

Electronic Design

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

VOL. 15 NO.

2

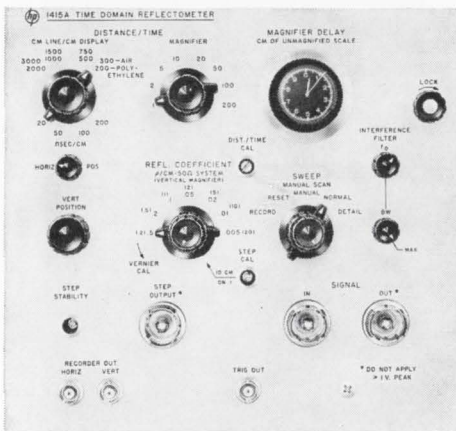
JAN. 18, 1967

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.

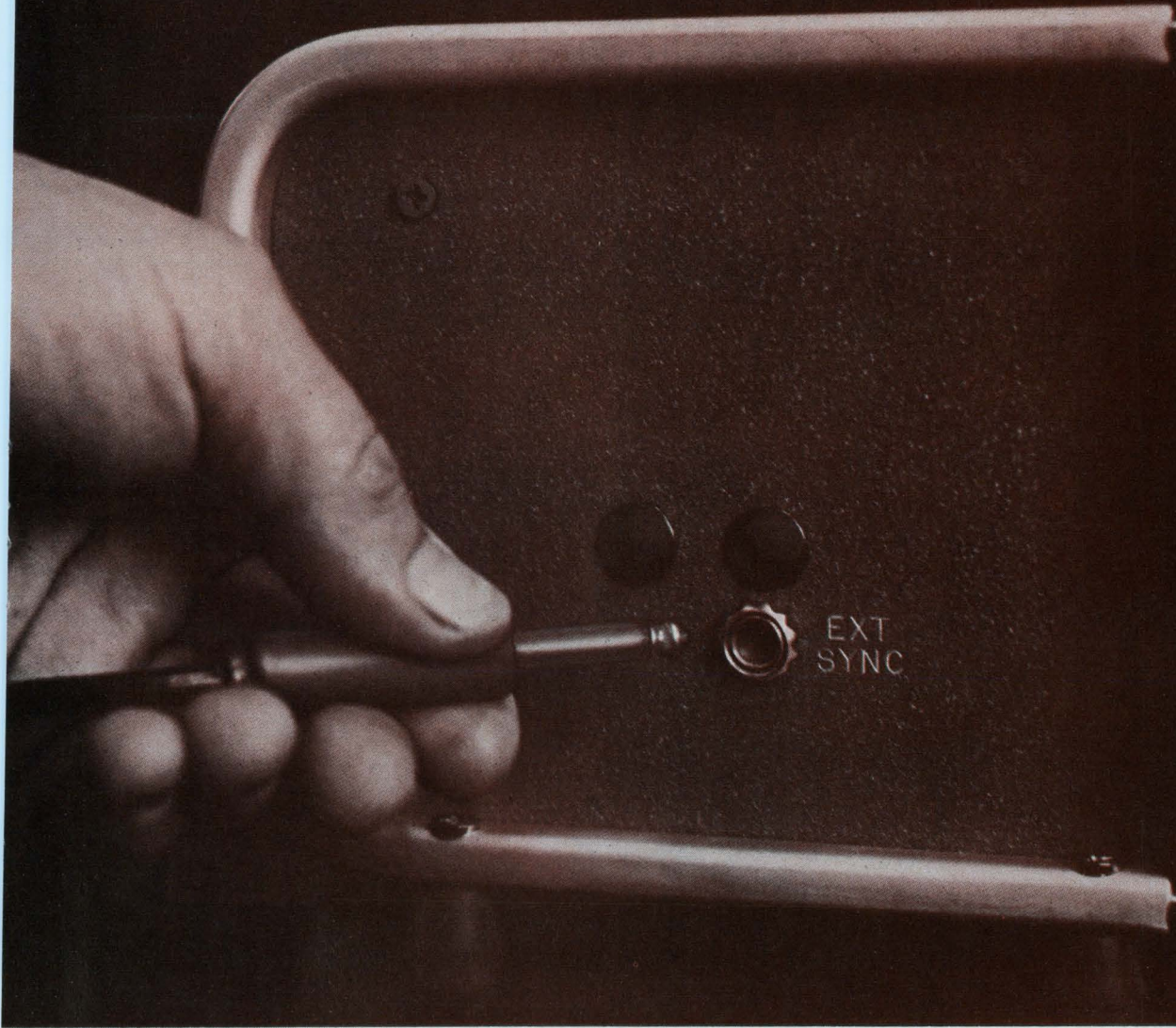
Accessories include Rise Time Converters which eliminate reflections beyond the bandwidth of interest, 75-ohm adapters, and a Susceptance Standard which gives direct readings of reactive discontinuities. Extensive "how-to" data is available in hp Application Notes 62, 67 and 75 and is yours for the asking.

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

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An extra measure of performance



"Sync-able" Oscillators



Type 1309-A . . . \$325 in U.S.A.

- 10Hz to 100 kHz
- Distortion <0.05%
- Calibrated attenuator



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Type 1311-A . . . \$225 in U.S.A.

- 11 fixed frequencies, 50 Hz to 10 kHz
- 1-watt output
- Distortion typically <0.1%

Each of these compact, solid-state oscillators can be phase-locked to an external frequency source. Or, they can furnish synchronizing signals to other instruments. These capabilities permit many applications never before possible with a general-purpose laboratory oscillator. For instance:

Several of these oscillators can be locked to a frequency standard to provide a highly stable signal for each station in a production setup. Thousands of dollars can be saved over current practices.

They can be used as frequency multipliers, since they can lock to a harmonic as well as to the fundamental frequency. Multiplying in this manner is more precise and more convenient than manually setting two different oscillators.

They can serve as high-Q filters. If a small signal (1 volt or less)

with distortion, noise, and hum is applied at the SYNC jack, this signal will appear "cleaned up" and amplified at the oscillator output terminals.

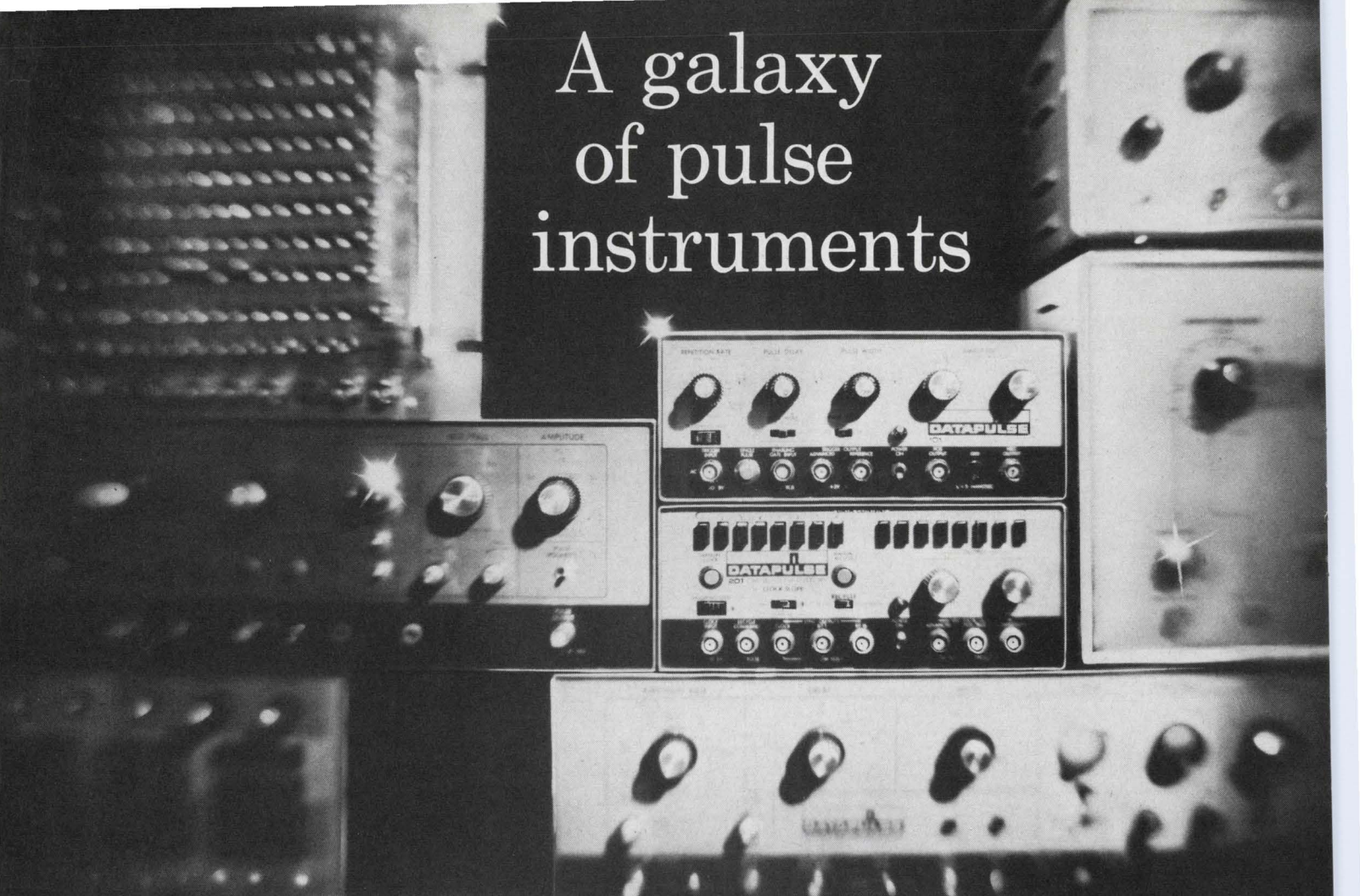
The constant-amplitude signal available at the SYNC jack can be used as a separate output to trigger a counter, scope, or other oscillator.

Other features common to all three of these oscillators are: solid-state circuitry, flat output, low distortion, high accuracy, small size, internal power supply, and low cost. There is no better oscillator value on the market.

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

GENERAL RADIO
ON READER-SERVICE CARD CIRCLE 3

A galaxy of pulse instruments



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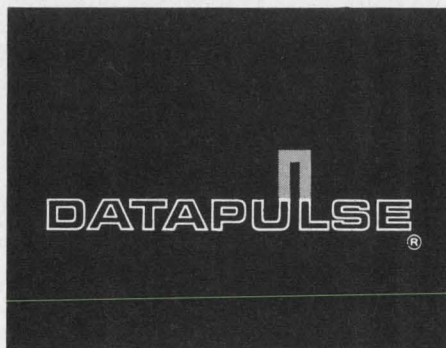
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VOL. 15 NO.

2

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

JAN. 18, 1967

NEWS

- 13 News Scope
- 17 **Commercial inertial is ready for take-off**
Airlines expect FAA approval this year for navigation systems that could speed air traffic.
- 21 **New gains made in optical communications**
Bell reports 3 modulators each use only about 1.5 mW of power per megahertz of bandwidth.
- 24 **All-optical loop improves optical memory**
Elimination of electronic transition in data path allows bandwidth to be increased with less distortion.
- 29 Washington Report
- 44 Letters
- 49 **Editorial: War is hell—and let's face it: it costs like it, too.**

TECHNOLOGY

- 52 **Simplify feedback amplifier** design with a set of straightforward equations that can be applied to a wide variety of circuits.
- 58 **IC bidirectional counters cost less**, are just as efficient as two unidirectional counters, and can be designed with RT micrologic.
- 66 **Put operational amplifiers to work** in four applications unusual and useful enough to win top honors in an industry-wide contest.
- 74 **Tunnel-diode circuits pave the way** to ultra-high-speed digital circuits required for wide-band, high-resolution communications systems.
- 82 Ideas for Design

PRODUCTS

- 92 **Cover Feature: IC voltage regulator** is externally adjustable.
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.
- 112 **Semiconductors: Silicon npn transistor** has 1000-volt breakdown.
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Reader Service card inside back cover

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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 $0.04\%/^{\circ}\text{C}$ typical. Maximum power

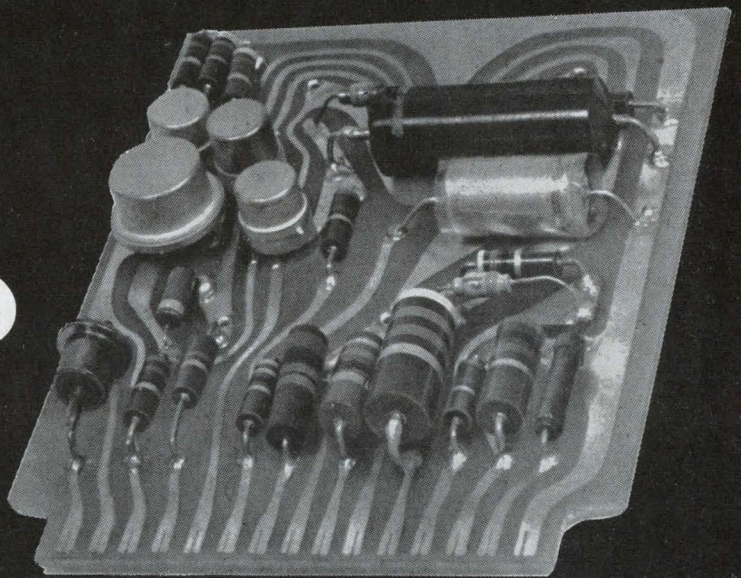
dissipation at 25°C case is 25 watts. And that's not all. The TO-3 configuration fits all standard sockets and heat sinks.

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.

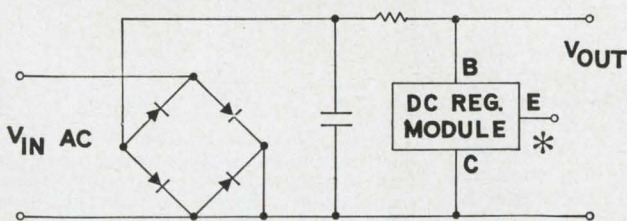
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regulator.

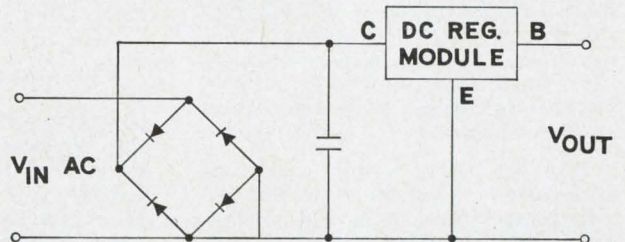
or this?



APPLICATION SCHEMATICS



*For external trim adjustment



Bendix Semiconductor Division

HOLMDEL, NEW JERSEY



ON READER-SERVICE CARD CIRCLE 5

"If you're buying our new integrated circuit op amp JUST for the 60,000 gain you may be missing several advantages!"

Certainly, our new MC1533 provides open-loop gain that's 15,000 higher than the next best. (Typically, 60,000 — with 40,000 guaranteed minimum). But, it also features extremely low temperature drift (for better stability) combined with low input offset voltage and gain adjustability, too. Best of all, it's competitively priced . . . and, available **RIGHT NOW!**

This extremely flexible operational amplifier sets new performance standards for a variety of applications. The high gain and temperature stability are extremely valuable for use in sensitive applications such as an integrator. Design simplicity and lower costs (because there's seldom a need to cascade) result from the added gain and low input offset voltage in other applications such as summing amplifiers, source followers, twin tee filters and oscillators.

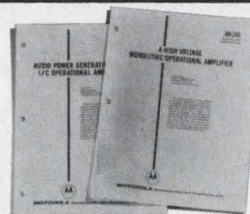
For an even wider range of applications, you can now get two different series of these state-of-the-art devices, in 10-pin TO-5 or flat-

pack, priced as low as \$15.00 (100-up). Here are some of the documented specifications that make it all possible:

CHARACTERISTICS	MC1533G	MC1433G
Price (100-up)	\$34.00	\$15.00
Power Dissipation	120 mW	120 mW
Operating Temp. Range	-55 to +125°C	0 to 75°C
Open Loop Voltage Gain — A_{VOL} (min.)	40,000	30,000
Voltage Drift With Temp. (Typ.)	$8\mu V/^\circ C$ ($T_A = -55^\circ C$ to $+25^\circ C$) $5\mu V/^\circ C$ ($T_A = +25^\circ C$ to $+125^\circ C$)	$10\mu V/^\circ C$ ($T_A = 0^\circ C$ to $+25^\circ C$) $8\mu V/^\circ C$ ($T_A = +25^\circ C$ to $+75^\circ C$)
Input Impedance (typ)	1 Megohm	600 Kohms
Output Voltage Swing*	± 12 volts	± 12 volts

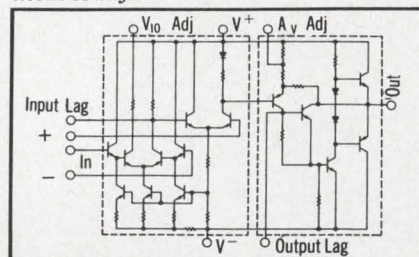
* ± 15 V Supply with R_L 2 Kohms

For complete details on the World's Best Op Amp Integrated Circuit, send for our data sheets and the Application Notes described at right. For immediate delivery on devices you'll want to try, contact your nearby Motorola franchised semiconductor distributor.



HOW TO USE HIGH GAIN OP AMP DESCRIBED IN TWO NOTES

Designing source followers, twin tee filters and oscillators, and high impedance voltmeters are presented as examples of the wide variety of applications for the MC1533 operational amplifier. In addition, three complementary audio frequency amplifiers are discussed, each using an MC 1533 to obtain the desired voltage gain and reduce the distortion figure. Motorola Application Notes 248 and 275 are sure to be valuable additions to your library of integrated circuit information. Send for them today!



The MC1533 is considered a multi-stage amplifier, and is constructed to best use the advantage of monolithic integrated circuits. The dotted lines separate the stages.

where the priceless ingredient is care!



MOTOROLA Semiconductors

MOTOROLA SEMICONDUCTOR PRODUCTS INC./P. O. BOX 955/PHOENIX, ARIZONA 85001/(602) 273-6900/TWX 910-951-1334

ON READER-SERVICE CARD CIRCLE 6

Reliability and price levels for every ER application



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

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

K } Molded — 100 PPM
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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.
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- K/M in Mepco's FE series molded metal film resistors . . . where economy can be achieved for ER applications.

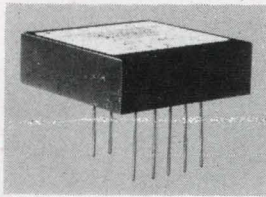
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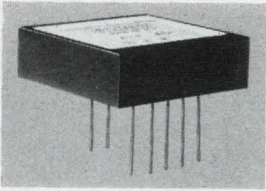


A Heritage of Reliability

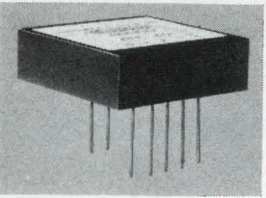
ON READER-SERVICE CARD CIRCLE 7



Think Costs, too!



Think Hybrid...



Think Amperex...

Now you can get performance with

The plain facts are that Amperex can design and manufacture—to your specifications—the hybrid integrated circuit you need, and can do it faster, better and more economically than any other source known to us.

Why? Because Amperex special production line methods and Amperex thin-film/LID circuit technology are way ahead of the field. After all, who would have more skill in substrate processing and in microminiature circuitry than a leading producer of high-performance transistors? And who would be better able to apply LID semiconductor assembly techniques than the company who invented the LID?

Our batch-processed, large-volume runs of hybrid IC devices made with Amperex LIDS (off-the-shelf items and custom-produced items for special systems requirements) offer high performance at low cost, plus a third big bonus—small size.

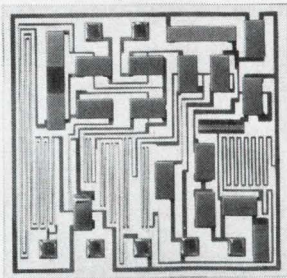
Amperex hybrids offer resistance values from 50 ohms to 300 kilohms with stabilities better than 1% over 2000 hours at 250°C; capacitance values from 10 pico-

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.

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 Ampli-



ATF-401 OP AMP BEFORE ENCAPSULATION

fiers • 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

Did You Know Sprague Makes 51 Types of Foil and Wet Tantalum Capacitors?

125 C FOIL-TYPE TUBULAR TANTALEX® CAPACITORS



Type 120D polarized plain-foil
Type 121D non-polarized plain-foil
Type 122D polarized etched-foil
Type 123D non-polarized etched-foil

ASK FOR BULLETIN 3602C

ON READER-SERVICE CIRCLE 161

FOIL-TYPE RECTANGULAR TANTALEX® CAPACITORS



Type 300D polarized plain-foil
Type 301D non-polarized plain-foil
Type 302D polarized etched-foil
Type 303D non-polarized etched-foil

ASK FOR BULLETIN 3650

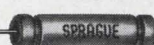
ON READER-SERVICE CIRCLE 162

FOIL-TYPE TANTALUM CAPACITORS TO MIL-C-3965C

CL20, CL21 tubular 125 C polarized etched-foil
CL22, CL23 tubular 125 C non-polar etched-foil
CL24, CL25 tubular 85 C polarized etched-foil
CL26, CL27 tubular 85 C non-polar etched-foil
CL30, CL31 tubular 125 C polarized plain-foil
CL32, CL33 tubular 125 C non-polar plain-foil
CL34, CL35 tubular 85 C polarized plain-foil
CL36, CL37 tubular 85 C non-polar plain-foil
CL51 rectangular 85 C polarized plain-foil
CL52 rectangular 85 C non-polar plain-foil
CL53 rectangular 85 C polarized etched-foil
CL54 rectangular 85 C non-polar etched-foil

ON READER-SERVICE CIRCLE 163

85 C FOIL-TYPE TUBULAR TANTALEX® CAPACITORS



Type 110D polarized plain-foil
Type 111D non-polarized plain-foil
Type 112D polarized etched-foil
Type 113D non-polarized etched-foil

ASK FOR BULLETIN 3601C

ON READER-SERVICE CIRCLE 164

SINTERED-ANODE TUBULAR TANTALEX® CAPACITORS



Type 109D elastomer seal 85 C
Type 130D elastomer seal 125 C
Type 137D hermetic seal 125 C

ASK FOR BULLETINS 3700F, 3701B, 3703

ON READER-SERVICE CIRCLE 165

SINTERED-ANODE CUP STYLE TANTALEX® CAPACITORS



Type 131D 85 C industrial-type
Type 132D 85 C vibration-proof
Type 133D 125 C vibration-proof

ASK FOR BULLETINS 3710B, 3711

ON READER-SERVICE CIRCLE 166

SINTERED-ANODE CYLINDRICAL TANTALEX® CAPACITORS



Type 140D
up to 175 C operation,
3/8" diam.
Type 141D
up to 175 C operation,
1 1/8" diam.

ASK FOR BULLETIN 3800

ON READER-SERVICE CIRCLE 167

SINTERED-ANODE RECTANGULAR TANTALEX® CAPACITORS



Type 200D negative terminal grounded
Type 202D both terminals insulated

ASK FOR BULLETIN 3705A

ON READER-SERVICE CIRCLE 168

SINTERED-ANODE TANTALUM CAPACITORS TO MIL-C-3965C

CL14 cylindrical, 3/8" diam.
CL16 cylindrical, 3/8" diam., threaded neck
CL17 cylindrical, 1 1/8" diam.
CL18 cylindrical, 1 1/8" diam., threaded neck
CL44 cup style, uninsulated
CL45 cup style, insulated
CL55 rectangular, both terminals insulated
CL64 tubular, uninsulated
CL65 tubular, insulated

ON READER-SERVICE CIRCLE 169

For comprehensive engineering bulletins on the capacitor types in which you are interested, write to:

Technical Literature Service
Sprague Electric Company
347 Marshall Street
North Adams, Mass. 01247

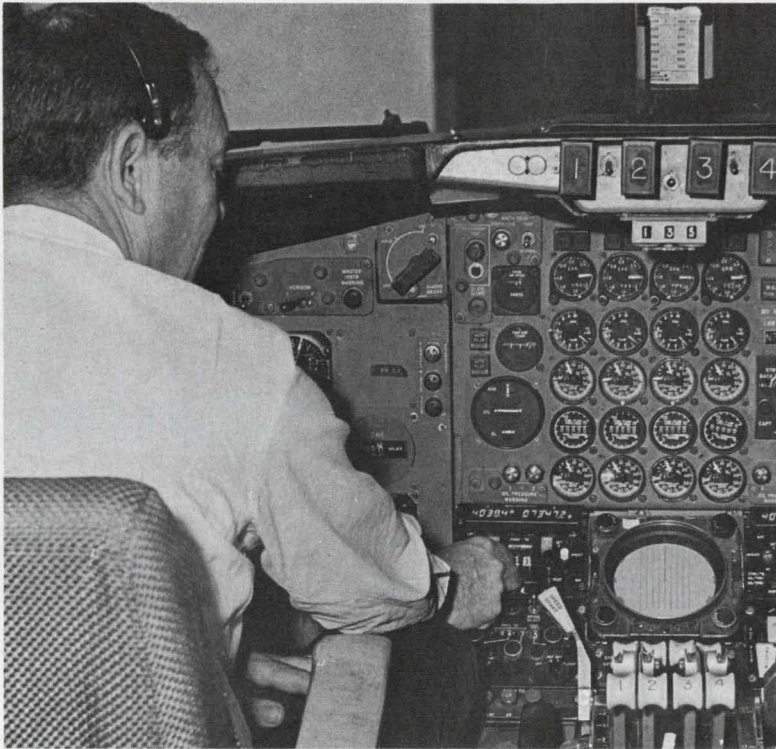
450-5158

SPRAGUE®

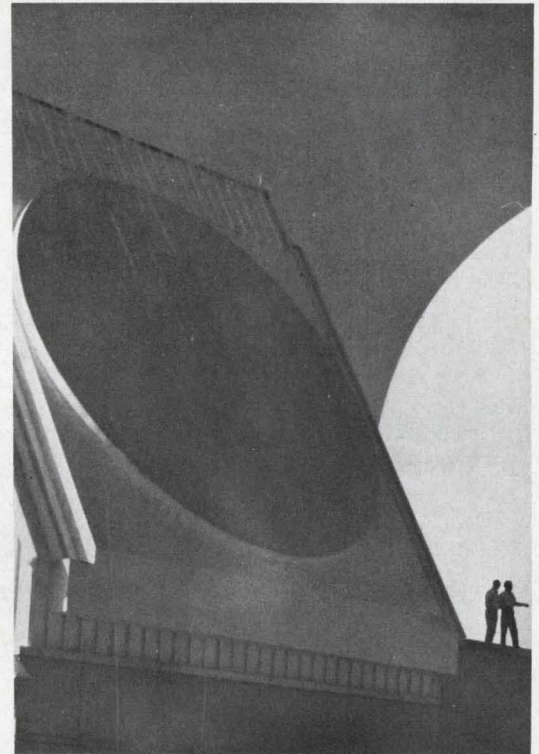
THE MARK OF RELIABILITY

Sprague® and '®' are registered trademarks of the Sprague Electric Co.

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

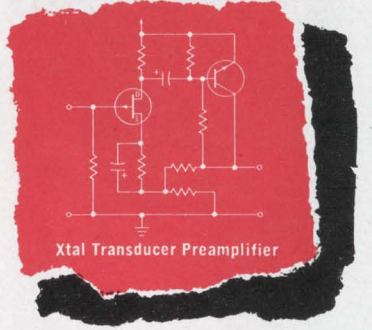
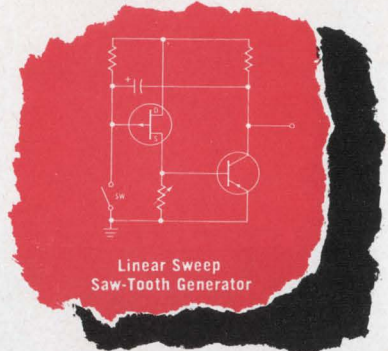
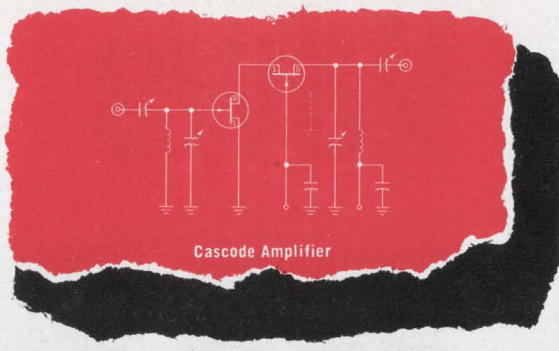
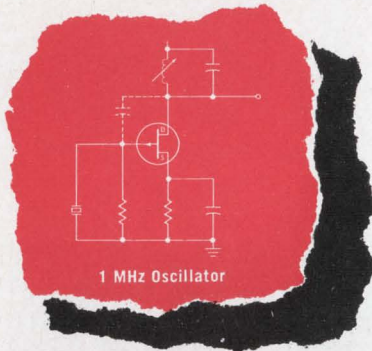
multipurpose computers. The light is delayed between concave spherical mirrors. Page 24

Also in this section:

Broadband light modulation is accomplished at less than a watt. Page 21

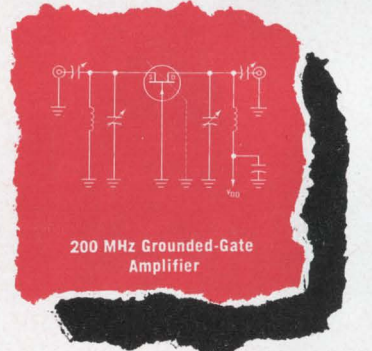
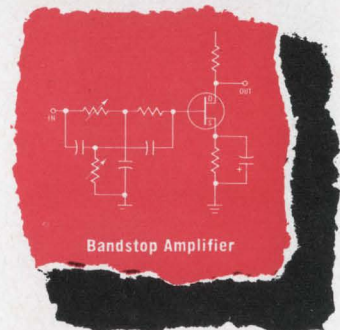
Thin film measures the speed of micrometeorites in space. Page 33

News Scope, Page 13 . . . **Washington Report**, Page 29 . . . **Editorial**, Page 49

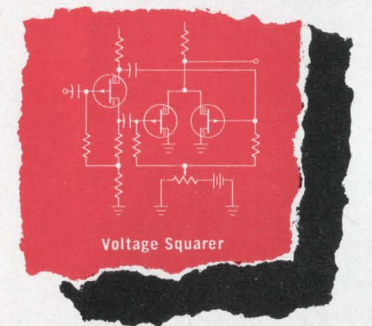
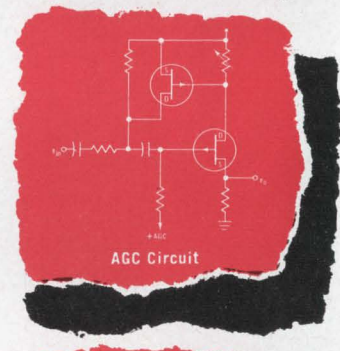


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V_P	-0.3	-10	-0.3	-1.5	-0.8	-4.0	-2.0	-10	V
I_{DSS}	0.2	20	0.2	1.0	0.9	4.5	4.0	20	mA

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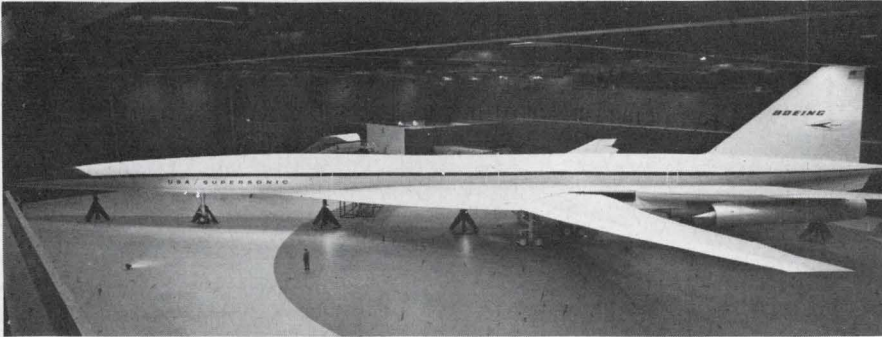
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ON READER-SERVICE CARD CIRCLE 10

News Scope

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 primar-

ily 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, Eng-

land, 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 Aero-bee 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 beginning 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 by-product 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.

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 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

Units shown actual size



Bourns Model 4210 Microtransformer



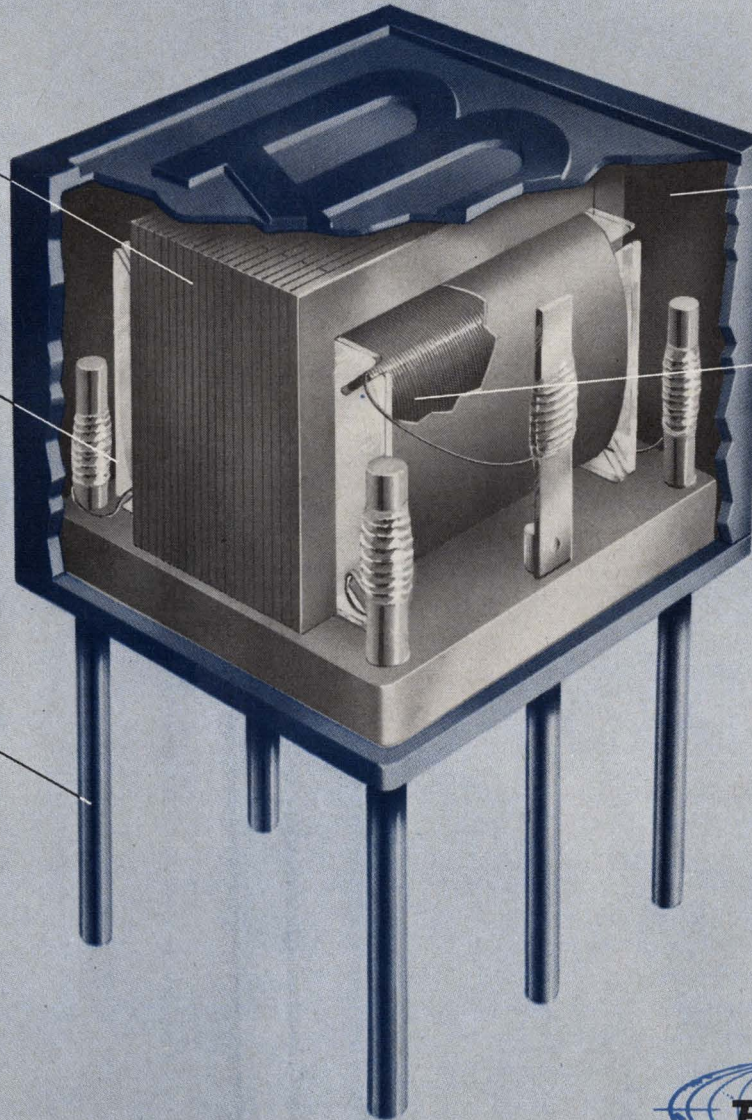
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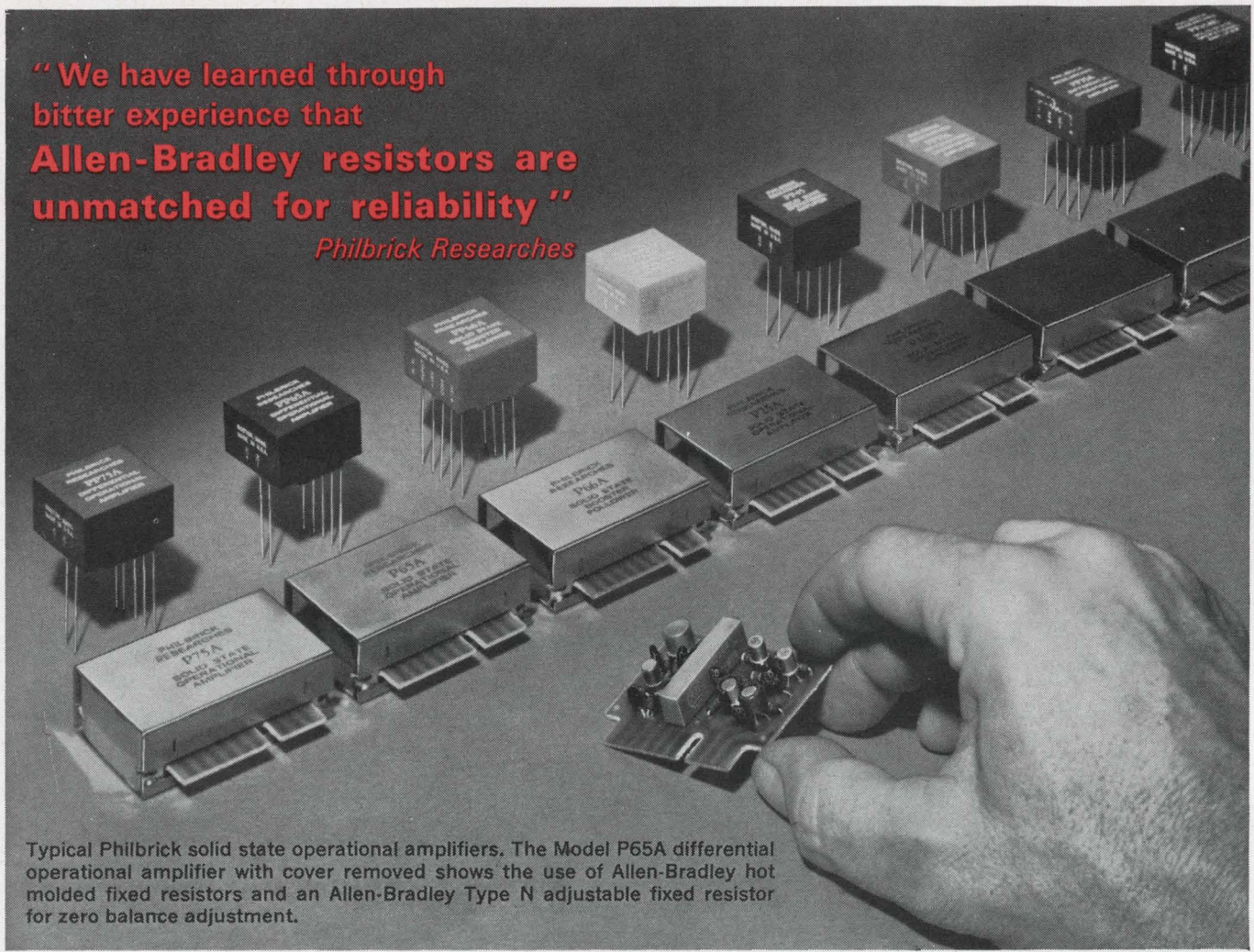
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Philbrick Researches

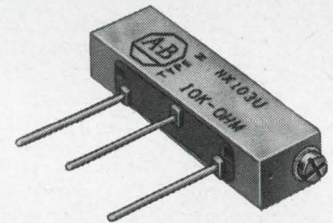


Typical Philbrick solid state operational amplifiers. The Model P65A differential operational amplifier with cover removed shows the use of Allen-Bradley hot molded fixed resistors and an Allen-Bradley Type N adjustable fixed resistor for zero balance adjustment.

TYPE BB 1/8 WATT	MIL TYPE RC 05
TYPE CB 1/4 WATT	MIL TYPE RC 07
TYPE EB 1/2 WATT	MIL TYPE RC 20
TYPE GB 1 WATT	MIL TYPE RC 32
TYPE HB 2 WATTS	MIL TYPE RC 42

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■ "Why have Allen-Bradley hot molded resistors been our first choice since the late 1940's? In a word: Reliability!" states Philbrick—the leading manufacturer of operational amplifiers. There's nothing accidental about this superiority of A-B resistors. A unique hot molding process using completely automatic machines, eliminates the "human element" and produces such uniformity from one resistor to the next—year in and year out—that long resistor performance can be accurately predicted. No instance of "catastrophic failures" has ever come to our attention.

Allen-Bradley Type N adjustable fixed resistors likewise use a solid hot molded resistance track. Adjustment is so smooth, it approaches infinite resolution—and settings remain fixed. Being noninductive, Type N controls can be used at high frequency, where wire-wound units would be completely unsatisfactory.

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



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ON READER-SERVICE CARD CIRCLE 12

ELECTRONIC DESIGN 2, January 18, 1967

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.

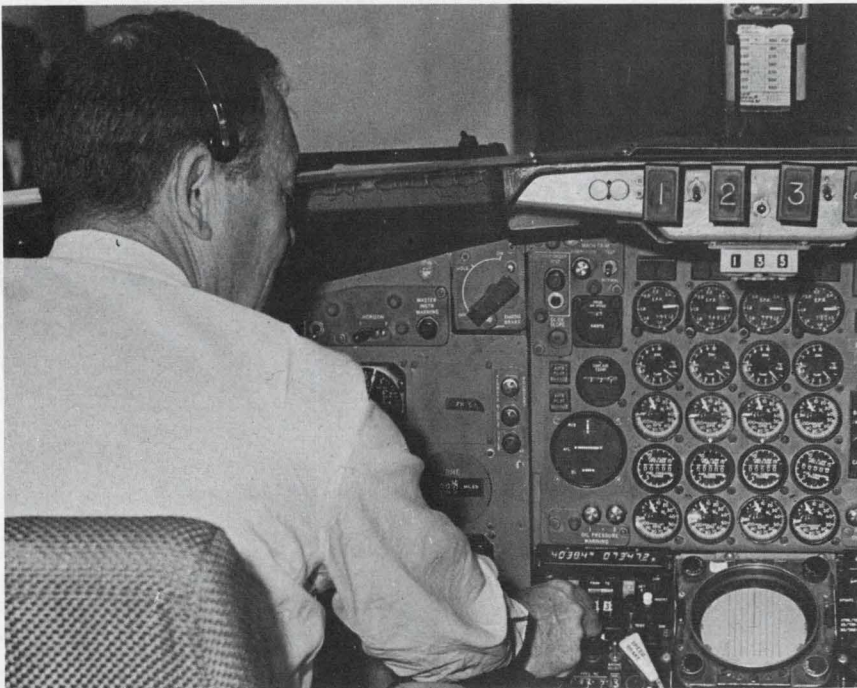
- Great-circle courses—the shortest distances between any two points on the earth—are computed automatically.

- 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.

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 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.

(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 air-

line, 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 “break-through” 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 switch-

es 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.

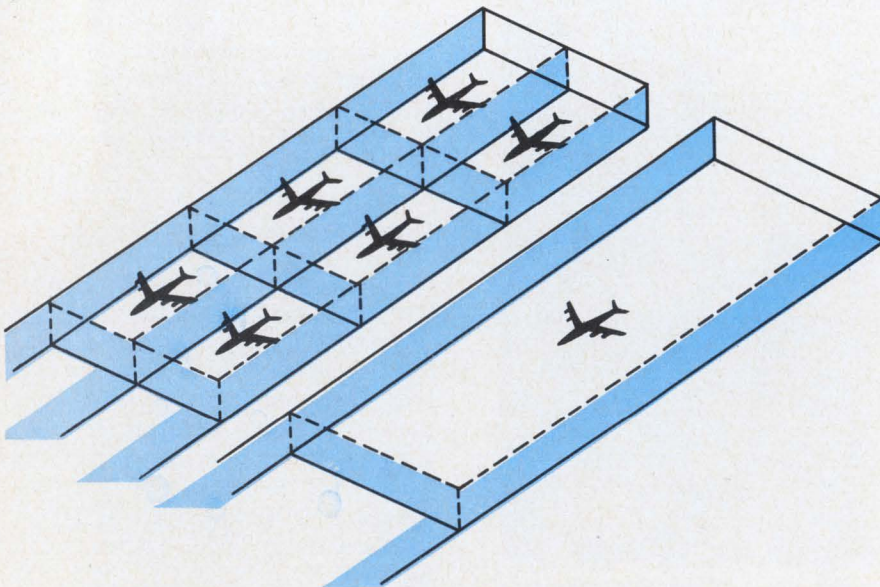
Hands-off operation

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-



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.



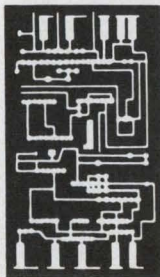
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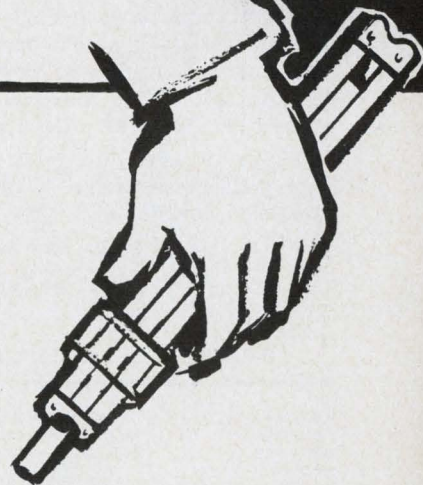
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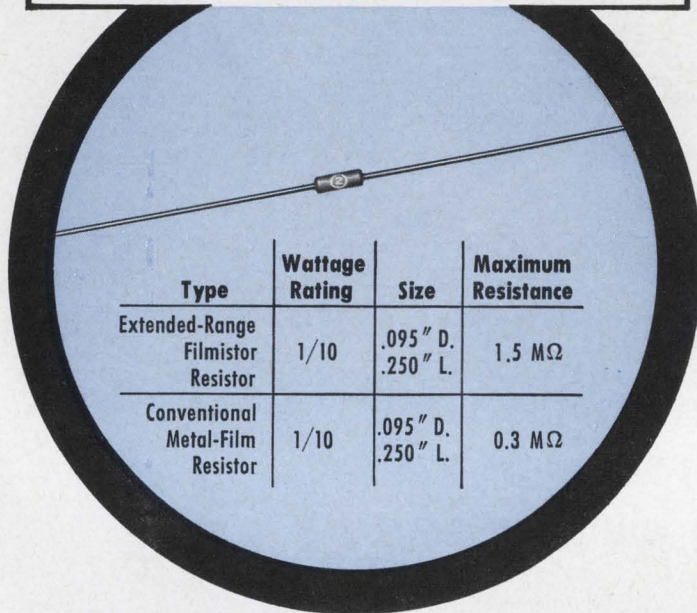
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NEWS

(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 "cocoon." 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, re-

quired 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.

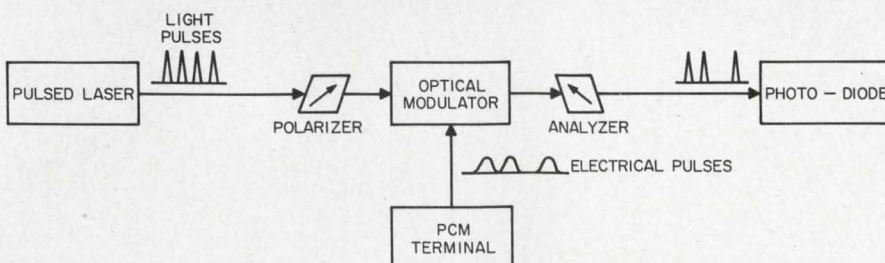
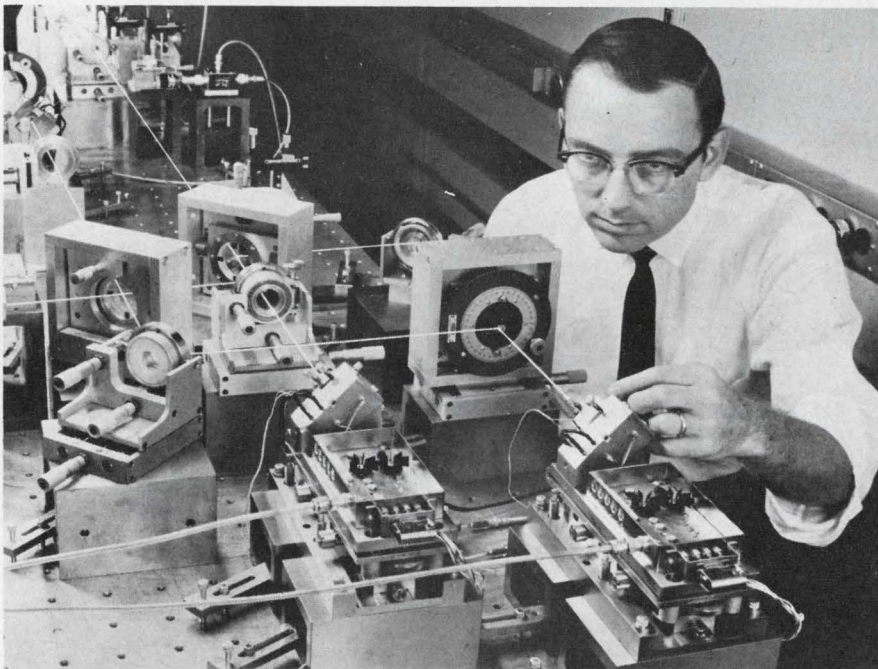
PCM experiments pressed

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.

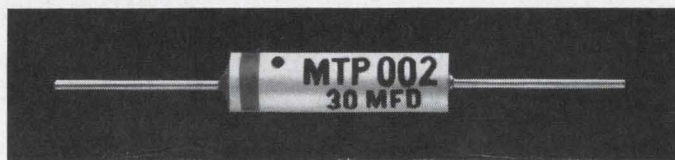
Because the laser pulses are of considerably shorter duration than the PCM pulse repetition period, several high-speed PCM signals, converted to optical pulses, can be multiplexed onto a single laser beam.

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-



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.

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ON READER-SERVICE CARD CIRCLE 15

NEWS

(optical, continued)

according 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.

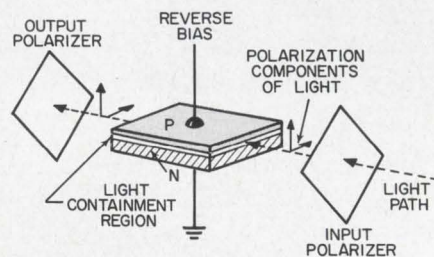
The modulator can also be used to encode a continuous light beam. In this mode, a drive power of one-fifth of a watt has produced 80-per cent modulation over a 220-MHz bandwidth, according to Bell.

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 semiconductor 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. ■ ■



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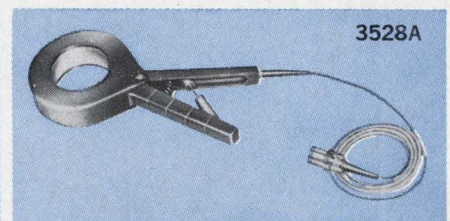
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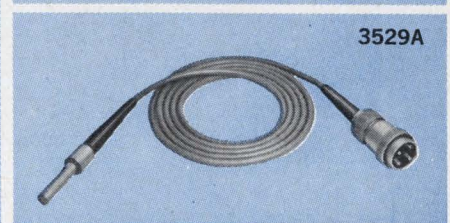
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ON READER-SERVICE CARD CIRCLE 16.

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 mem-

ories, 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.

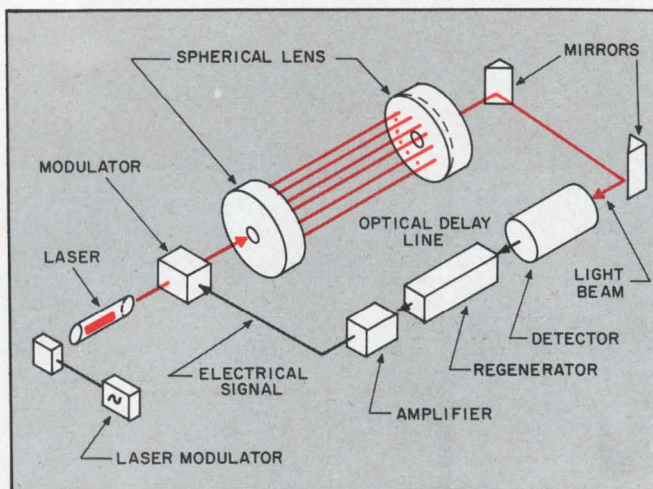
Like other memory units, both optical memories store information

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.

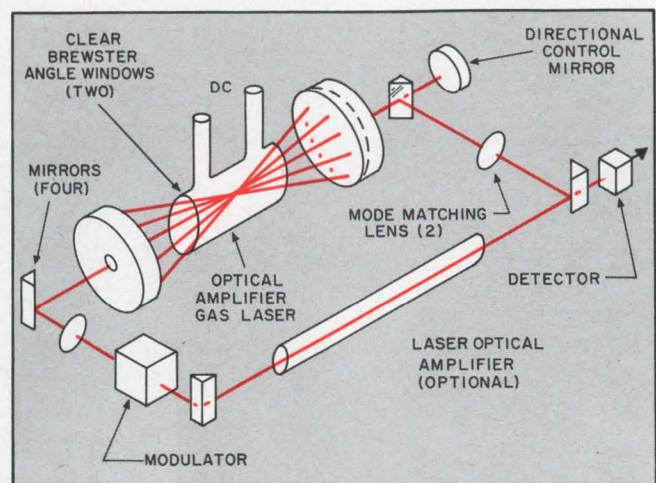
Light beam is folded

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.

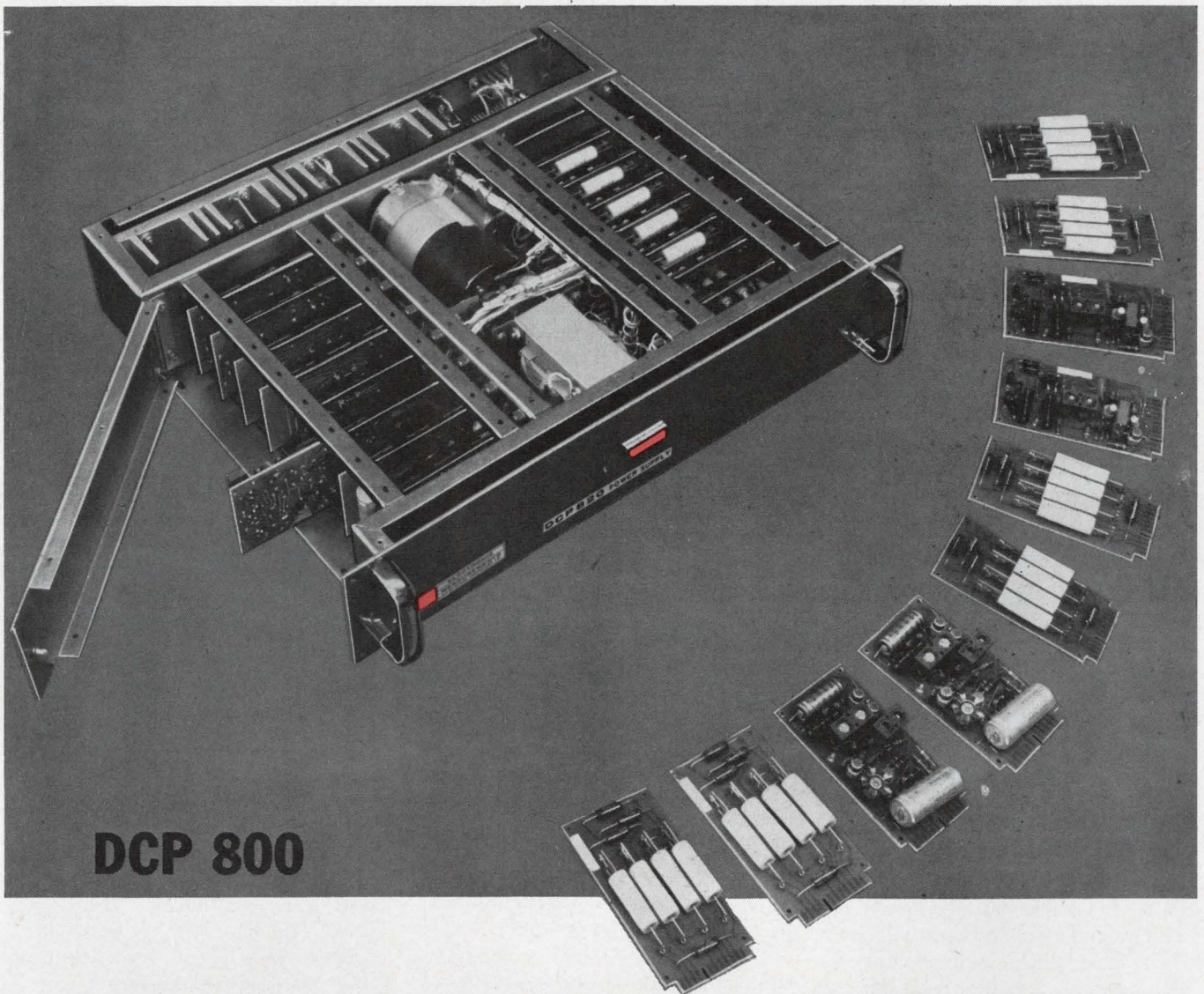
Because the light beam has no dispersion, information modulated into the laser beam is not distorted.



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 opto-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.



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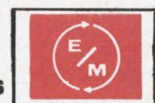
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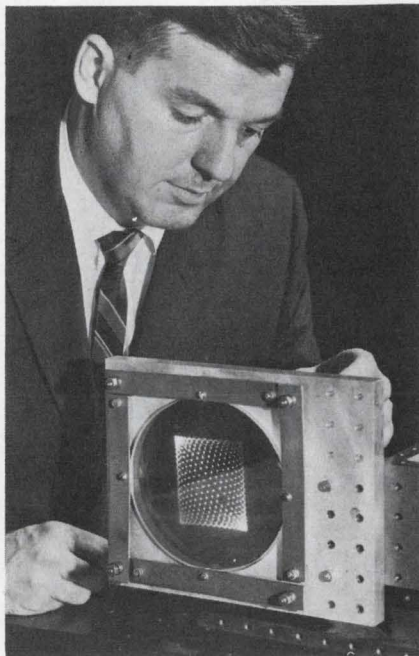
(optical memory, continued)

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- μ 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,



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.

on the other hand, would not be limited in this manner.

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 physi-

cist, 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 slightly 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.

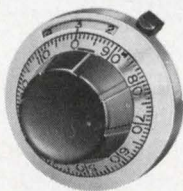
Herriott explains that optical memories can be used to correlate radar signals or equivalent sound. It can be used for shifting digital information, so that digital nonlinear processes can be carried out more rapidly. These applications depend on reports, high modulation rates and analog storage. ■ ■

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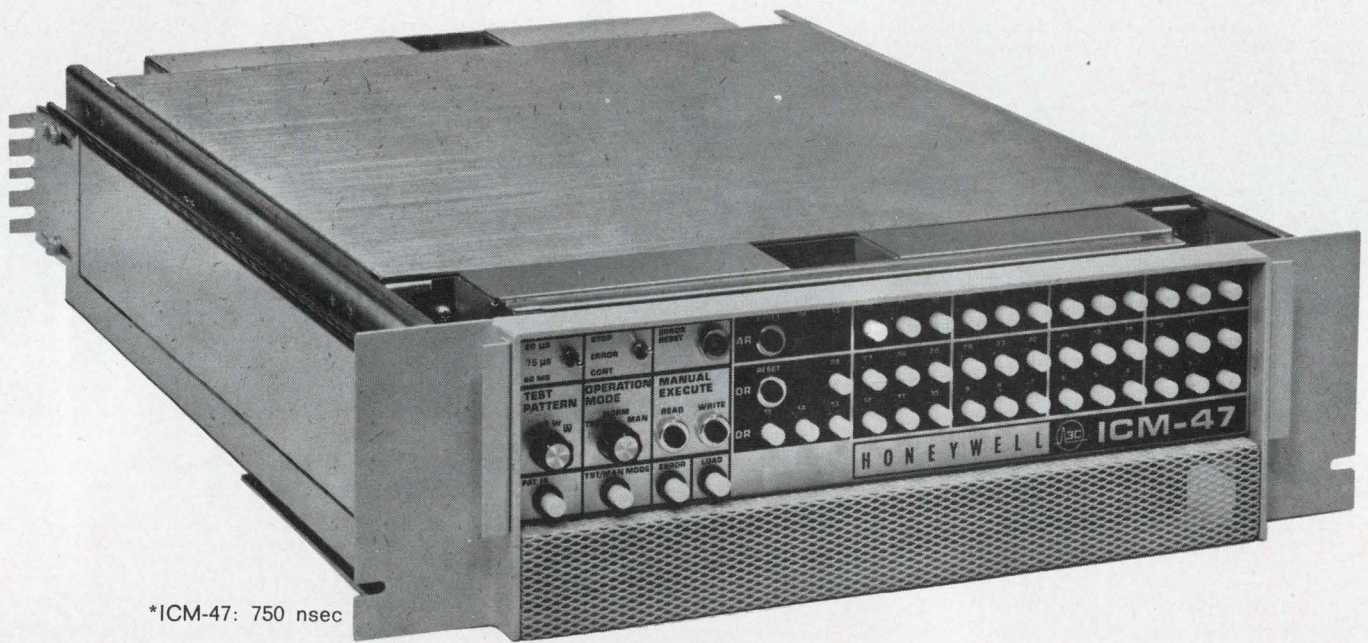
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Washington Report

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

Washington Report

CONTINUED

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

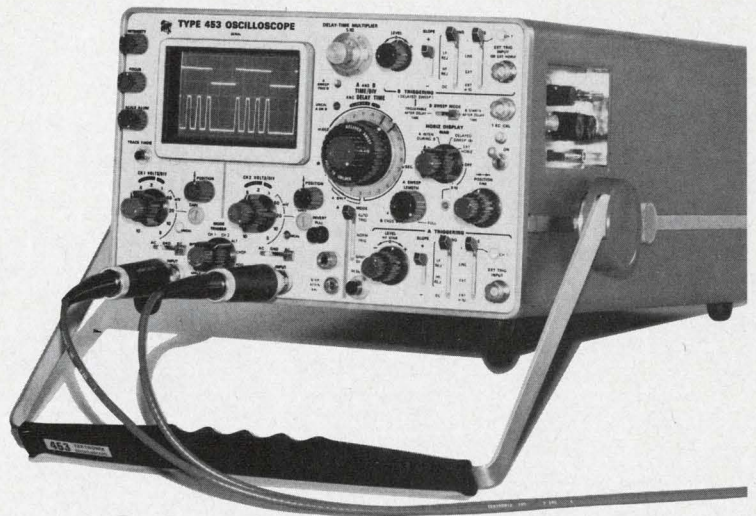
Officers of the U.S. Navy's Ship Systems Command believe that they may be on top of the problem of incorporating the multitude of shipboard antennas that are necessary now into the basic hull design and structure of the next generation of ships. Problems have included interference and the difficulty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

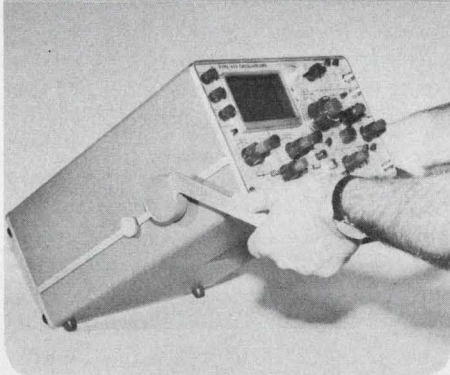
Tektronix Type 453 oscilloscope has

- 50 MHz Performance
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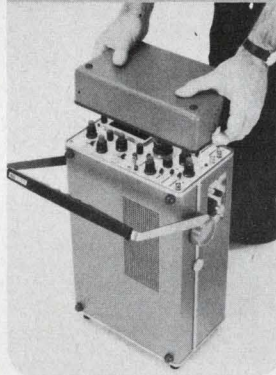


and-----it's designed to be carried!

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. Set-

ting 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 ($\pm 1\%$) 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

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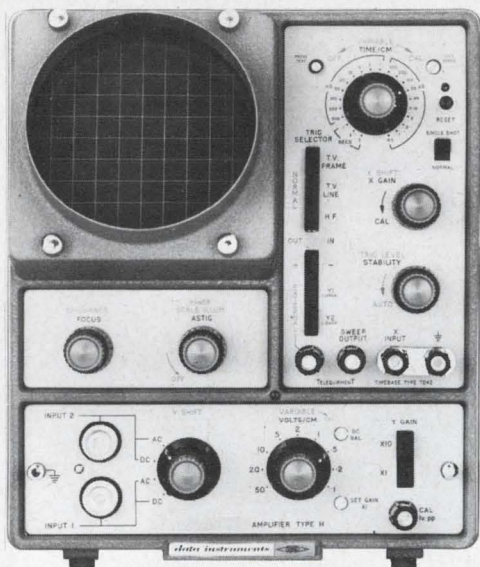
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The 4 inch, flat-faced PDA tube provides accurate and unambiguous viewing. It is available in a variety of phosphors and has a removable graticule with controlled edge lighting. An extremely reliable time base provides sweep speeds to .5 μ sec/cm in 22 precisely calibrated ranges with single shot and lockout. It also has neon indication when the time base is armed. It features rock steady triggering in a number of modes and the horizontal amplifier provides 10X expansion to 500KHz.

For those who want even more performance there is the D43A. This is a double beam scope giving two simultaneous 25MHz traces on a 4 inch tube. The main frame is \$515, and it accepts the same vertical amplifiers as the S43A. Each instrument is fully guaranteed for one year, and field and factory servicing are provided.

If your budget is pinching you (and even if it isn't) why not arrange for a demonstration of the S43A? We have a man in your area and it doesn't hurt to look. At \$23 a MHz it doesn't hurt at all.

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ON READER-SERVICE CARD CIRCLE 21

NEWS

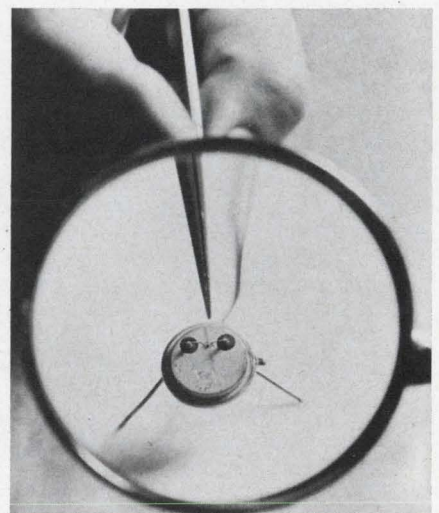
Three-terminal diode is FM transmitter

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. ■ ■

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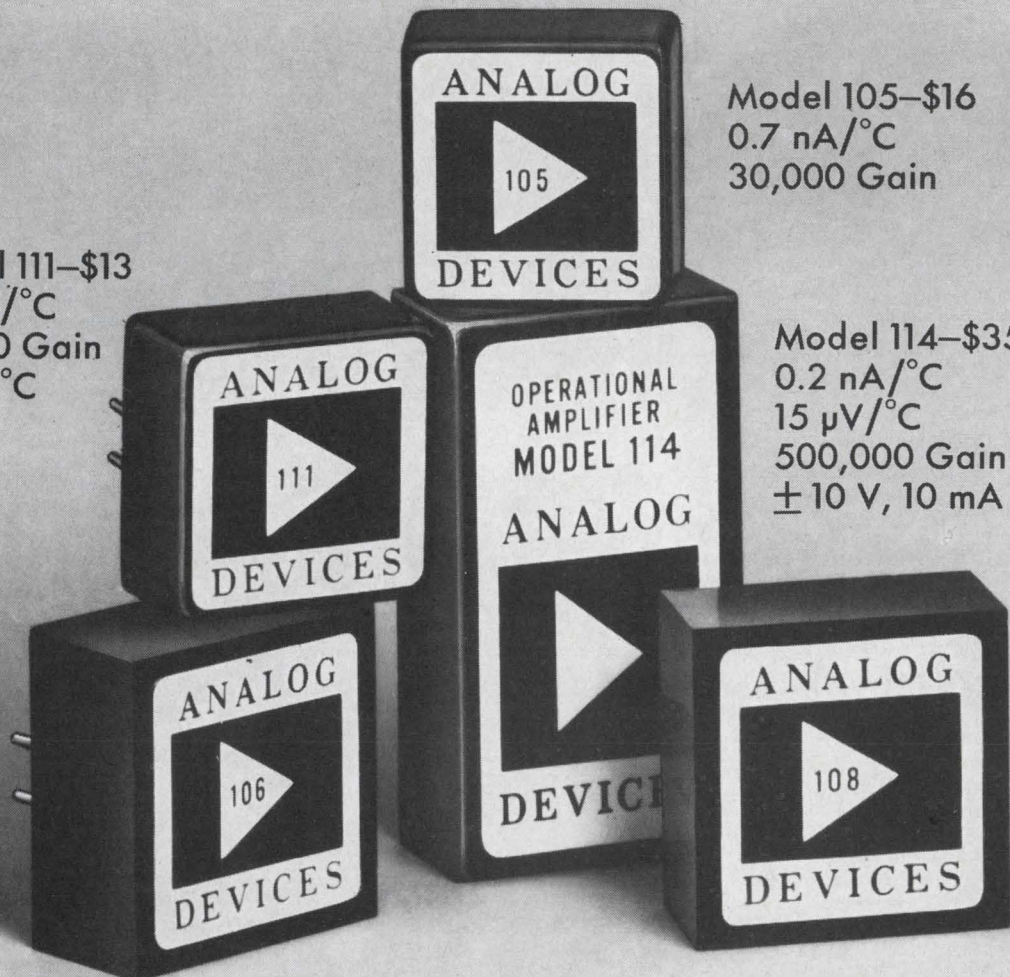
Prices Dropped, Specs Raised
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Model 114—\$35
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15 $\mu\text{V}/^\circ\text{C}$
500,000 Gain
 $\pm 10\text{ V}, 10\text{ mA}$

Model 106—\$21
0.7 $\text{nA}/^\circ\text{C}$
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Model 108—\$28
0.2 $\text{nA}/^\circ\text{C}$
100,000 Gain

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Max. drift and min. gain values for -25°C to $+85^{\circ}\text{C}$ range contrast with "typical" values given by many op amp manufacturers. Selection of $10\ \mu\text{V}/^{\circ}\text{C}$ and $5\ \mu\text{V}/^{\circ}\text{C}$ 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/ $^{\circ}\text{C}$	0.7 nA/ $^{\circ}\text{C}$	0.7 nA/ $^{\circ}\text{C}$	0.2 nA/ $^{\circ}\text{C}$	0.2 nA/ $^{\circ}\text{C}$
Offset Current—max.	20 nA	5 nA	5 nA	2 nA	2 nA
vs. temp.—max.	1 nA/ $^{\circ}\text{C}$	0.2 nA/ $^{\circ}\text{C}$	0.2 nA/ $^{\circ}\text{C}$	0.05 nA/ $^{\circ}\text{C}$	0.05 nA/ $^{\circ}\text{C}$
Input Impedance					
differential	200 k Ω	1 m Ω	1 m Ω	4 m Ω	4 m Ω
common mode	50 m Ω	100 m Ω	100 m Ω	500 m Ω	500 m Ω
Bandwidth	1.5 mHz	2 mHz	2 mHz	0.5 mHz	0.5 mHz
Voltage Drift—max.					
Model A	20 $\mu\text{V}/^{\circ}\text{C}$	20 $\mu\text{V}/^{\circ}\text{C}$	20 $\mu\text{V}/^{\circ}\text{C}$	20 $\mu\text{V}/^{\circ}\text{C}$	20 $\mu\text{V}/^{\circ}\text{C}$
Model B	—	10 $\mu\text{V}/^{\circ}\text{C}$	10 $\mu\text{V}/^{\circ}\text{C}$	10 $\mu\text{V}/^{\circ}\text{C}$	10 $\mu\text{V}/^{\circ}\text{C}$
Model C	—	5 $\mu\text{V}/^{\circ}\text{C}$	5 $\mu\text{V}/^{\circ}\text{C}$	5 $\mu\text{V}/^{\circ}\text{C}$	5 $\mu\text{V}/^{\circ}\text{C}$
Price (1-9)	\$13	A B C \$16 \$21 \$26	A B C \$21 \$26 \$31	A B C \$28 \$33 \$38	A B C \$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.

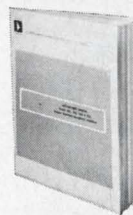
Consider—Who else offers an op amp with Model 111's specs at \$9.75 in 1,000 quantities? Who else has a unit (Model 105) with bias current drift below $0.7\ \text{nA}/^{\circ}\text{C}$ for only \$16? Where could you get a \$21 amplifier (Model 106) with 250,000 gain and 5 mA output? Or an amplifier (Model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

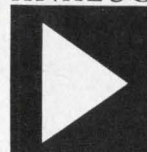
Catalog—Mark bingo-card to get Economy Line Catalog with full details on these 5 units.



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.

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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-

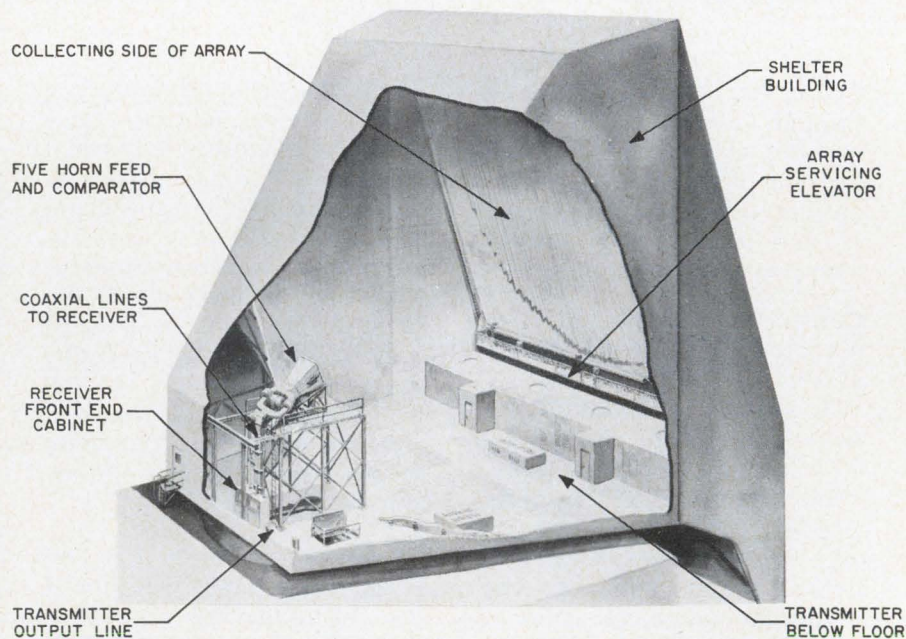
shifting elements of the lens collimate the incident spherical-wave front to a plane wave and steer the pencil beam that is formed.

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.

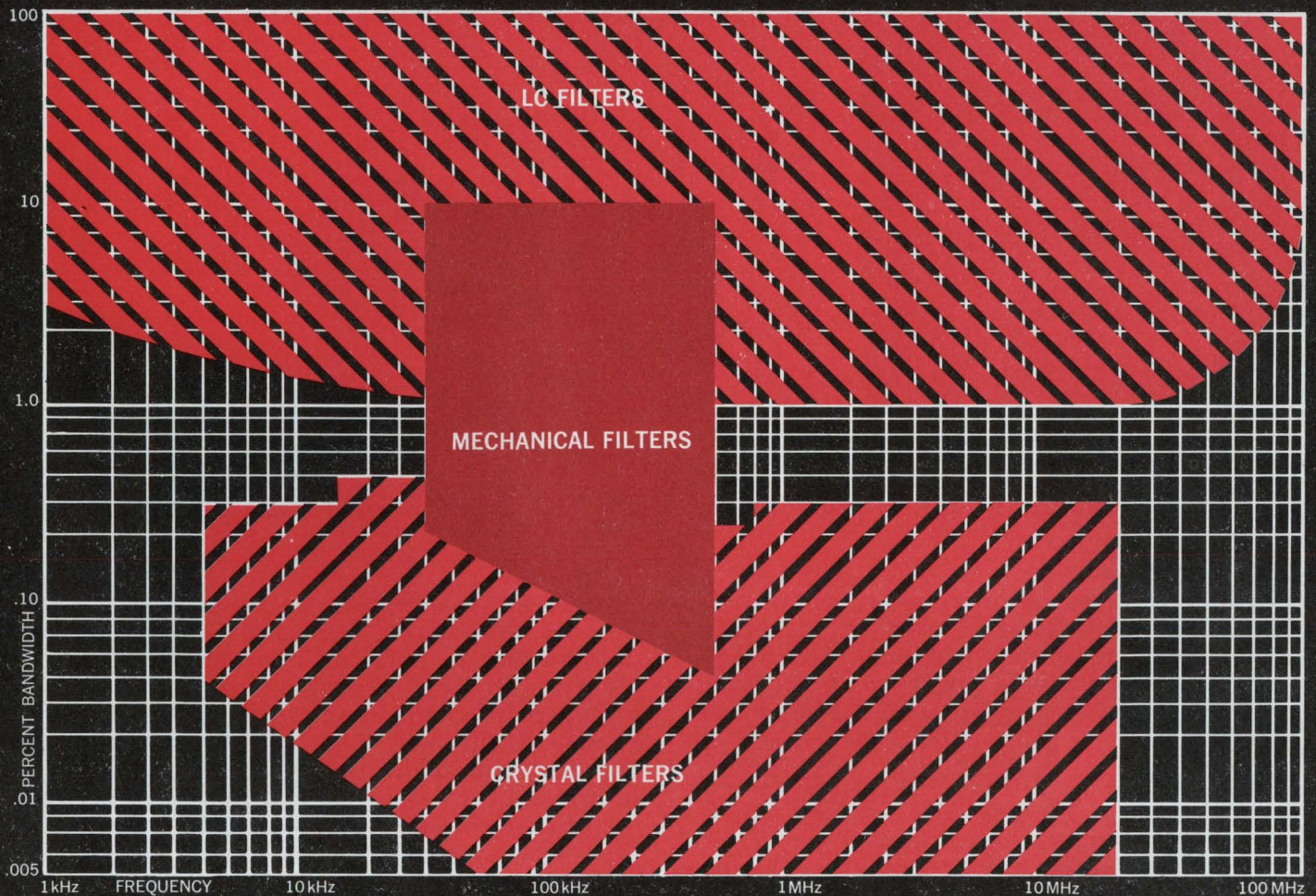
The lens array consists of radiating elements driven by three-bit digital phase shifters. All phase shifters are diode-controlled by the beam-steering unit. The beam-steering unit translates computer commands into the proper logic for actuating each individual phase shifter driver. The drivers set the 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.



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

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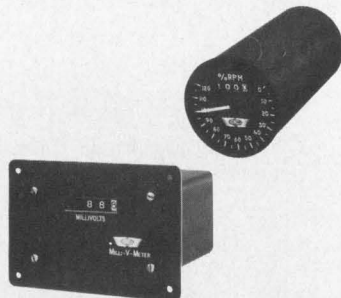
The instruments utilize the null-balance potentiometric principle to measure transducer output signals which are either linear or non-linear. The units follow non-linear functions with multiple, precisely calibrated, straight-line approximations. Non-linear curves of thermocouples, strain gauges or most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

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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.

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ON READER-SERVICE CARD CIRCLE 28

NEWS

(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 posi-



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

tioned 30 degrees from the vertical, Sperry engineers say it could be set horizontally, flush with the ground, in a hardened silo. ■ ■

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. ■ ■

ON READER-SERVICE CARD CIRCLE 29 ➤

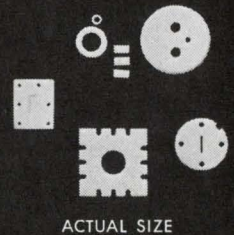


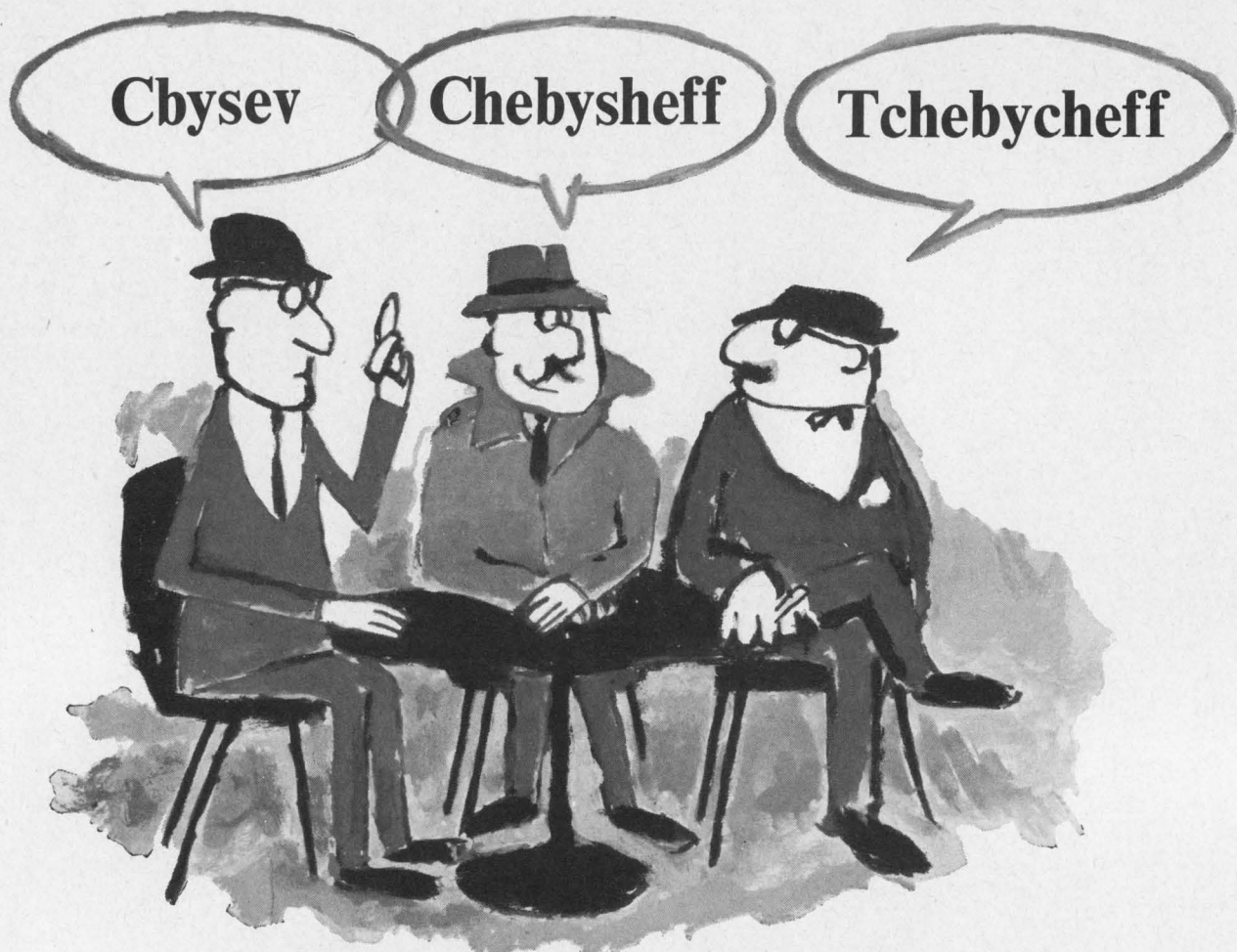
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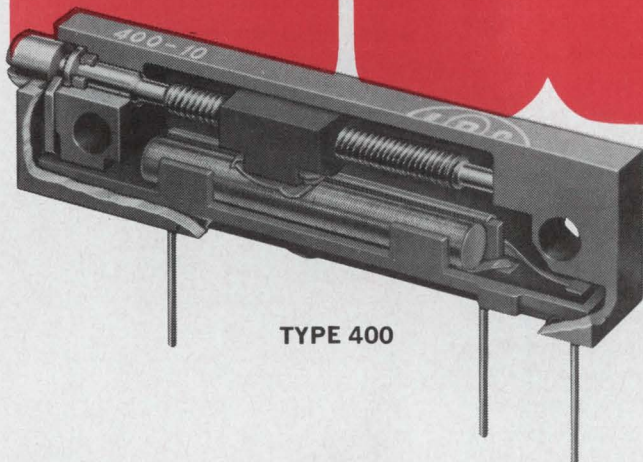
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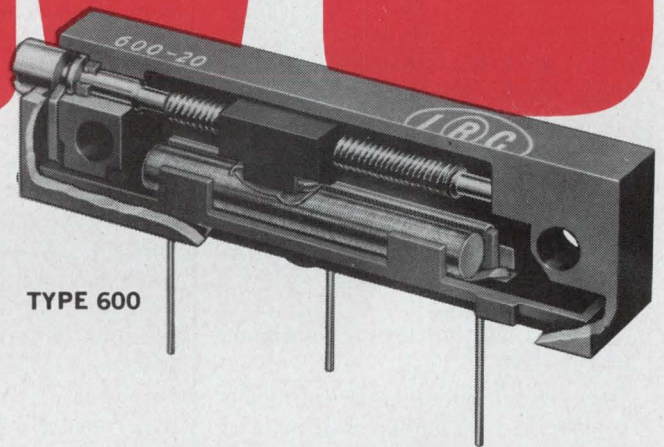
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These low-cost MIL-type units are the result of IRC's years of experience in building high-quality trimmers. Samples available

from local sales offices. For prices and data, write: IRC, Inc., 401 N. Broad St., Philadelphia, Pa. 19108.

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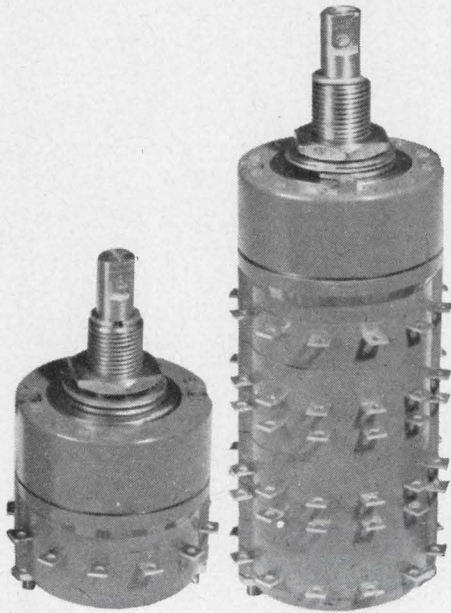
	TYPE 400	TYPE 600
MIL STYLE	RT-12*	RT-11
POWER	1 W @ 70°C	1 W @ 70°C
TOLERANCE	± 5%	± 5%
RESISTANCE	10 Ω to 50K Ω	10 Ω to 50K Ω
TEMPERATURE	-55°C to 150°C	-55°C to 150°C

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



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ON READER-SERVICE CARD CIRCLE 32

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

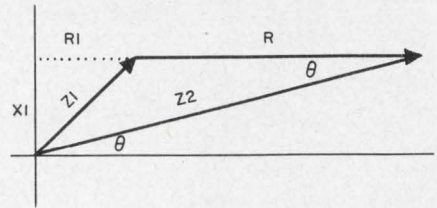
Equation is as easy as working with a diagram

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 re-

sistance 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:

$$\begin{aligned} |Z1|^2 &= R^2 + |Z2|^2 - 2R(R1 + R) \\ &= R^2 + |Z2|^2 - 2RR1 - 2R^2 \\ &= |Z2|^2 - R^2 - 2RR1; \end{aligned}$$

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

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

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:

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

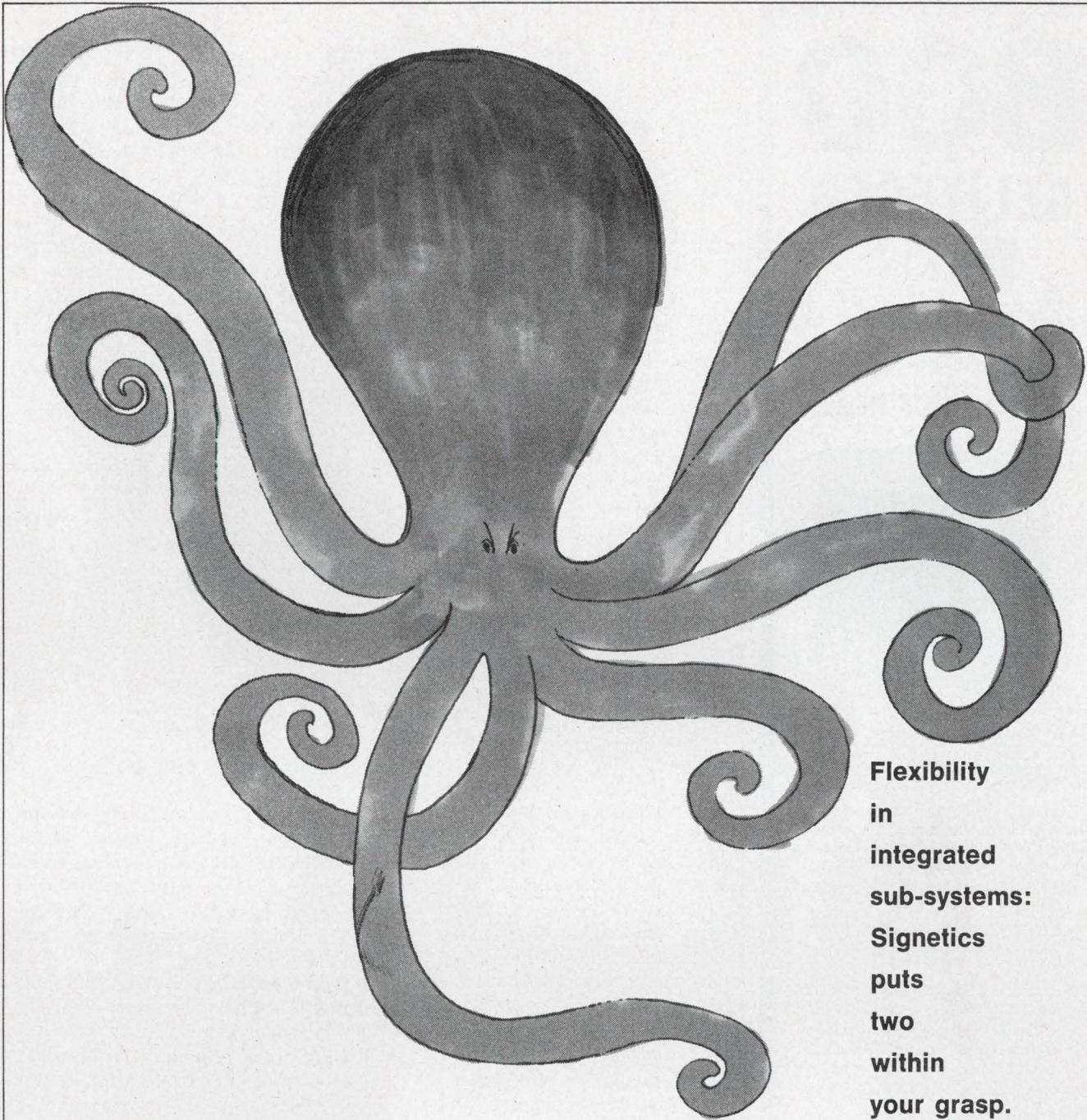
$$|Z2|^2 = (R1 + R)^2 + |X1|^2. \quad (2)$$

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:

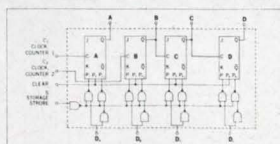
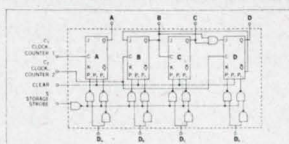
(continued on p. 46)



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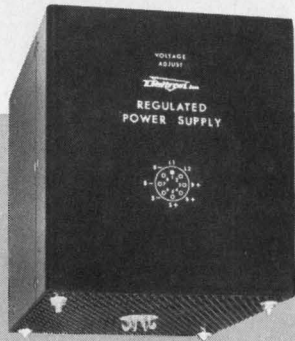


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ON READER-SERVICE CARD CIRCLE 34

LETTERS

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

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.

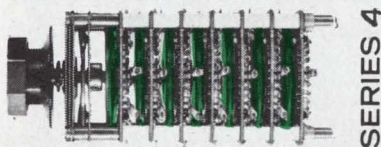
Accuracy is our policy

In "FET amplifier and relay in a TO-5 can operates directly off low-level microcircuitry" (not microcircuitry, 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 0.1Ω , increasing to a maximum of 0.2Ω " (not 1Ω and 2Ω , respectively, as printed). The values in the table of specs on p. 120 are correct.

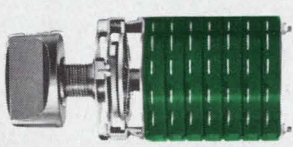
In "Signal generators 1.62-420 MHz" list, ED 27 (Signal Generator Reference Issue), Nov. 29, 1966, p. 26, Marconi Instruments points out that its model 2002 (listed in section SG-2) has an output of 1 volt, not 0.08 volt as printed.

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.

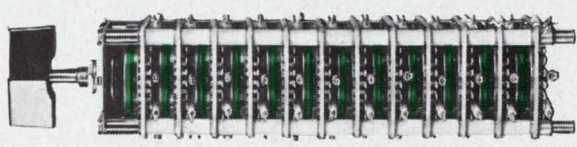
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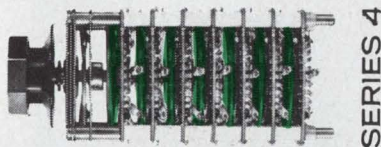


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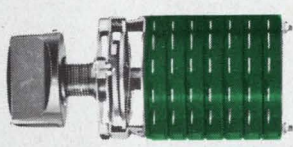


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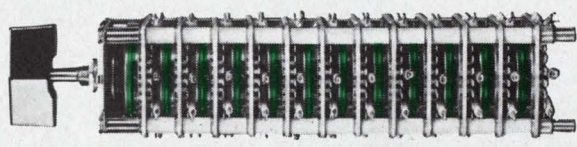
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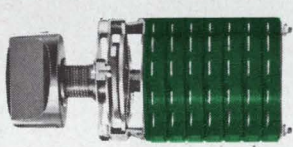


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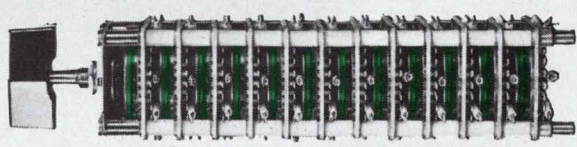
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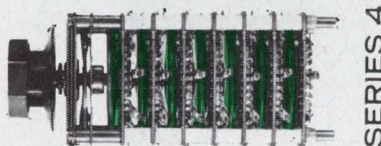


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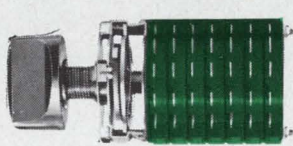


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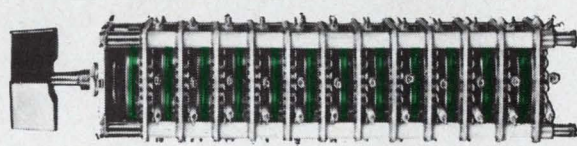
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EDITORIAL



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.

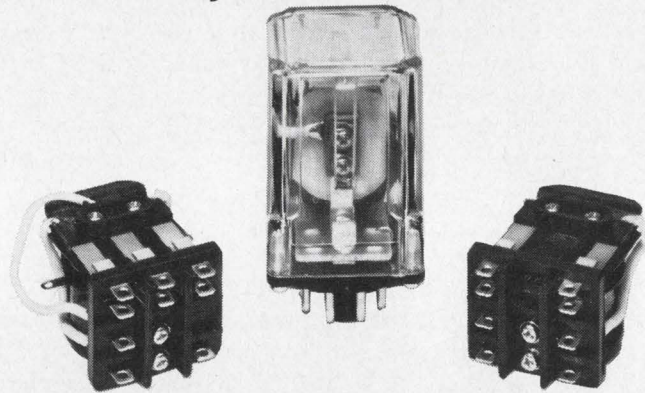
The old saying, "You get what you pay for," is still valid. Here's an actual case: Not too long ago the Government called for bids to modify the circuitry of an alarm box, designed to alert troops to chemical-warfare attack. The IFB also called for an insulated container, so the alarm could be used in 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

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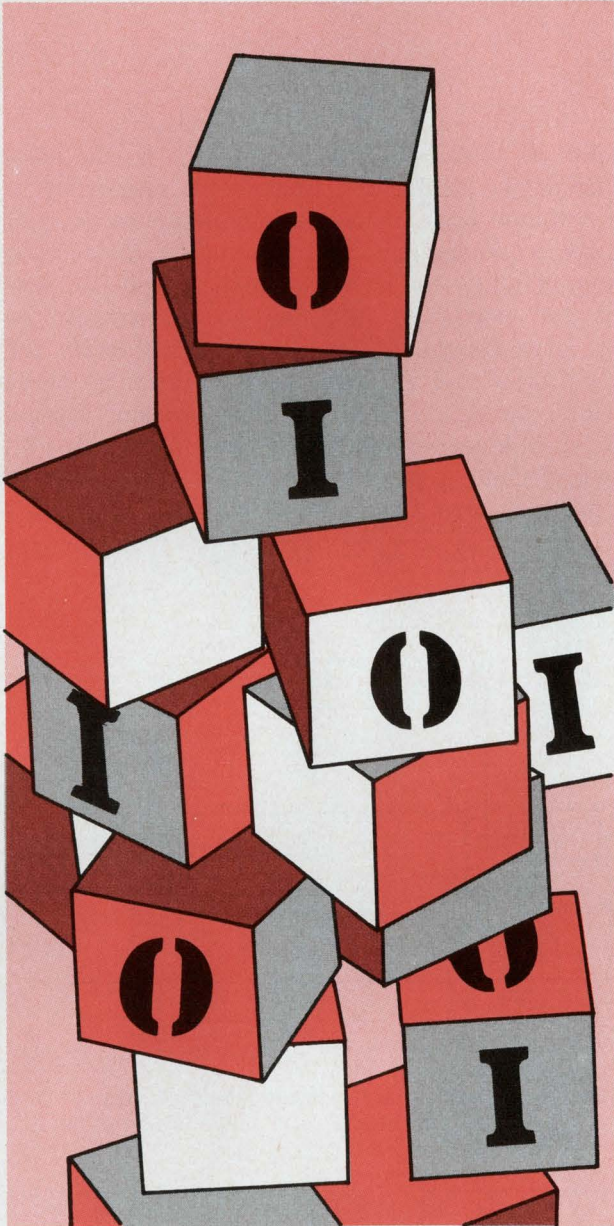
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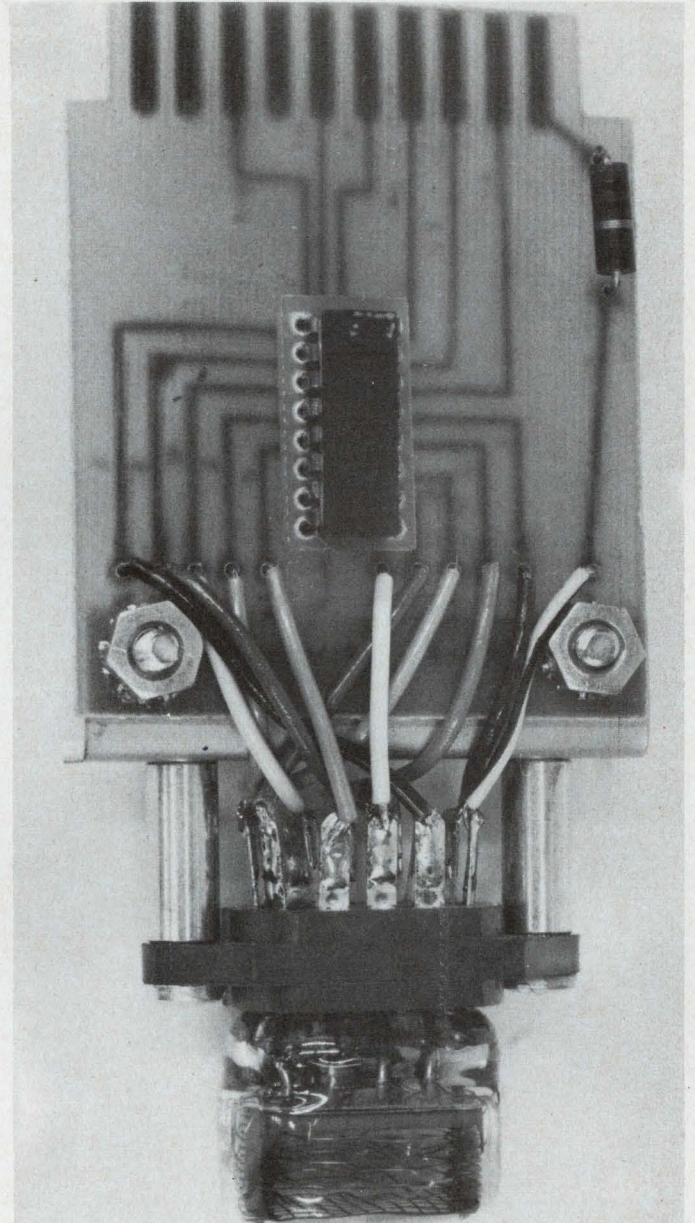
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ON READER-SERVICE CARD CIRCLE 37

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 a set of straightforward equations. Page 52

Contest-winning op-amp applications combine the useful with the unusual. Page 66

Ideas for Design. Pages 82 to 88

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.

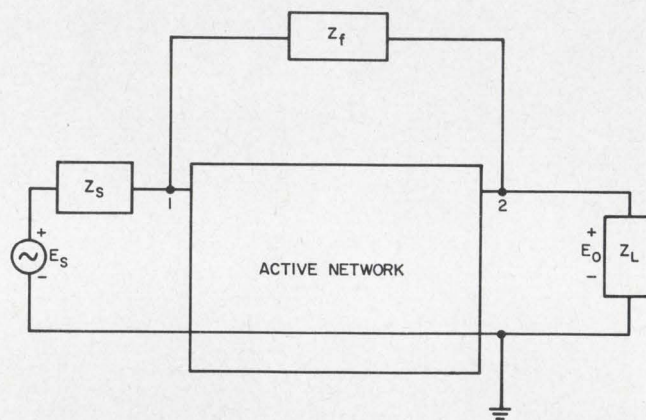
Fortunately, there is another way—a straightforward set of design equations for a specific, widely used class of small-signal feedback amplifiers that employ an impedance element in the feedback path between the output and input terminals (Fig. 1). Although a single-stage transistor amplifier will be 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.

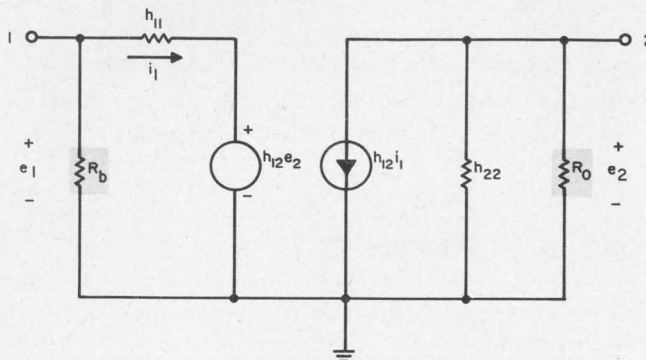
Hybrid parameter h_{12} is a measure of the

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:

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



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:

$$Z_o = R_o / (1 + h_{22} R_o). \quad (2)$$

The voltage gain, G_o , is:

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

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:

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

$$E_o / Z_L + (E_o - G_o e_1) / Z_o + (E_o - e_1) / Z_f = 0. \quad (4b)$$

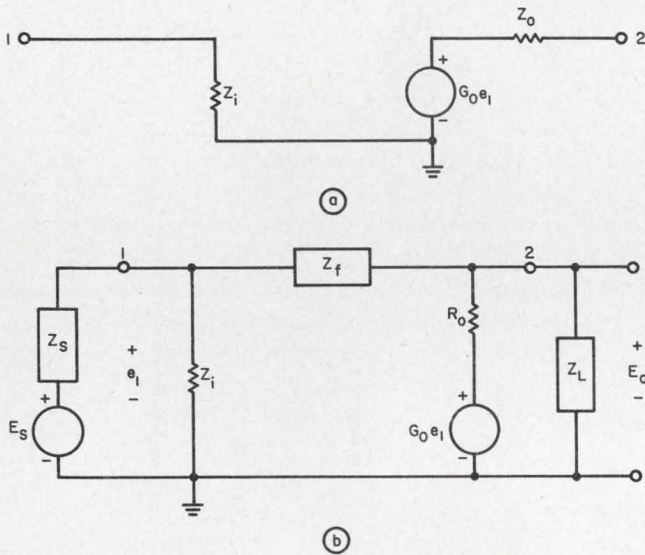
Solving for the transfer function gives:

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

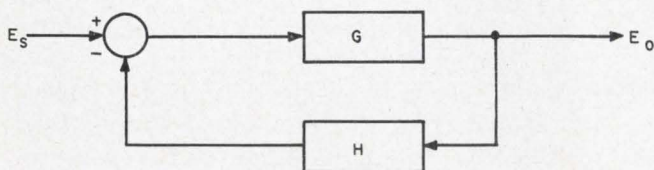
where

$$G' = G_o Z_L / (Z_o + Z_L). \quad (4d)$$

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 ($\beta \geq 50$), pentodes, and high-mu triodes ($\mu \geq 20$), $|G'| \gg 1$ and $|G'| \gg (Z_o || Z_L) / Z_f$. With this assumption, and letting $F(s) = E_o / E_s$, Eq. 4c becomes:

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

This can be rewritten in the simple form:

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

where

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

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

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 $Z_i \gg Z_s$ and $G_o \gg (Z_o / Z_i || Z_s)$ 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:

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

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:

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

and

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

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 $G^2 dH/dh_{21}$:

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

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

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

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

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

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

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:

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

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:

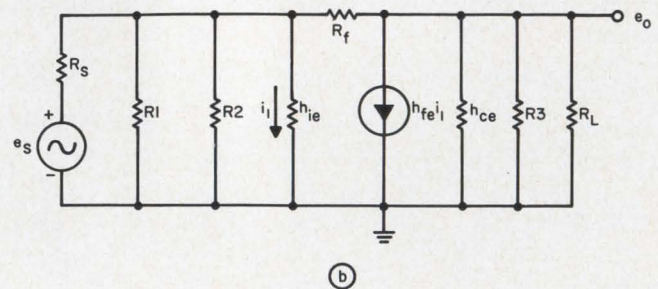
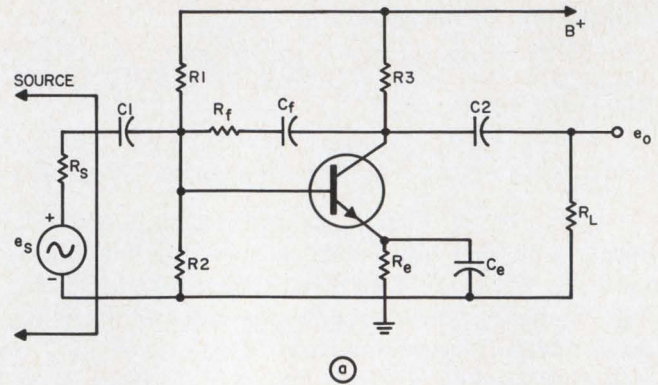
$$T = (1 - S) / \{ S - [1/(1 - G_o Z_i||Z_s/Z_o)] \}. \quad (8f)$$

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 frequen-



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.

cies of interest. Of course, if R_f is large enough, C_f may be omitted.

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 $R_1 = 180 \text{ k}\Omega$, $R_2 = 39 \text{ k}\Omega$, $R_3 = 12 \text{ k}\Omega$, and $R_e = 3.3 \text{ k}\Omega$. 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 $h_{ie} = 3.5 \text{ k}\Omega$, $h_{oe} = 11 \text{ }\mu\text{mho}$, $h_{fe} = 300$, and that a voltage gain of -50 is to be obtained from a source resistance, R_s , of $100 \text{ }\Omega$. 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 $R_b = R_1 || R_2 = (39)(180)/(219) = 32 \text{ k}\Omega$, and $R_o = R_3 = 12 \text{ k}\Omega$.

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

STEP 3: Eq. 3 is used to calculate $G_o = -h_{21} Z_o / h_{11} = -h_{fe} Z_o / h_{ie} = -(300)(10.6)/(3.5) = -917$. 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 $Z_i || Z_s = Z_i || R_s = (3.16)(0.1)/(3.26) = 0.097 \text{ k}\Omega$. 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:

$$G = (1+GH)F = (1+T)F = (9.52)(-50) = -476. \text{ Consequently, } H = T/G = (8.52)/(-476) = -0.0179.$$

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

STEP 7: The value of R_f (or Z_f) can now be computed from Eq. 5d:

$$R_f = Z_f = [(Z_i + Z_s)/Z_i] \{ [Z_o - G_o(Z_i || Z_s)] / HG_o \} = (3.26/3.16) [10.6 + (917)(0.097)/(0.0179)(917)] = 6.26 \text{ k}\Omega.$$

Either a 5.6-k Ω or a 6.8-k Ω , 10%-tolerant resistance can be effectively employed for Z_f in this design. The design of the circuit at mid-frequencies is now complete.

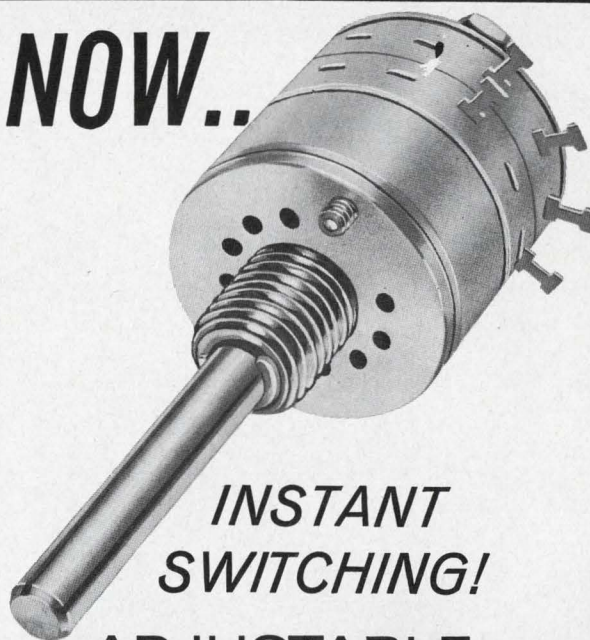
Although the synthesis of a particular transistor amplifier was considered, the procedure developed is applicable to a large class of N -stage amplifiers, having a net phase shift of $180(N)$ degrees, where N is an odd integer. In fact, the design procedure is applicable to any amplifier which can be 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 $Z_f/(1-G)$. ■ ■

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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.

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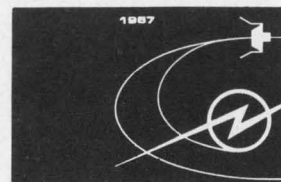
The Paris Electronic Components Exhibition, inaugurated in 1934 and which has been an international event since 1958 is by far the oldest in this field. It is strictly reserved for components' manufacturers and its 900 stands cover an area of 35 000 m², half of them held by foreign exhibitors. Its international character is underlined by an ever-increasing number of foreign visitors. On the same dates, and in neighbouring halls, the Audio Equipment Exhibition opens its doors to engineers and technicians of all countries.

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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 counter² 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.

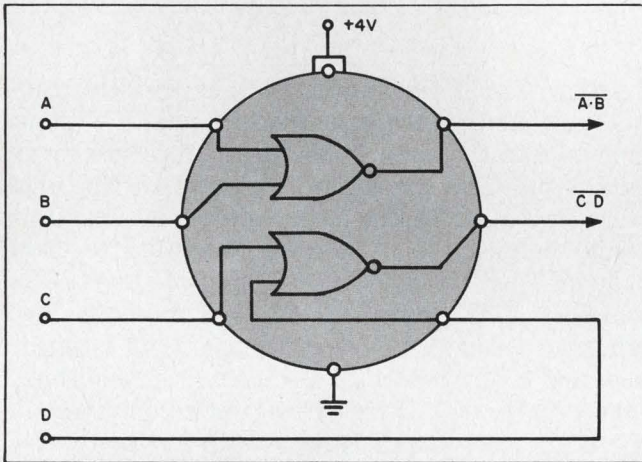
The use of the J-K truth table in Table 1 makes it possible to fill in the values for the various set and clear inputs to the J-Ks.

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 1s. 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 \bar{X}_n output). Since the set input (Q_{1s}) can be in either state (0 or 1), it is a ϕ 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 ϕ -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 1s in their rows.

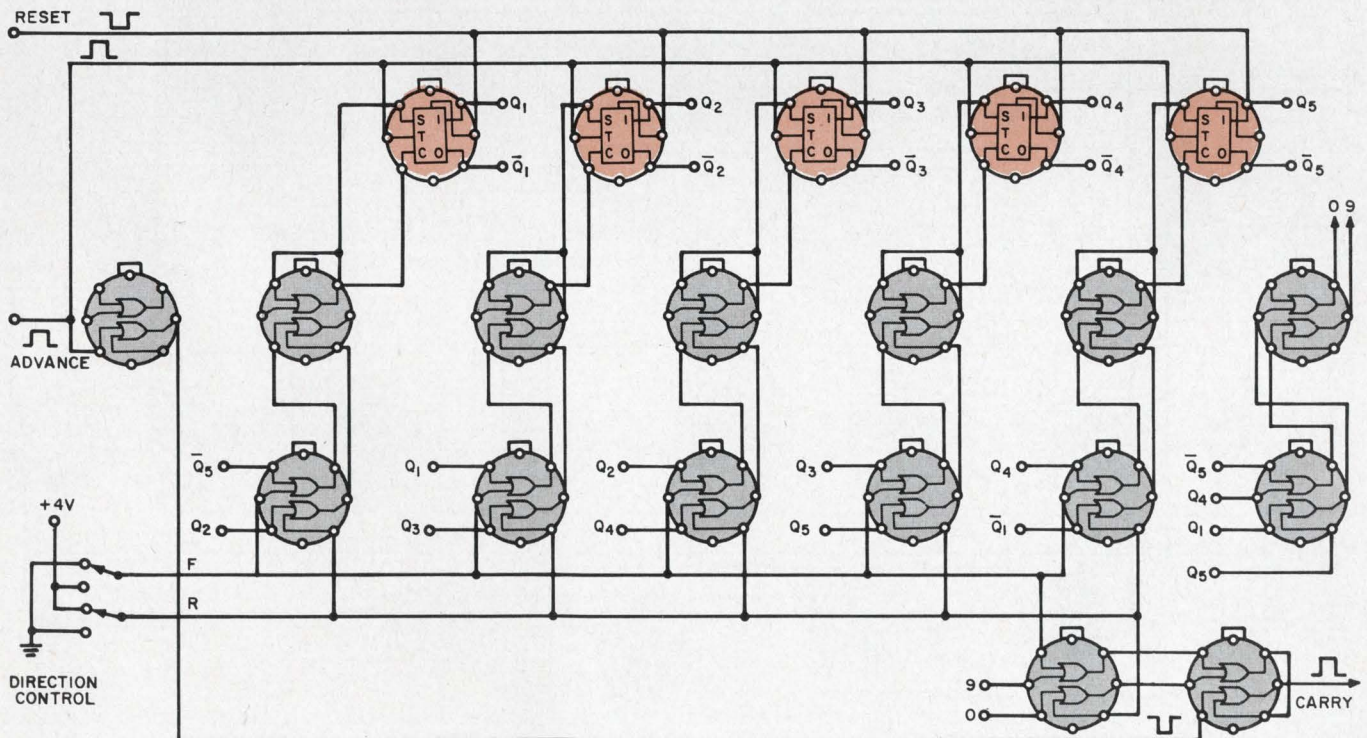
The switching functions are arrived at by summing the decimal equivalent values for the desired input. In this process the Σ_1 notation denotes that the switching function has the value 1 at that particular set of decimal values. Similarly the Σ_0



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 equivalent	J-K flip-flop output					Forward		Reverse	
		1	2	4	8	16	Q _{1S}	Q _{1C}	Q _{1S}	Q _{1C}
0	31	1	1	1	1	1	φ	1	φ	0
1	30	0	1	1	1	1	0	φ	1	φ
2	28	0	0	1	1	1	0	φ	0	φ
3	24	0	0	0	1	1	0	φ	0	φ
4	16	0	0	0	0	1	0	φ	0	φ
5	0	0	0	0	0	0	1	φ	0	φ
6	1	1	0	0	0	0	φ	0	φ	1
7	3	1	1	0	0	0	φ	0	φ	0
8	7	1	1	1	0	0	φ	0	φ	0
9	15	1	1	1	1	0	φ	0	φ	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:

$$Q_{1S} = F \cdot [\Sigma_1(0) + \Sigma_0(16, 24, 28, 30)] + R \cdot [\Sigma_1(30) + \Sigma_0(0, 16, 24, 28)],$$

$$Q_{1C} = F \cdot [\Sigma_1(31) + \Sigma_0(1, 3, 7, 15)] + R \cdot [\Sigma_1(1) + \Sigma_0(3, 7, 15, 31)].$$

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:

$$Q_{1S} = F \cdot \overline{Q_5} + R \cdot Q_2, \quad Q_{1C} = \overline{Q_{1S}}$$

$$Q_{2S} = F \cdot Q_1 + R \cdot Q_3, \quad Q_{2C} = \overline{Q_{2S}}$$

$$Q_{3S} = F \cdot Q_2 + R \cdot Q_4, \quad Q_{3C} = \overline{Q_{3S}}$$

$$Q_{4S} = F \cdot Q_3 + R \cdot Q_5, \quad Q_{4C} = \overline{Q_{4S}}$$

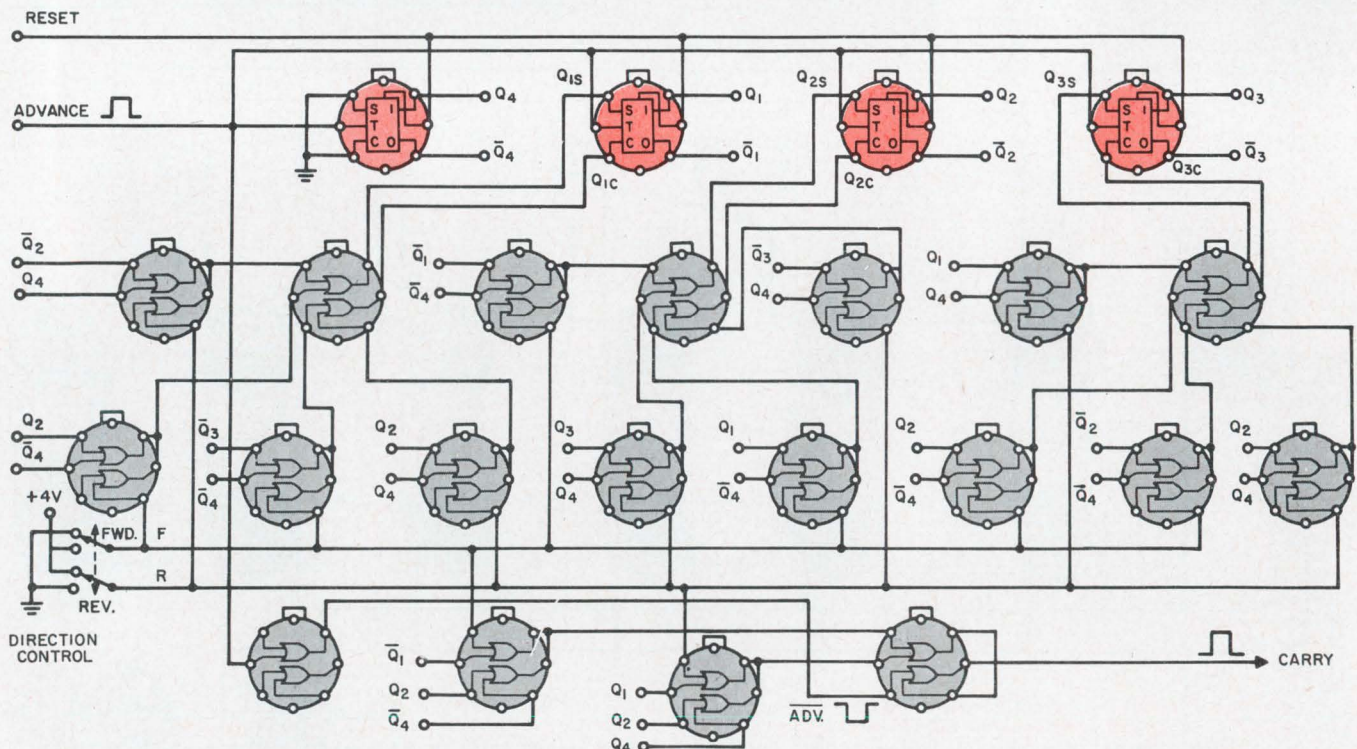
$$Q_{5S} = F \cdot Q_4 + R \cdot \overline{Q_1}, \quad Q_{5C} = \overline{Q_{5S}}$$

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

Table 2. Code for binary-quinary

Decimal output	Decimal equivalent	J-K flip-flop output				Forward		Reverse	
		1	2	4	8	Q_{1S}	Q_{1C}	Q_{1S}	Q_{1C}
0	15	1	1	1	1	ϕ	0	ϕ	1
1	7	1	1	1	0	ϕ	0	ϕ	0
2	13	1	0	1	1	ϕ	0	ϕ	0
3	5	1	0	1	0	ϕ	0	ϕ	0
4	9	0	0	0	1	ϕ	0	ϕ	0
5	1	1	0	0	0	ϕ	1	ϕ	0
6	8	0	0	0	1	0	ϕ	1	ϕ
7	0	0	0	0	0	0	ϕ	0	ϕ
8	10	0	1	0	1	0	ϕ	0	ϕ
9	2	0	1	0	0	1	ϕ	0	ϕ

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:



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 equivalent	J-K flip-flop output				Forward			Reverse		
		1	2	4	8	Q _{2S}	Q _{2C}	Q _{2T}	Q _{2S}	Q _{2C}	Q _{2T}
0	15	1	1	1	1	φ	φ	0	φ	0	1
1	14	0	1	1	1	φ	1	1	φ	φ	0
2	13	1	0	1	1	φ	φ	0	1	φ	1
3	12	0	0	1	1	1	φ	1	φ	φ	0
4	11	1	1	0	1	φ	φ	0	φ	1	1
5	10	0	1	0	1	φ	1	1	φ	φ	0
6	9	1	0	0	1	φ	φ	0	1	φ	1
7	8	0	0	0	1	1	φ	1	φ	φ	0
8	7	1	1	1	0	φ	φ	0	φ	1	1
9	6	0	1	1	0	φ	0	1	φ	φ	0

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

The logical functions required of the counter are synthesized with the RTL gate⁶ 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 Q₄ output and the quinary by Q₁ through Q₃ 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 Q₄ 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:

$$Q_{1S} = F \cdot [\Sigma_1(2) + \Sigma_0(0, 8, 10)] + R \cdot [\Sigma_1(8) + \Sigma_0(0, 2, 10)],$$

$$Q_{1C} = F \cdot [\Sigma_1(1) + \Sigma_0(5, 7, 9, 13, 15)] + R \cdot [\Sigma_1(15) + \Sigma_0(1, 5, 7, 9, 13)].$$

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.

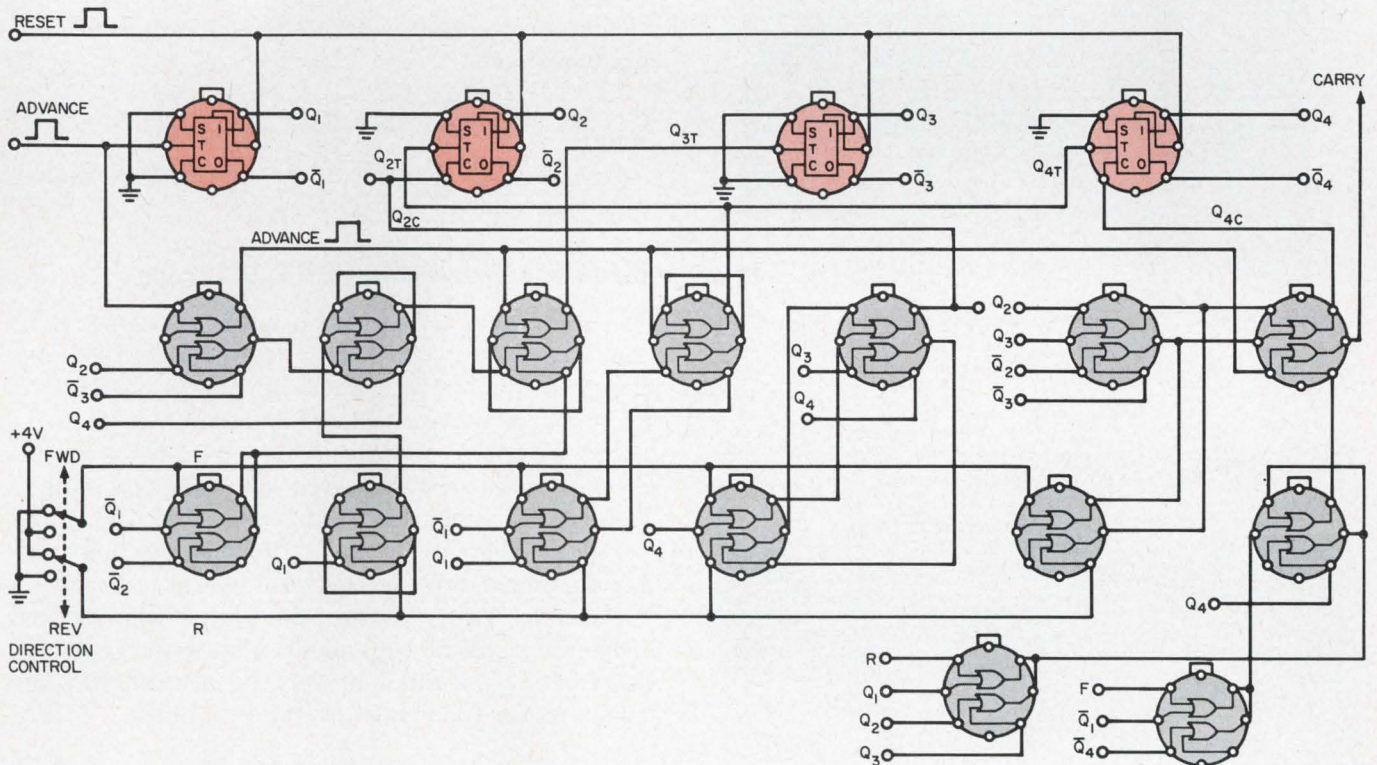
Following minimization of the switching functions, the results are:

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

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

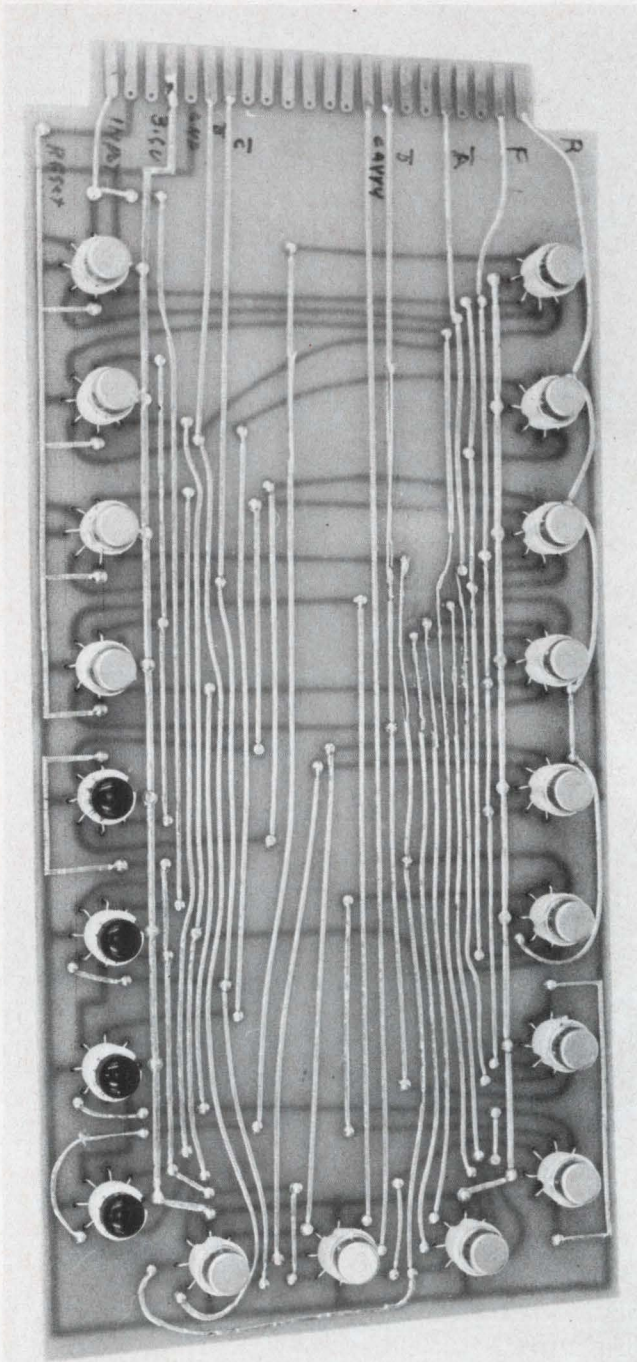
$$Q_{2S} = F(Q_1 \cdot \overline{Q_4}) + R(\overline{Q_3} \cdot Q_4)$$

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

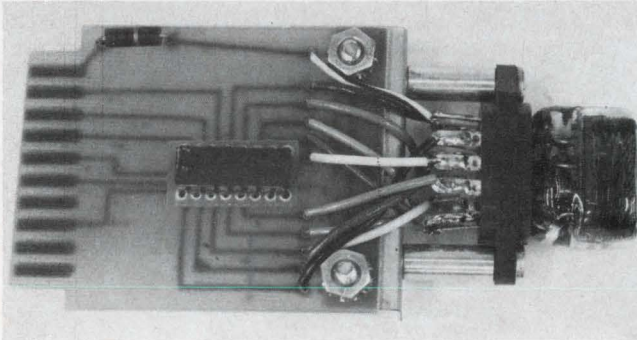


4. The 1-2-4-8 binary coded decimal decade uses only four flip-flops and 15 gates. Its code is the most popular

of the three, and an inexpensive decoder-driver-display is available. It interfaces easily with other equipment.



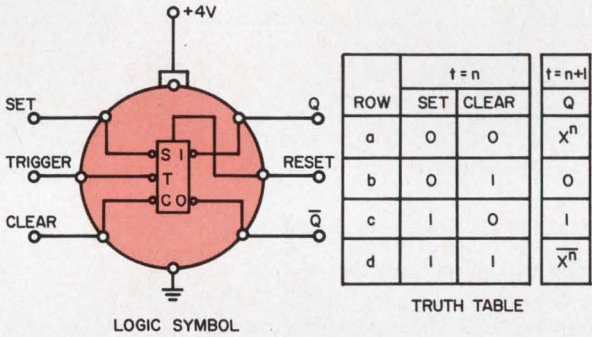
5. The 1-2-4-8- BCD decade counter can be constructed on a single printed-circuit board. The four flip-flops are located on the lower portion of the left edge.



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

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.



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

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

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

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

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-flop 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:

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

$$Q_{1T} = \text{Advance}$$

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

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

$$Q_{3T} = [F(\overline{Q_1} \cdot \overline{Q_2}) + R(Q_1)(\overline{Q_4} + Q_2 \cdot \overline{Q_3})] Advance$$

$$Q_{3C} = F \cdot Q_4 + R(\overline{Q_3} + \overline{Q_4})$$

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

The carry output is derived in a similar manner:

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

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.

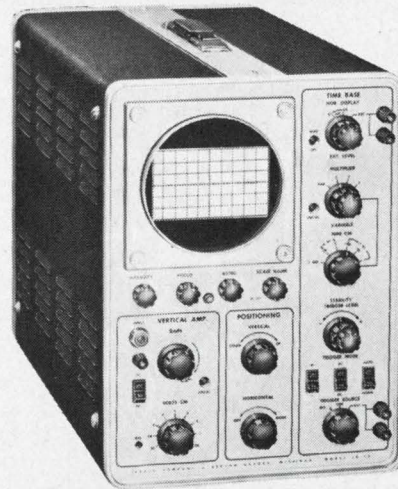
The table shows that the 1-2-4-8 BCD decade uses fewest logic elements of the three counters; of the decoders, that of the Modulo 10 requires fewest logic elements. The choice of code may be influenced by the input code of the equipment with which the counter will interface. For example, an inexpensive 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. ■ ■

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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 $C_{\mu L}$ 990 Decimal Decoder-Driver, Data Sheet (Mountain View, Calif.: Fairchild Semiconductor, July, 1965).

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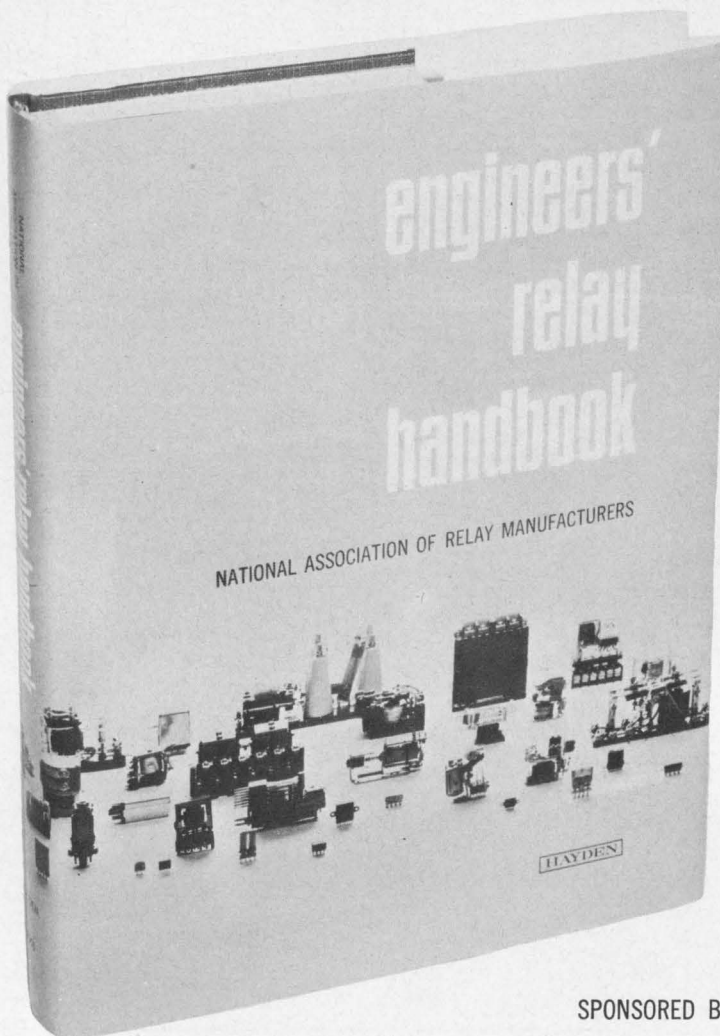
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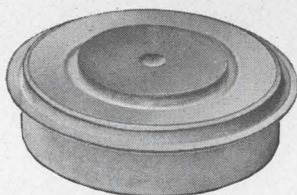


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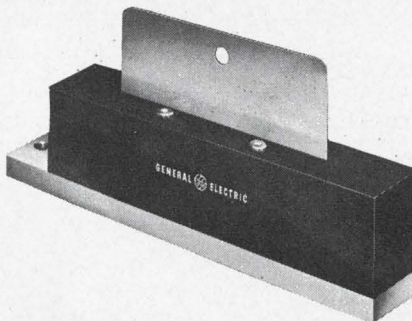
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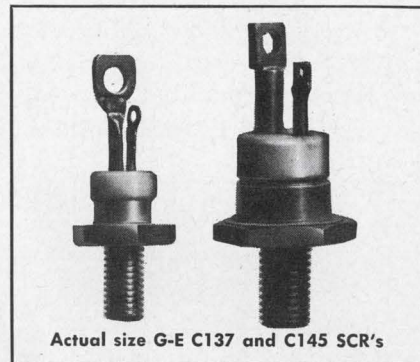
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New and unusual applications for operational amplifiers are constantly being found by designers. Here are four that were considered so unusual and useful that they received top honors in a design contest.

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 adapt-

able 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.

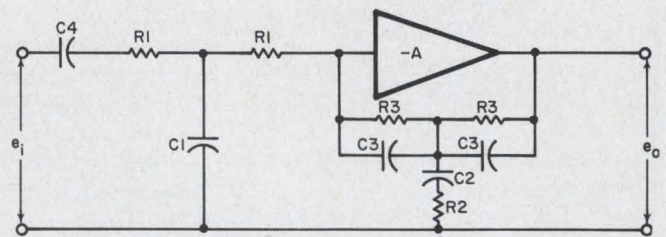
On-line double integration

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



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.

and feedback circuits of the amplifier (Fig. 1).

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

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

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

Making $C4 \gg C1$ and $R3 \gg R2$ 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

$$Z_f(s) = \frac{2 \{ [s + (1/2 R_2 C_3)] [s + (2/R_3 C_2)] \}}{C_3 \{ [s + (1/R_3 C_3)]^2 [s + (1/R_2 C_2)] \}} \quad (4)$$

Component values are chosen such that $R_1 C_1 = 4 R_2 C_3$; $R_3 C_2 = 4 R_1 C_4$, and $R_2 C_2 = R_3 C_3 = T_c$. Therefore:

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

$$\begin{aligned} \frac{Z_f(s)}{Z_i(s)} &= \frac{2}{R_1^2 C_1 C_3} \left\{ \frac{s}{[s + (1/R_3 C_3)]^3} \right\} \\ &= \frac{2 C_4}{T_c^2 C_3} \left\{ \frac{s}{[s + (1/T_c)]^3} \right\} \end{aligned} \quad (5)$$

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

$$e_o(t) = -(C_4/T_c^2 C_3) t^2 e^{-t/T_c} \quad (6)$$

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).

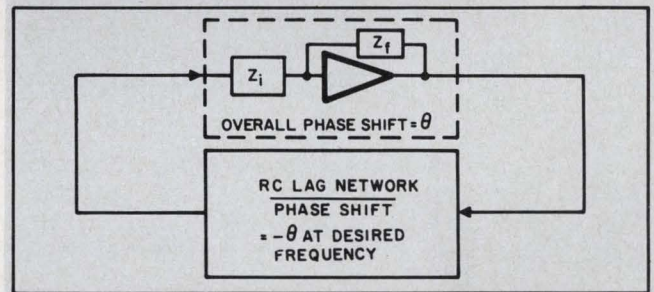
This circuit can be constructed with components of only 10% tolerances; polystyrene or similar precision capacitors are not necessary. The circuit will hold a zero indefinitely without the need for shorting relays. It will perform accurate double integrations over periods of several seconds.

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.

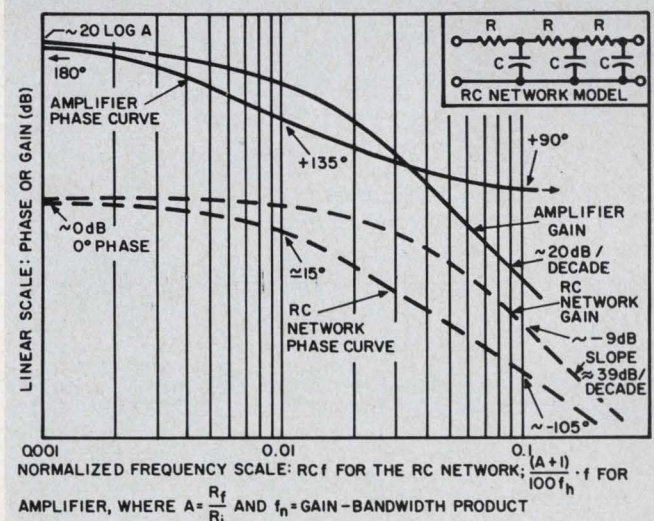
A typical oscillator, designed to operate at 100 kHz, appears in Fig. 4. Its frequency variation with RC, 1/RC, and amplifier gain, A, is shown in Fig. 5. These curves demonstrate that the frequency can be varied manually or remotely to provide a laboratory oscillator (13 kHz to 300 kHz) with a nearly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



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)

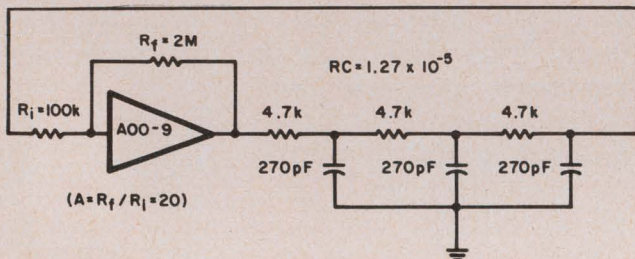
(continued from p. 67)

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

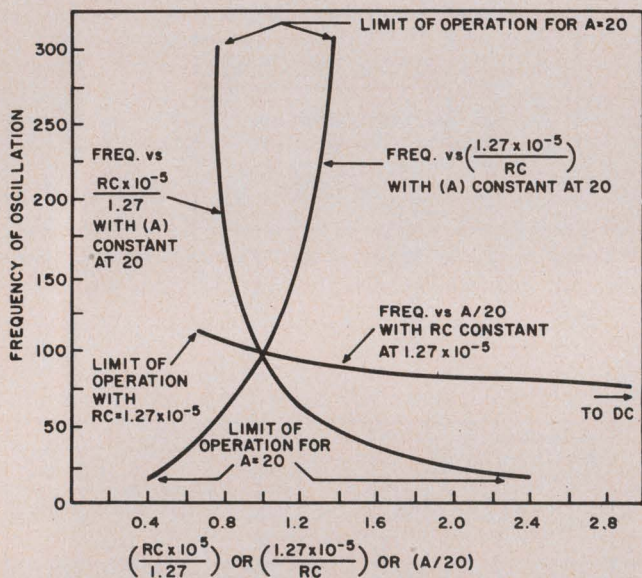
Feedback element sets modulation mode E

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.

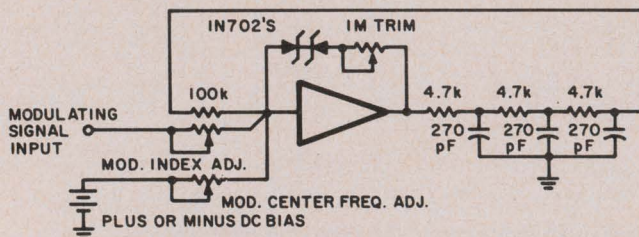
The circuit of Fig. 6 is the final configuration of



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

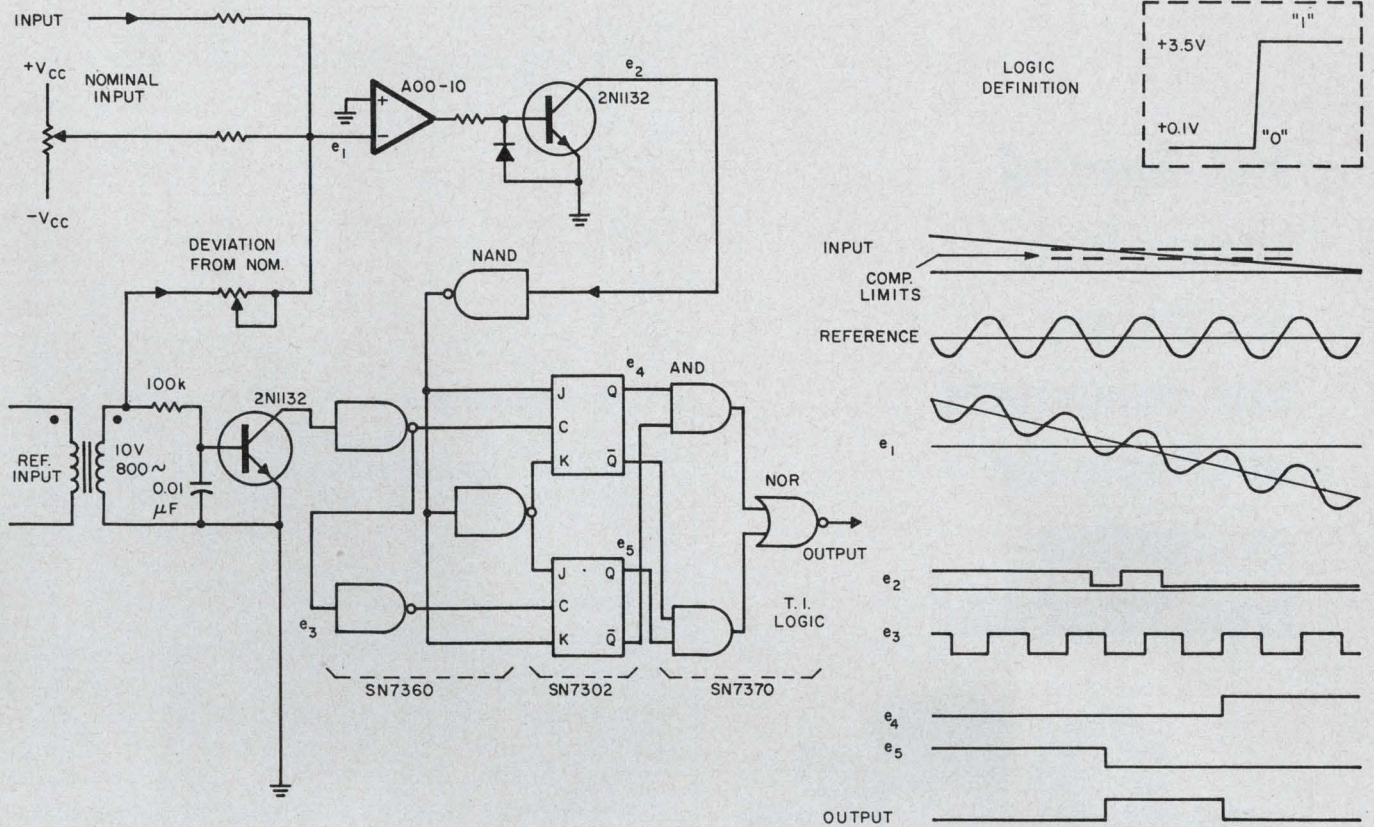
A comparator with two limits can be constructed from a stable operational amplifier with a few integrated gates and J-K flip-flops.

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.

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.



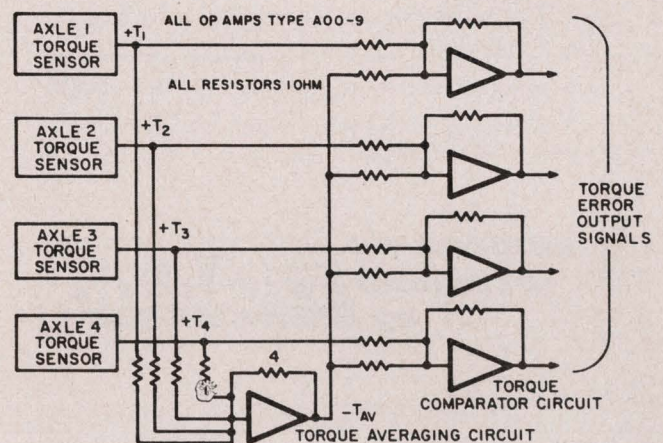
7. Op amp functions as dc comparator operating about the zero input level.

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.

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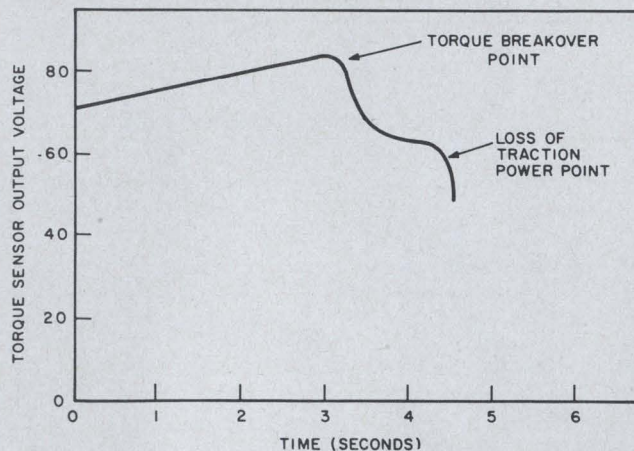
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ON READER-SERVICE CARD CIRCLE 43

(continued from p. 69)



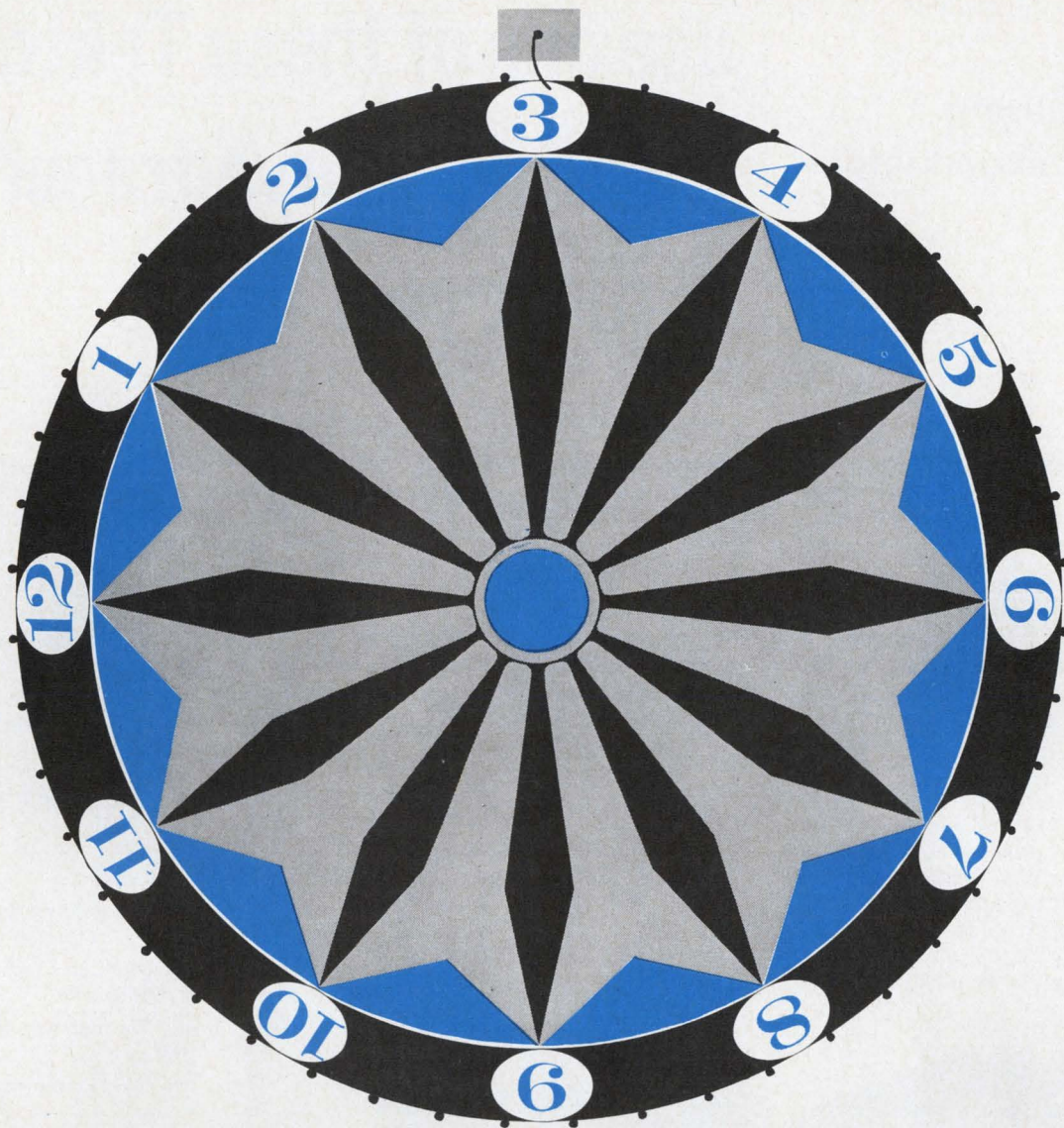
9. Slippage is preceded by torque breakover point, which can be detected by the system before actual slippage occurs.

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	4×10^7 (min)	5×10^7 (min)
Drift	$< 1 \mu\text{V}/^\circ\text{C}$	$< 0.5 \mu\text{V}/^\circ\text{C}$
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



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ON READER-SERVICE CARD CIRCLE 44

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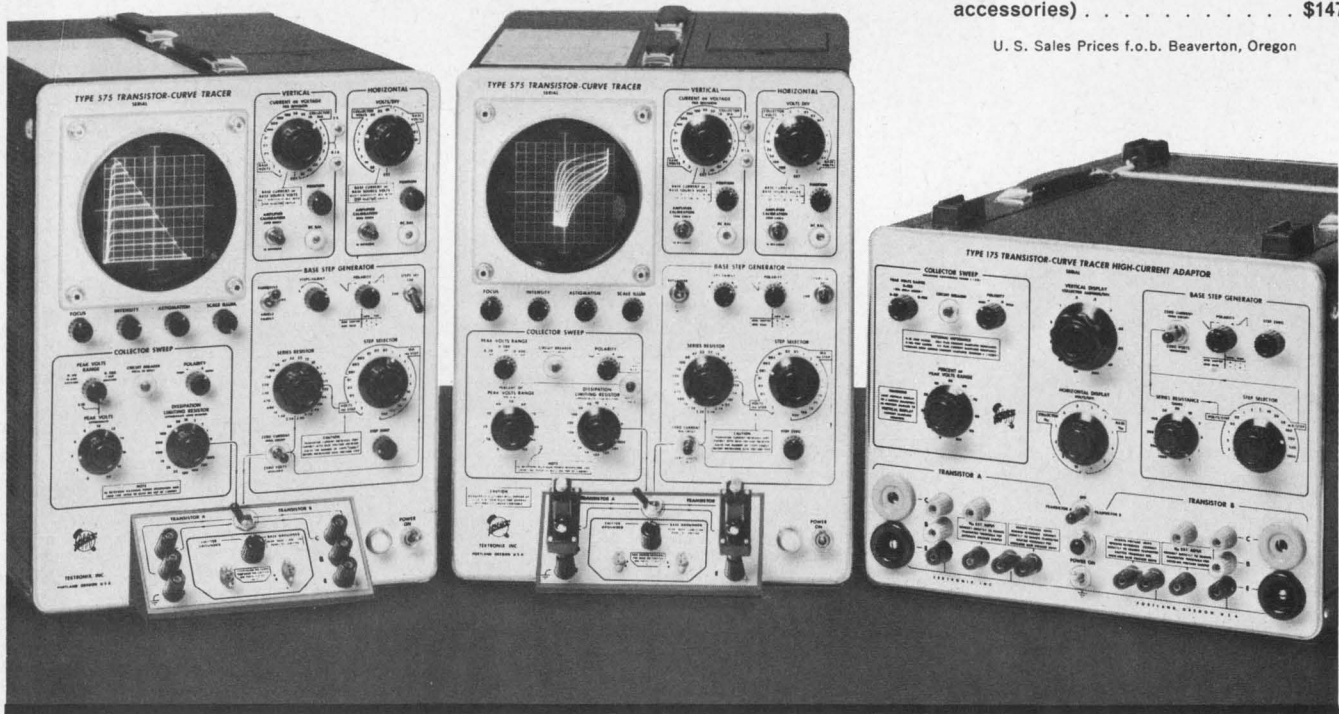
The Type 175 features collector sweep supply ranges of 0-200 A at 0-20 V and 0-40 A at 0-100 V. The Type 175 step generator provides current ranges from 1 mA/step to 1000 mA/step and voltage steps from 0.5 to 10 V/step with driving resistance selectable from 11 values ranging from 0.5 ohms to 1 k ohm.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

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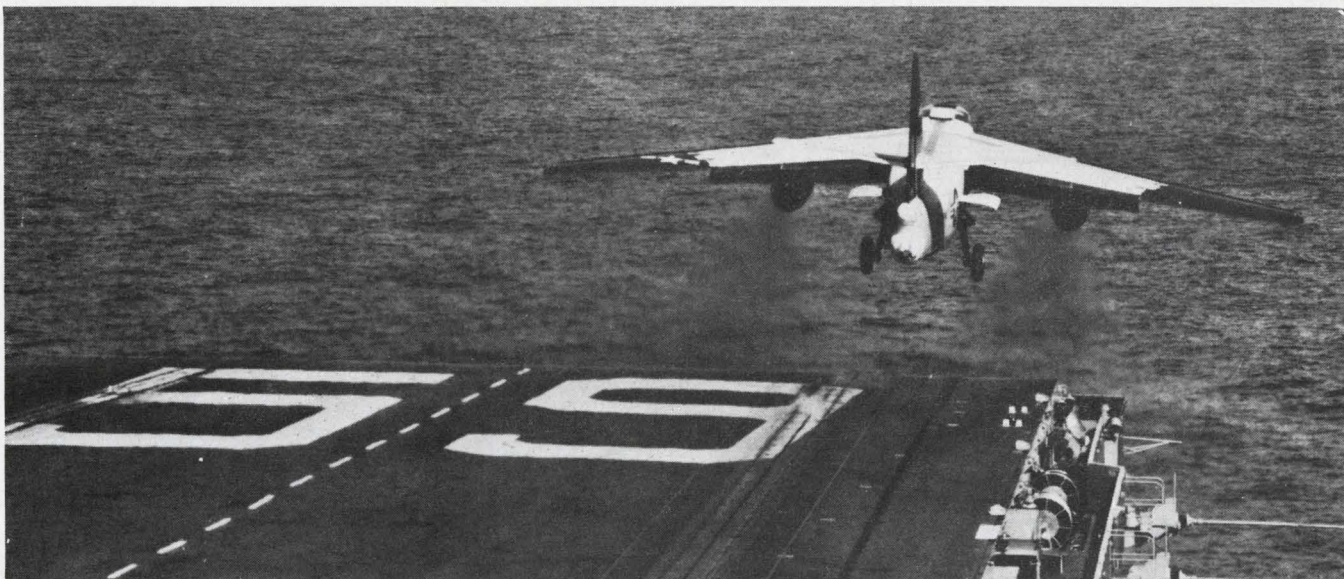


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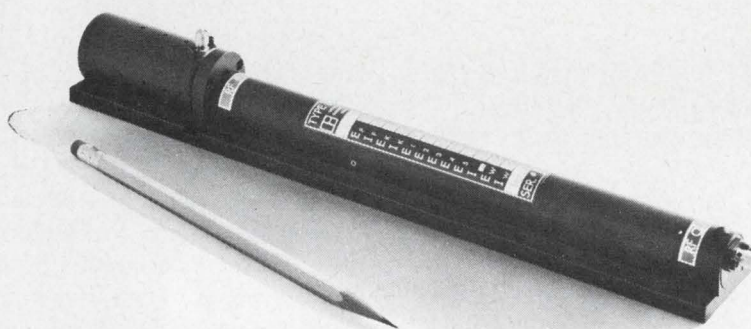


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Tunnel-diode circuits pave the way

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, pseudorandom code generators which were synchronized and whose outputs were fed into a comparator to generate error pulses if the outputs of the two code genera-

tors 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.

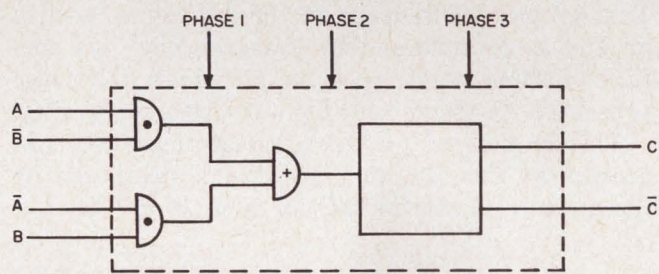
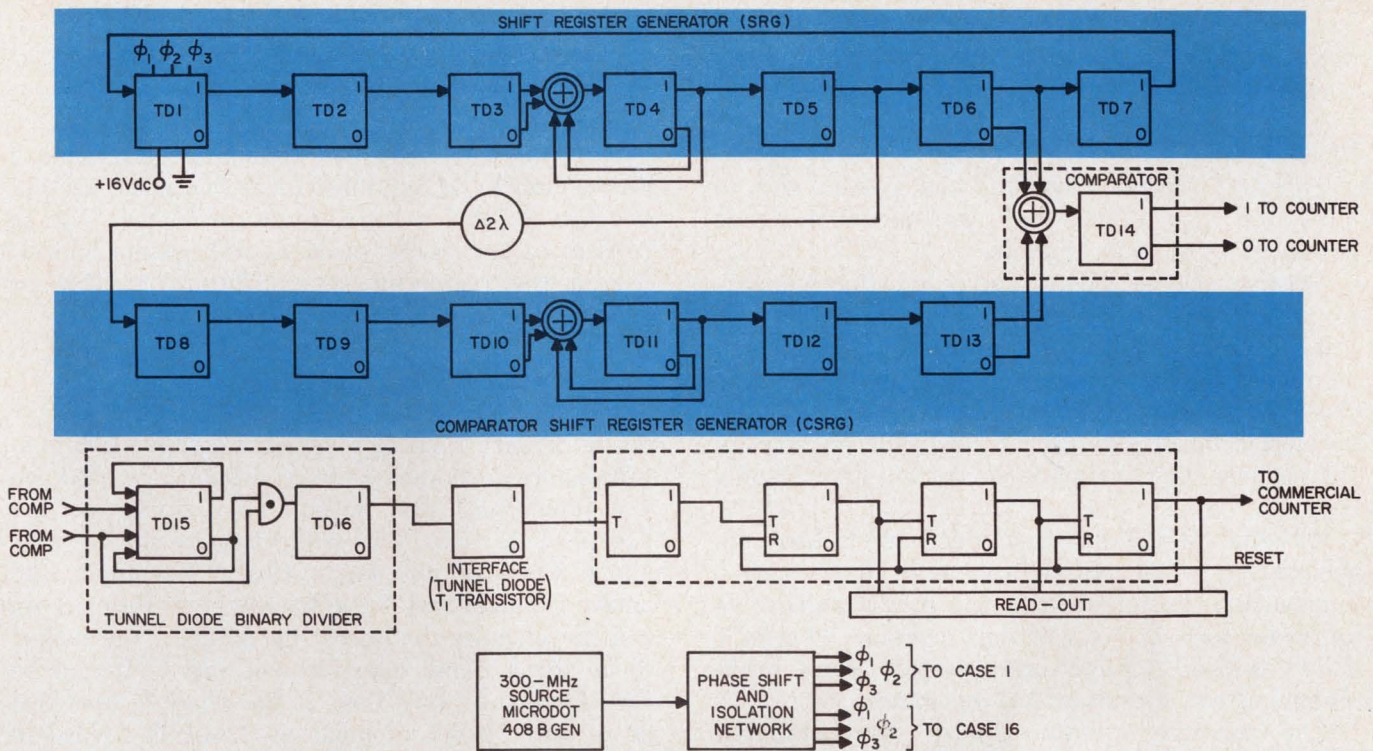
Prior to the final design of the circuit, an extensive study had shown that the tunnel diode was the only element available that would give successful ultra-high-speed operation. The study also showed that a tunnel-diode, stored-charge diode circuit should be capable of operation near 1 GHz, with a fan-out 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

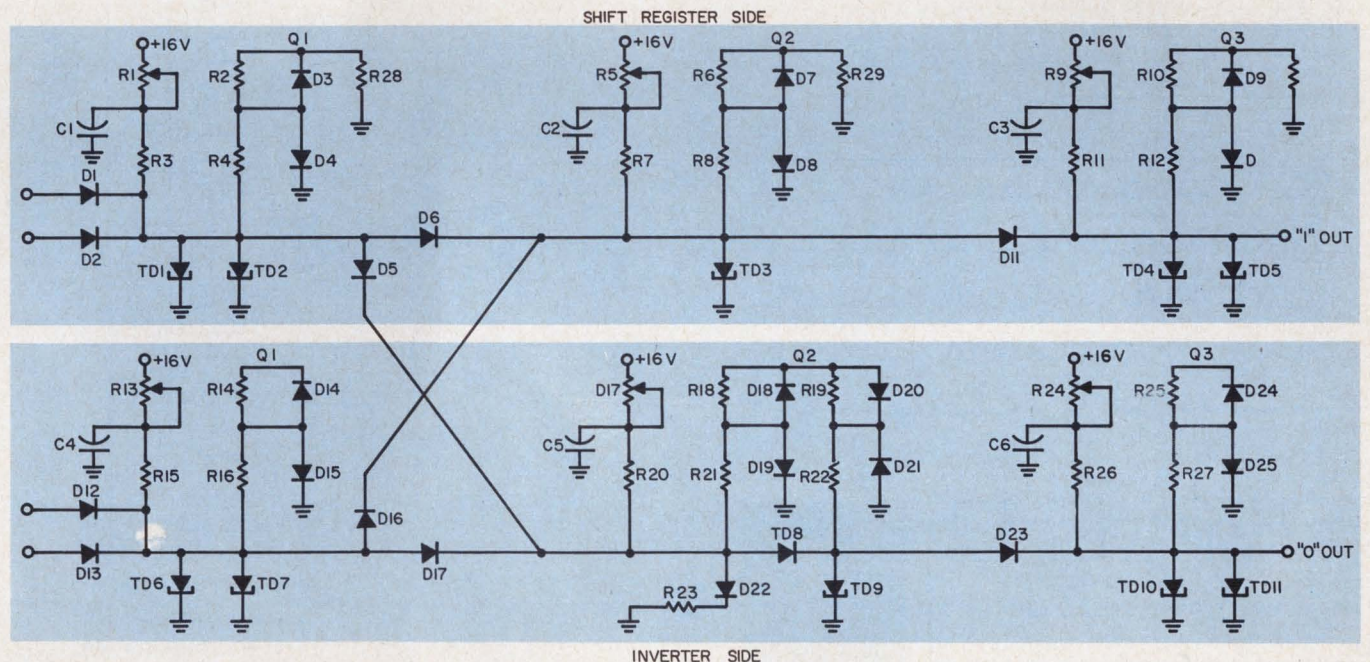
James A. Walker, Senior engineer, Fairchild Hiller Corp., Germantown, Md.



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 IN4121
 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.

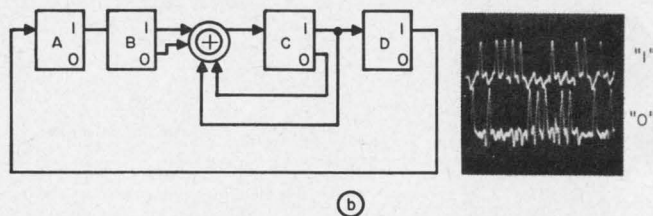
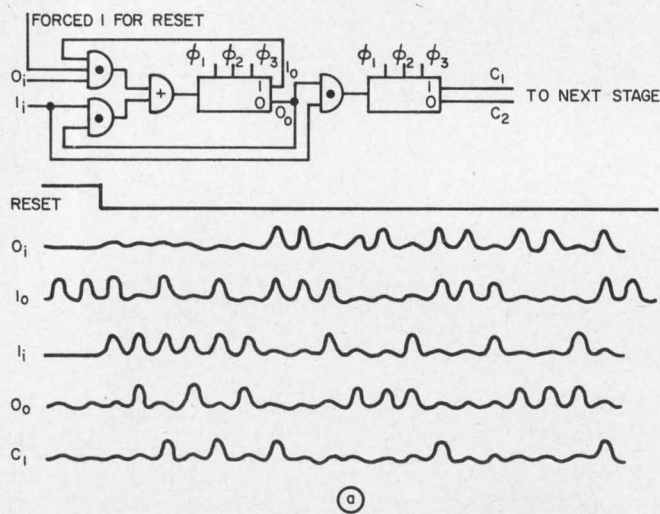
Although stable operation was hard to keep up, the system would run stably for an hour or so—long enough to make error rate measurements as an indication of system performance. Table 1 shows several typical measurement runs made when system operation was optimum.

The percentage errors figure was computed according to the formula:

$$\% \text{ errors} = N_e / N_b \times 100.$$

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 random-



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).

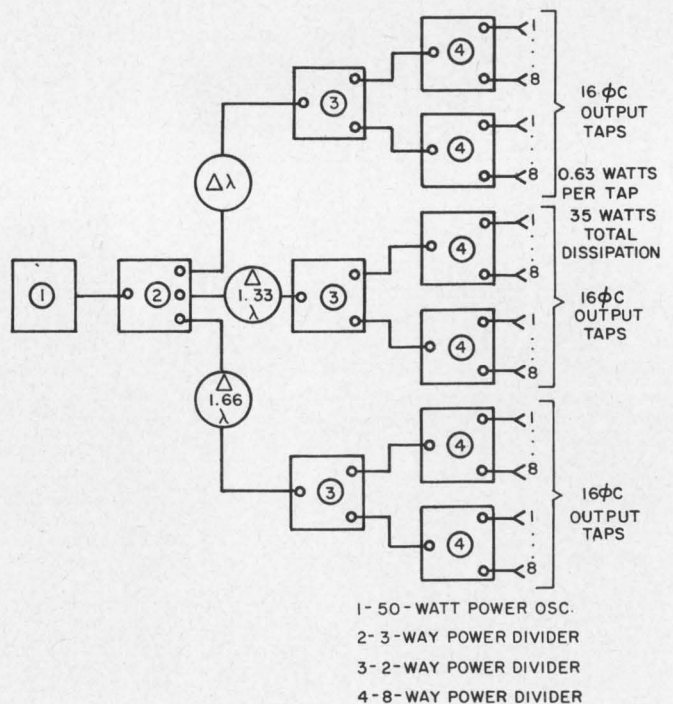
ly, several errors at a time, but tended to occur in groups ranging in size from 100 to 300 errors per group. Table 2 shows figures for a group error rate measurement.

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 (ϕ_1) and output (ϕ_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 ($I_c - I_d$).



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- 3- 2-WAY POWER DIVIDER
- 4- 8-WAY POWER DIVIDER

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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:

$$Z = 1/2\pi fC = 106 \Omega \quad (1)$$

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:

$$I_c = 0.5 \text{ V}/160 \Omega = 3 \text{ mA} \quad (2)$$

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.

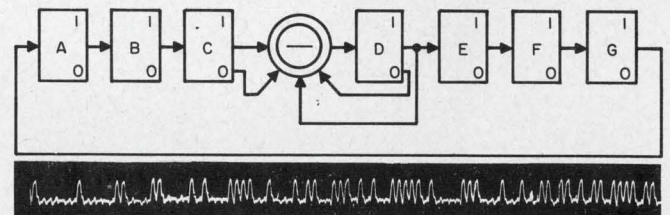
Reflected signals: Ideally the length of the connections, l , between cards should be as short as possible ($l \ll \lambda$), as on the code generator trays. Several places on the system, however, require the use of coaxial lines for signal routing, such as the connection between the two generator trays 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.

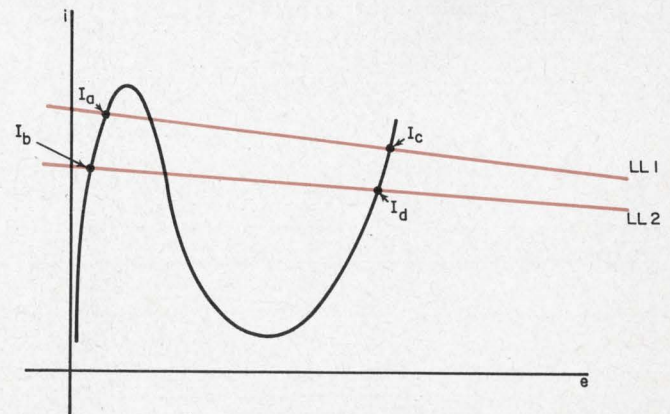
Run	Time (min)	% errors
1	3	0.0013
	7	0.0011
	11	0.0009
2	5	0.0003
	10	0.0004
	15	0.0005
3	5	0.00062
	10	0.00057
	15	0.00058
	25	0.00053

Table 2. Group error percentages.

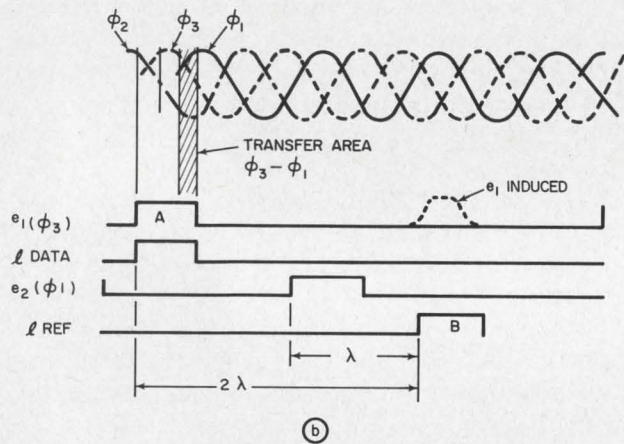
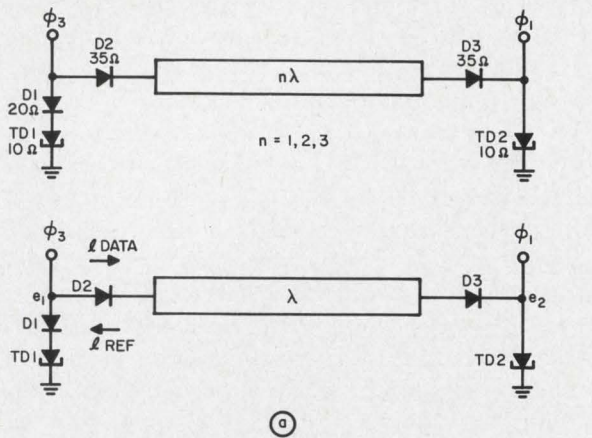
Time (min)	% group errors
2	5.5×15^{-6}
4	5.5×10^{-6}



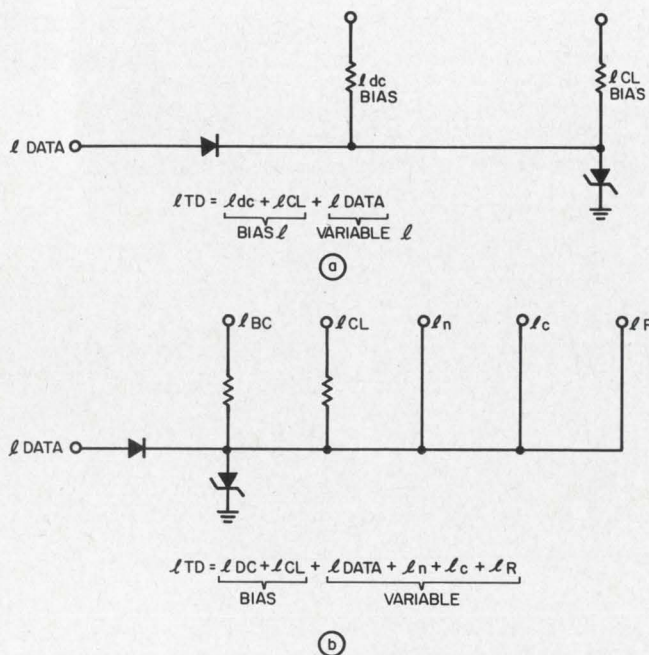
6. Shift register modules are connected to form a seven-stage pseudorandom code generator (top). Two of these generators are used in the system. The coded output waveform of one generator is shown at the bottom.



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 I 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:

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

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:

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

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. ■ ■



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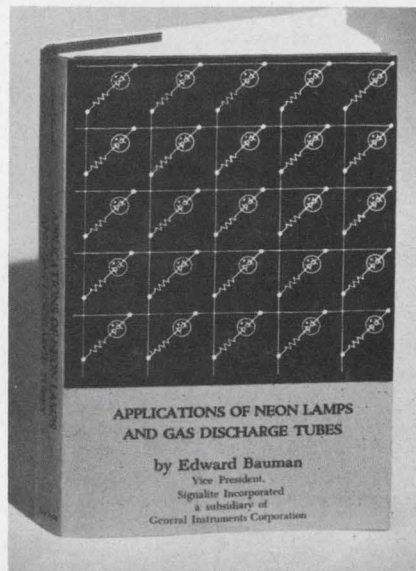
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Book Reviews



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

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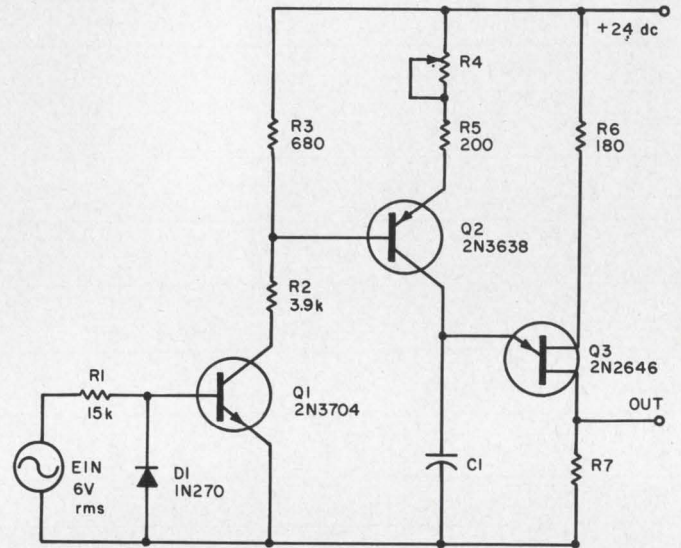
UJT and ac current source used to divide frequency

This circuit will divide an input sine-wave frequency by 2 to 20 depending on the setting of R_4 . 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 R_1 is such as to allow the generator, E_{IN} , to drive Q_1 into cutoff or saturation. When Q_1 is saturated, a voltage drop will be developed across R_3 , which will be matched by the sum of V_{BE} of Q_2 and the voltage drop across R_4 and R_5 created by Q_2 emitter current. Virtually all Q_2 emitter current becomes Q_2 collector current, which will charge C_1 . The magnitude of Q_2 emitter or collector current will be determined by the setting of R_4 . When Q_1 is cut off, Q_2 is also cut off, and C_1 can discharge only by means of negligible leakage current through Q_2 , Q_3 , or its own internal resistance.

Then, for each cycle of sine-wave input, one pulse of constant amplitude current will charge C_1 .

The circuit can be proportioned so that the capacitance of C_1 , the magnitude of the current pulse as established by R_4 , and the frequency of current pulses as established by the E_{IN} genera-



1. Switching current source Q_2 charges C_1 in steps up to the "firing" of Q_3 . The number of steps depends on R_4 , R_5 , and C_1 .

tor, will be sufficient periodically to charge C_1 , in steps, to a voltage level equal to the peak point of unijunction transistor Q_3 . At that point, C_1 will discharge through Q_3 and R_7 to the valley point of Q_3 . The period of the charge and discharge of C_1 can be made any exact multiple of the period of E_{IN} by proper adjustment of R_4 . The discharge of C_1 through R_7 will create an output voltage pulse across R_7 , which will be a predetermined submultiple of the frequency of E_{IN} .

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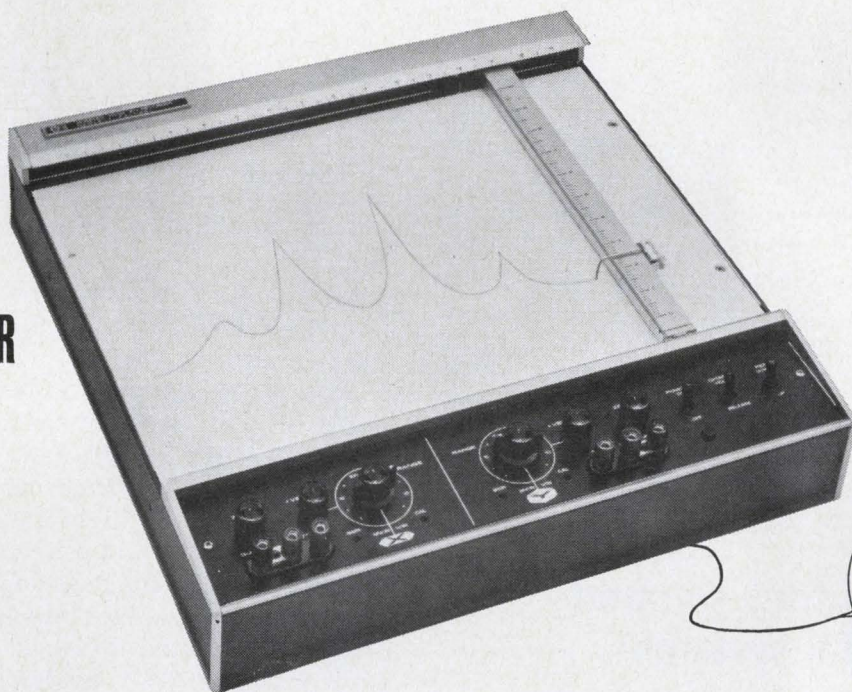
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Effects of temperature and R_4 variations

Input frequency (f_{IN})	Dividing multiple (N)	Temp ($^{\circ}C$)	R_7 (ohms)	Range of R_4 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

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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 $\pm 15\%$ 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 $\pm 10\%$ 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

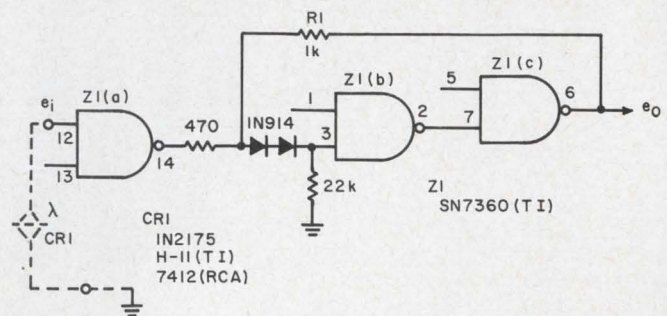
Photocell output squared with IC digital systems

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.

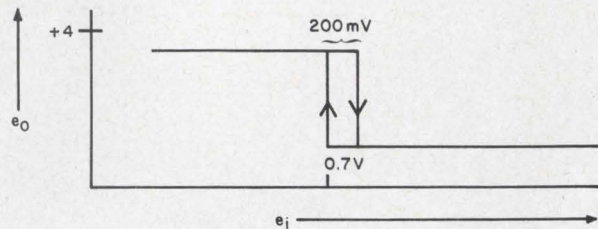
The circuit described here accomplishes this with a standard IC logic network and a few passive components. This approach will work with most optical shuttering applications that involve a nearby source of light, such as a punched-tape reader or code wheel.

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



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.

reaches a threshold level, the output of $Z1(c)$ will rapidly change state.

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).

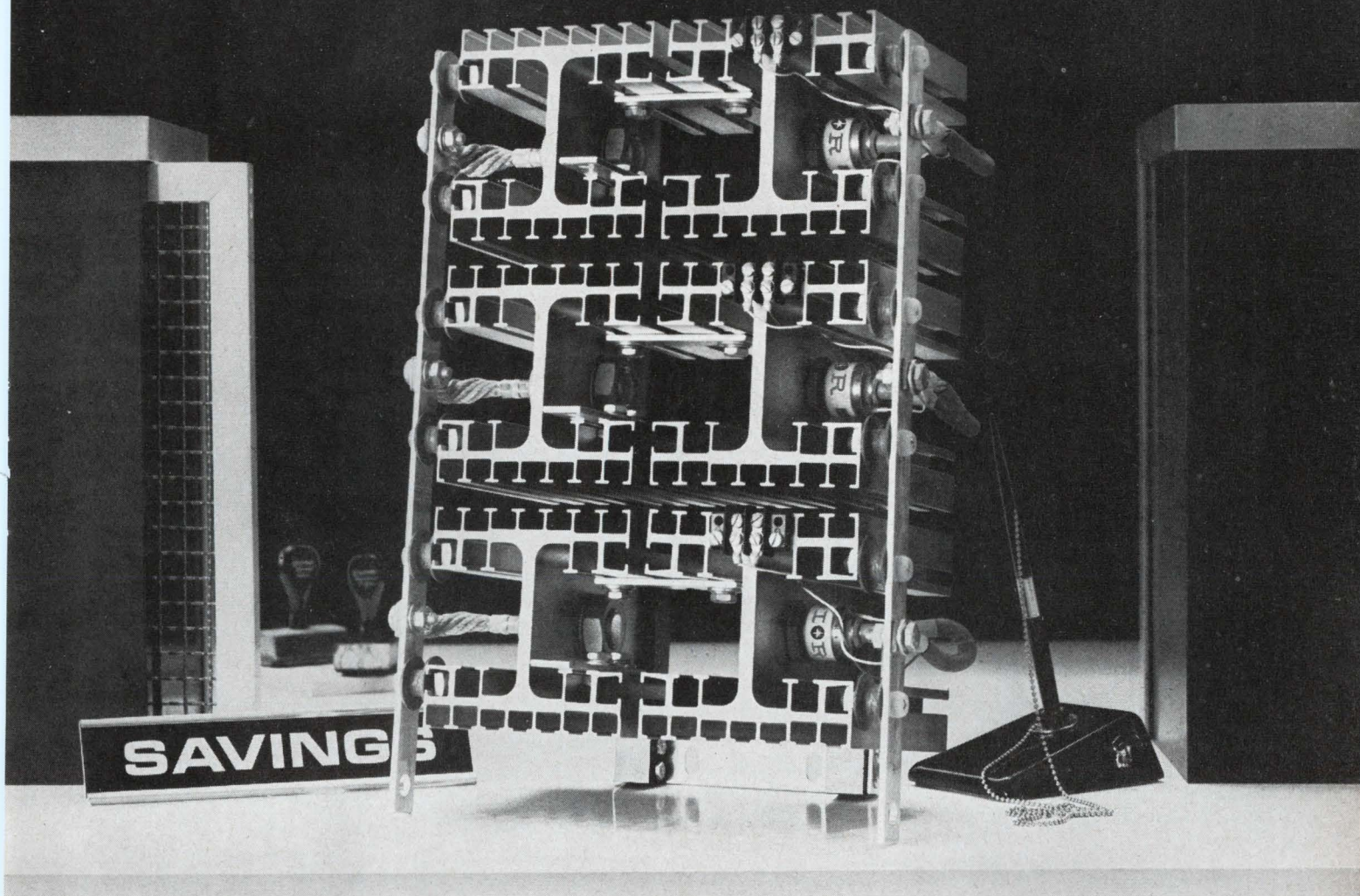
Harold E. Clupper, Senior Staff Engineer, ITT Federal Laboratories, Fort Wayne, Ind.

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



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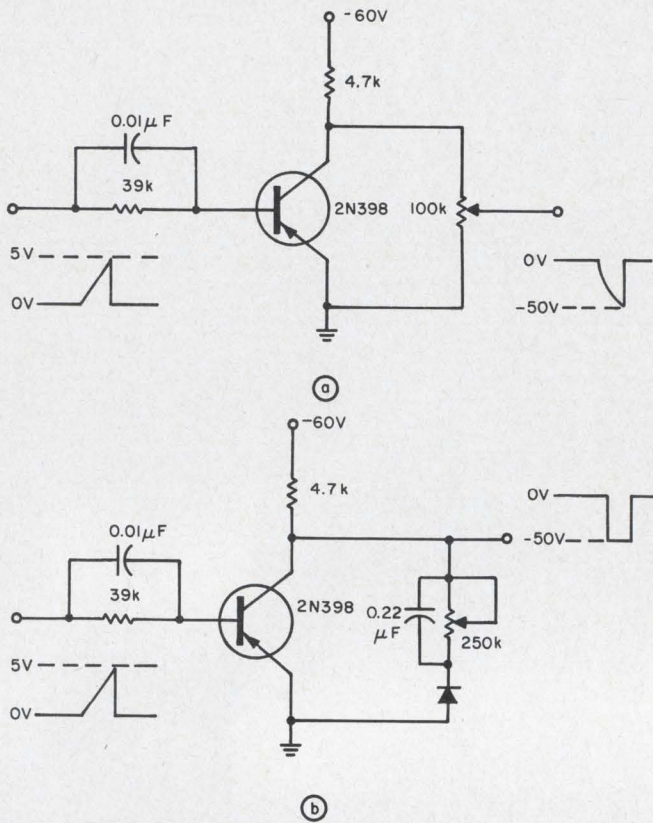
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Pulse amplitude can be varied over a wide range without affecting its rectangularity (b), by the addition of a diode and a capacitor to a commonly used circuit (a).

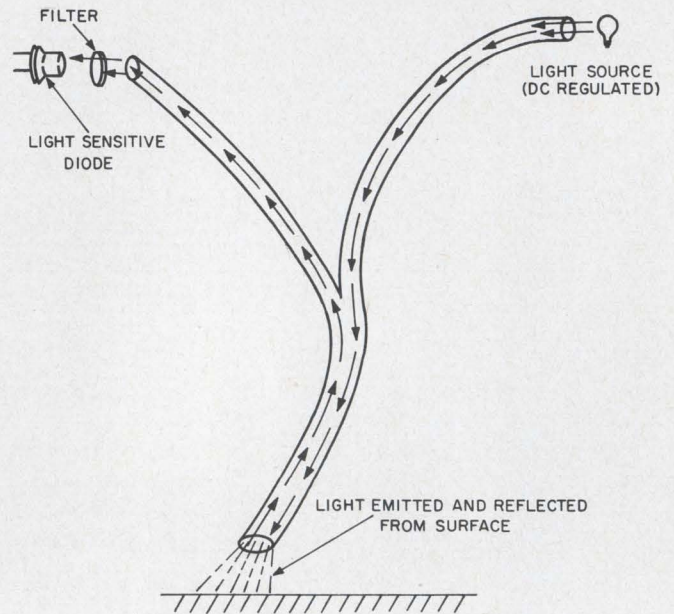
of the circuit allows the collector quiescent point to be shifted, while the zero reference level is established by saturation of the transistor during conduction. These features provide a rectangular pulse of an amplitude that is variable over the full range of the potentiometer.

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 (± 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 fiberoptic 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

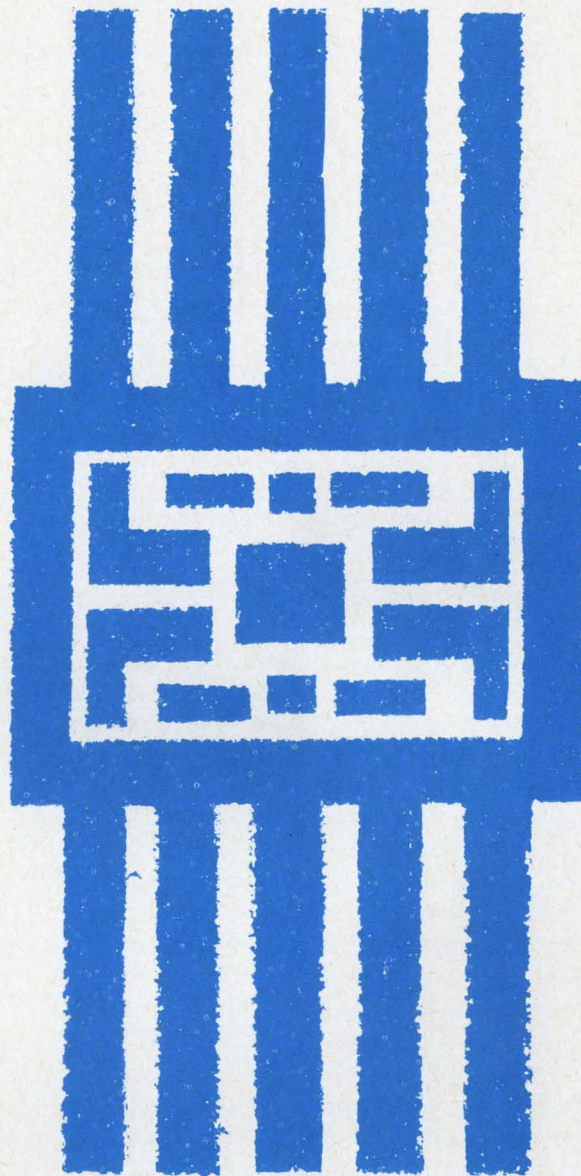
Pulse-width discriminator eliminates delay line

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 μ s to 3.5 ms.

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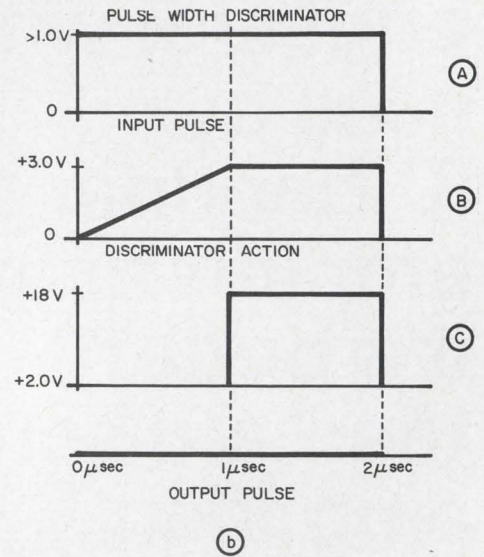
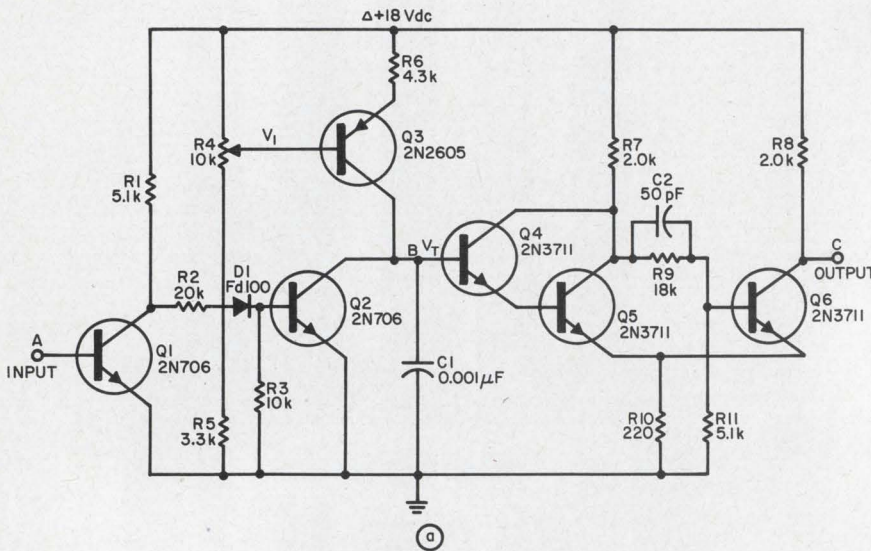
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ON READER-SERVICE CARD CIRCLE 51



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 Δt , 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:

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

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 Δt , 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 μ s 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:

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

assuming $\beta_4 = \beta_5 = 100$.

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

$$\Delta t = \Delta V (c/i) = (3 \times 10^{-9}) / (8.2 \times 10^{-7}) = 3.65 \text{ ms}. \quad (5)$$

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.

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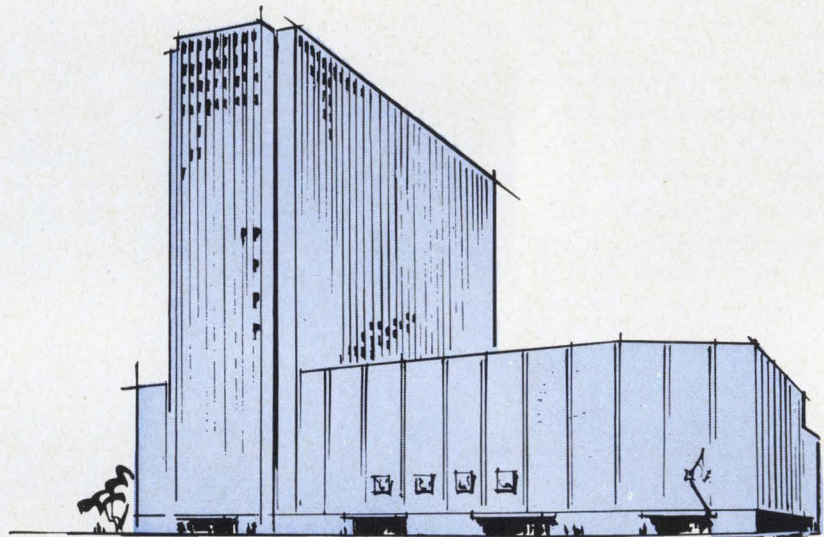
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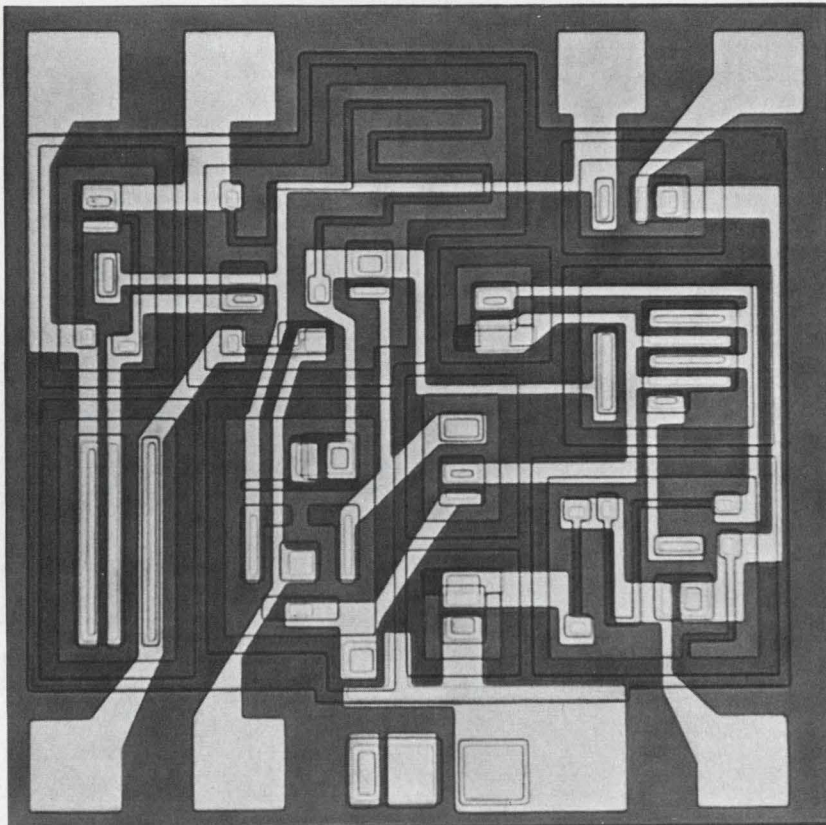
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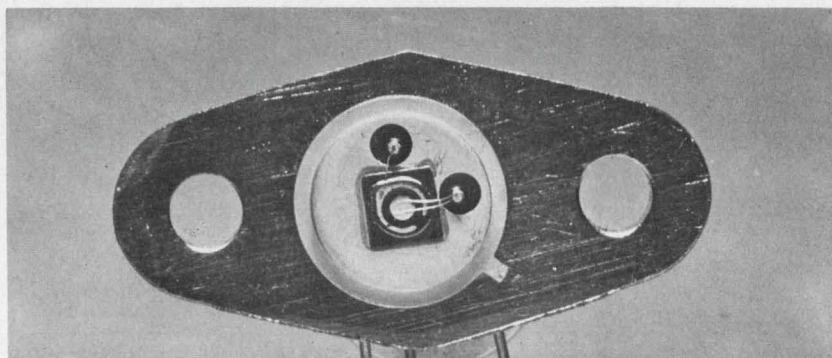
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ON READER-SERVICE CARD CIRCLE 53

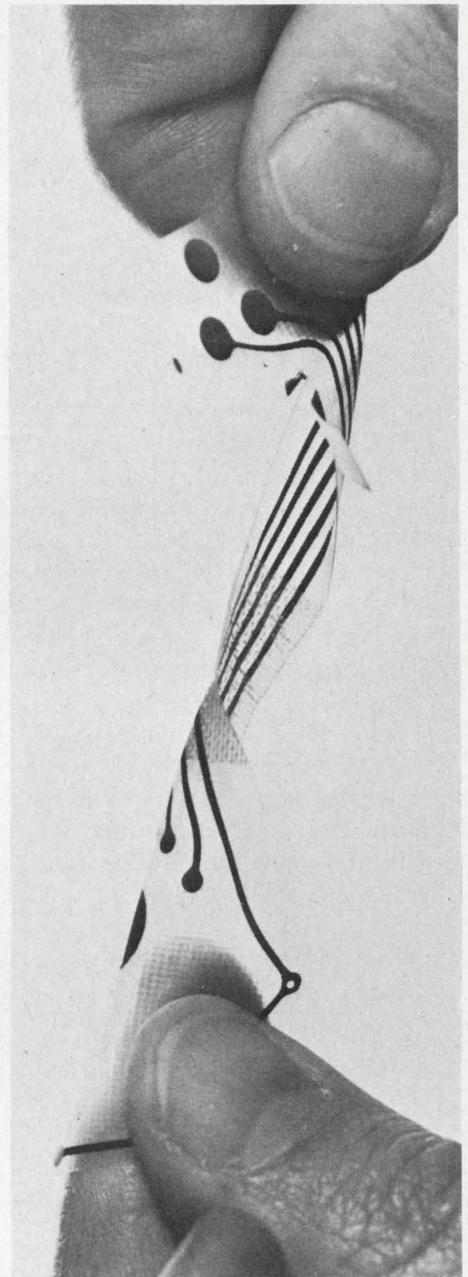
Products



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

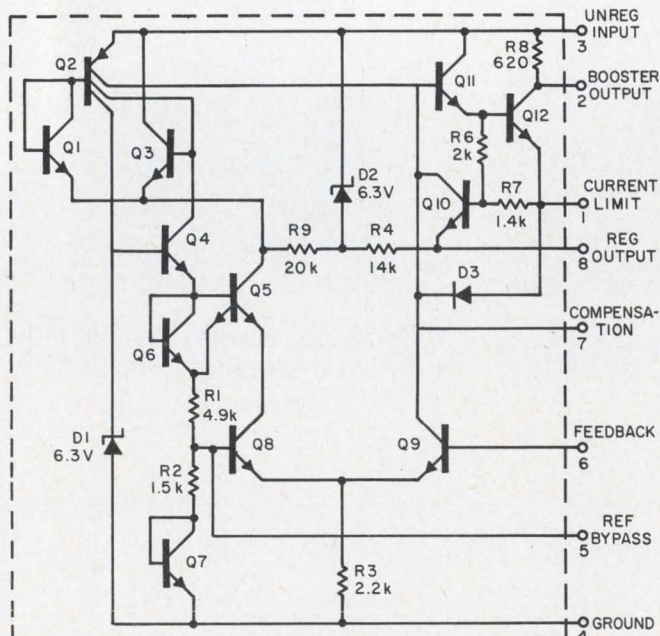
Open-air cryogenics without frost problems. Page 122

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.

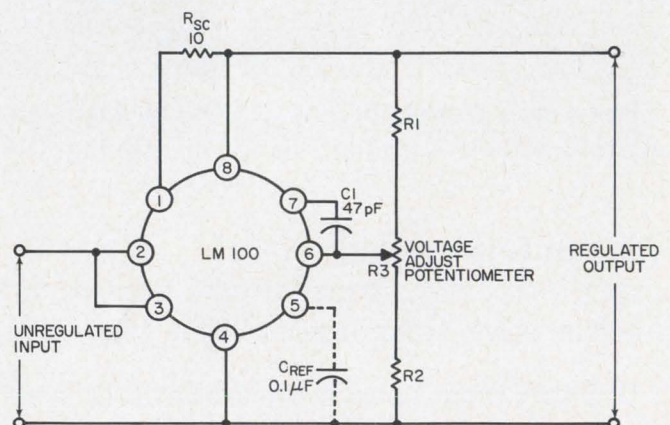


1. Basically a single-stage diff-amp with Darlington emitter-follower output, the regulator permits addition of pnp at Q12 for higher currents.

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.

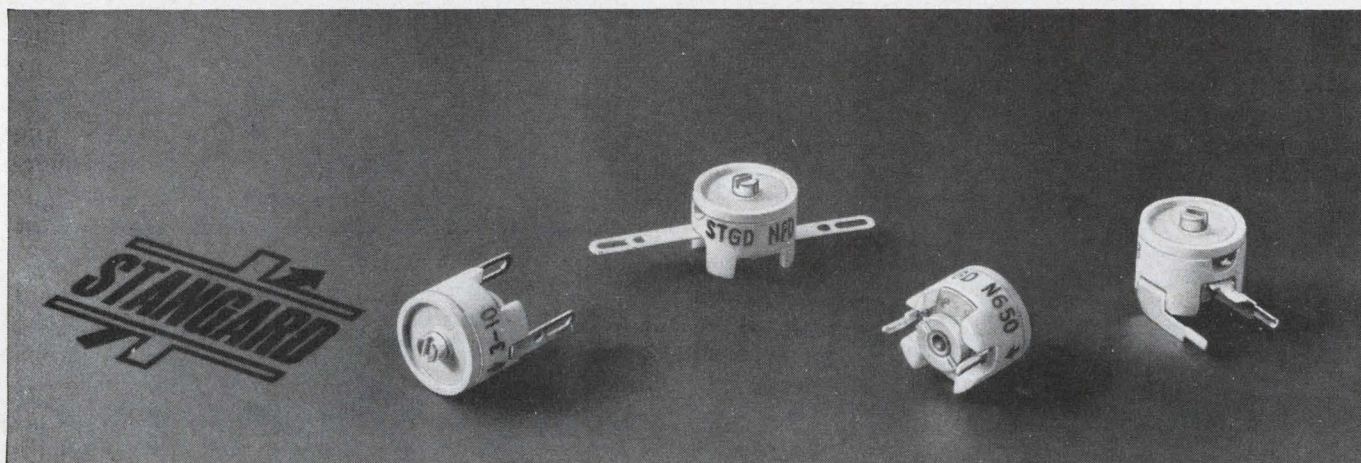
The collector of output transistor Q12, brought out separately, and 620- Ω emitter-base resistor R8 permit addition of an external pnp transistor for higher currents. This resistor is shorted out when the regulator is used without the external transistor.

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.

Announcing new low-cost Ceramic Disc Variable Capacitors



Capacitors shown enlarged 30%

JFD Stangard DVC Capacitors

These new Stangard variable ceramic disc capacitors represent an optimum balance of high quality and low cost for commercial and industrial applications.

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Stangard DVC's offer a unique feature . . . easy adjustment . . . from

either top or bottom. These $\frac{3}{8}$ " diameter Ceramic Disc Stangard capacitors meet or exceed the applicable specifications of MIL-C-81.

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ON READER-SERVICE CARD CIRCLE 54

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- μ F capacitor on the reference bypass terminal will cut noise inherent in the reference diode.

A basic regulator circuit is 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 Ω 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

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% / $^{\circ}$ C
Output noise voltage	0.005%
Long-term stability	0.1%
Standby current drain	1 mA
Minimum load current	1.5 mA

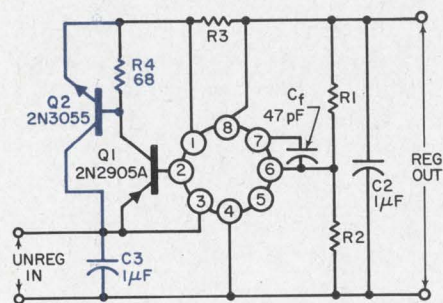
output terminals must be bypassed with low-inductance capacitors.

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.

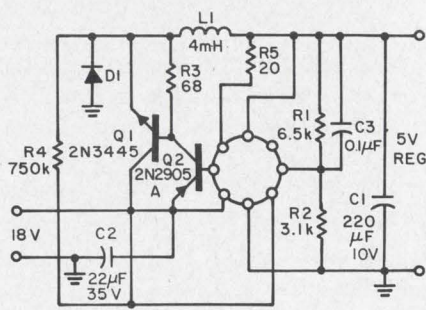
An external npn and pnp are cascaded to handle the output current. This regulated output is fed back through a resistive divider that determines the output voltage. The regulator is made to oscillate by applying positive feedback to the reference terminal through R4.

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.

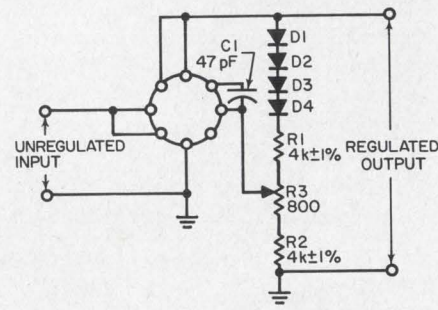
CIRCLE NO. 211



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.

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prototype hybrid circuits
you need this...

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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

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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. . . .



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ON READER-SERVICE CARD CIRCLE 55

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MC45		
MC46		
MC47		

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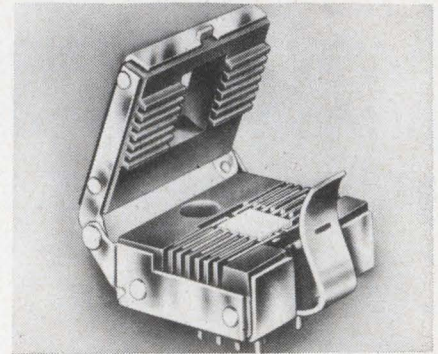
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SILICON HIGH VOLTAGE TRANSISTOR

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Electrical parameters are BV_{CBO} ranging from 200 volts to 1000 volts, nominal current gain (H_{FE}) of 50 at 20 mA and a gain-bandwidth-product (ft) of 20 MHz. Intended as high voltage switches for electro-luminescent read-out, as drivers for CRT's, high voltage amplifiers, and as replacements for low current SCR's. Available in plastic-capped TO-46 packages, with other configurations available upon request.

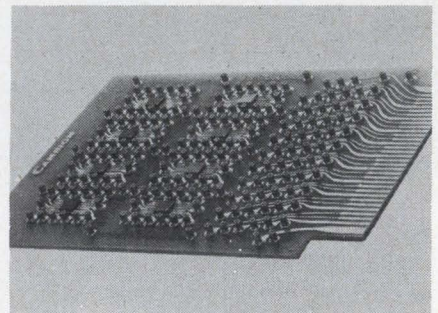


Flip-top IC sockets offered in polysulfone

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

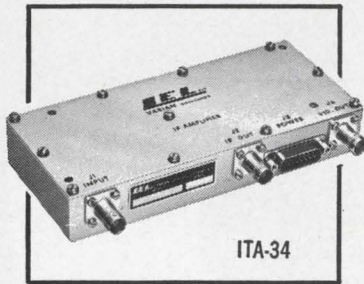
Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. Phone: (617) 876-2800. P&A: \$21.40 (10-49); stock.

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

Fast Recovery!

New, LEL IF Amplifiers, ITA-34, have 0.2 μ sec. recovery time and excellent pulse response. Ideal for a wide variety of microwave receiving system applications, they also feature high dynamic range and furnish both IF and detected outputs.



ITA-34

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C.F.	30 or 60 MHz
BW	3 or 8 MHz
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IF Gain (into 50 Ω)	75 dB (min.)
Video Gain (into 1000 Ω)	80 dB (min.)
Input	50 ohms
Input (lin. operation)	-15 dBm (max.)
Output (lin. operation)	+10 dBm (max.)
External AGC range	50 dB (min.)
N.F.	7 dB (max.)
Weight	20 oz.
Dimensions	6 $\frac{7}{8}$ " x 1 $\frac{1}{8}$ " x 3"
Connectors (IF and Video)	BNC
(Power)	DA 15
Power required	-20 VDC @ 70 mA
Temperature	-55° to +70°C
Price	\$325

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(ONE WEEK)

More than 100 other standard IF Amplifiers are available many with such special characteristics as broad bandwidth, gain-and-phase-match, low noise, extremely low power drain.

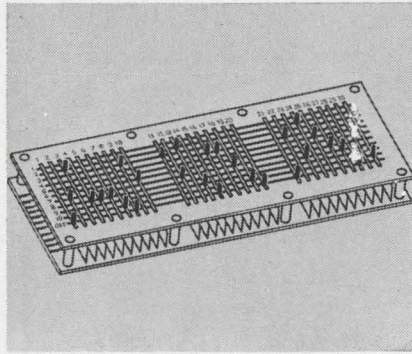
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COMPONENTS

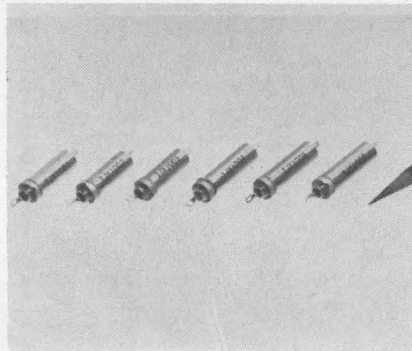


Crossbar selector replaces 30 wafers

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

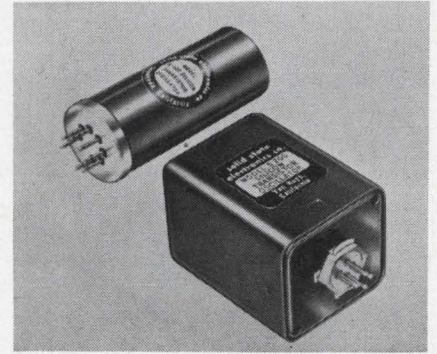


Submin EMI filters have low insertion loss

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

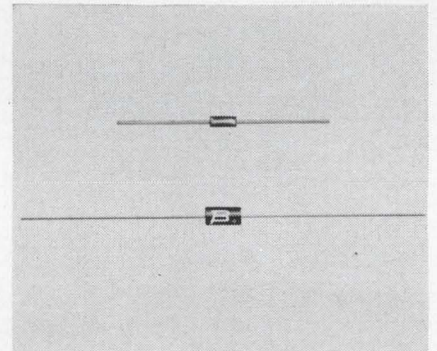


Transistor oscillator generates sine waves

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



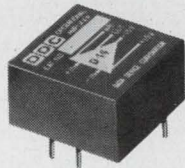
Micromin cap meets environmental specs

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

What company do you call when you need a standard operational amplifier to meet exceptional requirements?



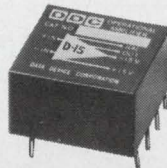
REQUIRED: HIGH SPEED
AT LOW COST

Model D-14
FFO: 500 KHz (inverting)
Gain Bandwidth: 20 MHz (inv.)
Slewing Rate: 30 V/ μ sec (inv.)
Stability: 0.8 nA/ $^{\circ}$ C;
10 μ V/ $^{\circ}$ C
Price: \$45 (1-9)



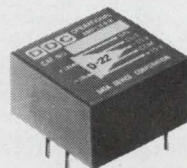
REQUIRED: 20 V OUTPUT,
HIGH STABILITY

Model D-20-B
Output: 20 V @ \pm 20 mA
Gain: 180,000
Stability: \pm 5 μ V/ $^{\circ}$ C;
 \pm 0.3 nA/ $^{\circ}$ C
Initial I_0 : \pm 10 nA
Price: \$80



REQUIRED: FET, ULTRA-
HIGH Z, \$75

Model D-15
Input Impedance: 10¹¹ ohms
Initial I_0 : 10 pA
FFO: 35 KHz, either input
Stability: 10 pA/ $^{\circ}$ C
Price: D-15, 15 μ V/ $^{\circ}$ C—\$75
DK-15, 35 μ V/ $^{\circ}$ C—\$45



REQUIRED: 20mA OUTPUT,
HIGH STABILITY

Model D-22
Output: \pm 20 mA @ \pm 10 V
Gain: 180,000
Stability: 5 μ V/ $^{\circ}$ C;
0.45 nA/ $^{\circ}$ C
Initial I_0 : 5 nA
Price: \$65 (1-9)

Quantity prices on request

All specs typical @ 25 $^{\circ}$ C.

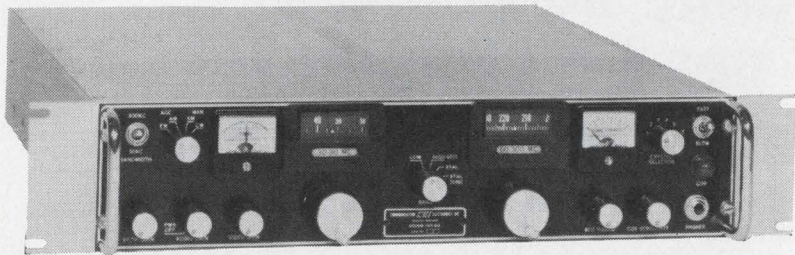
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CEI's Sensitive New VHF Receiver



Six Crystal-Controlled Frequencies... Plus Continuous 30-300 MHz Tuning in Two Bands

Meet a new and unusual VHF receiver from CEI. The Type 952 provides AM, FM and CW reception throughout the 30-300 MHz range, while also offering six switch-selectable crystal-controlled frequencies within the 100-150 MHz range.

The receiver's full frequency range is covered in two bands—30-90 MHz and 60-300 MHz—with accurate tuning facilitated by a long steel tape dial. IF bandwidths of 50 and 300 kHz are selectable at the front panel; video and audio outputs are provided from the bandwidth selected, and a built-in BFO operates with either bandwidth when the CW mode is selected.

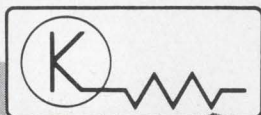
Sensitivity, stability and operating flexibility are outstanding. For full information about the 952's unusual features and performance, please contact:



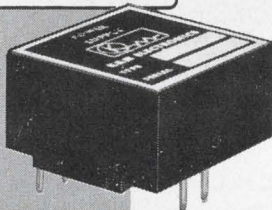
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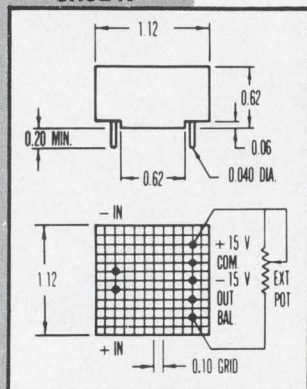
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MODEL KM 43

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CASE A



The Model KM 40 series was designed for instrumentation and computer applications and may be utilized in both airborne and ground equipment, in addition to performing industrial control functions.

Featuring . . .

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- LOW VOLTAGE OFFSET DRIFT 20 MICROVOLTS/°C
- FREQUENCY COMPENSATED
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- FULL POWER OUTPUT, 30 KHZ
- ULTRA HIGH IMPEDANCE, 10¹² OHMS
- HIGH GAIN, 200,000 @ 5K LOAD

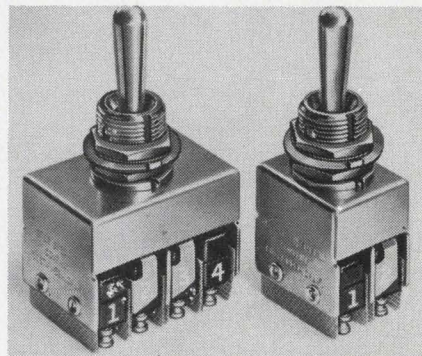
Ideal for Integrators, Sample and Hold and High Impedance VTVM Systems.

Custom Units for Specialized Applications Designed Upon Request.



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COMPONENTS

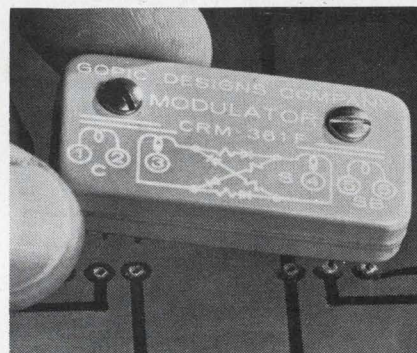


Three-position toggle provides quick transfer

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

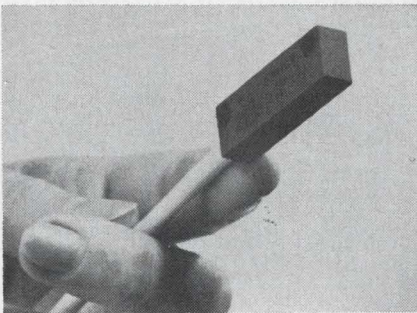


Analog multiplier has 10-MHz upper limit

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 highest 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

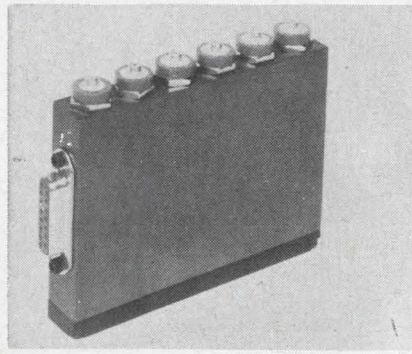


Ac-dc magnetic switch has long operating life

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

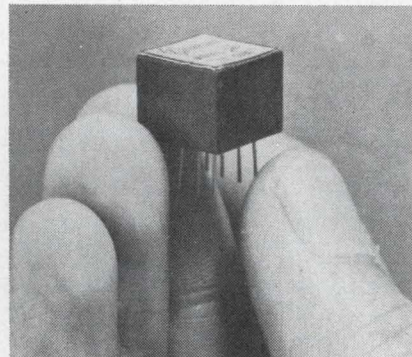


Modular coax switch has isolated points

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



Differential amplifier based on hybrid ICs

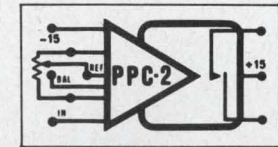
Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. Phone: (415) 686-6660. Price: \$47 in 100 lots.

Hybrid integrated circuitry is cited as the key to stability for the model 161 differential amplifier. Key specifications of the unit are a $25 \mu V/^\circ C$ 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 Ω . 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.

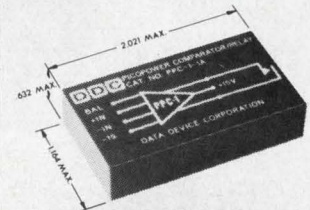
CIRCLE NO. 225

What company do you call for new ideas in analog comparators?

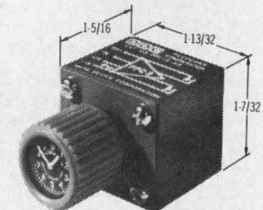
PPC-1 and PPC-2 ultra-sensitive relay and fast comparators.



Sensitivity: 200 μV
 Repeatability: 50 μV
 Response Time: < 1 ms
 Contacts: 1A, 2A, 1C
 Cost: In moderate quantities:
 PPC-1 < \$30; PPC-2 < \$75



PPC-1 (for P.C. mounting)



PPC-2 (panel mounting) with ten-turn trip level adjustment

All specs typical @ 25°C.

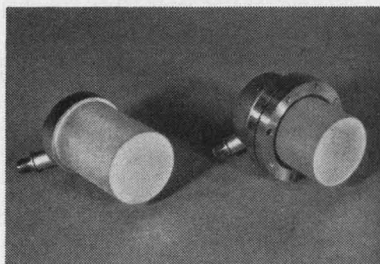
Write, call, TWX or circle the card. We'll send detailed data or evaluation samples.

DDC
 DATA DEVICE CORPORATION

Right!

Data Device Corporation
 240 Old Country Road Dept. ED 17D
 Hicksville, L. I., New York 11801
 Phone: 516-433-5330
 TWX: 510-221-1874

Requirement: How many antennas are needed to accomplish the functions of beacon tracking, command and voice communications during launch, flight and the critical reentry high temperature phase of the Apollo Mission?



Solution: One! Amecom's Unified S-Band Antenna that operates from 2100 MHz to 2300 MHz, provides circular polarization with a maximum ellipticity of 2 db and a gain of 6 db!

This antenna has been qualified to survive reentry heats of up to 3000°F.

It has been subjected to thermal inputs of 14,500 BTU/ft.² for over one-half hour with no performance deterioration.

The Apollo S-Band Antenna is similar to the Amecom C-Band models that are being used on Gemini and Apollo spacecraft and missile testing programs.

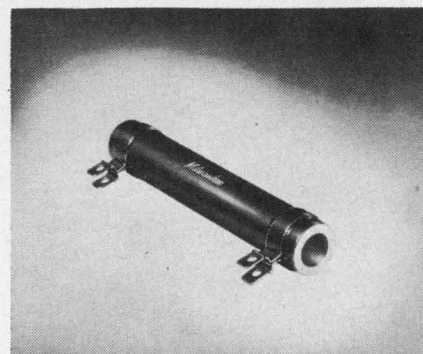
The Problem Solvers of Amecom's Antenna Systems Department will be pleased to review the hard-to-meet temperature requirements for antennas in your missile, rocket or space project.

Call or write: Amecom Division, 1140 East-West Highway, Silver Spring, Md. 20910. Tel: (301) 588-7273.

AMECOM | 
DIVISION OF LITTON INDUSTRIES

ON READER-SERVICE CARD CIRCLE 63

COMPONENTS



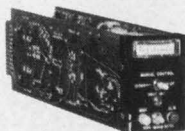
Quick terminals now on wirewounds

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

**SAMPLE AND
HOLDHOLDHOLDHOLDHOLDHOLDHOLD
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ANALOG CONTROL SIGNALS

PD & C's new Model 102 Analog Memory Device makes continuous, trouble-free operation of process control a practical, economical reality. When a disruption of incoming data occurs, Model 102 retains the last valid signal to within 1% for over an hour, permitting service to be maintained until the input can be restored. Eliminates costly downtime and maintenance interruptions.

Find out more today.

 **PACIFIC DATA
& CONTROLS**
6406 S. E. Foster Rd. • Portland, Oregon 97206

ON READER-SERVICE CARD CIRCLE 64

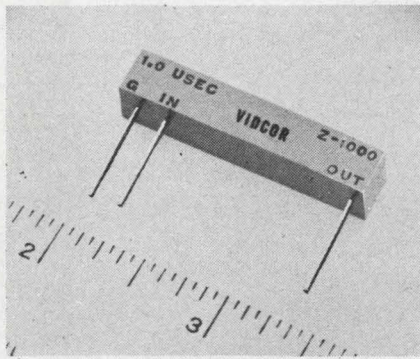


FM microtransmitters for vhf band

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 10⁴ is provided by a crystal-controlled oscillator.

CIRCLE NO. 227

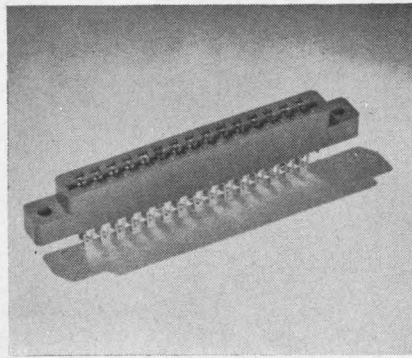


Delay line claims 60% smaller size

Vidcor Corp., 730 Centinela Ave., Inglewood, Calif. Phone: (213) 678-4024.

This 1- μ s 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 k Ω . The dielectric withstands 300 Vdc. Leads are of tinned Dumet and are spaced for standard 0.1-in. circuit board grids.

CIRCLE NO. 228

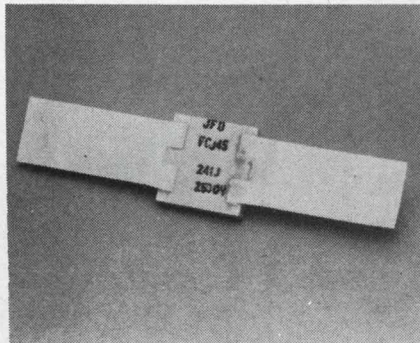


PC connectors have "bellows" contacts

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

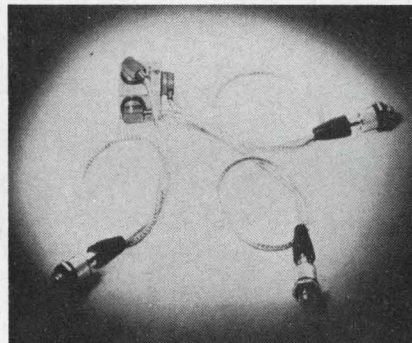


Miniature RF capacitors take high voltage

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

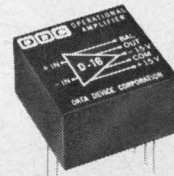
Columbia Research Labs., Inc., MacDade Blvd. & Bullens Lane, Woodlyn, Pa. Phone: (215) 532-9464.

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.

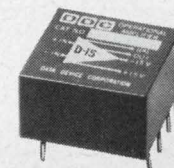
CIRCLE NO. 231

What company do you call for low cost, high input impedance amplifiers?

These low cost DDC operational amplifiers make high stability integrator circuits easy.



MODEL D-16
Z_{in} Common Mode: 1.6 x 10⁹ Ω
Z_{in} Differential: 0.7 x 10⁸ Ω
I_{os} Either Input: 1 nA
Stability I Δ t: 0.1 nA/°C
Stability V Δ t: 10 μ V/°C
Output 11 V @ 2.2 mA
Price: (1-9): \$38.



MODEL D-15 (FET)
Input Impedance: 10¹¹ ohms
Initial I_{os}: 10 pA
FFO: 35 KHz, either input
Stability: 10 pA/°C
Price: D-15, 15 μ V/°C—\$75 (1-9)
DK-15, 35 μ V/°C—\$45 (1-9)

All specs typical @ 25°C.

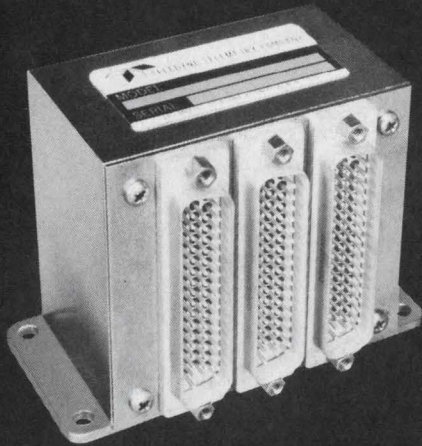
Write, call, TWX or circle the card. We'll send detailed data or evaluation samples.

DDC
DATA DEVICE CORPORATION

Right!

Data Device Corporation
240 Old Country Road Dept. ED 17C
Hicksville, L. I., New York 11801
Phone: 516-433-5330
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500,000 Bits/Second PCM SYSTEMS



710 PCM SYSTEMS require as little as 26 cubic inches and weigh as little as 30 ounces. Space and weight are saved in Type 710 Microcircuit PCM Systems because they use MEMA*.

Provides up to 256 channels of high, low and/or digital inputs.

FET analog input gates.

Offset and scatter below ± 25 microvolts.

Backcurrent below ± 0.1 microampere.

NRZ 10-bit word output.

Sample rates from 1 to 50,000 words.

*Micro Electronic Modular Assemblies, a high density integrated circuit packaging concept developed by TELEDYNE, INC.

For complete information on Teledyne Telemetry components and systems contact:

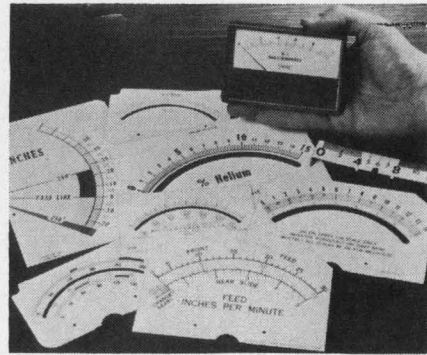


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12964 Panama Street
Los Angeles, California 90066
Phone (213) 870-9831
TWX: 910 343 6855

ON READER-SERVICE CARD CIRCLE 66

COMPONENTS

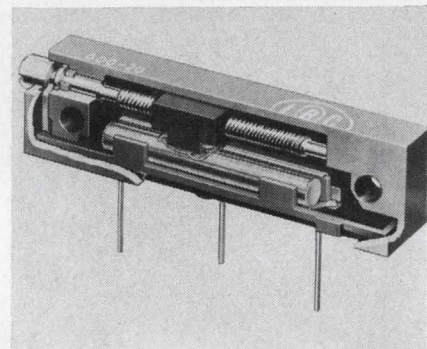


Custom meter scales read your way

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

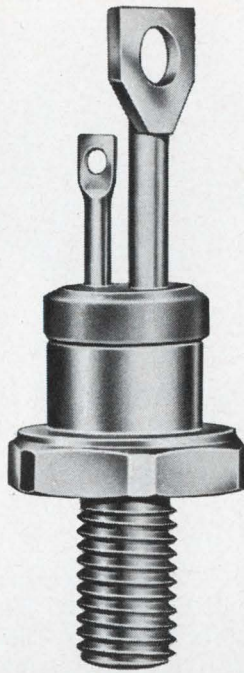


Wirewound trimmer has isolated elements

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 k Ω $\pm 5\%$ are available. The units are rated at 1 W at 70°C.

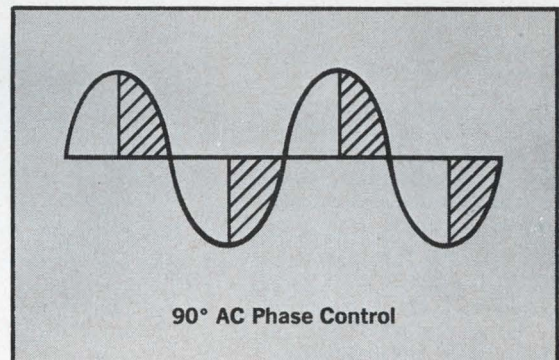
CIRCLE NO. 233



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?



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 _____

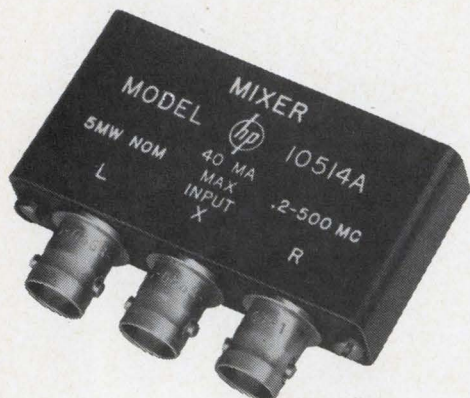
Address _____

City & State _____ Zip _____

67R1

ON READER-SERVICE CARD CIRCLE 67

This mixer



goes up to 500 MHz

But the price goes below \$180

New production techniques (you'll detect some in the outer case, for example) now make possible a lower-priced, high-performance mixer from HP.

You can use the 10514A Double Balanced Mixer for extracting the sum or difference of two frequencies, or as a modulator, spectrum generator, phase detector, current-controlled attenuator, frequency doubler, or for extending the range of spectrum analyzers.

Features include: range of 200 kHz to 500 MHz (to dc on one port), excellent balance, flat response, low noise (7 dB max. noise figure to 50 MHz; 9 dB max. to 500 MHz) and low intermodulation. And the price is low, too: \$180 each, and even lower in quantity. Printed circuit board version (10514B) also available.

For additional information contact your local HP field engineer, or write Hewlett-Packard, Palo Alto, California 94304. Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

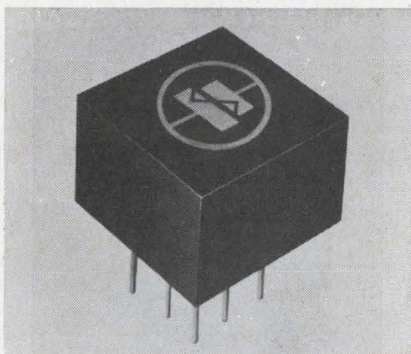


An extra measure of quality

2249

ON READER-SERVICE CARD CIRCLE 68

COMPONENTS

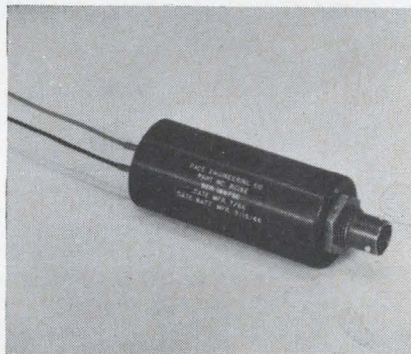


Analog multiplier has no hysteresis error

Transmagetics, 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

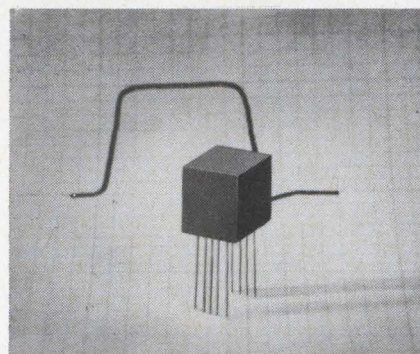


Solid-state compensator completely self-powered

Whittaker Corp., 12838 Saticoy St., North Hollywood, Calif. Phone: (213) 781-8950.

With a reference accuracy of $\pm 0.5^\circ$ 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

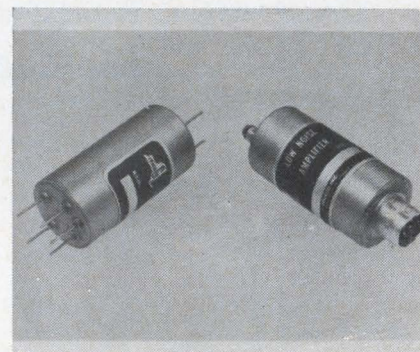


Pulse transformers for PC applications

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 μ s. Either Dumet or nickel terminals are provided.

CIRCLE NO. 236



Remote-switched gain in low-noise preamp

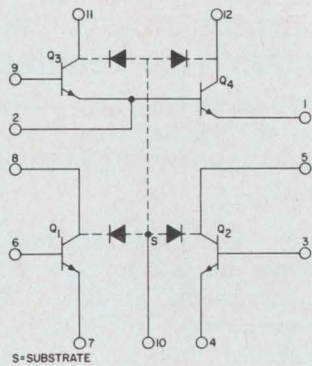
Ithaco, Inc., 413 Taughanock Blvd., Ithaca, N. Y. Phone: (607) 272-7640.

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 μ V max and an internal divider net permits injection of a calibration signal.

CIRCLE NO. 237

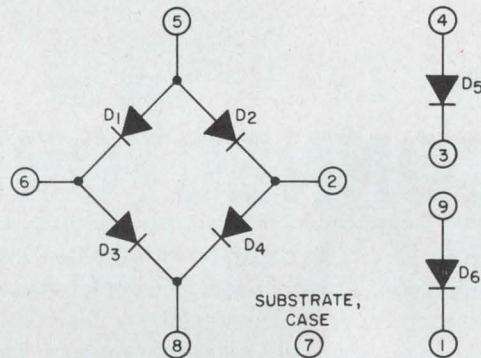
ON READER-SERVICE CARD CIRCLE 69 ➤

RCA LINEAR CIRCUITS GO FLEXIBLE...LOW COST



4-TRANSISTOR ARRAY CA3018 \$1.50 (1000+)

- excellent transistor match and tracking
- transistor $f_T = 400$ MHz typ
- optimum lead arrangement for reduced Miller effect
- 12-lead TO-5 style package



6-DIODE ARRAY CA3019 \$1.50 (1000+)

- excellent diode match
- built-in temperature stability
- low leakage
- 10-lead TO-5 style package

MONOLITHIC-DEVICE MATCH PLUS NEW DESIGN FREEDOM, NEW ACCESSIBILITY

Here are the performance benefits of integrated circuit active devices, *plus* complete design freedom in the selection of passive components. Plug these two important new RCA integrated circuit devices into your breadboards and include them in your production plans now, for:

CA3018

- 100 MHz Cascode Amplifiers
- Final IF Ampl and 2nd Det
- Tuned RF Amplifier
- Cascode Video Amplifier

CA3019

- Ring and shunt modulator
- Double-stage limiter
- Mixer
- Analog switches
- Gates for chopper-modulator

FOR FURTHER INFORMATION check your local RCA Representative—or contact your RCA Distributor for his price and delivery. For literature, write Section LCG1-3, Commercial Engineering, RCA Electronic Components and Devices, Harrison, N. J. 07029.

CA3018 and CA3019 NOW IN DISTRIBUTOR STOCKS.

CHECK RCA'S GROWING LINEAR LINE FOR:							
CA3000	CA3001	CA3002	CA3004 CA3005 CA3006	CA3007	CA3008 CA3010 CA3015 CA3016	CA3011 CA3012	CA3013 CA3014
DC Ampl	Video Ampl	IF Ampl	RF Ampls	AF Ampls	Opr Ampls	Wideband Ampls	Wideband Ampl-Discriminators



ELECTRONIC COMPONENTS AND DEVICES

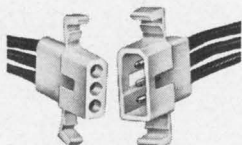
The Most Trusted Name in Electronics

NEW MINIATURE

NYLON CONNECTORS

Up to 15 circuit capacity with these low-cost, miniature nylon connectors! Contacts automatically crimped to leads, then securely snap-lock into the housings. Positive polarity prevents misconnections and integral mounting ears provide easy panel installation.

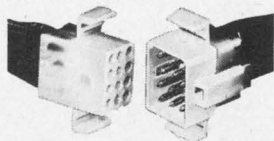
Model 1625-3
Compact three circuit unit for independent circuit isolation.



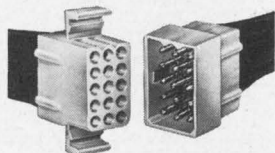
Model 1625-9
Nine circuit connections for fast, multiple circuit wiring.



Model 1625-12
Twelve independent circuits are provided with this unit.



Model 1625-15
Up to 15 separate circuits in this space saving connector.



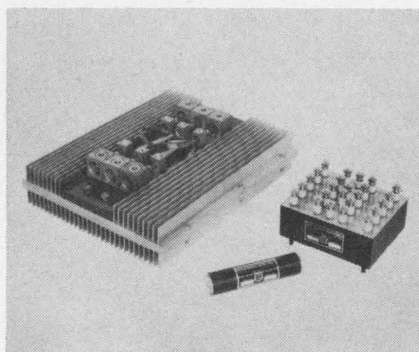
Write for complete specifications and samples on any of these connectors.

MOLEX® PRODUCTS COMPANY
5235 Katrine Avenue
Downers Grove, Illinois 60515
(312) 969-4550 TWX 910-695-3533



ON READER-SERVICE CARD CIRCLE 70

COMPONENTS

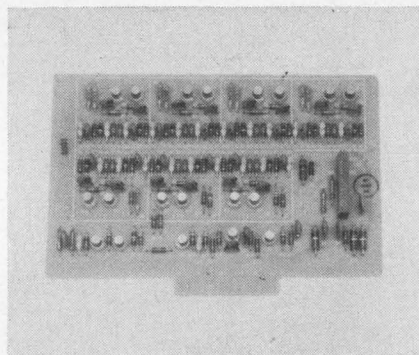


Current shunts allow 0.005% dc readings

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

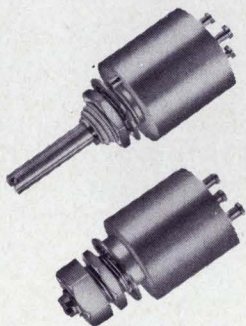
Micro Instrument Co., 12901 Crenshaw Blvd., Hawthorne, Calif. Phone: (213) 679-8237. Price: \$150.

Single or repetitive voltage transients in pulse widths from dc to 100 μ s 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 μ s or longer into a dc output and holds there until reset or keyed by a higher voltage.

CIRCLE NO. 239

"POT" LUCK

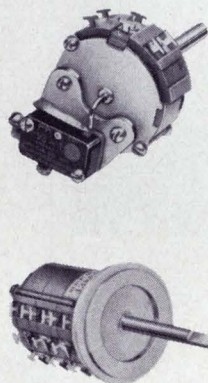
not when you specify **Clarostat!**



SERIES 57, 57EM

Single Turn Wire-Wound Potentiometer designed to meet miniaturization needs.

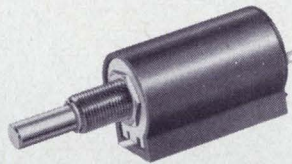
Resistance Range: Standard to 25K ohms. Special to 100K ohms. Tolerance: Standard $\pm 10\%$, Special to $\pm 3\%$. Linearity: Standard $\pm 2.0\%$. Power Rating: Standard 2W @ 70°C, derated to zero @ 150°C. Weight: .25 oz.



SERIES 42BM, 42CM

Single Turn Wire-Wound Potentiometer controls from 1 to 20 circuits simultaneously.

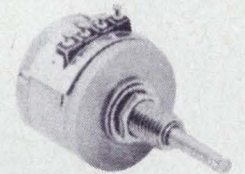
Resistance Range: To 100K ohms. Tolerance: Standard $\pm 5\%$, Special $\pm 1\%$. Linearity: Standard $\pm 1\%$, Special $\pm .15\%$. Power Rating: Standard 3W @ 40°C, derated to zero @ 105°C.



SERIES 62

10 Turn Precision Potentiometer designed for industrial instrumentation.

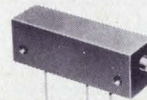
Resistance Range: to 100K ohms. Tolerance $\pm 5\%$. Linearity: 0.25% Absolute. Power Rating: 2W @ 25°C, derated to zero @ 85°C. Maximum Number of Turns: 10. Weight: 1.34 oz.



SERIES 54M

Single Turn Vari-Phase Precision Potentiometer features external, individual cup phasing.

Resistance Range: To 300K ohms. Tolerance: Standard $\pm 5\%$. 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 $\pm 5\%$, Special $\pm 2\%$. 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.

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.

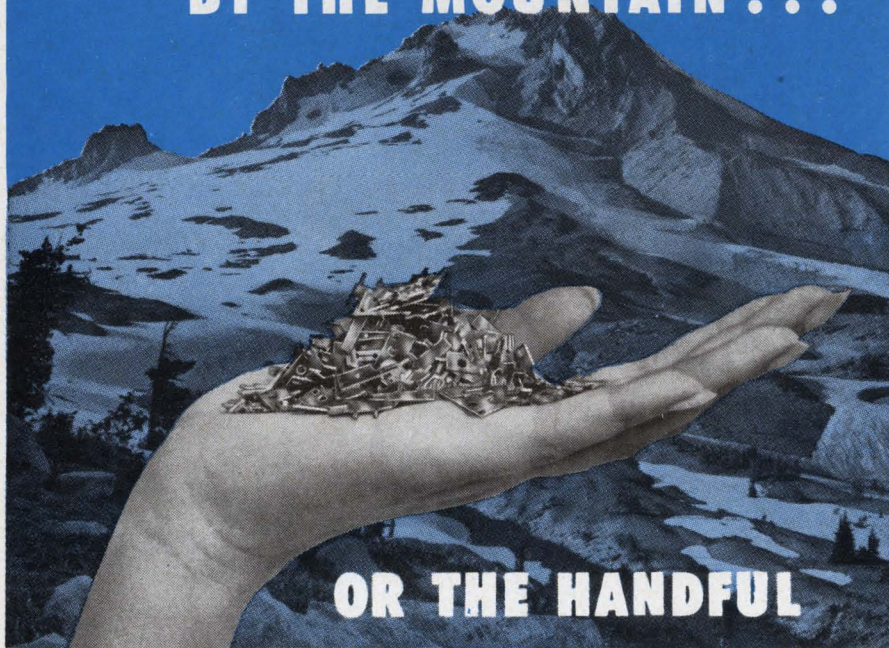
If you would rather take chances with your potentiometers, you don't want Clarostat. For when you specify Clarostat, there is no such thing as pot luck.

CLAROSTAT

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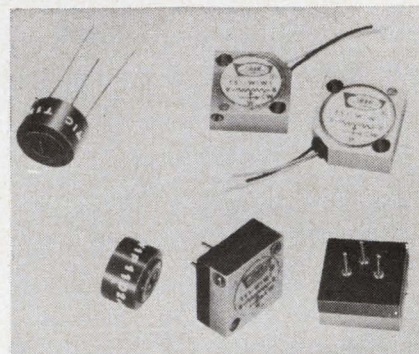
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COMPONENTS



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 k Ω . Both types are manufactured to meet or exceed MIL-R-27208A.

CIRCLE NO. 240



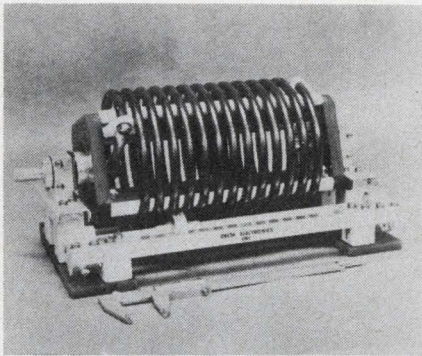
Operational amplifier drives deflection coils

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/ μ s, 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

ON READER-SERVICE CARD CIRCLE 72

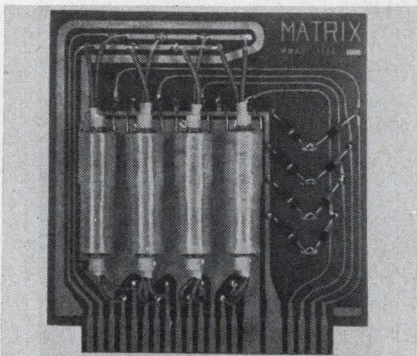


Variable inductor designed for long life

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 reliability are required. Range of stock inductors is from 0.06 to 12 μ 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

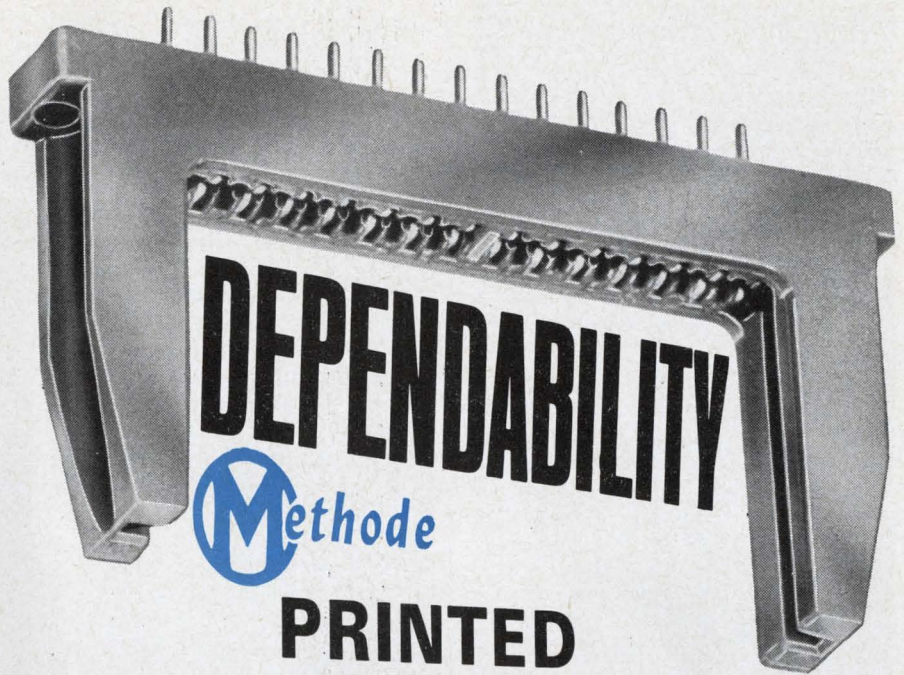


PC switch module has high reliability

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



DEPENDABILITY Methode PRINTED CIRCUIT CONNECTORS

If your design requirements need printed circuit connectors of exceedingly high quality, but your design application is such that you do not need connectors made to military specifications . . . talk to METHODE.

We stock a full line of dependable Reli-acon printed circuit connectors from the largest to the smallest sizes with a variety of contact designs. And all Reli-acon connectors are made to rigid quality standards that give you the reliability you need . . . without paying the premium prices that mil spec. connectors command. However, Methode's MIL-C-21097B fully approved connectors are available to meet your military requirements.

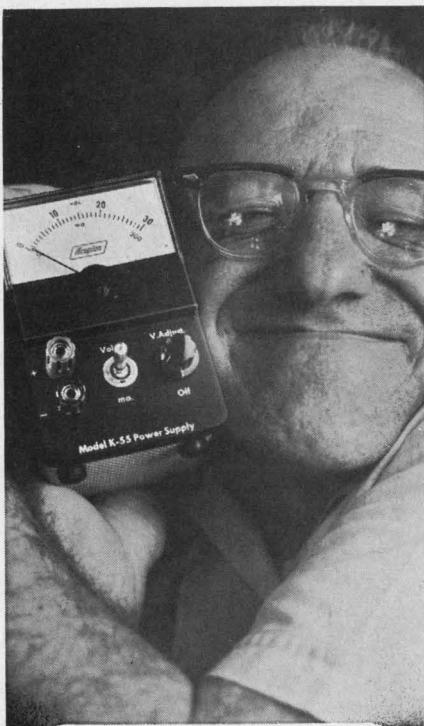


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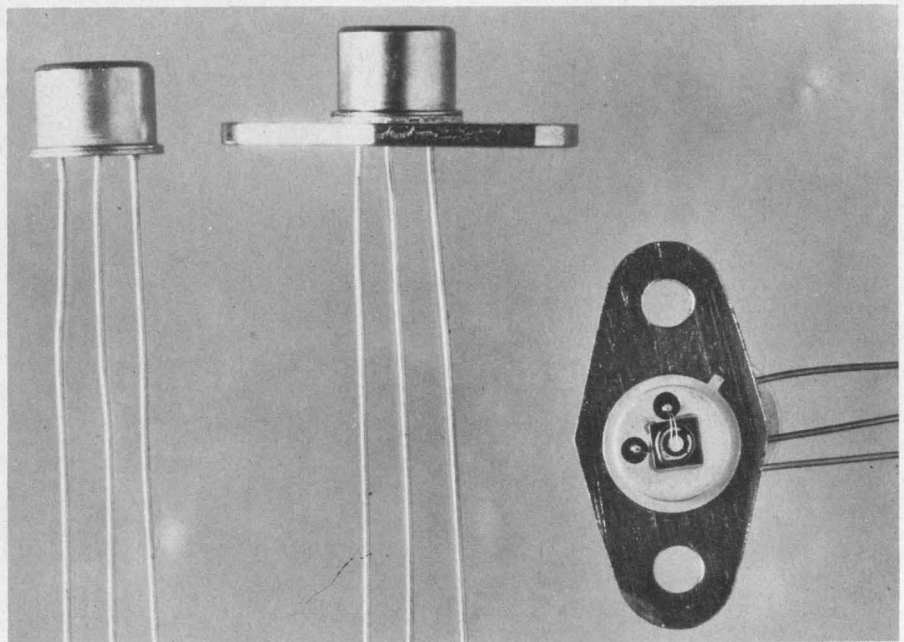
ON READER-SERVICE CARD CIRCLE 73



Why not enjoy the luxury of your own power supply?

Now, for only \$98, you can enjoy the luxury of a laboratory power supply right on your own bench. Acopian's new K55 Power Supply delivers 300 ma over an adjustable range of 1.25 to 30 volts DC. It is voltage regulated, all silicon, and electronically protected against shorts. It weighs only three pounds.

Availability? Acopian's usual three days, of course. Get complete information from your local Acopian representative or write Acopian Corp., Easton, Pennsylvania. Phone: (215) 258-5441.



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.

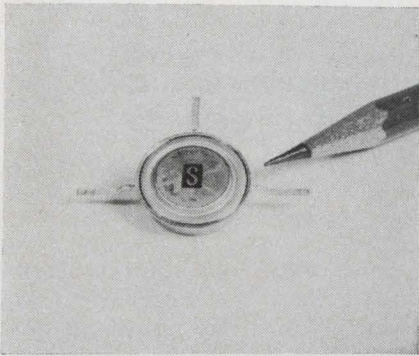
The transistors should find many new applications. For example, in a differential amplifier configuration, it is possible to obtain a 20-V p-p sine wave. This application is typical of electrostatic CRT deflection plate drivers. Low-deflection sensi-

tivities 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

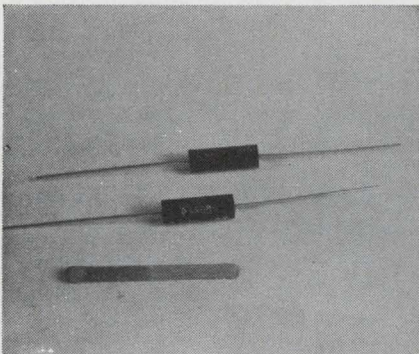


Si power transistors available in flat-packs

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



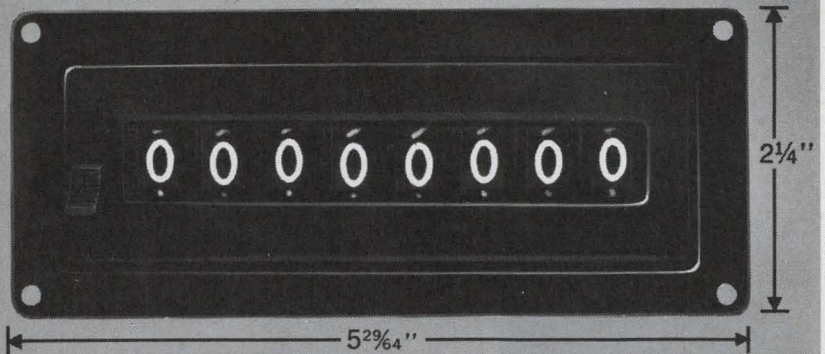
Silicon resistors detect temperature

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 de-rated to zero at 150°C. Resistance values are available from 68 Ω to 10 kΩ.

CIRCLE NO. 246

LOOK WHAT HAPPENED WHEN WE INVENTED PLANETGEAR® TO REPLACE THE OLD GENEVA



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ON READER-SERVICE CARD CIRCLE 76

SEMICONDUCTORS

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

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116

TEST EQUIPMENT

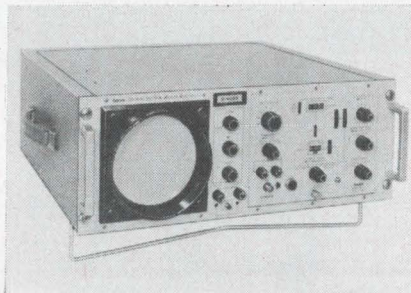


Ordinary scopes made microwave receivers

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

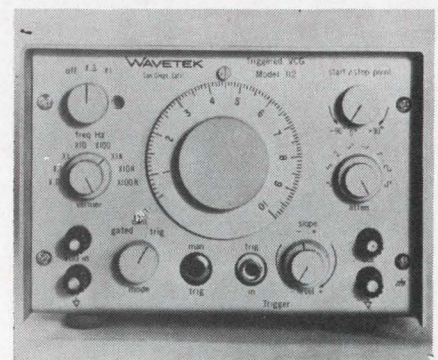


Video module joins spectrum analysis group

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

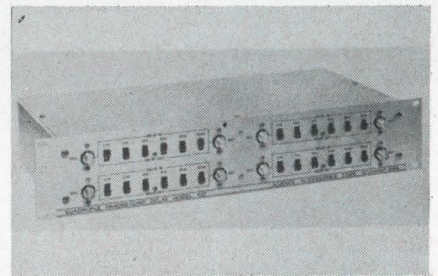


Function generator features versatility

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

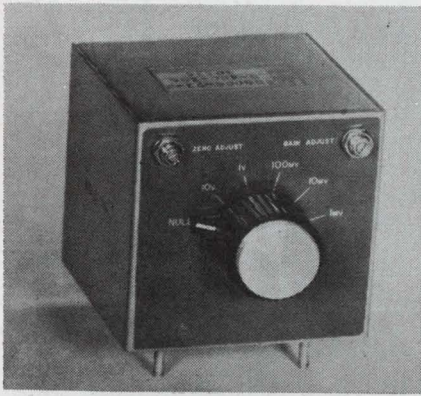


Precision delays switch in 10-ns increments

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 strip-line 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

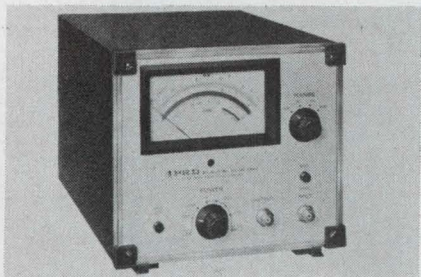


Ac/dc demodulator linear to 0.1%

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 k Ω with output below 1 k Ω . Gain is 1000 to 5000 and isolation between input, output and dc ground is 50 M Ω .

CIRCLE NO. 257



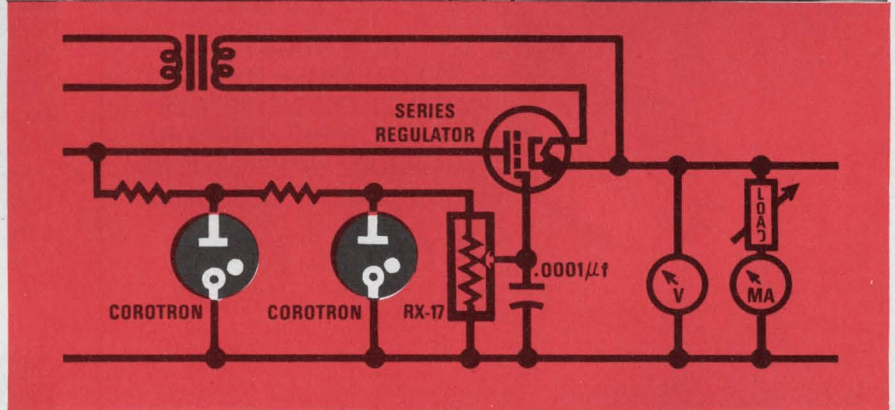
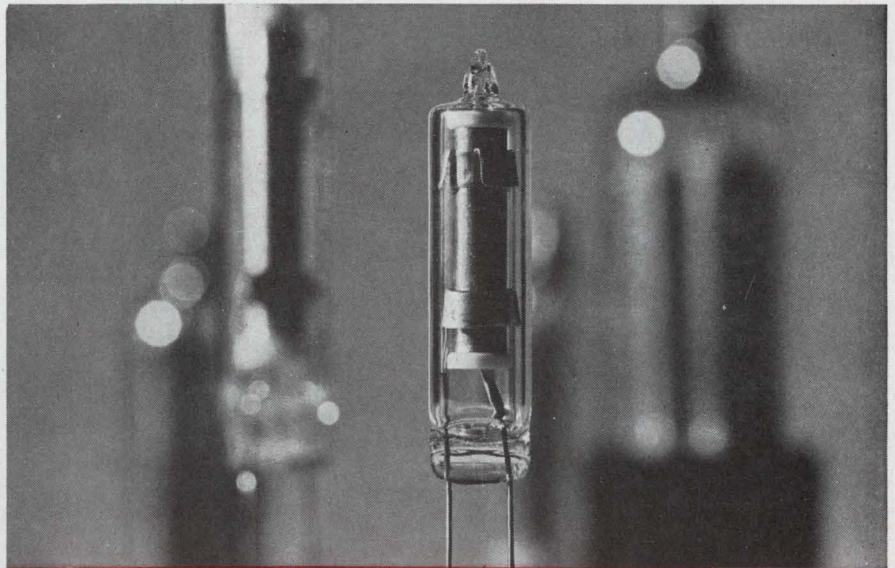
Power meter stands high RF environments

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

Versatility and simplicity in variable, regulated power supplies



REFERENCE AND REGULATION TO 30KV

Voltage regulation can never be better, nor more stable, than the reference voltage. And you'll never find a better reference than Victoreen diodes, high-voltage equivalents of Zener diodes. But, unlike Zeners, Victoreen HV diodes are available in voltage ranges from 350 to 30,000 volts.

Unexcelled as a stable reference voltage source, a Victoreen HV diode can also be used alone as a simple shunt regulator, as a DC coupling element, etc. For Space-Age applications, you get a lot of bonuses, too — small cubage, light weight, resistance to high heat, high vibration and high accelerations to 2000g in some models. Victoreen HV diodes are unaffected by ambient light.

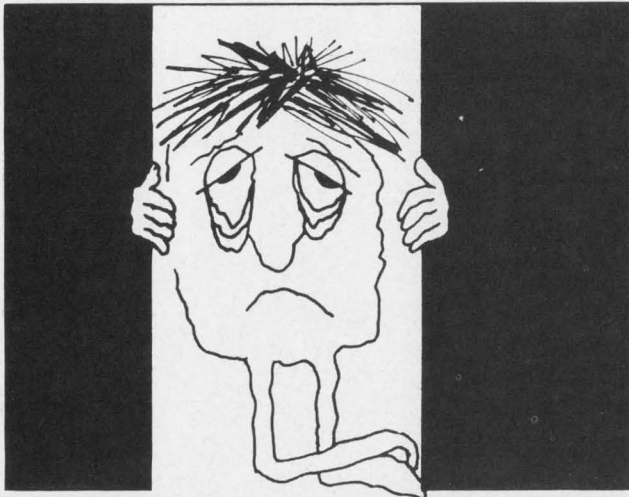
From the positively exotic to the commercial, if you have a voltage regulation problem in the range of 350 - 30,000 volts, quickly contact our Applications Engineering Department.

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*T.M., Sanders Associates, Inc.

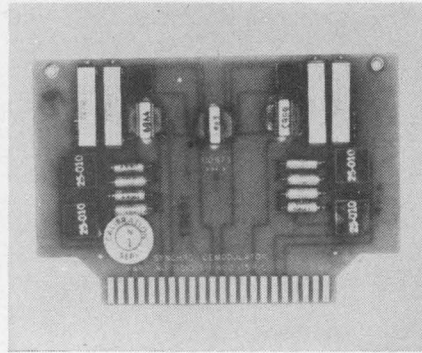


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TEST EQUIPMENT

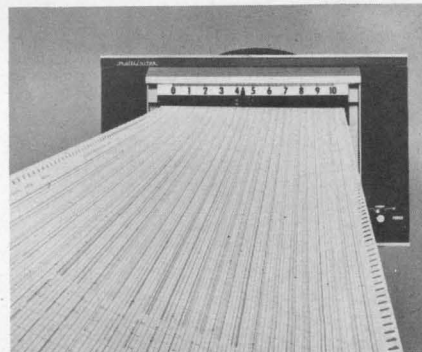


Synchro/dc converter accurate to 3 minutes

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

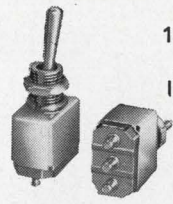


Multipoint recorder prints dots and numbers

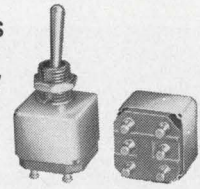
Texas Instruments, Inc., 3609 Buf-
falo Speedway, Houston. Phone:
(713) 526-1411. P&A: \$1450; 60
days.

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



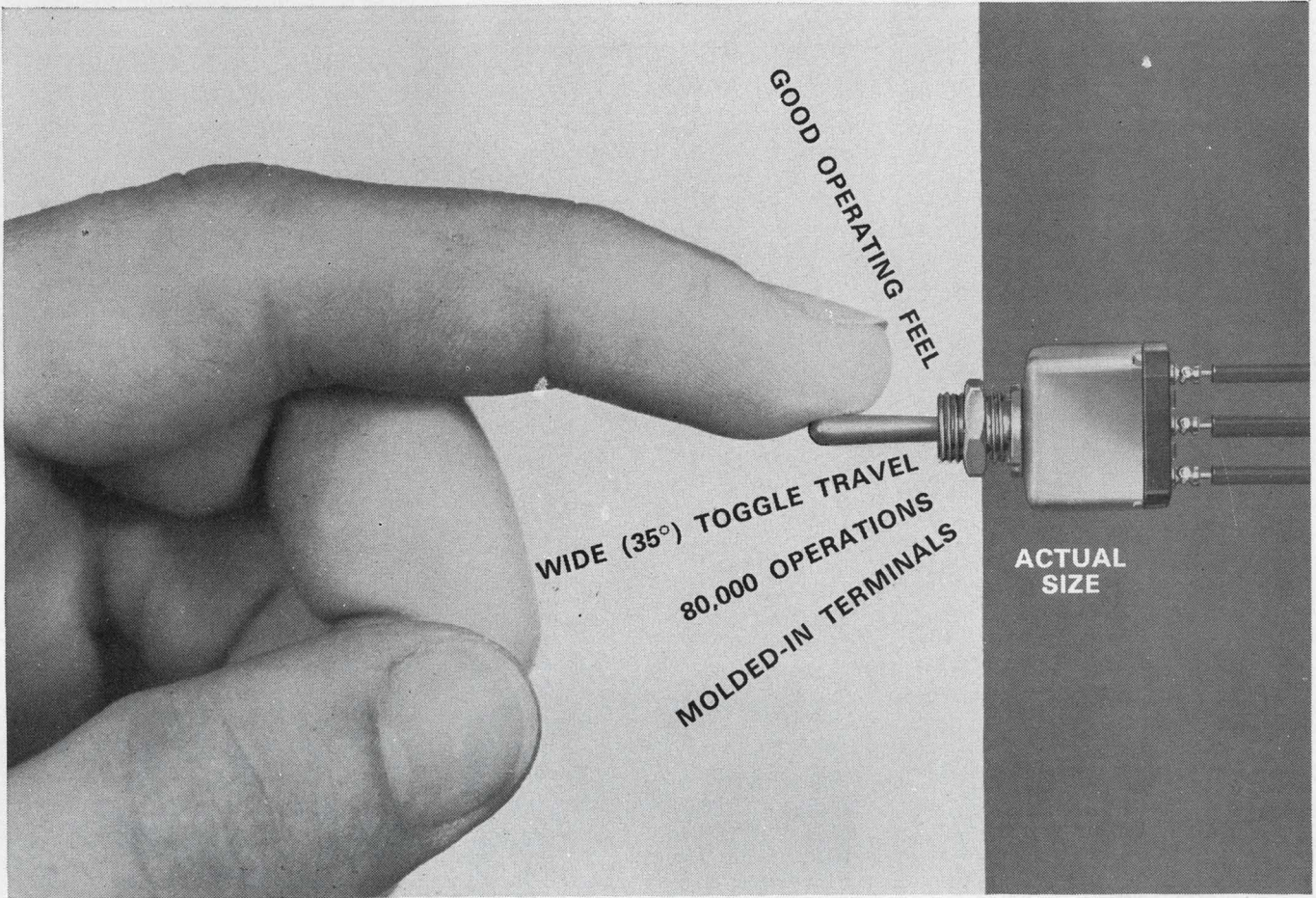
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AVAILABLE
IN THE NEW
TW
LINE.



SPDT

DPDT

- Maintained ON, Momentary ON
 - Maint. ON, Maint. ON
 - Mom. ON, OFF, Mom. ON
 - Maint. ON, OFF, Maint. ON
 - Maint. ON, OFF, Mom. ON



Biggest value yet in space-saving toggle switches

Here's the new little toggle that's big in the features you need. Space-saving size—only $\frac{5}{8}$ " behind the panel. Good operating feel—positive detents, optimum forces, positive return spring on momentary versions. Full versatility, too—ten versions offering SPDT or DPDT, 2 or 3 positions, maintained or momentary contact, 30 vdc or 115 vac, 5 amps resistive, 2 amps inductive.

Call a Branch Office or Distributor (Yellow Pages, "Switches, Electric"). Ask about TW switches. Or, write for Catalog 51.

MICRO SWITCH

FREEPORT, ILLINOIS 61032

A DIVISION OF HONEYWELL

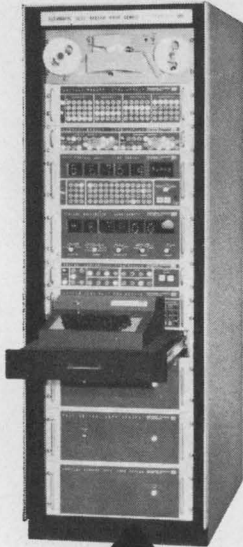
HONEYWELL INTERNATIONAL—Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

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...with the Auto Data 9400 Automatic Test System from

3M High speed GO/NO-GO comparisons, as well as DC, AC and resistance measurements, can be performed economically and reliably with the model 9400 system. Modular construction techniques are used throughout the system to provide off-the-shelf availability with "custom design" versatility. Complete provisions are included in the 9400 Series for logging, handling, and classifying. Economical and easy to use punched tape is provided for ease of programming and fast program change to satisfy small or large volume testing.

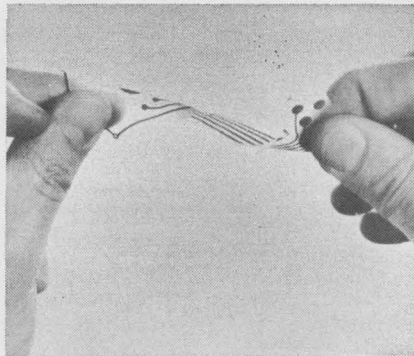
Write for detailed specifications.

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COMPANY

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PHONE: (805) 482-1911 • TWX: 510-866-7099

ON READER-SERVICE CARD CIRCLE 83

MATERIALS

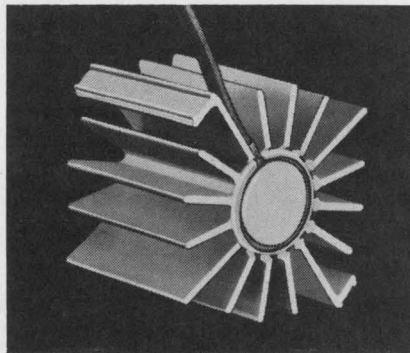


"Tough-job" laminate solves cable problems

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

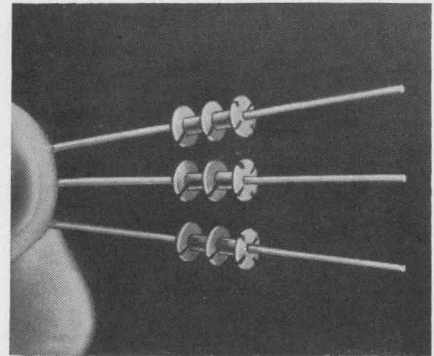


Ceramic heater set in aluminum body

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

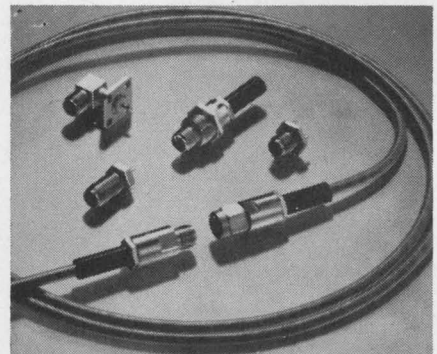


Resistor bobbins have four slots

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

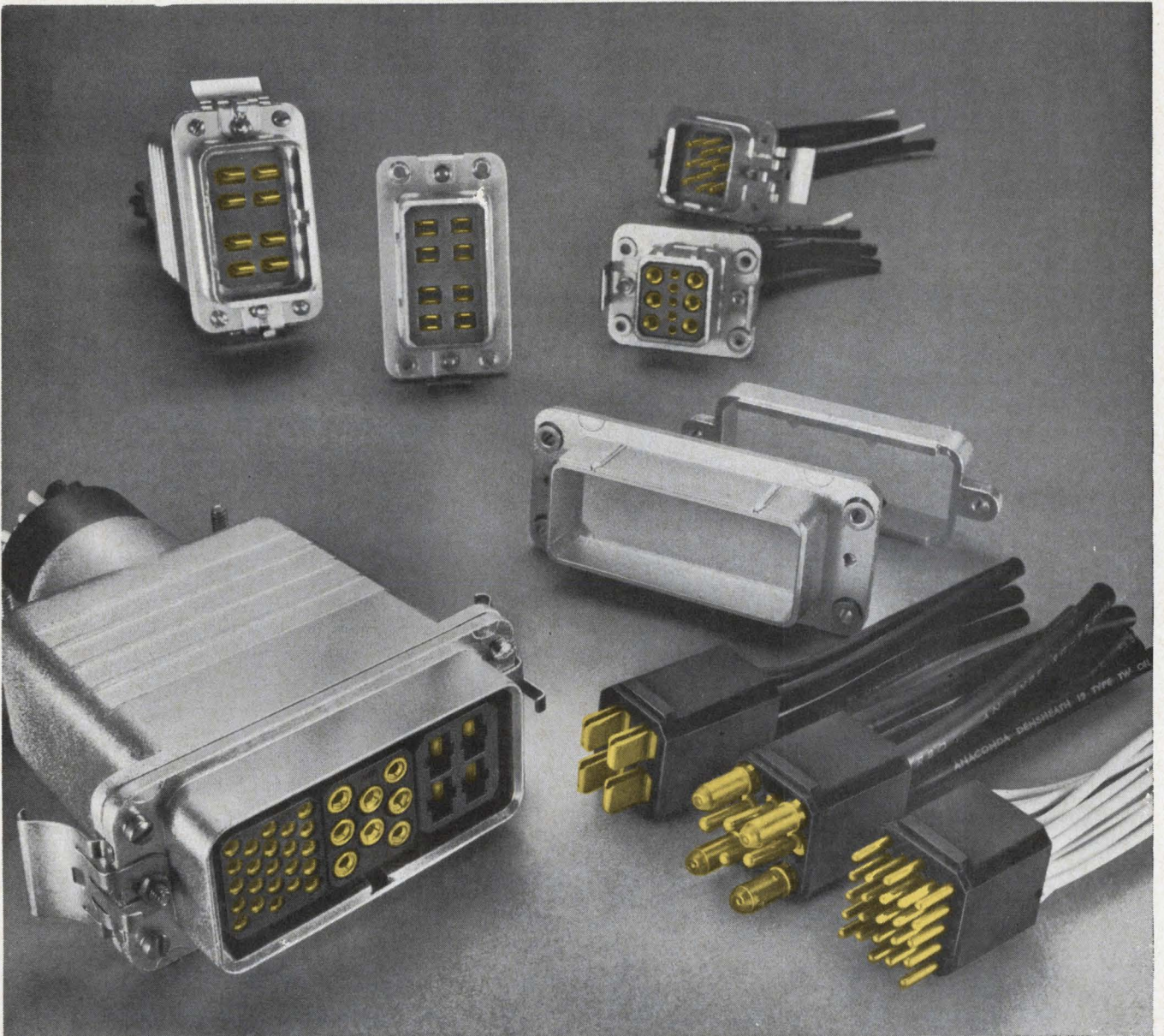


Coax connector line includes 8 types

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 feed-thrus 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.

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AMP
INCORPORATED
 Harrisburg, Pennsylvania

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Telrex

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Telrex Communication Engineering Laboratories provides the Most Technically-Perfected, Finest Communication Arrays — Precision Engineered, Manufactured, Tuned, Matched, Calibrated and "Balun" Fed for "Balanced-Pattern" and Maximum S/N Ratio.

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ANTENNAS AND
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The Standard of Comparison, and the Choice of the Discriminating, Successful, Communication Engineer.

Telrex Antennas and Antenna Systems provide Optimum Performance and Reliability per element, per dollar, from 500 Kc to 1500 Mc.

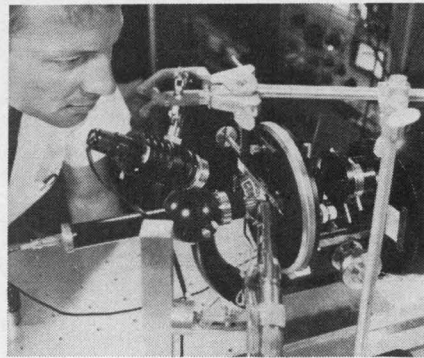
Send for free Military, Commercial Tech Catalog CMS67, illustrating Antennas and Systems, Rotator-Selsyn-Indicator Systems, "Baluns," Towers, Masts and Accessories.

COMMUNICATION SYSTEMS SINCE 1921 **telrex** Engineering Laboratories
ASBURY PARK, N. J. 07712, U.S.A.

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give...so more will live
HEART FUND

PRODUCTION EQUIPMENT

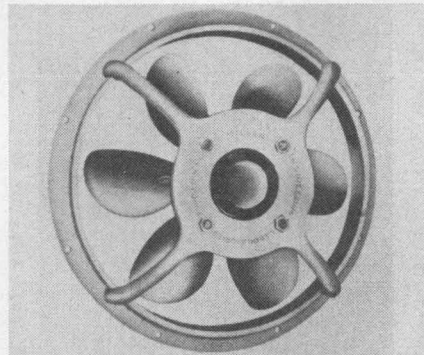


**Open-air cryogenics
without frost problems**

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 ft³/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

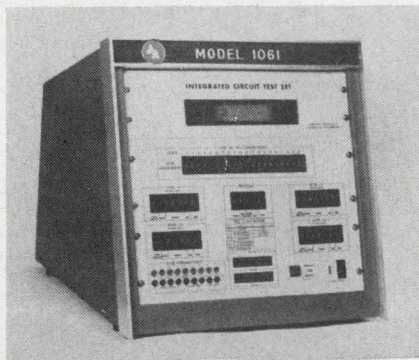


**MIL-type fans
use aluminum castings**

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



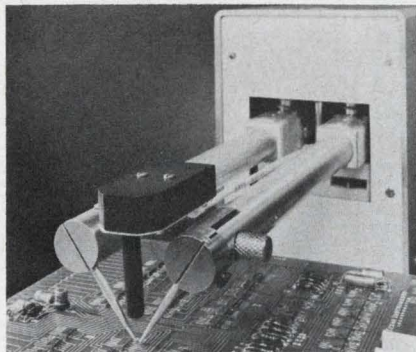
IC tester gives digital readout

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



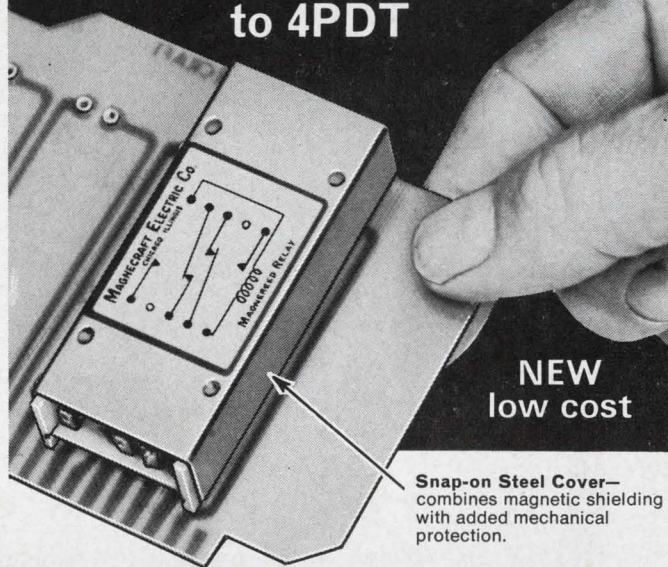
Automatic circuit bonder has infrared detection

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

Extra Reliable Multi-pak MPC Reed Relays to 4PDT



NEW
low cost

Snap-on Steel Cover—combines magnetic shielding with added mechanical protection.

MPC Features that assure stability

1. Rigid one-piece Terminal Supports and Pins are riveted into mortised positions on Epoxy Resin Terminal boards.

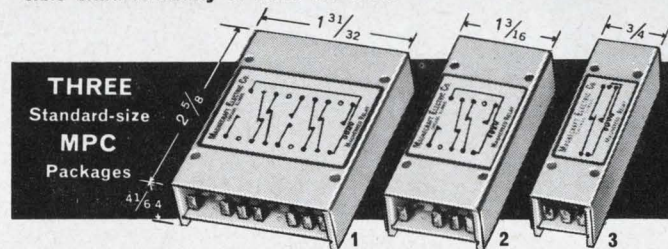
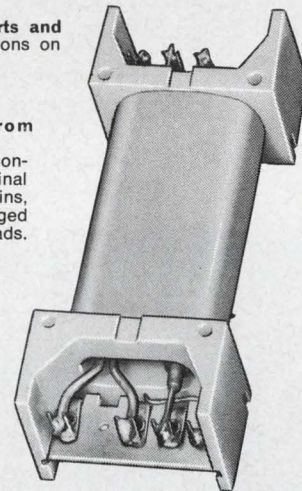
2. Contact Leads are protected from stresses that affect relay adjustment.

With the capsule in final position the contact leads are soldered to the rigid terminal supports. Stresses on the terminal pins, such as occur when the pins are plugged into the board, cannot transmit to the leads.

3. Great dielectric strength. The Nylon bobbin provides insulation from the circuit board and mechanical protection for the glass capsule.

4. Wide space between PC Pins. Pins for 0.062" holes are spaced on multiples of 0.200".

5. The unique design concept makes possible extra reliability at NEW low cost.



THREE
Standard-size
MPC
Packages

Size 1—available* with up to 4 form C or 7 form A dry reed contacts; also 7 form A Mercury-Wetted contacts.

Size 2—available* with up to 2 form C or 3 form A dry reed contacts; also 3 form A Mercury-Wetted contacts.

Size 3—available* with 1 form A, 1 form C, or magnetic latching dry reed contacts and Mercury-Wetted contacts; also in special high voltage and high current types.

*Furnished custom-built with contact combinations and ratings to specifications. Popular combinations and ratings for standard voltages in stock for immediate shipment.

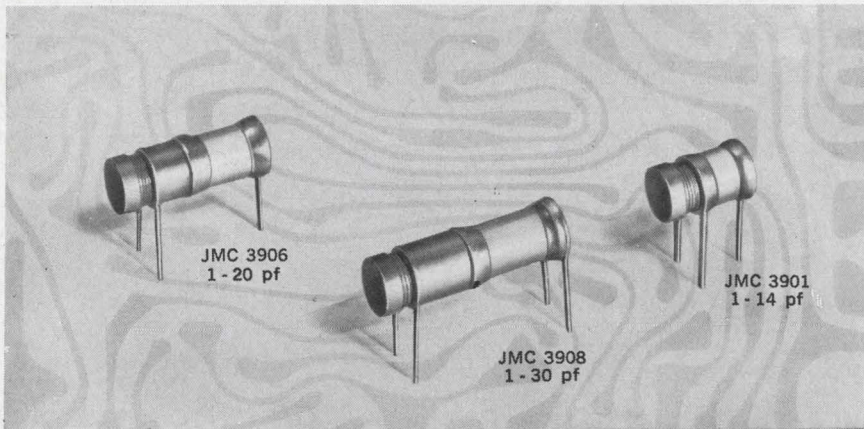
Send for literature describing the widest selection of Mercury-Wetted and Dry Reed Relays.

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5575 N. Lynch, Chicago, Ill. 60630

(312) 282-5500

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High Q Air Capacitors!

Get accuracy and tuning stability with Johanson Variable Air Capacitors. High Q—Low Inductance makes units suitable for VLF to UHF applications. Low temperature coefficient.

Working Voltage 250 V DC at from -55°C to $+125^{\circ}\text{C}$. All units are hermetically sealed.

Here's top reliability for military and industrial applications.

Write for catalog on

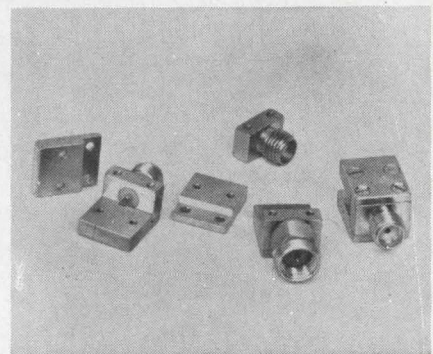
Johanson

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MANUFACTURING CORPORATION

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ON READER-SERVICE CARD CIRCLE 87

MICROWAVES



Stripline connectors simplify assembly

Elpac, Inc., 3760 Campus Dr., Newport Beach, Calif. Phone: (714) 546-8640.

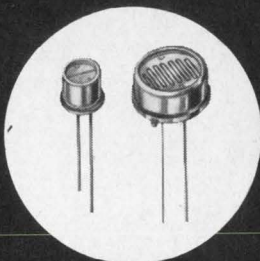
Designed for end-mounting on stripline circuit boards, these miniature microwave connectors have solid Teflon dielectric. The heat-treated beryllium copper center contact tab makes it possible to precut the stripline board to exact length and complete the assembly with a minimum of effort. The connectors mate with OSM, BRM and NPM connectors.

CIRCLE NO. 269

Photocell Decay Problems?

*Typesetter
lost a zero.
This should be
.0006*

Try Type 7H

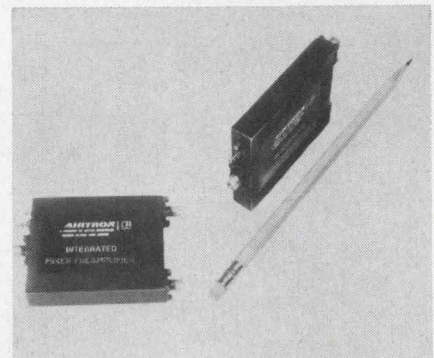


Clairex Type 7H Photocells now offer decay times of .006 sec @ 100 ft-c. Couple this with 240 ohms @ 100 ft-c, CdS stability, and your problems are solved. Available in TO-18 and TO-5 cases. And 6 resistance ranges.

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1239 Broadway, New York, N.Y. 10001
212 MU 4-0940

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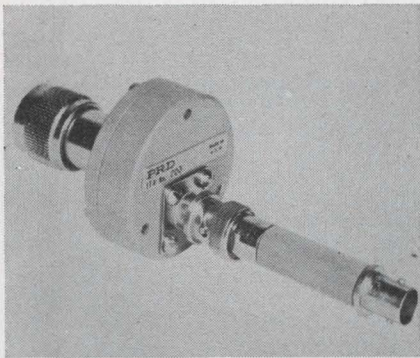


Mixer-preamps pre-aligned, calibrated

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

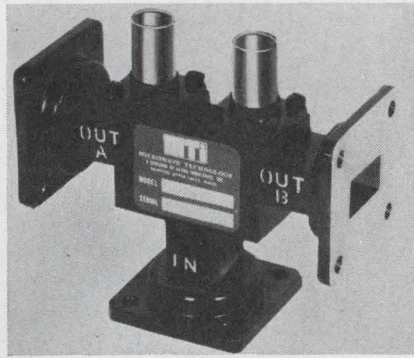


Bolometer mount attuned to system

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

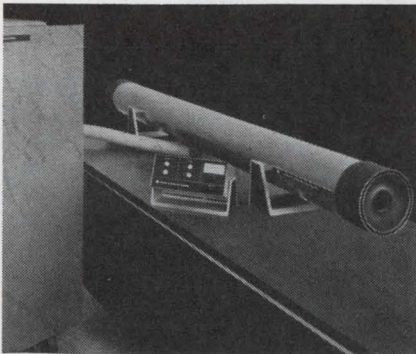


Ku-band diode switch has 20-W capability

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

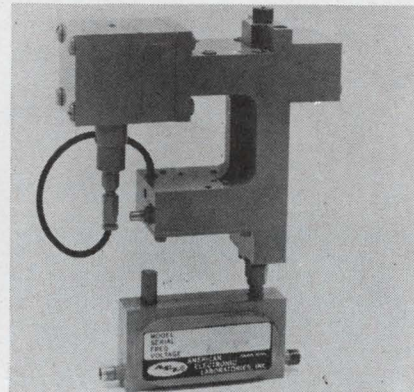


Cw gas laser produces 75 watts

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 CO₂, nitrogen and helium. In either industrial or lab applications, its major feature is its ability to provide a continuous energy density beyond 10⁶ watts/cm². A complete system consists of a service console, a control unit and the laser head.

CIRCLE NO. 272



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

how to tame a temperature problem



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retains its flexibility and electrical properties in continuous operation at temperatures up to 155°C. Even after 1000 hours, it will not crack when bent 180° around a mandrel. Constructed of closely woven fiberglass, it is thoroughly impregnated and uniformly coated with modified acrylics, making it compatible with most wire enamels and encapsulants and resistant to oils, acids, alkalis, jet fluid, fox and water. Good resistance to abrasion and cut-through—non-wicking. Write for samples, data and prices.

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INSULATING TUBINGS AND SLEEVINGS
HIGH TEMPERATURE WIRE AND CABLE

Design Aids

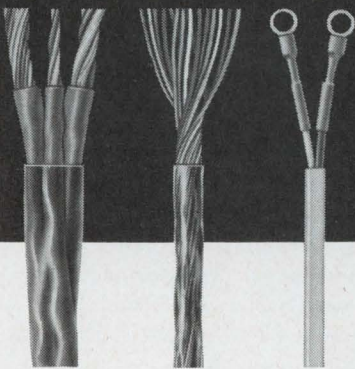
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THE L. S. STARRETT COMPANY - World's Greatest Toolmakers - ATHOL, MASSACHUSETTS, U. S. A.			
FRACTION OR DRILL SIZE	DECIMAL	TAP SIZE	FRACTION OR DRILL SIZE
1/64	.0156	7/64	.1094
1/32	.0312	9/64	.1406
3/64	.0469	11/64	.1719
1/16	.0625	13/64	.2031
5/64	.0781	15/64	.2344
3/32	.0938	17/64	.2656
1/8	.1250	19/64	.2969
9/64	.1406	21/64	.3281
7/32	.2188	23/64	.3594
1/4	.2500	25/64	.3906
5/16	.3125	27/64	.4219
3/8	.3750	29/64	.4531
7/16	.4375	31/64	.4844
1/2	.5000	33/64	.5156
5/8	.6250	35/64	.5469
3/4	.7500	37/64	.5781
7/8	.8750	39/64	.6094
1	1.0000	41/64	.6406
		43/64	.6719
		45/64	.7031
		47/64	.7344
		49/64	.7656
		51/64	.7969
		53/64	.8281
		55/64	.8594
		57/64	.8906
		59/64	.9219
		61/64	.9531
		63/64	.9844
		65/64	1.0156
		67/64	1.0469
		69/64	1.0781
		71/64	1.1094
		73/64	1.1406
		75/64	1.1719
		77/64	1.2031
		79/64	1.2344
		81/64	1.2656
		83/64	1.2969
		85/64	1.3281
		87/64	1.3594
		89/64	1.3906
		91/64	1.4219
		93/64	1.4531
		95/64	1.4844
		97/64	1.5156
		99/64	1.5469
		101/64	1.5781
		103/64	1.6094
		105/64	1.6406
		107/64	1.6719
		109/64	1.7031
		111/64	1.7344
		113/64	1.7656
		115/64	1.7969
		117/64	1.8281
		119/64	1.8594
		121/64	1.8906
		123/64	1.9219
		125/64	1.9531
		127/64	1.9844
		129/64	2.0156
		131/64	2.0469
		133/64	2.0781
		135/64	2.1094
		137/64	2.1406
		139/64	2.1719
		141/64	2.2031
		143/64	2.2344
		145/64	2.2656
		147/64	2.2969
		149/64	2.3281
		151/64	2.3594
		153/64	2.3906
		155/64	2.4219
		157/64	2.4531
		159/64	2.4844
		161/64	2.5156
		163/64	2.5469
		165/64	2.5781
		167/64	2.6094
		169/64	2.6406
		171/64	2.6719
		173/64	2.7031
		175/64	2.7344
		177/64	2.7656
		179/64	2.7969
		181/64	2.8281
		183/64	2.8594
		185/64	2.8906
		187/64	2.9219
		189/64	2.9531
		191/64	2.9844
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		595/64	9.296

HST

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THE BELDEN WAY



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We stock the colors . . . the sizes . . . the lengths. Who else can take care of so many of your applications with immediate service from stock?

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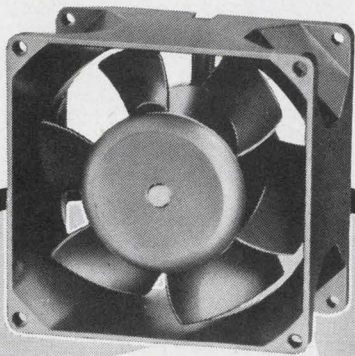
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a 3 1/2" fan
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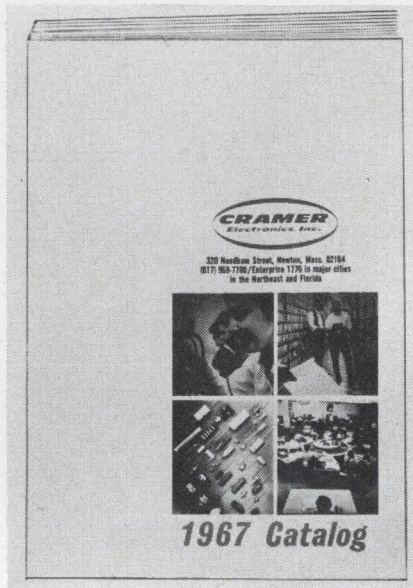
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PAMOTOR, INC.

312 SEVENTH STREET • SAN FRANCISCO, CALIF.

ON READER-SERVICE CARD CIRCLE 97

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

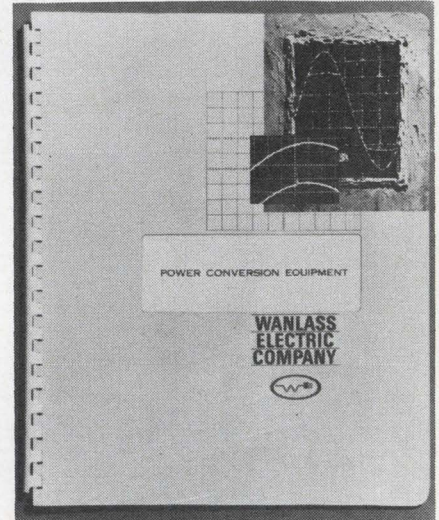
This 16-page paper, dealing with today's state-of-the-art input conditioning, emphasizes constant current techniques. Frequency response of constant current power supplies, and guarding and shielding for input conditioners are explored. B & F Instruments, Inc.

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.

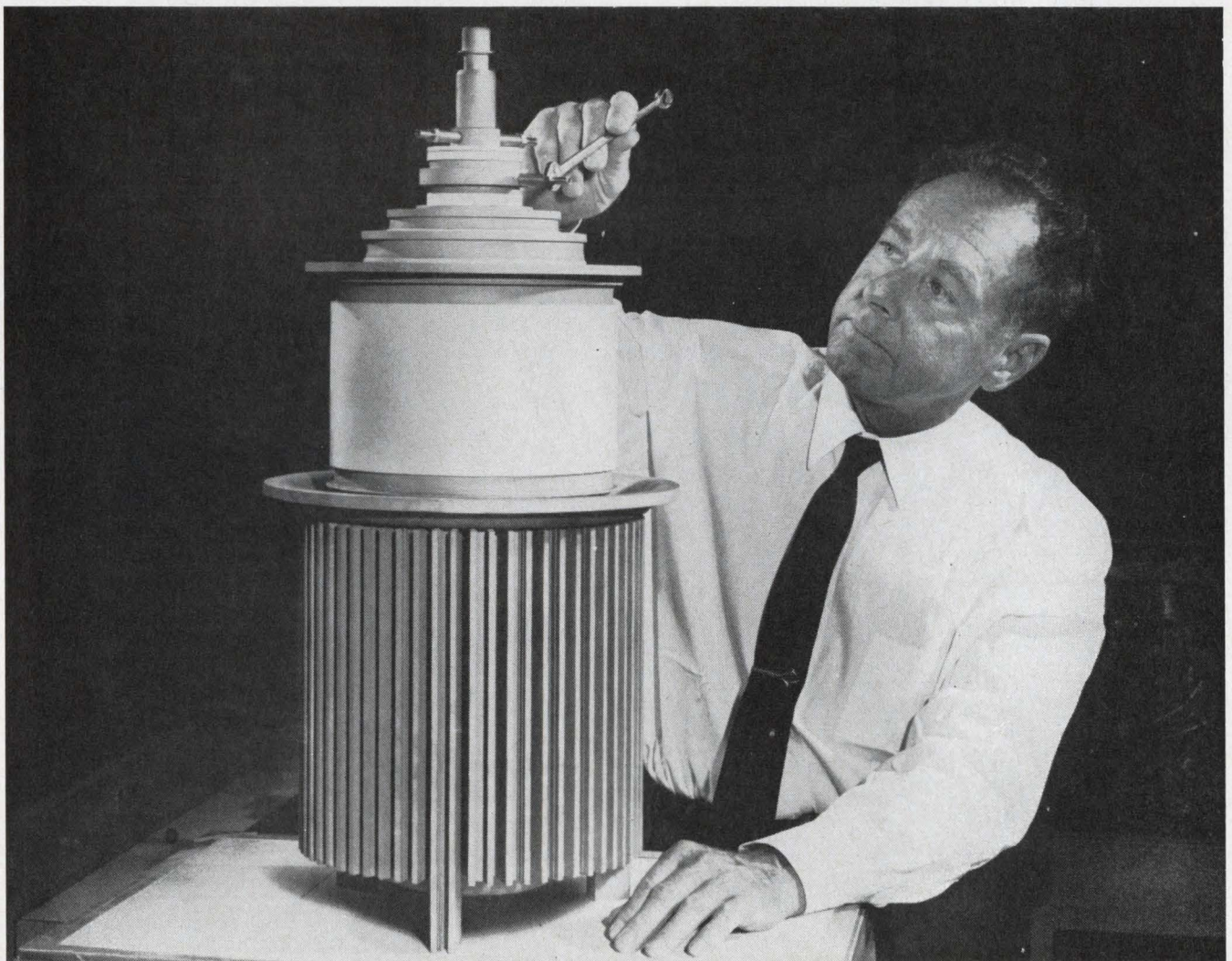
CIRCLE NO. 281

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

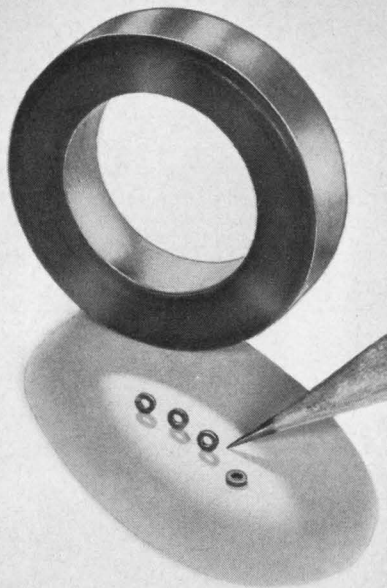


ON READER-SERVICE CARD CIRCLE 91

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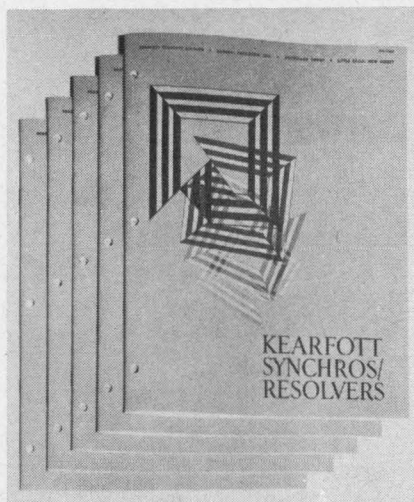
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NEW LITERATURE



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

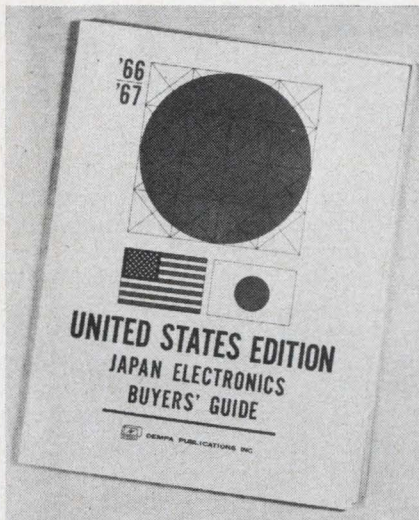
A 2-page illustrated data sheet describing the KH model 3100 solid-state variable band-pass filter includes a composite graph of maximally flat, and transient-free, frequency-response modes. Oscilloscope photographs of these responses are shown. Krohn-Hite Corp.

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

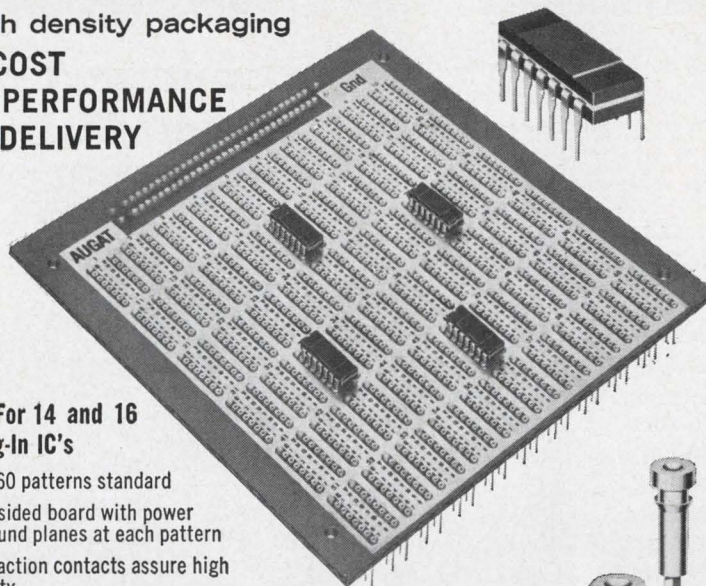
A 2-page, 2-color brochure describes a pulse counter and storage device, used with the manufacturer's scanning transmitter to count accurately and reliably randomly occurring pulses such as watt-hour pulses originating in a remote station, and transmit the total count to a master station. Quindar Electronics, Inc.

CIRCLE NO. 292

IC PACKAGING PANELS

for high density packaging

**LOW COST
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FAST DELIVERY**



**PANELS For 14 and 16
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Request Catalog 364 describing our complete line of integrated circuit products for Testing, Breadboarding and Packaging.

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ON READER-SERVICE CARD CIRCLE 94

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- 69 Technical Sessions at the New York Hilton. Hours: Mon. 9:30-12:00 a.m.; 2:00-4:30 p.m. — other days 9:00-11:30 a.m.; 2:00-4:30 p.m.
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ON READER-SERVICE CARD CIRCLE 95

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)

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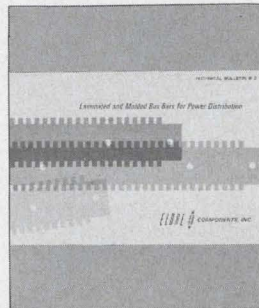
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Microfilm copies of all 1961, 1962, 1963, 1964 and 1965 issues of ELECTRONIC DESIGN are available through University Microfilms, Inc., 313 N. First Street, Ann Arbor, Mich.

Design Data from

Laminated and Molded Bus Bars For Power Distribution



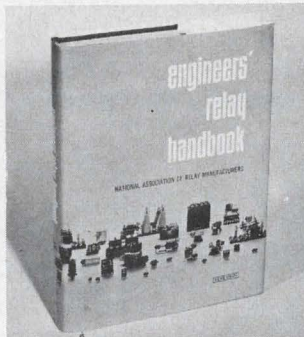
A 16 page Technical Bulletin is now available, describing a new concept in power distribution. Basic mechanical and electrical design principles, along with descriptive pictures and diagrams, are included in this bulletin. These compact buses can replace bulky cable harnesses and repetitive wiring for 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

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Engineers' Relay Handbook



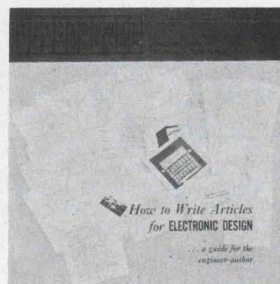
A definitive work that is fast becoming a standard reference text for the relay user. Prepared and edited by the National Association of Relay Manufacturers, this book is a complete guide to the principles, properties, performance characteristics, application requirements, specifications, and testing 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.

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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.

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Manufacturers

Advertisements of booklets, brochures, catalogs and data sheets. To order use Reader-ServiceCard.

Schweber Catalog of Westinghouse Semiconductors



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

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Solid-Jacketed MicroCoax Cable



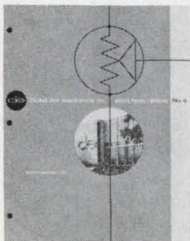
MicroDelay Division's new Bulletin 202C describes miniature solid-jacketed coaxial cable providing total shielding and improved environmental stability. Seamless tubular jackets of copper, aluminum and stainless steel eliminate crosstalk and attenuation problems. More than 25 MicroCoax combinations of 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.

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Costa Mesa, California 92626

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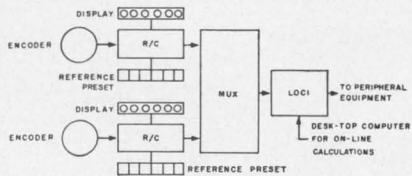
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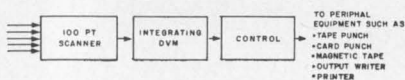


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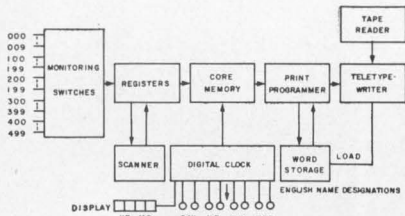
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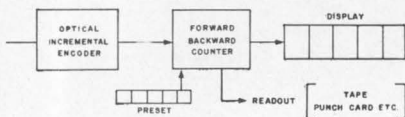
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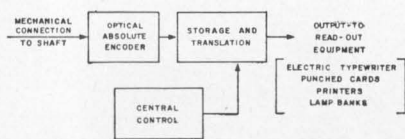
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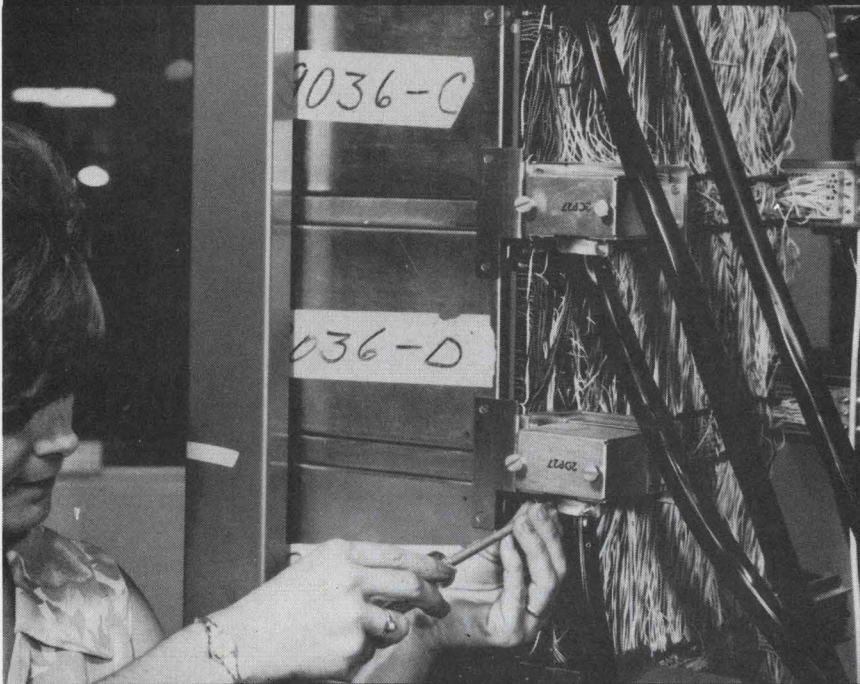
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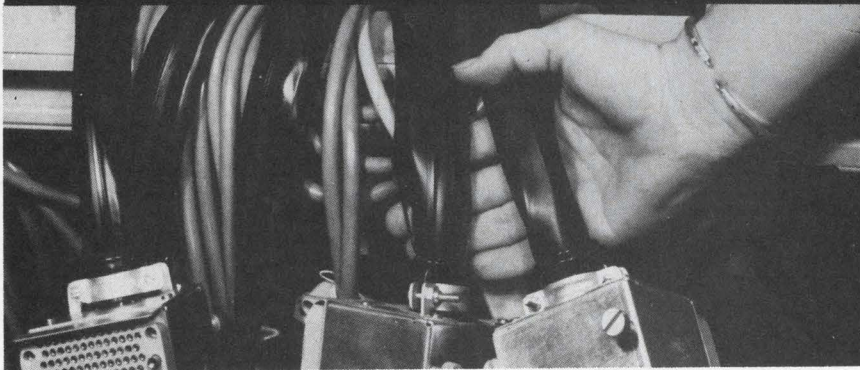
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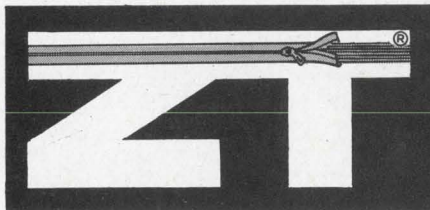
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Jan. 19-20

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

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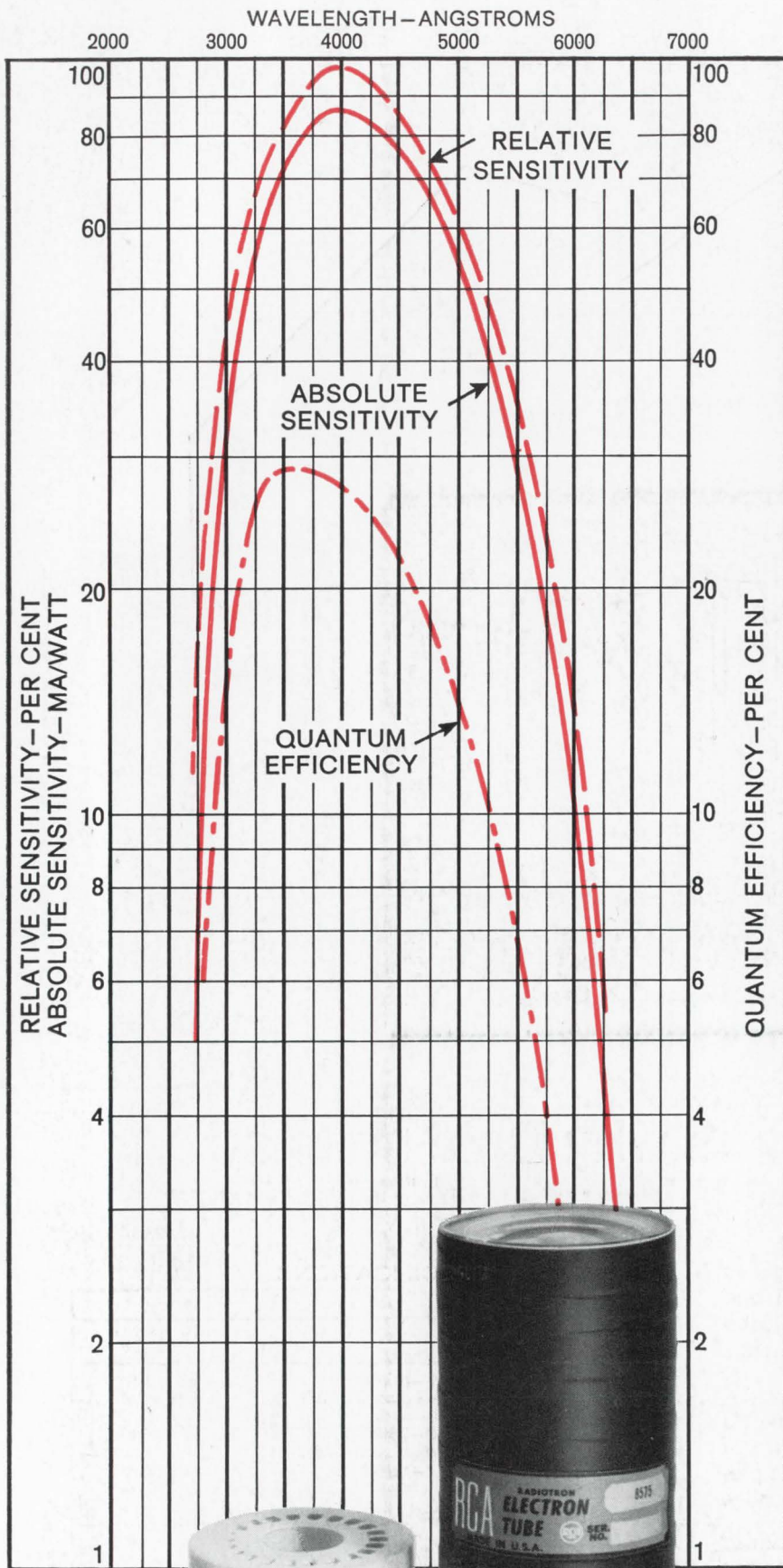
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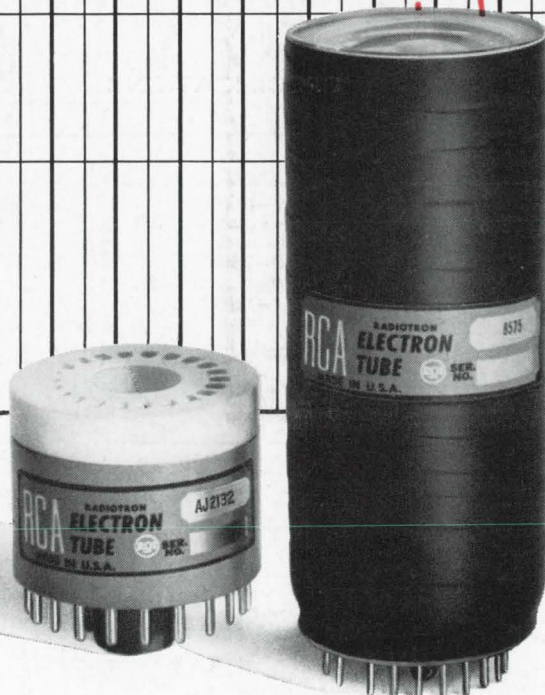
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