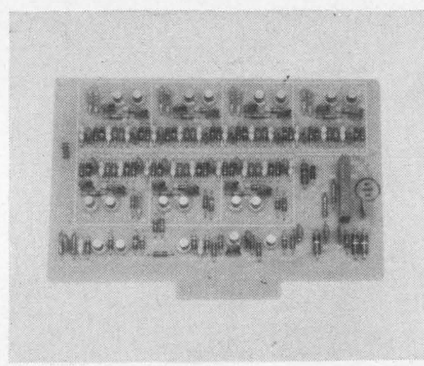


## Current shunts allow 0.005% dc readings

*Julie Research Laboratories, Inc., 211 W. 61st St., New York. Phone: (212) 245-2727. P&A: $50 to $400; stock.*

A new line of high-current shunts are said to allow 0.005% dc measurements at 10 A. The line, designated CS-106, is air-cooled and packaged fin-type, cylindrical and regular rectangular. Resistance values range 0.01 to 0.1 Ω and current ranges 0 to 50 A. For taking current readings, the resistors are used in conjunction with a ratio set.

**CIRCLE NO. 238**



## Voltage memory card monitors transients

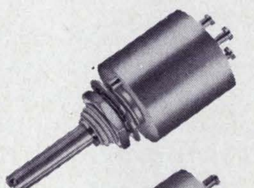
*Micro Instrument Co., 12901 Crenshaw Blvd., Hawthorne, Calif. Phone: (213) 679-8237. Price: $150.*

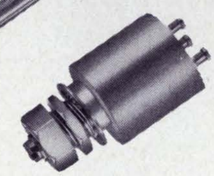
Single or repetitive voltage transients in pulse widths from dc to 100 μs are monitored by the Model 52221. The voltage memory card is used with an external meter and power supplies and mounts on the user's equipment. It converts the peak amplitude of any input signal of 100 μs or longer into a dc output and holds there until reset or keyed by a higher voltage.

**CIRCLE NO. 239**

# "POT" LUCK

## not when you specify Clarostat!

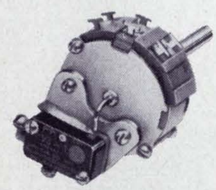


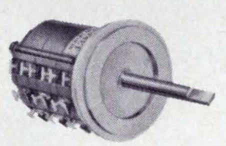


**SERIES**
57, 57EM

**Single Turn Wire-Wound Potentiometer designed to meet miniaturization needs.**

Resistance Range: Standard to 25K ohms. Special to 100K ohms. Tolerance: Standard ±10%, Special to ±3%. Linearity: Standard ±2.0%. Power Rating: Standard 2W @ 70°C, derated to zero @ 150°C. Weight: .25 oz.

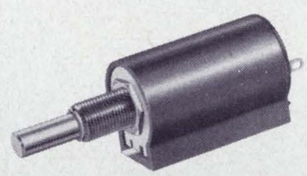




**SERIES**
42BM, 42CM

**Single Turn Wire-Wound Potentiometer controls from 1 to 20 circuits simultaneously.**

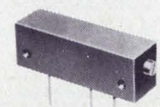
Resistance Range: To 100K ohms. Tolerance: Standard ±5%, Special ±1%, Linearity: Standard ±1%, Special ±.15%. Power Rating: Standard 3W @ 40°C, derated to zero @ 105°C.



**SERIES 62**

**10 Turn Precision Potentiometer designed for industrial instrumentation.**

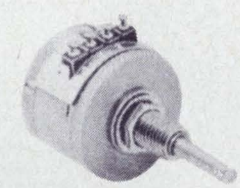
Resistance Range: to 100K ohms. Tolerance ±5%. Linearity: 0.25% Absolute. Power Rating: 2W @ 25°C, derated to zero @ 85°C. Maximum Number of Turns: 10. Weight: 1.34 oz.

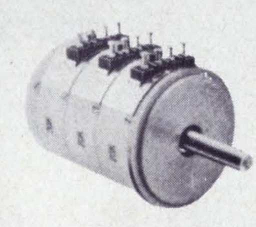


**SERIES 76**

**High Resolution Precision Miniature Trimming Potentiometer.**

Resistance Range: 100 ohms to 20K ohms standard. Tolerance: Standard ±5%, Special ±2%. Power Rating: 0.75W @ 85°C, derated to 0W @ 150°C. Maximum Number of Turns: 11, Weight: .01 lbs. Printed circuit or solder lug terminations.





**SERIES**
54M

**Single Turn Vari-Phase Precision Potentiometer features external, individual cup phasing.**

Resistance Range: To 300K ohms. Tolerance: Standard ±5%. Linearity: 0.25% Absolute. Power Rating: 2W @ 25°C, derated to zero @ 85°C. Maximum Number of Turns: 10. Weight: 1.34 oz.

Choose a potentiometer that doesn't measure up to specifications and it is usually because of lack—not luck. Lack of stability—lack of ability to withstand any one of the catalog of extremes to which pots may be subjected.

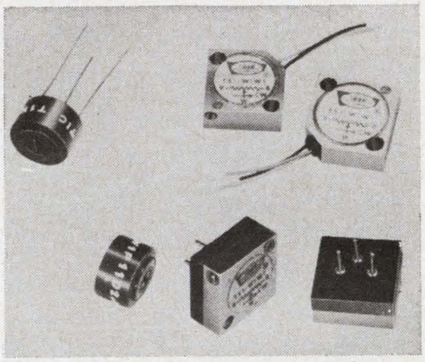
But specify Clarostat and you select a precisely designed potentiometer—so reliable—so stable, there is little or no chance of failure under the most rugged conditions.

If you would rather take chances with your potentiometers, you don't want Clarostat. For when you specify Clarostat, there is no such thing as pot luck.

CLAROSTAT

CLAROSTAT MFG. CO., INC. DOVER, NEW HAMPSHIRE

ON READER-SERVICE CARD CIRCLE 71



## Submin trimmer series set for solid-state

*Technology Instrument Corp. of Calif., 850 Lawrence Dr., Newbury Pk., Calif. Phone: (805) 498-2165.*

Two series of MIL-spec submin trimmers, the TT1 and TS1, are designed for use with solid-state circuitry and plug-in cards. The "transistor can" TT1 trimmers are below 0.333-in. in diameter and less than 0.2-in. high. The square-type YD1 provides nine options at standard values from 50 Ω to 20 kΩ. Both types are manufactured to meet or exceed MIL-R-27208A.

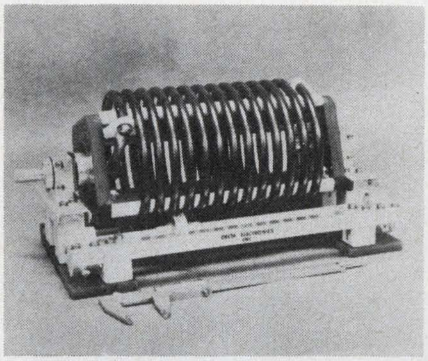
**CIRCLE NO. 240**


## Operational amplifier drives deflection coils

*Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. Phone: (602) 294-1431. P&A: $175; stock to 3 wks.*

The Model 1555 operational amplifier is said to be ideal for driving high speed deflection coils for display and readout. Features include a unity gain bandwidth of 15 Mhz, a slew rate of 100 V/μs, input impedance at $10^{10}$ Ω and an output of ±10 V at 100 mA. Other specs include a dc open-loop gain of 100 dB and a 1-MHz full-power response.

**CIRCLE NO. 241**

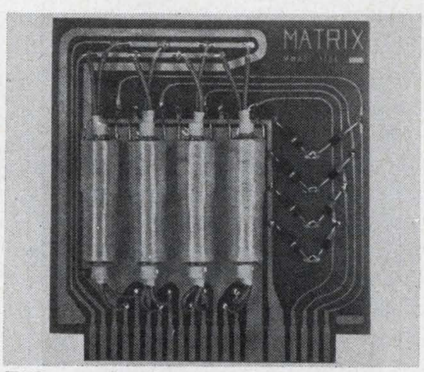


## Variable inductor designed for long life

*Delta Electronics, Inc., 4206 Wheeler Ave., Alexandria, Va. Phone: (703) 836-3133.*

Production units of the RVI variable capacitor series endure 50,000 end-to-end traverses without deterioration. They are designed for commercial and military applications where long-life and relability are required. Range of stock inductors is from 0.06 to 12 $\mu$H. Current rating is 40 A at 4 MHz in free air and 50 A under forced-air cooling. The rotary design includes a contact that consists of a compound-contoured roller riding on a silver-plated shaft.

**CIRCLE NO. 242**

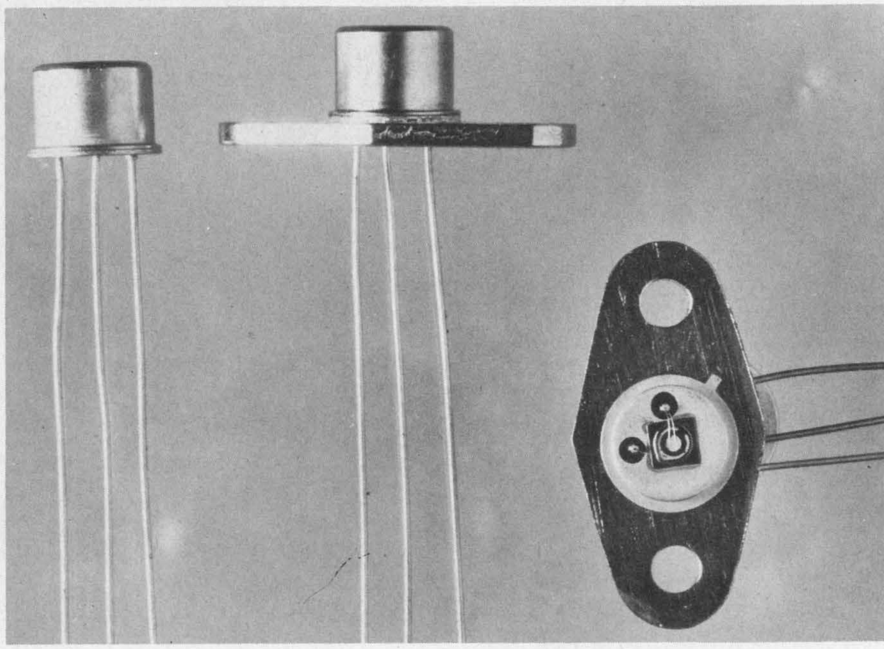


## PC switch module has high reliability

*Matrix Co., 9119 Desoto Ave., Chatsworth, Calif. Price: approx. $30 per card.*

An audio bandswitch module capable of 20 million operations affords true balanced line on switched shield coax operation. Applications include studio audio, telephone and teletype systems, computer interface networks, and instrumentation scanning systems.

**CIRCLE NO. 243**



# Silicon npn transistor has great potential — 1000 volts

*MS Transistor Co., 80-02 51 Ave., Elmhurst, N.Y. Phone: (212) 478-3134. P&A: $52.60 (MST), $55.60 (MSP), 1 to 99; stock.*

Solid-state devices continue to enter previously exclusive vacuum tube territory. Npn silicon mesa transistors will operate in a linear mode up to 1000 volts.

No longer engineering rarities, the stock units have the high-voltage capabilities, a 40-MHz gain-bandwidth product and few, if any, of the tradeoffs.

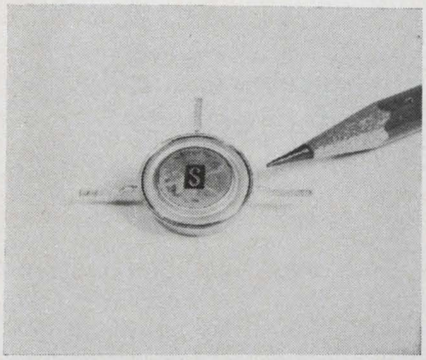
For example, in the MSP-100, $V_{CE(SAT)}$ is 1.6 V at a collector current of 20 mA and a base current of 5 mA. This is much lower than most high-resistivity, high-voltage units. $BV_{CE(SAT)}$ is 1 V max, again at a 20-mA collector current. The device can switch a minimum of 20 mA in the "on" state to a minimum of 1000 V in the "off" state. The MST device (TO-5) is rated at 2 W at 100°C case and the MSP (MD-14) is rated at 5 W.

The transistors should find many new applications. For example, in a differential amplifier configuration, it is possible to obtain a 20-V p-p sine wave. This application is typical of electrostatic CRT deflection plate drivers. Low-deflection sensitivities usually occur with CRTs that use high voltages for acceleration and brightness. With the 1000-V devices, CRTs which worked well with vacuum tube circuitry can now be used. Use as electroluminescent drivers also is feasible. The devices can be used to drive the essentially capacitive load by running class A stages in a series push-pull configuration.

In addition, many standard applications can be extended. For example, these transistors can be operated from a 120-, 240- or 480-Vac line. All that is needed is a simple full-wave rectifier to convert the ac to dc and a capacitive filter. An inverter can be designed that will operate from rectified and filtered line voltage, convert to a higher frequency and then transform to other voltages. The resulting power supply will have a much smaller transformer and will be much lighter.

As a line-operated audio amplifier with a FET as an input stage, the transistor forms a high-input-impedance combination with a high-voltage output. This is the closest solid-state device to a pentode. The transistors also can replace SCRs in applications where a base turn-off and high speed are desired.

**CIRCLE NO. 244**

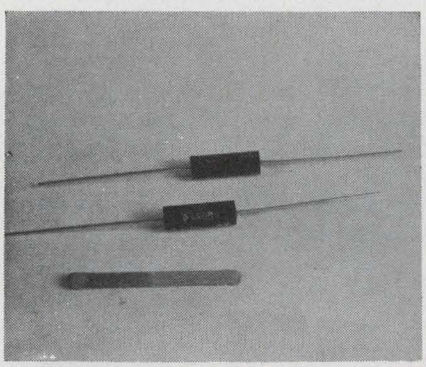


## Si power transistors available in flat-packs

*Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. Phone: (305) 848-4311. Availability: stock.*

For space reductions, the SDT 8100 series of transistors offer flat-pack profiles and the manufacturer's standard 20 and 30-A transistor specs. The new series can be specified to the electrical characteristics of the 2N3597-99, the MHT 8002-03, 8012-13, 8015-16, 8045, 8070-71 and 8301-04. The primary application for these new package-styled devices is seen as switches on circuit boards.

**CIRCLE NO. 245**



## Silicon resistors detect temperature

*Vector Div. of United Aircraft, Southampton, Pa. Phone: (215) 355-2700.*

Called "Tempistors," a line of temperature compensating resistors are designed for positive temperature compensation of electronic circuits. The Tempistors are axial-lead, epoxy-encapsulated units with rated full load at 100°C linearly derated to zero at 150°C. Resistance values are available from 68 Ω to 10 kΩ.

**CIRCLE NO. 246**

## Microwave transistor in ceramic package

*KMC Semiconductor Corp., Parker Road, RD 2, Long Valley, N. J. Phone: (201) 876-3811. P&A: $250 each (1 to 9), $125 each (100); stock.*

This silicon transistor in a ceramic package is designed for broad-band amplification and as a tunable oscillator. It will operate at frequencies thru 4 GHz. Specifications include a guaranteed 40-mW output at 2.5 GHz when used as an oscillator. Max frequency is typically 4.6 GHz. The case is completely nonmagnetic for YIG tuned applications. The size of the package in nominally 0.06-in.$^3$, adaptable for IC or printed circuits.

**CIRCLE NO. 247**

## Premium FETs at regular prices

*Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. Phone: (408) 245-1000. Price: $2.55-$3.20 (in 100 lots).*

Priced in the range of many industrial applications, the 2N4338-41 n-channel junction FETs give tight parameter control in small-signal amplifiers. These devices offer a three-to-one ratio in $V_p$, $I_{DSS}$ and $g_{fs}$ ranges. $I_{GSS}$ is below 100 pA and max noise is 1 dB at 1 kHz.

**CIRCLE NO. 248**

## Selenium photocell has linear surface response

*International Rectifier, 233 Kansas St., El Segundo, Calif. Phone: (213) 678-6281.*

An output linearity of 1% is constant for all points on the light-sensitive surface of these cells. Selenium is chosen for the similarity of its spectral response to that of the human eye. Custom manufactured, the cells can be furnished in a variety of shapes, including circular, and in lengths to four feet.

**CIRCLE NO. 249**

## Infrared laser diode for safety devices

*RCA, Electronic Components & Devices, 415 S. 5th, Harrison, N. J. Phone: (201) 485-3900.*

Called solid-state injection lasers, these gallium arsenide devices are designed for use in automotive safety devices and "secure" communications systems for ships, aircraft and spacecraft. They range in size from that of a kernel of corn (2 W) to that of a pencil eraser (50 W). Such infrared light has good fog penetration, and its invisibility and the directionality of the beam reduce intercept possibility.

**CIRCLE NO. 250**

## Small signal npns take high voltage

*Microsemiconductor Corp., 11250 Playa Court, Culver City, Calif. Phone: (213) 870-2974. P&A: from $3.50 (100); stock.*

These high-voltage, small signal, silicon npn transistors, with low leakage currents, are designed to meet MIL-S-19500 requirements. With $BV_{cbo}$ from 200 to 1000 V and a nominal $h_{fe}$ of 50 at 20 mA, they have a gain-bandwidth product of 20 MHz. They are available in TO-46 packages, or in other configurations on request.

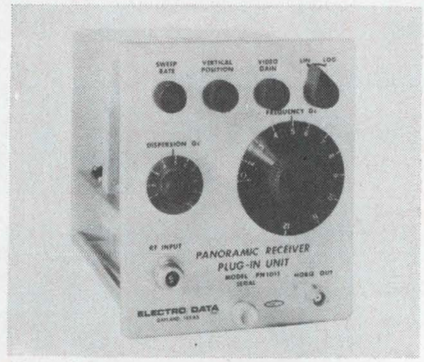
**CIRCLE NO. 251**

## Reference diodes for voltage standards

*Motorola Semiconductor Products, Inc., Box 955, Phoenix. Phone: (602) 273-6900.*

Temperature-compensated zener diodes, claiming higher accuracy than unsaturated standard cells, are offered for use as reference standards in equipment requiring a high degree of long-term voltage stability. The diodes can be open- or short-circuited without degradation.

**CIRCLE NO. 252**

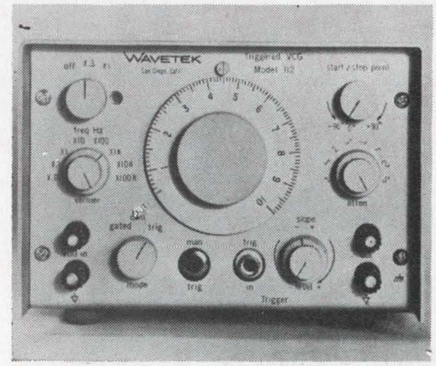



## Ordinary scopes made microwave receivers

*Electro/Data, Inc., 3130 Benton St., Garland, Tex. Phone: (214) 272-1731.*

Ordinary Tektronix 500 series and letter-series scopes can be converted to wide-band microwave receivers. The PN1000 series of plug-in modules cover three frequency ranges, 120 to 1200 MHz, 500 to 5000 MHz and 1200 to 12,000 MHz. Each is YIG-tuned and provides a panoramic display of the input on the scope face. Either the entire frequency spectrum or any segment can be displayed.

**CIRCLE NO. 253**

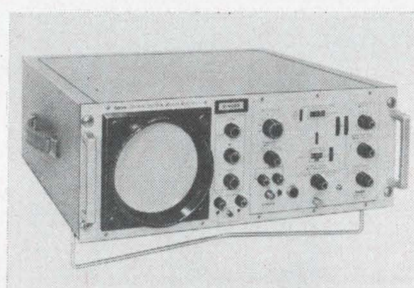



## Function generator features versatility

*Wavetek, 8159 Engineer Rd., San Diego, Calif. Phone: (714) 279-2200. Price: $795.*

Built-in sweep capability allowing internal or external voltage control, with manual control from front panel or external pulse or gate, is featured in the model 114 VCG. The unit offers both sweep and hold mode, and triggered sweep, with nine simultaneous outputs, including a monitor of the sweeping voltage. It generates sine, square, triangle and sine-squared waveforms over a range of 0.0015 Hz to 1 MHz.

**CIRCLE NO. 255**

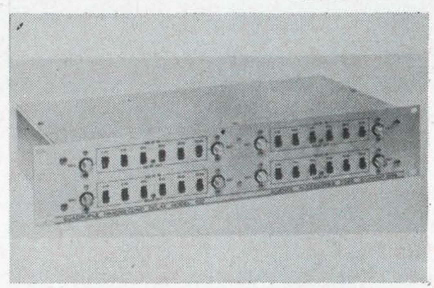


## Video module joins spectrum analysis group

*The Singer Co., Metrics Div., 915 Pembroke St., Bridgeport, Conn. Phone: (203) 366-3201.*

A video-frequency module has been added to the family of spectrum analyzer units housed in the RTA-5 and TA-2 main frames. The VR-4 provides 0 to 25-MHz coverage in a single pre-set scan. 50 kHz to 5 MHz continuously adjustable sweep widths which can be centered anywhere from 0 to 25 MHz, and phase-locked 500-Hz to 50-kHz continuously adjustable sweep widths. The minimum resolution is 200 Hz.

**CIRCLE NO. 254**

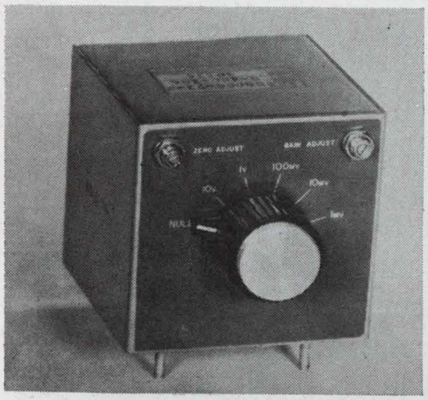


## Precision delays switch in 10-ns increments

*Science Accessories Corp., 65 Station Plaza, Southport, Conn. Availability: stock.*

These 2- and 4-unit high-precision delay instruments operate in the nanosecond range with typical accuracies of ±20 ps for each setting. Each unit provides switchable delays of from 1 to 63 ns in increments of 1 ns. Both models employ coax cables interconnected by stripline sections, and handle up to ±1500 V with input and output impedances of 50 Ω. They are designed to fit standard 19-in. rack panels.

**CIRCLE NO. 256**



## Ac/dc demodulator linear to 0.1%

*Natel Engineering Co., Inc., 7129 Gerald Ave., Van Nuys, Calif. Phone: (213) 782-4161. P&A: $350 to $450; 30 days.*

A five-range ac-to-dc converter/demodulator is designed to operate at a variety of input levels. Input ranges are 0 to 1, 0 to 10, 0 to 100 mV rms and 0 to 1 and 0 to 10 V. Input impedance is over 750 kΩ with output below 1 kΩ. Gain is 1000 to 5000 and isolation between input, output and dc ground is 50 MΩ.

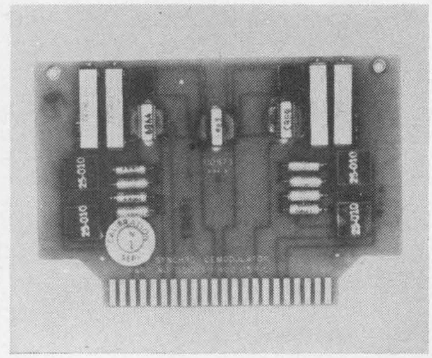
**CIRCLE NO. 257**

## Power meter stands high RF environments

*PRD Electronics, Inc., 1200 Prospect Ave., Westbury, N. Y. Phone: (516) 334-7810.*

An RF shield encases the measuring circuitry of the type 6690 peak power meter, allowing it to operate accurately in high-RF environments. A cutoff tube is used in conjunction with the range switch for extreme attenuation of the RFI. Full-scale readings of 30, 100 and 200 mW are covered in four steps with an accuracy of ±0.2 dB. In the narrow-band position, the instrument is capable of making accurate measurements below 5 mW.

**CIRCLE NO. 258**

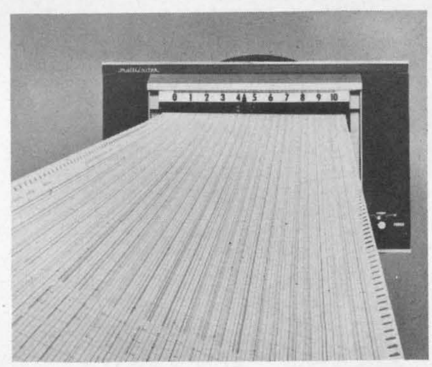


## Synchro/dc converter accurate to 3 minutes

*Natel Engineering Co., Inc., 7129 Gerald Ave., Van Nuys, Calif. Phone: (213) 782-4161. P&A: $250; 30 days.*

Matched dual-demodulator Model 2D505C accepts a 3-wire output from synchro and provides an accuracy of 3 minutes of arc. Linearity of the demodulators is rated better than 0.1% and tracking is better than 0.05%. The two dc signal outputs correspond to sine and cosine of synchro shaft angle.

**CIRCLE NO. 259**

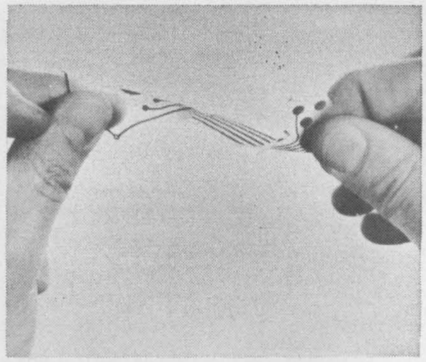


## Multipoint recorder prints dots and numbers

*Texas Instruments, Inc., 3609 Buffalo Speedway, Houston. Phone: (713) 526-1411. P&A: $1450; 60 days.*

This 1- to 24-point strip-chart recorder affords finger-tip selection of any of three different printing modes (dots only, dots and numbers, and dots with periodic numbers). Multicolor printing, reference compensation for thermocouples and automatic inhibition of the servo system during printing and switching, combine to make the unit applicable to a wide variety of scientific, medical and industrial uses.

**CIRCLE NO. 260**

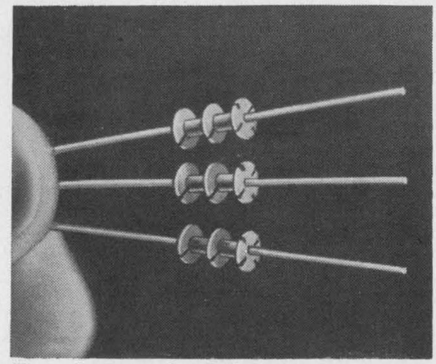


## "Tough-job" laminate solves cable problems

*Nelco, 481 Canal St., Stamford, Conn. Phone: (203) 324-4181.*

The usual disadvantages of a thermoset polymeric system are said to be eliminated in the "Flexiglas 6100" epoxy-glass copper-clad laminate for contoured printed circuitry and flat cabling. The material, in 0.003-in. thicknesses can be folded around a 0.02-in. mandrel without fracture or permanent deformation. With this flexibility, Flexiglas 6100 combines a temperature tolerance as high as 500° F. It can be resoldered repeatedly without degradation.

**CIRCLE NO. 261**

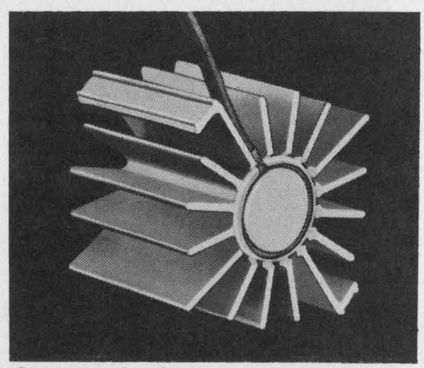


## Resistor bobbins have four slots

*Plasmetex Industries, 8217 Lankershim Blvd., North Hollywood, Calif. Phone: (213) 767-1532.*

Calibration of wirewound resistors is said to be facilitated by the presence of four termination slots in a line of molded bobbins. The molded-in lead wires, AWG 20, withstand an axial pull of five pounds. Other advantages cited for these bobbins are mechanical strength of the basic thermosetting material, high dielectric, dimensional stability and low moisture absorption.

**CIRCLE NO. 262**

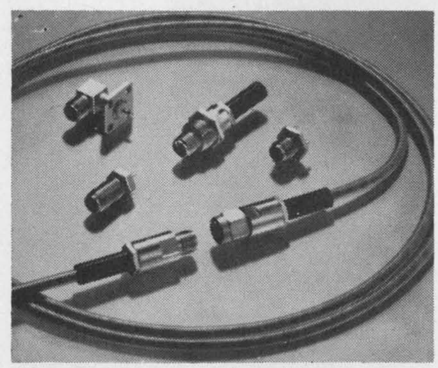


## Ceramic heater set in aluminum body

*Thermal Engineering & Design Co., 217 Ash Street, Akron, Ohio. Phone: (216) 535-5761.*

A new heater unit is based on a ceramic element solidly embedded in a finned aluminum radiator. One model now in production is rated 750 W at 120/240 Vac and has a resistor core of 1-in. diameter by 2-1/2-in. long. The radiator of this unit spreads the heat over 80 in.$^2$ for the equivalent of 9.3-W/in.$^2$.

**CIRCLE NO. 263**

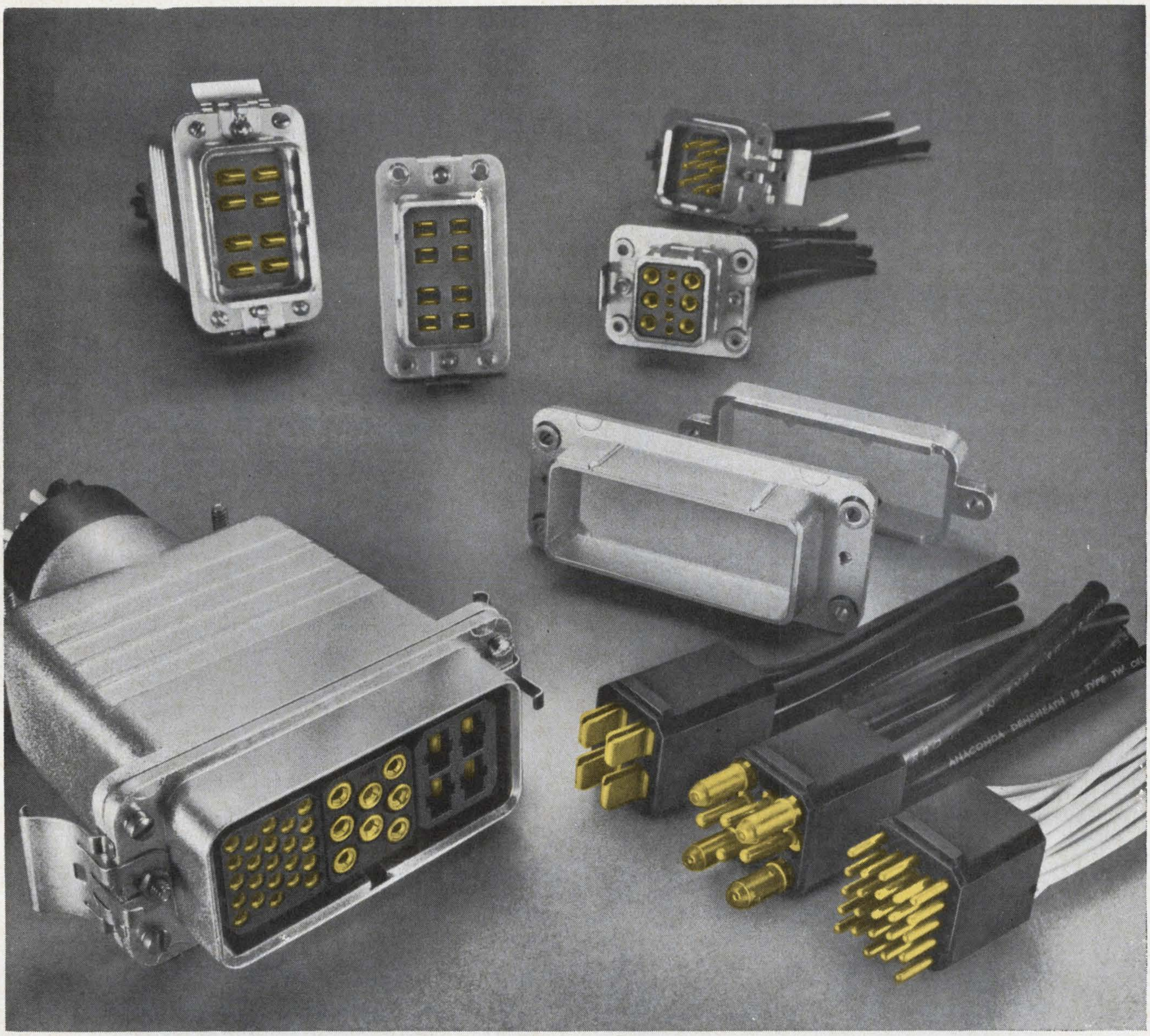


## Coax connector line includes 8 types

*Cinch-NuLine, 10105 Sixth St, Minneapolis. Phone: (312) 467-1321.*

The NCM series of miniature RF connectors initially includes eight types; 4 cable connectors, 3 feedthrus and a PC board connector. All have common interface mating with connector types such as OSM, BRM and SRM. They meet the specs of MIL-C-39012. Rated vswr is 1.3 to 10 GHz, insertion loss is 0.15 dB and leakage protection is −90 dB from 2 to 3 GHz.

**CIRCLE NO. 264**



# Go 1, Go 2, Go 3 . . . with Series "G"!

As you can see, something new has been added to our connector line. They've gone modular. Now you can stylize your electronic equipment from front to back, get all three kinds of service—signal, power, coaxial—from one basic housing style.

You no longer need a different connector for each type of circuit in your product. AMP's Series "G" Connectors are designed so you can "go" with one, two, or three modular inserts for the exact combination of contact types you want. Inserts are available in either diallyl phthalate or general purpose phenolic with numbered cavities for one or more of these types:

- Type I—#12 screw machine pin and socket power contact
- Type II, III and III(+)—regular signal circuit pin and socket contacts
- Type IV—miniature coaxial contact
- Type XII—new 35-amp stamped and formed power contact
- New subminiature COAXICON* contact

Designed for rugged, dependable performance as well as flexibility, Series "G" Connector shells are two-piece cast aluminum. They consist of a polarized two-piece shell and retainer plate for easy, drop-in assembly of the modules. And, they're available with floating bushings or locking springs, so you can use them equally well for rack-and-panel mounting, service drops, and in-line hook-up applications.

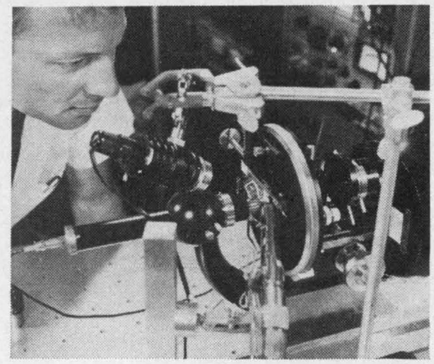
Try this new connector concept in your engineering designs. You'll get all kinds of service . . . with style! It's the practical way to cut inventory costs, too. Write today for complete details.

*Trademark of AMP INCORPORATED

**AMP**
**INCORPORATED**
Harrisburg, Pennsylvania

A-MP* products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • Mexico • Spain • West Germany

ON READER-SERVICE CARD CIRCLE 84

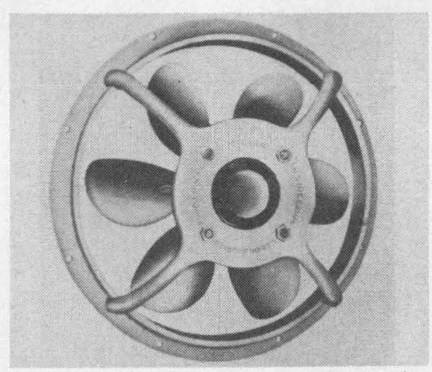


## Open-air cryogenics without frost problems

*MRC Corporation, Route 303, Orangeburg, N. Y. Phone: (914) 359-4200. P&A: $2190 (basic unit); 6 wks.*

The "Cryo-collimator" provides cooling down to $-180°C$ without frost. The system cools with a jet of gaseous nitrogen which is completely surrounded by a second stream of nitrogen at room temperature. The movable system holds 15 liters of liquid nitrogen in a dewar, delivering 40 $ft^3$/hour to the nozzle at a temperature of $-180°C$. The basic model cools for three hours and optional filling capabilities allow 4-hour or indefinite operation.

**CIRCLE NO. 265**

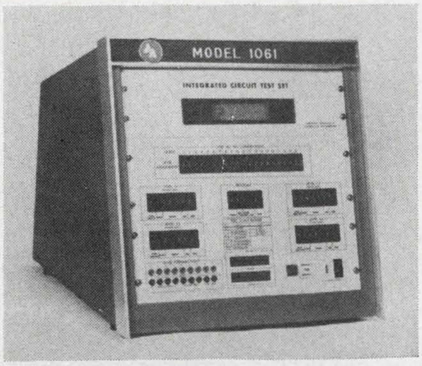


## MIL-type fans use aluminum castings

*McLean Engineering Labs., Princeton Junction, N. J. Phone: (609) 799-0100. Price: from $19.95.*

Ring fans are based on axial flow aluminum castings and are said to provide MIL-spec reliability. Push and pull airflows are available to 395 cfm. Dimensions are 8-1/2-in. or 10-1/4-in. diameter. The fans are driven by a 115-V, 50 to 60-Hz single-phase motor.

**CIRCLE NO. 266**

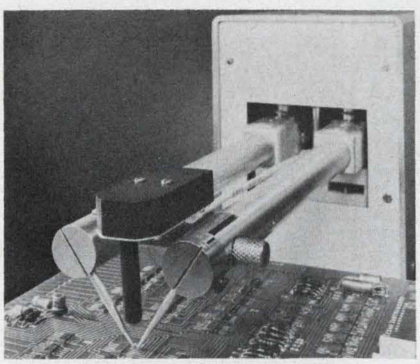



## IC tester gives digital readout

*Aerotronic Associates, Inc., Contoocook, N. H. Phone: (603) 746-3141.*

The AA model 1061 IC test set is offered as a standard tester for ICs, thin-film networks and other semiconductors.

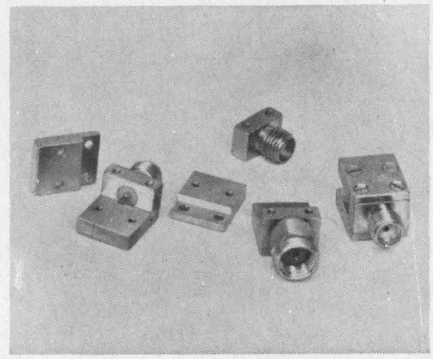
It features a digital readout for both current and voltage, a Kelvin matrix and digit-switch programing. Power supplies and/or readout can be connected in series or between leads of the device under test. Adapters are available for various IC packages and to provide multiple testing. **CIRCLE NO. 267**



## Automatic circuit bonder has infrared detection

*Texas Instruments, Inc., 3609 Buffalo Speedway, Houston. Phone: (713) 526-1411. Price: about $2000.*

No direct contact is needed for this bonder to sense temperature at joints of PC boards and wiring assemblies. Infrared detection automatically controls joint temperature within $\pm 3\%$ once bonding mode and temperature have been selected. The device performs welding, brazing, hard and soft solder and bonding operation. The power supply has a capability of 10,000 watt-seconds. **CIRCLE NO. 268**



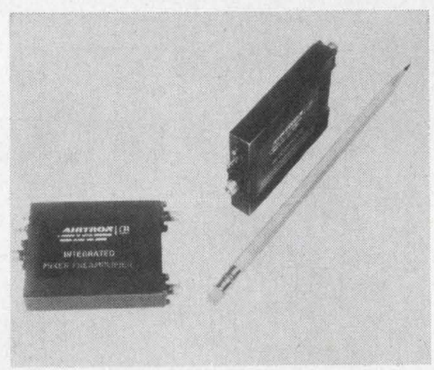
## Stripline connectors simplify assembly

*Elpac, Inc., 3760 Campus Dr., Newport Beach, Calif. Phone: (714) 546-8640.*

Designed for end-mounting on stripline circuit boards, these miniature microwave connectors have solid Teflon dielectric. The heat-treated beryllium copper center contact tab makes it possible to precut the stripline board to exact length and complete the assembly with a minimum of effort. The connectors mate with OSM, BRM and NPM connectors.

**CIRCLE NO. 269**



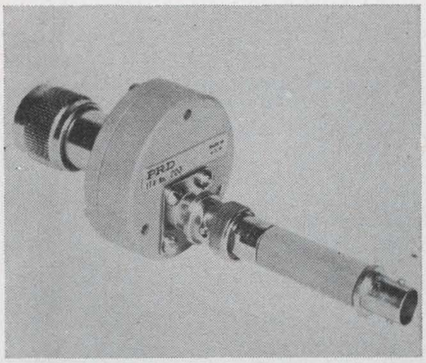


## Mixer-preamps pre-aligned, calibrated

*Airtron Div. of Litton Industries, Morris Plains, N J. Phone: (201) 539-5500.*

In radar, space communications and guidance applications, a series of mixer-preamplifiers eliminate the problem of mixer to preamp compatibility. For example, the range of the model AGMOM-A in this line is 4.2 to 4.4 GHz. It offers 1.4 vswr, noise of 8.5 dB and a preamp gain of 25 dB. Frequencies from 0.5 GHz to 8 GHz are offered in the line with a max vswr of 2 and IF centers from 20 to 400 MHz.

**CIRCLE NO. 270**

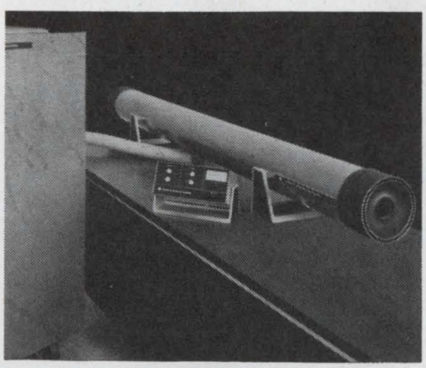


## Bolometer mount attuned to system

*PRD Electronics Inc., 1200 Prospect Ave., Westbury, N. Y., Phone: (516) 334-7810.*

Designed particularly for systems applications, the Type 627-AM1 is a fixed-tuned coax bolometer mount. The mount consists of a length of 3/8-in. coax line, a bolometer or thermistor housing and a filter net. A disk-type transducer is used in the mount. Basic units cover a range of 500 MHz to 10 GHz with N and BNC connectors available.

**CIRCLE NO. 271**

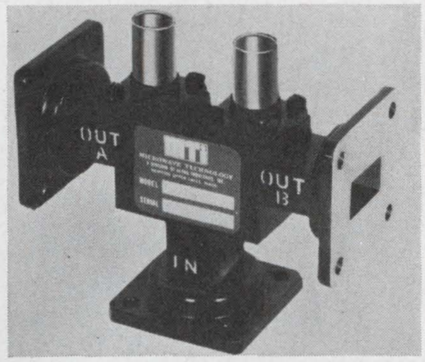


## Cw gas laser produces 75 watts

*Coherent Radiation Lab., 932 East Meadow Dr., Palo Alto, Calif. Phone: (415) 328-1840. P&A: $8250; 60 days.*

With an output wavelength of 10.6 microns, the model 40 gas laser system is capable of producing cw power of over 75 watts. The gas is a mixture of $CO_2$, nitrogen and helium. In either industrial or lab applications, its major feature is its ability to provide a continuous energy density beyond $10^6$ watts/cm$^2$. A complete system consists of a service console, a control unit and the laser head.

**CIRCLE NO. 272**

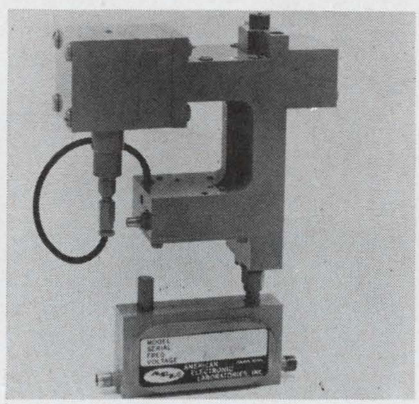



## Ku-band diode switch has 20-W capability

*Alpha Industries, Inc., 381 Elliot St., Newton Upper Falls, Mass. Phone: (617) 969-6480.*

Covering the frequency range of 15.4 to 15.6 GHz, this spdt diode switch has cw power handling capabilities of 20 W. Insertion loss is rated at 1 dB max with a switching speed of 150 ns. Isolation is 25 dB min. Both waveguide and coax models are available at 0.2 to 18 GHz in spst and single-pole, multithrow configurations.

**CIRCLE NO. 273**



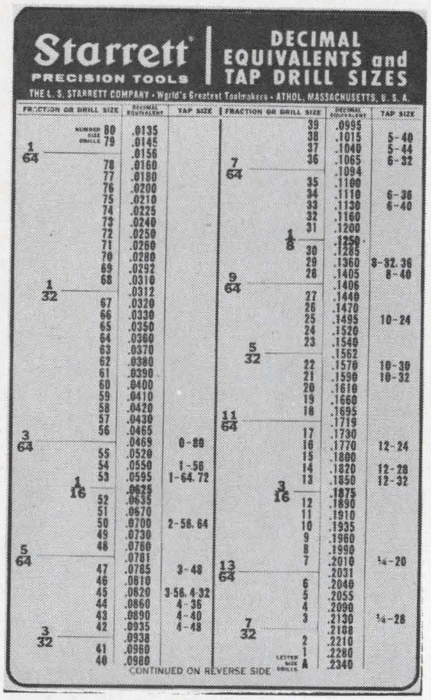
## Parametric amplifier pumped by an avalanche

*American Electronic Laboratories, Inc., Box 552, Lansdale, Pa. Phone: (215) 822-2929. P&A: $4595; 90 to 129 days.*

The pump source for the PAR 1612A parametric amplifier is an avalanche diode oscillator. The amplifier is tunable over the 2.2- to 2.3-GHz telemetry band has a max noise figure of 2.5 dB. Use of the avalanche diode oscillator, rather than a klystron, is said to reduce size while improving over-all reliability. Max dimensions of the unit are 4-1/8 x 5-1/2 x 1-5/16-in.

**CIRCLE NO. 274**

# Design Aids




## Tap drill card

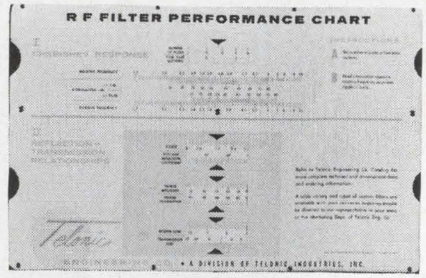
A handy pocket-sized plastic chart converts fractions or drill sizes to decimal equivalents and tap drill sizes. The L.S. Starrett Co.

**CIRCLE NO. 293**


## Decibel conversion slide rule

This "Ballantine Rule" may be used to convert volts or millivolts to dB at any desired zero decibel power reference, or vice versa. It also shows the relationships of gain and loss existing between decibels, voltage and current ratios and power ratios. The reverse side may be used to find squares and square roots, reciprocals, logarithms and dB/ratio conversions when the dB value is large. A handy wallet-sized card is included which also performs the voltage ratio/dB conversion. A full set of instructions accompanies these useful tools. Ballantine Laboratories, Inc.

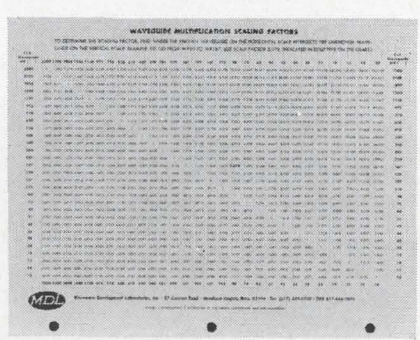
**CIRCLE NO. 294**




## RF filter slide chart

A handy 3-section slide rule provides specification data for microwave filter design. The 6-1/2 x 10-in. chart has three sections. The first, "Chebishev Response," gives the degree of attenuation at various frequencies for 2- to 19-pole filters. "Reflection-Transmission Relationships," section two, gives voltage and power reflection/transmission characteristics and loss in dB for various vswr. The "Bandpass" section three shows attenuation and bandwidth characteristics for 2- through 6-section filters, as well as bandwidth and insertion loss for various types of filters. Telonic's 45-page 1967 catalog is included with the rule. Telonic Engineering Co.

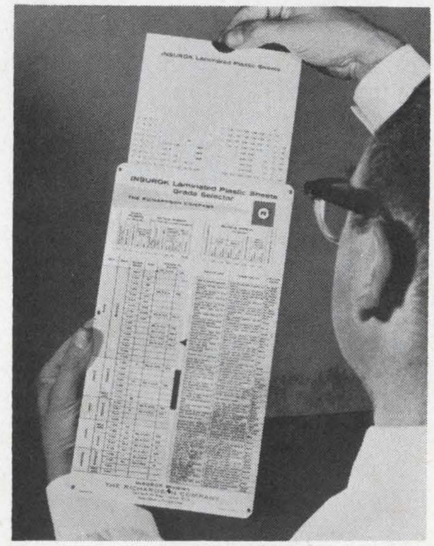
**CIRCLE NO. 295**




## Waveguide scaling factors

Standard EIA waveguide sizes WR2300 through WR3 are tabulated on a handy 3-hole punched notebook page. Electrical and mechanical specs, JAN flange references and a cross-reference between EIA waveguide, WR and JAN waveguide RG numbers are included. The reverse side lists convenient factors for scaling designs from one waveguide size to another. Microwave Development Labs., Inc.

**CIRCLE NO. 296**



## Plastics selector slide chart

A variety of specifying information is given on this slide chart for users of high-pressure laminated plastic sheets, tubes and rods. The chart provides physical, electrical and mechanical properties, industrial and MIL specs, application types, characteristics and colors. INSUROK Div., Richardson Co.

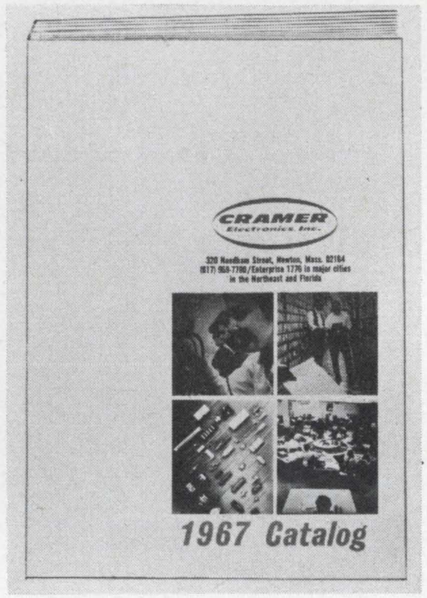
**CIRCLE NO. 297**


## Miniature lamp calculator

A circular slide rule determines miniature incandescent lamp characteristics at voltages other than the catalog design voltage. For varying application voltages, candlepower factor, life factor and current factor are read out in the appropriate windows. The reverse side of the rule is a standard Mannheim slide rule.

*Available on company letterhead from Chicago Miniature Lamp Works, 4433 N. Ravenswood Ave., Chicago.*

# New Literature




## Buyer's guide

The 1967 Cramer Buyers Guide for Electronics is now available. The 500-page industrial catalog lists and describes over 60,000 electronic components and products that are available from this distributor. Manufacturer's part numbers, not house numbers, are used throughout and an index, ordering instructions and price information are included. Cramer Electronics, Inc.

CIRCLE NO. 275

## Transducer conditioning

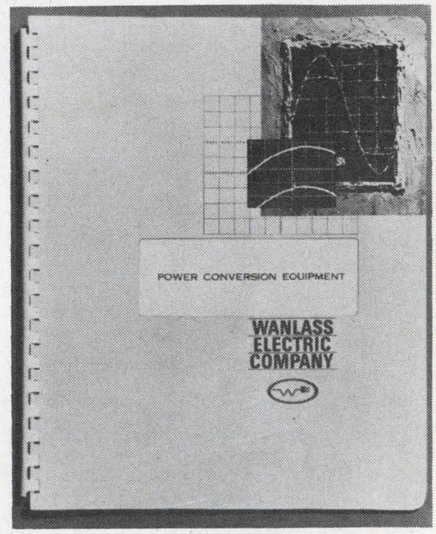
This 16-page paper, dealing with today's state-of-the-art input conditioning, emphasizes constant current techniques. Frequency response of constant current power supplies, and guarding and shielding for input conditioners are explored. B & F Instruments, Inc.

CIRCLE NO. 276

## Memory products

A brief history of memory core development, with highlights of memory product manufacturing facilities and capabilities illustrates typical memory planes and stacks for commercial, industrial and military use. Indiana General Corp.

CIRCLE NO. 277




## Power converter catalog

Ten lines and 199 models of power conversion equipment are described in the new Wanlass catalog. Included are details on voltage regulators, power supplies and a line filter that removes SCR spikes. Wanlass Electric Co.

CIRCLE NO. 278

## Pilot light catalog

A four-page brochure on pilot lights, light assemblies, individual sockets and multi-socket strips and short slide-base lamps is available. It provides complete details on connections, mounting, and assembly, along with all dimensional data. Industrial Devices, Inc.

CIRCLE NO. 279

## Pulse equipment

Four loose-leaf data sheets cover a switching time meter, pulse amplifier, pulse transformer, and pulser accessories. The units operate in the 5- to 25-ns range. E-H Research Laboratories, Inc.

CIRCLE NO. 280

## PC laminates

A new, four-page brochure describes properties and specifications of unclad and copper-clad laminates for use in microwave and high-frequency printed circuits. Dodge Fibers Corp.

CIRCLE NO. 281

# EIMAC 250 kW tetrode now ready for tomorrow's super-power transmitters

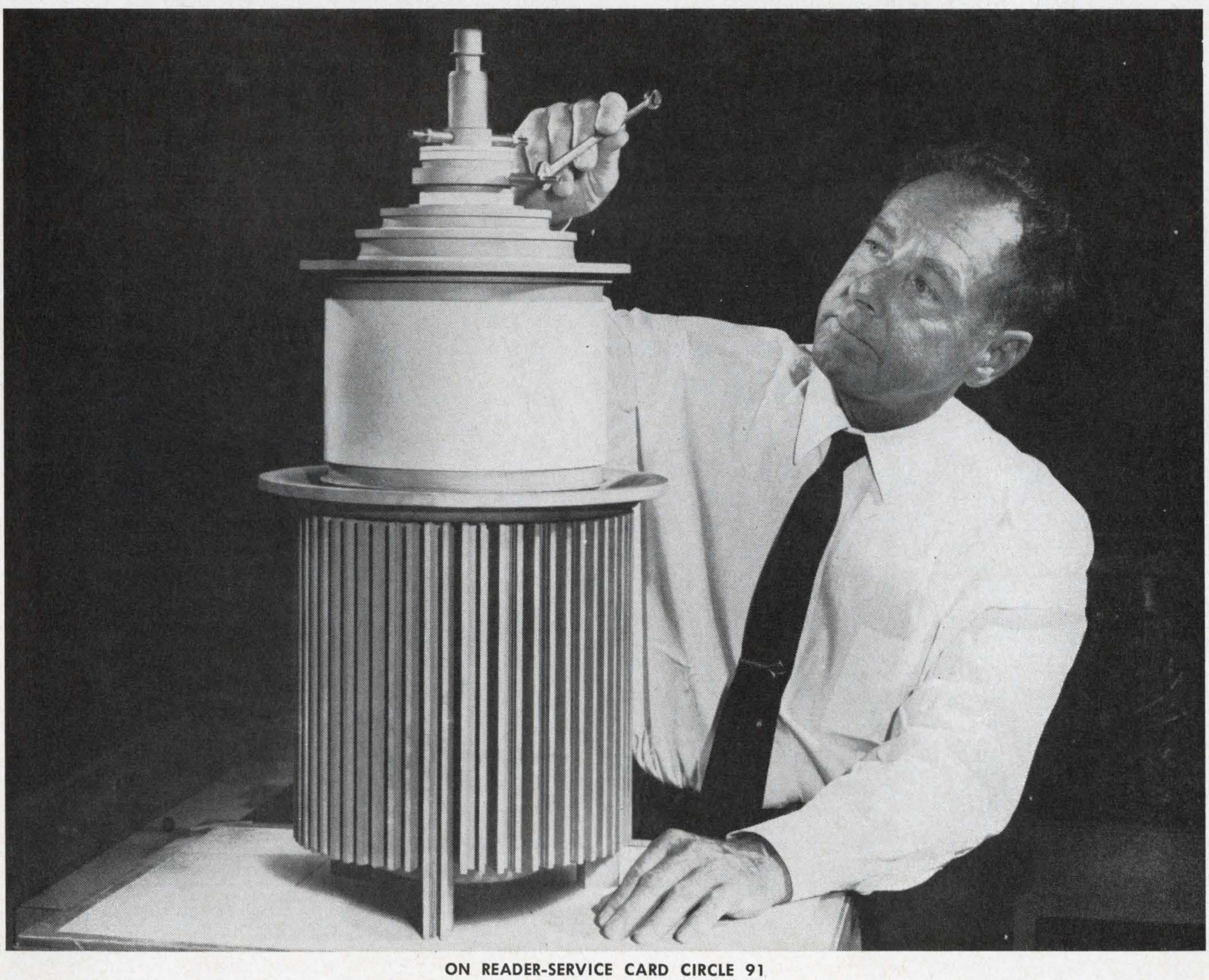
The EIMAC 4CV250,000C is the world's highest power tetrode. It is designed for service in super-power broadcast transmitters, and was developed on the foundation of technology which produced its "little brother," the hundred-kilowatt 4CV100,000C, now used by the USIA. The giant new vapor-cooled tube combines high power gain with long life. Vapor cooling is accepted as an efficient and economical method of cooling in advanced broadcast systems. As EIMAC's latest addition to its line of power tetrodes, the 4CV250,000C is ideally suited for service as an audio modulator, a pulse modulator, or a regulator, and as an rf amplifier in linear accelerators. Ready now for the super-power transmitters of the future, this 250 kW tetrode is another example of how EIMAC's experience in power tube technology paves the way for the developments of tomorrow. For a power tube to fit your needs—big or small—write Product Manager, Power Grid Tubes, or contact your nearest EIMAC distributor.

**TYPICAL OPERATION**

(as a Plate-Modulated Power Amplifier at Frequencies below 30 MHz)

| | |
|---|---|
| DC Plate Voltage | 14 kV |
| DC Screen Voltage | 800 V |
| Peak AF Screen Voltage (for 100% Modulation) | 800 V |
| DC Grid Voltage | −800 V |
| DC Plate Current | 29 Amps |
| DC Screen Current | 3.6 Amps |
| DC Grid Current | 1.8 Amps |
| Peak RF Grid Voltage | 1200 V |
| Grid Driving Power | 2.5 kW |
| Plate Output Power | 292 kW |

EIMAC
Division of Varian
San Carlos, California 94070



ON READER-SERVICE CARD CIRCLE 91


## Synchro/resolver catalog

A wide variety of synchros and resolvers are included in catalog J66-1066. A special section for system designers provides information on applications. Other general data are provided in the form of curves, graphs, photos and diagrams. General Precision, Aerospace Group.

**CIRCLE NO. 282**

## Instant switching

This bulletin gives information on completely enclosed 1/2-in. rotary switches with adjustable stops. The bulletin includes complete information on electrical and mechanical features, and charts giving type numbers, number of possible poles per deck and the maximum number of positions per pole. RCL Electronics.

**CIRCLE NO. 283**

## Plastic testing

Brief accounts and diagrams of standard tests on plastics as well as frequently used conversion tables are provided by a 40-page booklet. The book is intended as a ready reference text on ASTM and other plastic tests. Celanese Plastics Co.

**CIRCLE NO. 284**

## Word indicator lights

Ten pages of text and diagrams describe the company's "push-to relamp" miniature, illuminated word indicators for military and commercial equipment. Master Specialties Co.

**CIRCLE NO. 285**


## Circuit board boxes

Instant organization is covered in a new brochure on circuit board boxes. Providing both catalog information and description, the brochure covers the manufacturer's complete line. Panel Controls Corp.

**CIRCLE NO. 286**

## Detector mounts

Five new technical bulletins are available, describing the company's high-sensitivity detector mounts. Included in these bulletins is information on features, applications, typical specifications, and dimensional drawings for each of the detector mounts. American Electronic Labs., Inc.

**CIRCLE NO. 287**

## Variable band-pass filter

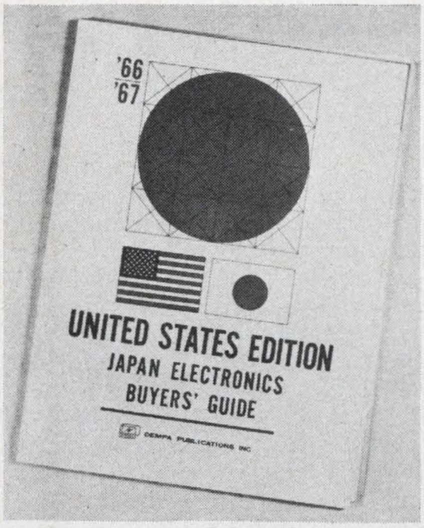
A 2-page illustrated data sheet describing the KH model 3100 solid-state variable band-pass filter includes a composite graph of maximally flat, and transient-free, frequency-response modes. Oscilloscope photographs of these reponses are shown. Krohn-Hite Corp.

**CIRCLE NO. 288**

## The chips are in

A mounting package that makes possible solderless, pressure contact mounting of microcircuit flat-packs on PC cards is described in a four-page brochure. Card files and equipment drawers are also described. Scanbe Mfg. Corp.

**CIRCLE NO. 289**




## Japan buyers guide

American representatives of Japanese electronic equipment manufacturers are listed in a comprehensive directory. Including an alphabetical section and a product section, this reference gives name, address, phone number, telex number and cable address for each listing. Products are classified into twenty groups from batteries to TV receivers.

*Available for $4 from Dee Company, Suite 103C, 10639 Riverside Drive, N. Hollywood, Calif.*

## Telemetry products

This catalog describes electromechanical and solid-state commutators and multicoders, FM telemetry products, amplifier products and PCM components and systems. Also included are miscellaneous telemetry products such as solid-state differential signal adaptors, in-flight voltage calibrators, etc. General Devices, Inc.

**CIRCLE NO. 291**

## Pulse counter

A 2-page, 2-color brochure describes a pulse counter and storage device, used with the manufacturer's scanning transmitter to count accurately and reliably randomly occurring pulses such as watt-hour pulses originating in a remote station, and transmit the total count to a master station. Quindar Electronics, Inc.

**CIRCLE NO. 292**

## Miniature op-amps

A data sheet describing Melcor's economy line of miniature operational amplifiers contains performance specifications, with limits, for all models. Outline drawings and typical applications are included. Melcor Electronics Corp.

**CIRCLE NO. 306**

## Reprints Available

The following reprints are available free and in limited quantities. To obtain single copies, circle the number of the article you want on the Reader-Service Card.

*Planning to use MOS arrays?* (No. 307)

*Avalanche circuits are more versatile than you think* (No. 308)

*Rid mixers of spurious signals* (No. 309)

## Accuracy Policy

It is the policy of ELECTRONIC DESIGN:

**To make reasonable efforts to insure accuracy of editorial matter.**
**To publish promptly corrections brought to our attention.**
**To reserve the right to refuse any advertisement deemed misleading or fraudulent.**

All editorial correspondence should be sent to:

Howard Bierman, Editor
ELECTRONIC DESIGN
850 Third Avenue
New York, N. Y. 10022

## Subscription Policy

ELECTRONIC DESIGN is circulated free of charge to qualified design engineers in the U.S., Western European Continent and Britain. To establish your qualifications, send ELECTRONIC DESIGN the following information on your company's letterhead: Your name, engineering title, description of your design duties and a list of your company's major products. The letter must be signed by you personally.

Subscription rates for nonqualified subscribers—*$25* a year in the U.S., *$35* in all other countries. Single copy, *$1.50*.

## Change of Address

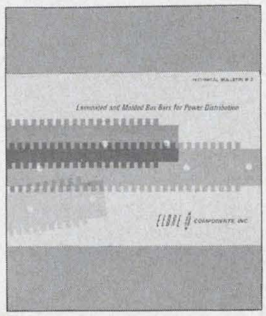
A subscriber's change of address requires a restatement of his qualifications. To expedite the change, and to avoid missing any issues, send along a label from a back opy.

## Microfilm Copies

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.

# Design Data from

## Laminated and Molded Bus Bars For Power Distribution

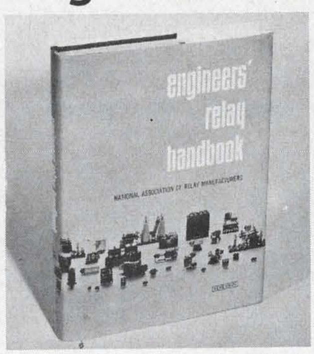


A 16 page Technical Bulletin is now available, describing a new concept in power distribution. Basic mechanical and electrical design principles, along with descriptive pictures and diagrams, are included in this bulletin. These compact buses can replace bulky cable harnesses and repetitive wiring for computer or modular application. This method of construction satisfies the demanding requirements of low inductance and resistance of high speed, solid state systems, while controlling electrical noises.

**Eldre Components, Inc.**
**1239 University Avenue**
**Rochester, New York 14607**

**171**

## Engineers' Relay Handbook

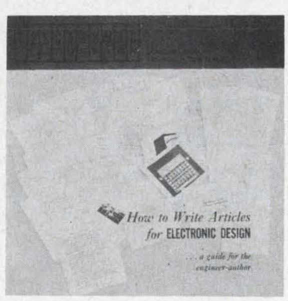



A definitive work that is fast becoming a standard reference text for the relay user. Prepared and edited by the National Association of Relay Manufacturers, this book is a complete guide to the principles, properties, performance characteristics, application requirements, specifications, and testing of relays. Systems and product engineers will find the *Handbook* an indispensable help in determining the correct types of relays for their applications. For further information about this unique sourcebook, write Dept. ED

**Hayden Book Co., Inc.**
**116 W. 14th Street**
**New York, N. Y. 10011**

**173**

## How To Write Technical Articles




A guide for the engineer-author, "How to Write Articles for Electronic Design" shows how easy it is to write for publication—once the engineer knows what to write and how to write it. The Author's Guide includes a complete run-down of the types of articles published by Electronic Design—plus detailed instructions on how to prepare technical articles and short special features. A MUST for every "would-be-writer" in the electronics industry. Send for your complimentary copy by circling the number to the right.

**Electronic Design**
**850 Third Avenue**
**New York, N.Y. 10022**

**175**

# Manufacturers

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

## Schweber Catalog of Westinghouse Semiconductors


This 20-page catalog condenses the Westinghouse semiconductor line for quick, easy reference. The index is arranged in four main groupings—Transistors, Thyristors, Rectifiers, and Rectifier Assemblies. There are 17 sub-headings. The dimensional outline drawings are unusually elegant and suitable for blueprint reproduction. Short texts precede each grouping explaining salient features and device technology.

**Schweber Electronics**
**Westbury, New York 11591**
**516—334-7474**

# 172

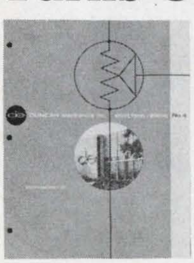
## Solid-Jacketed MicroCoax Cable


MicroDelay Division's new Bulletin 202C describes miniature solid-jacketed coaxial cable providing total shielding and improved environmental stability. Seamless tubular jackets of copper, aluminum and stainless steel eliminate crosstalk and attenuation problems. More than 25 MicroCoax combinations of solid metal jackets, dielectrics and conductors, as catalogued in this bulletin, are stocked in O.D.'s from 0.250" to 0.020" for immediate shipment.

**MicroDelay Division**
**UNIFORM TUBES, INC.**
**Collegeville, Pa. 19426**

# 174

## Potentiometers, Switches & Turns-Counting Dials



A four-page, two-color short-form catalog from Duncan Electronics, Inc., gives complete specifications and prices on Duncan's precision multi- and single-turn potentiometers for both military and commercial applications. Also included are details on Duncan's Series 60 and 80 turns-counting dials designed for use with multi-turn potentiometers; non-linear potentiometer information for log, trig, empirical, or other forms of non-linear functions; and precision commutator switches for use either individually or in ganged assemblies with potentiometers and other switching devices.

**Duncan Electronics, Inc.**
**2865 Fairview Road**
**Costa Mesa, California 92626**

# 176


**Electronic Design**

## Advertising Representatives

**New York 10022**
Robert W. Gascoigne
Thomas P. Barth
Samuel M. Deitch
Richard W. Nielson
*850 Third Avenue*
*(212) PLaza 1-5530*
*TWX: 867-7866*

**Philadelphia**
Fred L. Mowlds, Jr.
*P. O. Box 206*
*Merion Station, Pa. 19066*
*(215) MO 4-1073*

**Boston**
Richard Parker
*7 Redstone Lane*
*Marblehead, Mass. 01945*
*(617) 742-0252*

**Chicago 60611**
Thomas P. Kavooras
Berry Conner, Jr.
*720 N. Michigan*
*(312) 337-0588*

**Cleveland**
Robert W. Patrick
*8410 Treetower Drive*
*Chagrin Falls, Ohio 44107*
*(216) 247-7670*

**Los Angeles 90303**
Stanley I. Ehrenclou
Terrence D. Buckley
W. James Bischof
*2930 W. Imperial Highway*
*Inglewood, Calif.*
*(213) 757-0183*

**San Francisco**
Ashley P. Hartman
*175 South San Antonio Rd.*
*Ste. 243*
*Los Altos, Calif. 94022*
*(415) 941-3084*

**Southwestern 75206**
Tommy L. Wilson
*6200 North Central Expressway*
*Dallas, Tex.*
*(214) EMerson 1-2311*

**London W. 1**
Brayton C. Nichols
*44 Conduit Street*

**Verviers, Belgium**
Andre Jamar
*1, Rue Mallar, 1*
*(087) 253.85*

**Tokyo**
Yoshihiro Takemura
*International Planning Service, Inc.*
*Room 231 Tokyu-Mita Bldg.*
*1, Shiba-Mita Koun-cho*
*Minato-ku, Tokyo*

BPEA BPA

AMERICAN BUSINESS PRESS, INC.

# Advertisers' Index

# Designer's Datebook

JANUARY

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

FEBRUARY

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | | | | |

**Jan. 19-20**

**Institute—Computer Aid for Reliability Analysis of Electronics** (Milwaukee) Sponsor: University of Wisconsin; C. L. Brisley, Director, Engineering Center for Postgraduate and Professional Development, The University of Wisconsin, 600 W. Kilbourn Ave., Milwaukee, Wis. 53203.

**Jan. 21**

**Quality Control Conference** (Pomona, Calif.) Sponsor: ASQC; S. Roy Wood, Reliability Mgr., Aeroject-General Corp., 11711 Woodruf Ave., Downey, Calif. 90240

**Jan. 31-Feb. 2**

**Circuit Design by Computer —Tutorial Symposium** (New York City) Sponsor: New York University; M. B. Goldin, New York University, University Heights, New York, N. Y. 10453

**Feb. 7-9**

**Winter Convention on Aerospace & Electronic Systems** (Los Angeles) Sponsor: IEEE, G-AES; D. Traitel, Electro-Optical Systems, 300 N. Halstead, Pasadena, Calif.

**Feb. 14-17**

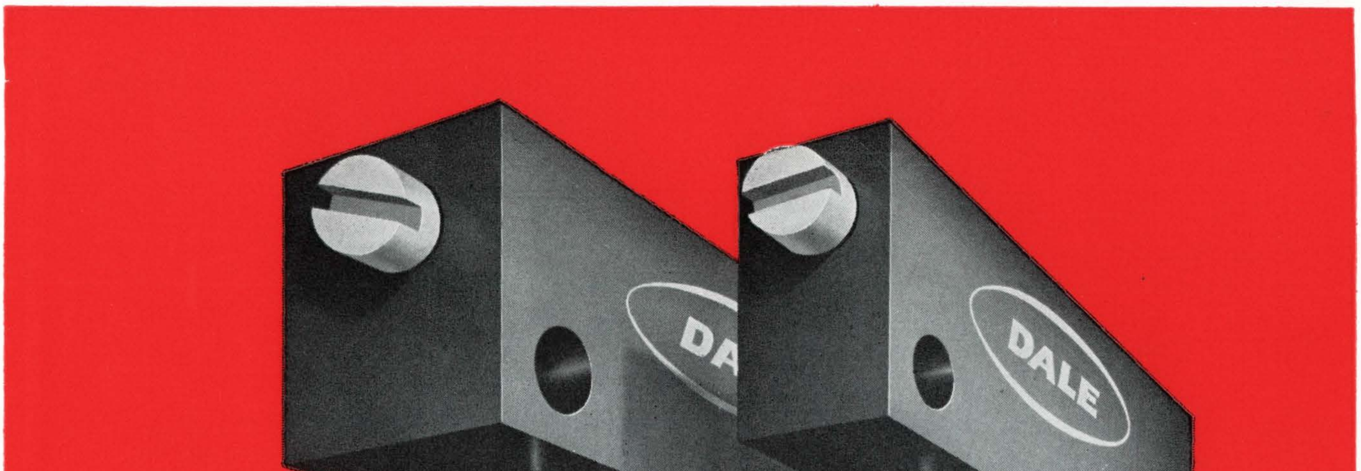
**Electronic Packaging Conference** (New York City) Sponsor: Society of Automotive Engineers, Inc.; A. J. Favata, SAE, 485 Lexington Ave.. New York, N. Y. 10017

**Feb. 15-17**

**International Solid-State Circuits Conference** (Philadelphia) Sponsors: IEEE, University of Penn.; Lewis Winner, 152 W. 42 St., New York, N. Y. 10036

**Feb. 20-24**

**Winter Institute on Advanced Control** (Gainesville, Fla.) Sponsor: National Science Foundation, Univ. of Florida; Prof. O. I. Elgerd, EE Dept., Univ. of Fla., Gainesville, Fla. 32601




# 2 very good reasons why Dale sells so many Commercial Wirewound Trimmers

**PERFORMANCE:** Dale's 2100 and 2200 series are the commercial counterparts of RT-11 and RT-10 respectively. They can be sealed for just a few cents per unit, yielding mil-level performance in all areas except temperature.

**PRICE:** Competitive and then some! Check Dale's new lower commercial prices. They were made possible through an extensive value analysis program which actually improved overall unit quality.

**DELIVERY:** New automated production facilities plus a factory stocking program combine to put your order in your plant without delay.

*Simplify trimmer ordering—a call to Dale will do it. Phone 564-3131, Area Code 402*

**SPECIFICATIONS**

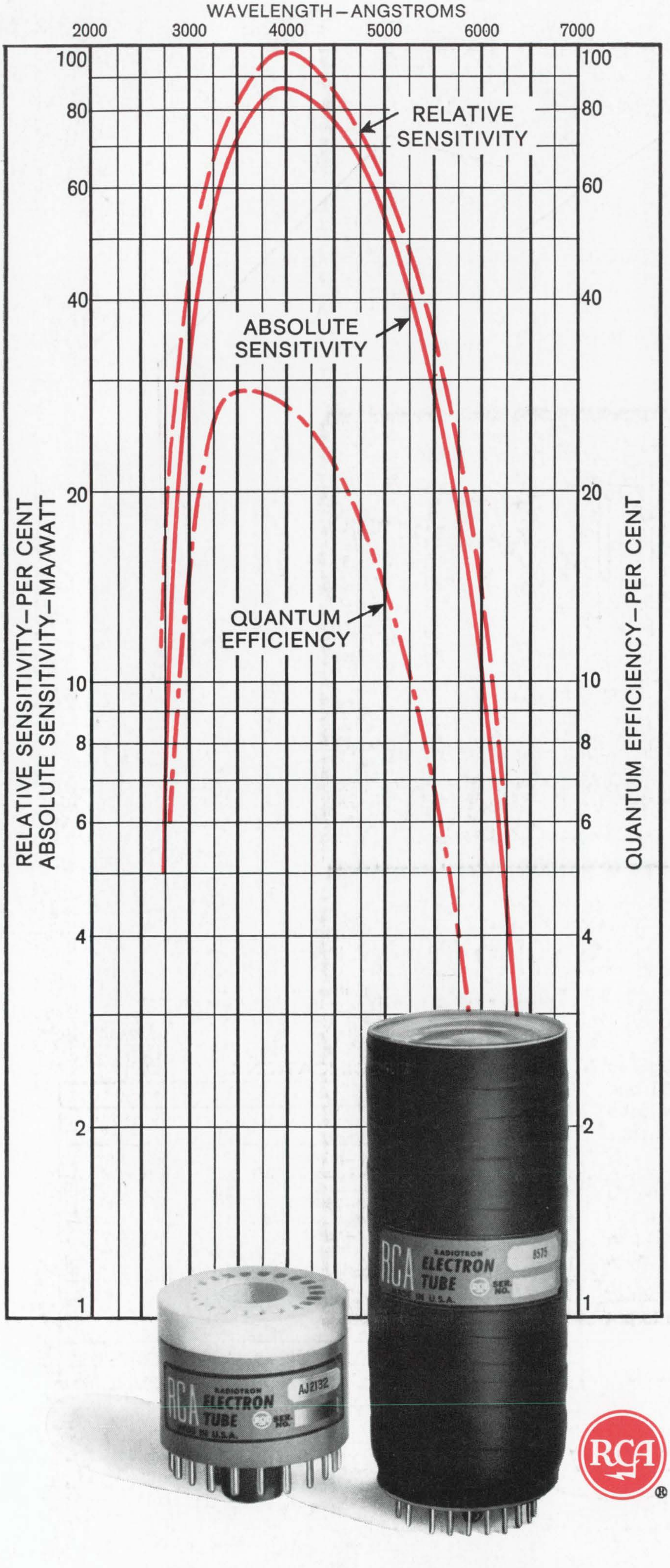
| | 2100 | 2200 |
|---|---|---|
| **CASE DIMENSIONS** | .28 high x .31 wide x 1.25 long | .18 wide x .32 high x 1.00 long |
| **STANDARD MODELS** | **2187**—printed circuit pins, 21 AWG gold plated. **2188**—28 AWG stranded vinyl leads. **2199**—solder lug, gold plated. | **2280**—printed circuit pins, 22 AWG gold plated. **2292**—solid wire, 26 AWG gold plated. **2297**—28 AWG stranded vinyl leads. |
| **POWER RATING** | 1 watt at 70° C, derating to 0 at 125° C | |
| **OPERATING TEMPERATURE RANGE** | −65° C to + 125° C | |
| **ADJUSTMENT TURNS** | 25 ± 2 | 15 ± 2 |
| **RESISTANCE RANGE** | 10 ohms to 100K ohms | 10 ohms to 50K ohms |
| **STANDARD TOLERANCE** | ± 10% standard (lower tolerances available) | |

***Write for Catalog B***

DALE®

**DALE ELECTRONICS, INC.**
1328 28th Avenue, Columbus, Nebraska
In Canada: Dale Electronics, Canada, Ltd.

SEE OUR SPECIFICATIONS IN THE MICROFILM CATALOG FILE VSMF




# Bialkali Photocathode in RCA-8575 offers Typical QE of 28% at 3850 Å

## Adapt This Photomultiplier For Your Present Equipment

Now, the highly efficient RCA Bialkali Photocathode can be employed in existing equipment through the use of an adapter, RCA-AJ2132. Designed especially for the RCA-8575 Photomultiplier, the adapter brings the excellent performance characteristics of this RCA tube type to systems now using 56AVP, 6810A, or 7264.

Proved in the unparalleled success of the RCA-8575, the RCA Bialkali Photocathode is now available in six new standard photomultiplier tube types. These new tubes offer up to a 50% increase in quantum efficiency when compared with their prototype units having S-11 response . . . and a dark-current reduction of up to 100 to 1.

Designed for scintillation counting and other low-light-level measurement systems, other RCA Photomultipliers with RCA Bialkali Photocathodes are available with standard base, semi-flexible leads, or potted voltage dividers.

Ask your RCA Representative about the advantages of RCA Bialkali Photocathodes in upgrading your existing system performance. For technical data on the RCA-8575, other specific photomultipliers, and the adapter type AJ2132, write: RCA Commercial Engineering, Section A18Q-3, Harrison, N. J. 07029.

**RCA PHOTOMULTIPLIERS**

| Nominal Size | No. of Stages | Prototype | Bialkali Type |
|---|---|---|---|
| 3/4″ | 10 | 7767 | 4516 |
| 1½″ | 10 | 6199 | 4517 |
| 2″ | 10 | 6342A | 4518 |
| 2″ | 10 | 8053 | 4523 |
| 2″ | 12 | —— | 8575 |
| 3″ | 10 | 8054 | 4524 |
| 5″ | 10 | 8055 | 4525 |

ALSO AVAILABLE FROM YOUR RCA INDUSTRIAL TUBE DISTRIBUTOR

RCA Electronic Components and Devices

The Most Trusted Name in Electronics

ON READER-SERVICE CARD CIRCLE 204