Electronics

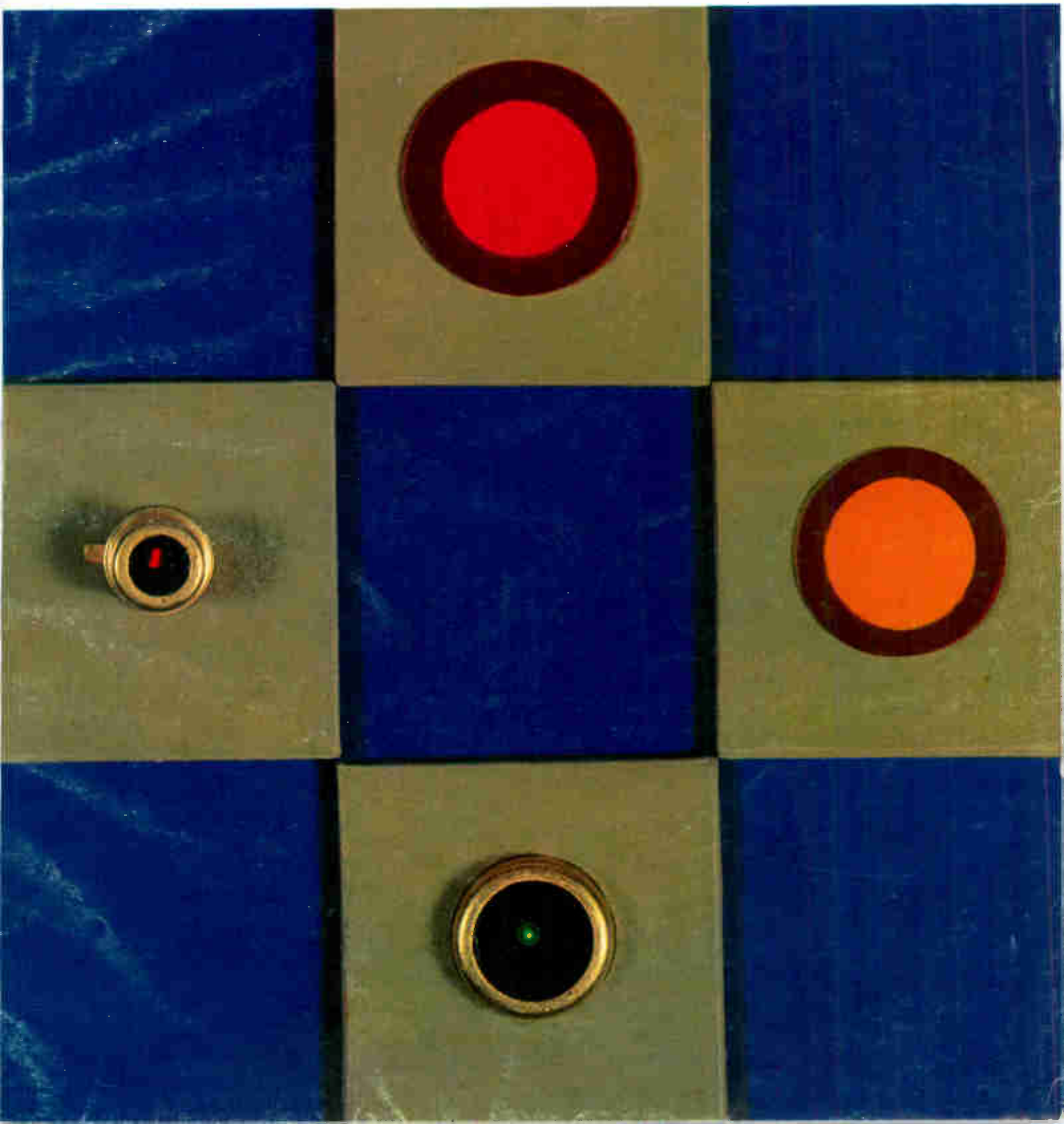
Tuning integrated circuits: page 114

Hall-effect multipliers for computers: page 120

Correcting errors in digital links: page 125

November 15, 1965
75 cents
A McGraw-Hill Publication

Below: Some new optoelectronic devices for new applications: page 98



PIONEERS IN MINIATURIZATION

HERMETICALLY SEALED

NOW to MIL-T-27B

VARIABLE INDUCTORS

HIGH-Q plus HIGHEST STABILITY

IMMEDIATE DELIVERY FROM STOCK

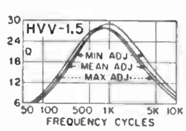
For almost a third of a century UTC has pioneered in the development of transformers, electric wave filters, high Q coils, magamps and similar iron core components. Highest engineering talent plus the most complete facilities for research and testing has made UTC the leading supplier in the industry for both stock and custom built components. UTC Variductors (stock variable inductors) have served as a simple solution to tuned circuit for almost 20 years . . . for oscillators, equalizers, filters, tuned radio circuits, etc.

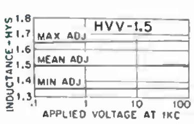
NEW! - VERNIER

HVV VARIDUCTOR™

HERMETICALLY SEALED

NARROW RANGE





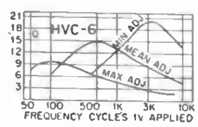
The HVV Variductors have been designed to emphasize extremely high stability with temperature, level, shock and vibration commensurate with the highest obtainable Q. They are ideal for precise matching to other components such as capacitors with standard 10% tolerance. Units are provided with a vernier adjustment variation of ±10% through 900° rotation of adjustment screw on top of case. Setting is positive. There are 12 units in the stock line with mean inductances ranging from .006 Hy to 150 Hys. Specific mean inductances other than stock items are available on special order. Manufactured and guaranteed to MIL-T-27B, MIL type TF4RX20YY. Drawn metal case: 1⅛" long, 25/32" wide, 1-7/32" high (including adjustment screw); weight: 2 ounces. Effective Q over a wide frequency range and variation of inductance with applied AC voltage are illustrated for a typical unit. Patent pending.

HVC VARIDUCTOR™

HERMETICALLY SEALED

WIDE RANGE

HVC units are usable over a wide frequency range and have high stability with temperature and voltage change. Nominal inductance values of 12 stock units in series range from .006 Hy to 150 Hys. The variable inductance range of each unit is +200%, −70% of nominal value through 900° rotation of adjusting screw on top of case. Setting is positive. Case size and weight is the same as HVV. U.S. Patent No. 2,879,489.



TVC VARIDUCTOR™

TVC Variductors are identical to the HVC units, but provide taps at 30% and 50% of total turns. Different taps are available on special order. U.S. Patent No. 2,879,489.

WIDE RANGE

VIC VARIDUCTOR™

COMMERCIAL GRADE

Nominal inductance values of 22 stock items in this series range from .0085 Hy to 130 Hys. Mean inductance may be varied +85%, −45% through 600° rotation of adjustment screw in side of case. Rugged die cast case: 1-11/13" long, 1¼" wide, 1-7/16" high; weight 5½ ounces.

AND "SPECIAL" CUSTOM BUILT UNITS TO YOUR SPECIFICATIONS

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

UNITED TRANSFORMER CORP.

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Circle 900 on reader service card

DISTORTION ANALYZERS GO SOLID-STATE

to offer you harmonic distortion measurements 5 cps to 600 kc with 0.1% full-scale distortion sensitivity...plus these features:

- **"AUTOMATIC NULLING" for simple, fast measurements**
- **0.3 v rms input sensitivity for 100% Set Level reference**
- **300 μv rms voltmeter full-scale sensitivity (residual noise <25 μv)**

Solid-state design in four Hewlett-Packard distortion analyzers offers you extended frequency range, greater Set Level sensitivity, improved selectivity, greater overall accuracy, unprecedented ease of use. All four measure total distortion down to 0.1% full scale, 5 cps to 600 kc, with harmonics indicated to 3 mc. They measure voltage 300 μv to 300 v full scale, have flat frequency response 5 cps to 3 mc. Distortion analyzer and voltmeter input terminals are the same. One-megohm input impedance. Floating input and floating, low-distortion output for scope or true rms voltmeter monitoring.

Two models feature automatic fundamental nulling (>80 db rejection): Manually null to less than 10% of the Set Level reference, flip a switch, and nulling is completed automatically. No more tedious tuning on the more sensitive ranges! Two other models employ high reduction gear drive to aid manual tuning.

Two of the analyzers provide a switchable high-pass filter which attenuates frequencies below 400 cps on signals greater than 1 kc . . . removes hum and gives you pure distortion measurements.

Two models incorporate an amplitude modulation detector that covers 500 kc to greater than 65 mc, measures distortion at carrier levels as low as 1 v. Options include an indicating meter with VU ballistic characteristics (01) and rear terminals in parallel with front input terminals (02).

Ask your Hewlett-Packard field engineer for a demonstration of the model incorporating features most useful to your application. Or write for technical data on all four models to Hewlett-Packard, Palo Alto, Calif. 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva; Canada: 8270 Mayrand St., Montreal.

Model	Automatic Fundamental Nulling	High-Pass Filter	AM Detector	Gear Reduction Tuning	Price
331A				√	$590
332A			√	√	$620
333A	√	√			$760
334A	√	√	√		$790

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

HEWLETT hp PACKARD
An extra measure of quality

421

Circle 1 on reader service card

Type 230-A

10 to 500 MC POWER AMPLIFIER

— for Low-Level Applications

The BRC Power Amplifier Type 230-A is the ideal RF amplifier for low-level applications exhibiting a typical noise figure of 6 to 8 db. Three tuned, cascaded stages of grounded-grid amplification provide up to 30 db gain and a maximum power output of 5 watts. Typical applications include:

RECEIVER PRE-SELECTOR — The Type 230-A, when used as a pre-selector with conventional communications receivers, will readily provide fractional microvolt sensitivities.

TUNED SELECTIVE FILTER — BRC 230-A provides a convenient means for the selective amplification of RF signals in the 10 to 500 Mc. range with excellent rejection of undesired frequencies.

HARMONIC AMPLIFIER — The new power amplifier may be used to amplify desired harmonics in the output of signal generators and frequency synthesizers thereby extending their useful range.

FREQUENCY COUNTER PRE-AMPLIFIER — Type 230-A as a pre-amplifier for conventional frequency counters, such as the (hp) 524/525, will provide a 15 to 30 times improvement in input sensitivity. Remote, off-the-air frequency measurements of FM broadcast and communication transmitters may be readily performed.

RF MILLIVOLTMETER PRE-AMPLIFIER — When used as a pre-amplifier for RF millivoltmeters, such as the (hp) 411, the 230-A will provide 15 to 30 times improvement in sensitivity.

HEWLETT PACKARD hp *BOONTON DIVISION*

GREEN POND ROAD, ROCKAWAY, NEW JERSEY 07866
Tel. (201) 627-6400 TWX: (510) 238-8461 Cable Address: BOONRACO

RF RANGE: 10 to 500 Mc.
BAND RANGES: 10-18.5 Mc., 18.5-35 Mc., 35-65 Mc., 65-125 Mc., 125-250 Mc., 250-500 Mc.

RF GAIN: 30 db (10-125 Mc.)
27 db (125-250 Mc.)
24 db (250-500 Mc.)

RF BANDWIDTH: >700 Kc.*(10-150 Mc.)
>1.4 Mc.*(150-500 Mc.)
*Frequency interval between points 3db down from max. response

RF OUTPUT:
RANGE: Up to 15 volts*
*Across external 50 ohm load
IMPEDANCE: 50 ohms.

CALIBRATION:
0.2 to 3 volts f.s.; increments of approx. 5%.
1.0 to 10 volts f.s.; increments of approx. 5%.
2.0 to 30 volts f.s.; increments of approx. 5%.
ACCURACY: ±1.0 db of f.s. (10-250 Mc.).
±1.5 db of f.s. (250-500 Mc.).
LEAKAGE: Effective shielding is greater than 40 db.

RF INPUT:
LEVEL: ≤0.316 volts* (10-125 Mc.)
≤0.446 volts* (125-250 Mc.)
≤0.630 volts* (250-500 Mc.)
*For 10 volt output into 50 ohms
IMPEDANCE: 50 ohms

AM RANGE: Reproduces modulation of driving source 0-100% up to 5 volt max. carrier output

AM DISTORTION: <10% added to distortion of driving source

FM RANGE: Reproduces modulation of driving source except as limited by the RF bandwidth

FM DISTORTION: Negligible distortion added to distortion of driving source for deviations and modulation frequencies <150 Kc.

INCIDENTAL AM: <10% added to modulation of driving source at 150 Kc. deviation

MOUNTING: Cabinet for bench use; by removal of extruded strips suitable for 19" rack mounting

POWER REQUIREMENTS:
105-125/210-250 volts,
50-60 cps, 150 watts

Price: **$1200.00** F.O.B. Rockaway, N. J.

Electronics

November 15, 1965
Volume 38, Number 23

Electronics Review

Probing the News

Electronics Abroad

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I. Design

II. Application

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Readers Comment

Getting a bad name?

To the Editor:

When choosing integrated circuits, a buyer has to beware when manufacturers tell him what leak rates mean. Because of package deterioration, I fear that integrated circuits are going to fail at a wholesale rate after a period of use and give the integrated circuit industry a bad name that will be hard to live down.

There is considerable disagreement as to how much additional protection a "planar passivated" silicon device requires. In the temperature and humidity controlled clean rooms where they are manufactured, they function without any packaging at all, and may be stored unpackaged for long periods without any degradation except surface moisture leakage which is remedied by drying under a heat lamp.

However, most users of semiconductors ship their equipment all over the world with little or no control or knowledge of the amount of water vapor, sulphur dioxide, smog, or other chemically active agents in the air surrounding the equipment. For this reason, they generally require their semiconductors to be "hermetically" sealed.

A hermetic seal is specified as not exceeding a certain "leak rate" measured in cubic centimeter per second. Since the purpose of the package is to prevent an exchange between the atmosphere in the package and the atmosphere outside the package, the effectiveness of the package may be indicated by the time required for a volume of ambient gas, equal to the volume of the package, to penetrate the package. Ideally, this time should be long, compared to the expected life of the device.

Consider the low profile TO-5 can. The leak rate is normally specified at less than 1×10^{-8} cc/sec and the volume of the package is 0.11 cc. The "exchange time" would be 130 days. However, the situation is really better than that, because the helium leak detectors commonly used to measure leak rates are not sensitive much below 1×10^{-8} cc/sec, so most of the

Did you know Sprague makes...?

UNICIRCUIT® RCTL INTEGRATED CIRCUITS

(8x actual size)

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

Circle 261 on reader service card

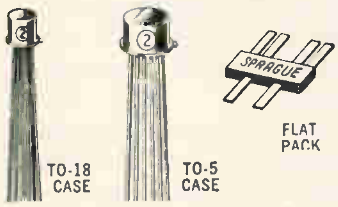
UNICIRCUIT® RTL INTEGRATED CIRCUITS

TO-5 CASE

Types US-0708 through US-0721 . . . Fully interchangeable mW digital building blocks featuring power consumption of 4 mW/node and propagation delay of 40 nanoseconds.

Circle 262 on reader service card

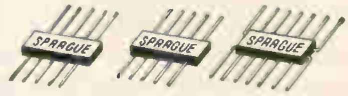
DIFFERENTIAL AMPLIFIER TRANSISTOR PAIRS



NPN or PNP • Matched characteristics.
h_{FE} = 10-20%. ΔV_{BE} = 5-20 mV.
ΔV_{BE}/Temp = 5-20 μV/°C.

Circle 263 on reader service card

MULTIPLE TRANSISTORS (NPN-PNP PAIRS/QUADS)

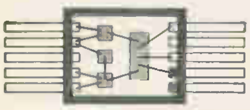


AMPLIFIERS SWITCHES CHOPPERS

Pairs	Quads
2 NPN	4 NPN
2 PNP	4 PNP
1 NPN—1 PNP	2 NPN—2 PNP

Circle 264 on reader service card

UNICIRCUIT® CUSTOM HYBRID CIRCUITS



Combine monolithic silicon circuits with Ni-Cr alloy resistors. Close resistance tolerances, low temperature coefficient, ±2% resistor matching.

Circle 265 on reader service card

LOW-COST HERMETICALLY-SEALED PLANAR TRANSISTORS

TN55-TN58
Low Level Amplifiers
TN59-TN64
General Purpose Switch/Amplifiers
TN79-TN80
Chopper Transistors
TN81
Power Amplifier
TN237-TN238
Gold Doped Core Drivers

TO-18 CASE

TO-5 CASE

Circle 266 on reader service card

SILICON ALLOY REPLACEMENT TRANSISTORS

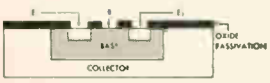
FULL PLANAR RELIABILITY

2N327A	2N945	2N1026
2N328A	2N946	2N1469
2N329A	2N1025	2N1917

Sprague makes 82 standard high-emitter-voltage full planar silicon alloy replacement types.

Circle 267 on reader service card

DUET* HIGH-VOLTAGE DUAL-EMITTER TRANSISTORS



New Type 3N123 low-cost transistor with 25-volt rating now available.

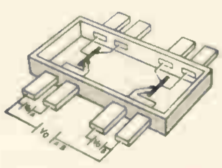
• • •

Sprague makes more dual-emitter chopper transistors than any other source.

*Trademark

Circle 268 on reader service card

TWIN DUET* DUAL-EMITTER TRANSISTORS IN FLAT PACKS



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

*Trademark

Circle 269 on reader service card

For complete technical data on any of these products, write to Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Massachusetts 01248.

455-5152

SPRAGUE®
THE MARK OF RELIABILITY

'Sprague' and '②' are registered trademarks of the Sprague Electric Co.

PULSES

Type 1398-A Pulse Generator

2.5 c/s to 1.2 Mc/s

0.1 μsec to 1.1 sec

The Type 1398-A is designed to meet a broad range of pulse testing needs in a single, economical package. Like the popular Type 1217, this new Pulse Generator has repetition rates that allow it to reach easily from low frequencies to the high speeds of computer circuits, while its continuously adjustable 0.1-μsec to 1.1-sec duration control covers the entire range of commonly used pulse widths. Other features include high power output (to 60 mA, positive and negative) and fast rise and fall times (less than 5 nanoseconds).

This new pulse generator produces a full complement of synchronizing signals. Positive and negative "prepulses" are simultaneously available in advance of the output pulses. A delayed sync pulse, coincident with the late edge of each output pulse, is also provided for triggering other pulse generators (to form composite pulses, e.g.). The power supply is built into the 12″ x 5¼″ x 8¼″ cabinet.

SPECIFICATIONS (Type 1398-A)

Pulse Repetition Frequency

Internally Generated: 2.5 c/s to 1.2 Mc/s.

Externally Controlled: Aperiodic, dc to 2.4 Mc/s with 1-V, rms, input (0.5 V at 1 Mc/s and lower). Output pulse is started by negative-going input transition.

Output-Pulse Characteristics

Duration: 100 ns to 1s in 7 decade ranges, ± 5% of reading or ± 2% of full scale or ± 35 ns, whichever is greater.

Rise and Fall Times: Less than 5 ns into 50 or 100 Ω; typically 60 ns + 2 ns/(pF external load capacitance) into 1 kΩ (60 V).

Voltage: Positive and negative 60-mA current pulses (60 V into 1-kilohm load) available simultaneously. Dc coupled, dc component negative with respect to ground.

Overshoot and Noise: Less than 10% of amplitude with correct termination.

Rampoff: Less than 1%.

Synchronizing Pulses:

Prepulse: Positive and negative 8-V pulses of 150-ns duration. If positive sync terminal is shorted, negative pulse can be increased to 100 V.

Delayed-Sync Pulse: Consists of a negative-going transition of approx 5 V and 100-ns duration, coincident with the late edge of the main pulse, immediately followed by a positive transition of approx 5 V and 150 ns.

Stability: With external-drive terminals short-circuited, prf jitter and pulse-duration jitter are each 0.04%. (Jitter figures may vary somewhat with range switch settings, magnetic fields, etc.)

Duty Ratio Restrictions: None.

Price: $535. in U. S. A.

1.2 amperes, positive or negative

less than 50-nanosecond rise & fall times

repetition rates up to 1 Mc/s

Type 1397-A Pulse Amplifier

This new instrument makes available signals that formerly required much more specialized and expensive equipment.

As an amplifier, it provides the high output levels and short rise and fall times used in testing radar circuits, switching arrays, etc. Its operation is essentially linear, and it has a transconductance of 0.5-mho (2 V in produces 1 A out). When used with the GR Type 1217 or Type 1398-A Pulse Generator, it supplies pulses of up to 1.2 Amperes (60 V into 50 Ohms) with typical rise and fall times of 30 nanoseconds. The output is direct-coupled with ground reference and can be switched to be either positive or negative.

A second "variable-transition-time" mode of operation allows the Type 1397-A to be used as a pulse *shaper*. In this mode, the rise and fall times can be continuously adjusted. The resulting transitions (both linear and exponential) are particularly useful in determining rise-time ranges of other devices, and in the testing of inductors, transformers, semiconductors, and other components.

SPECIFICATIONS (Type 1397-A)

Mode	Input Impedance	Drive Required	Rise and Fall Times
NORMAL	100Ω or 100kΩ shunted by approx 50 pF, switch selected	—3 V, p-to-p minimum	<50 ns (typically 30 ns) with input rise and fall times of <20 ns
VARIABLE Linear	30 kΩ, approx	—30 V, p-to-p, approx, minimum	0.2 to 100 μs, approx, linear, continuously adjustable
Exponential	100Ω	—3 to —4 V, p-to-p, approx	0.5 to 500 μs, approx; exponential, continuously adjustable

Output (ground reference; dc coupled):

Rampoff: Approx 25% with 5-ms pulse duration

Overshoot: 10%, or less, of minimum transition time

Amplitude: 1.2 A, p-to-p, max (60 V into 50Ω). 1 A, p-to-p, with 10% duty ratio. Automatic overload protector with manual reset.

Amplitude Variation: 20% for duty ratio changes from minimum to 10%. With ± 10% line voltage changes, positive output variation is ± 10%, negative output is ± 5%.

Internal Shunt: Positive output, 50Ω or open circuit; negative output, 50, 100Ω, or open circuit.

Transfer Characteristics: Operation approximates linear amplifier in normal mode.

Transconductance: 0.5℧ (2 V in produces 1 A out).

Inherent Delay: 50 ns between input pulse and output pulse.

Max. Duty Ratio: 10%.

Terminals: Input, Type 938 Binding Posts; output, GR874 recessed, locking connector.

Price: $495. in U. S. A.

IN CANADA: Toronto 247-2171, **Montreal** (Mt. Royal) 737-3673
IN EUROPE: Zurich, Switzerland — London, England

50 ANNIVERSARY

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Circle 6 on reader service card

TO-5 cans may be one or two orders of magnitude better than specified.

If the guaranteed hermeticity of the TO-5 can is less than assuring, look at the new and popular flatpack. The volume of a typical ¼ × ¼-inch flatpack is 0.013 cc and if a leak rate is specified, it is likely to be 1×10^{-6} cc/sec. In this case a volume equal to the package volume leaks in every 3.5 hours. Such a package does little more than keep the rain off.

Since the volume of the flatpack is only $\frac{1}{10}$ the volume of the low profile TO-5, to achieve the same isolation from the environment the flatpack must have $\frac{1}{10}$ the leak rate of the TO-5.

Frances Hugle

Director
Research and Engineering
Stewart-Warner Microcircuits
Sunnyvale, Calif.

Defining Darlington

To the Editor:

It may be a small point, but the circuit of Ingemar Ingemarsson in the Designer's casebook [Nov. 1, p. 69] should not be called a Darlington circuit. The Ingemarsson circuit may do everything claimed but it remains simply two cascaded emitter-followers. A Darlington circuit is usually thought to be two cascaded emitter-followers in which the impedance in the emitter of the first stage consists entirely of the input impedance of the following stage.

The advantage of this is that $Z_{i2} \cong h_{fe1} = r_{e2}$ is used as the emitter impedance of the first stage so that the over-all input impedance is $Z_i \cong h_{fe1} = h_{ie2} = r_{e2}$ which can be very large. In addition, an a-c voltage gain of 0.98 is not spectacular for emitter followers and is greatly improved upon with a true Darlington circuit for which $A_v \cong 1 - h_{ie}/Z_i$ which may be greater than 0.999.

Alex Schapira

New York, N. Y.

LOCI was first

To the Editor:

In a world where technological change is measured in weeks, it is understandable that a few are several weeks behind. What is not understandable is how Olivetti-Underwood can be nearly one year behind. The machine described as the world's first desk-top computer [Nov. 1, p. 32] has no features not already offered by the LOCI-2 computer developed and manufactured by the Wang Laboratories of Tewksbury, Mass. The LOCI-2 was introduced in December, 1964.

Let it therefore be known that the Programma 101 is **not** the world's first desk-top computer. Anyone doubting this is invited to visit me or the Wang Laboratories with or without an Olivetti representative and/or Programma 101 for a demonstration of the LOCI-2 which has been in customer hands for more than six months.

Earl F. Gill

Paddock-Joslow Co.
Silver Spring, Md.

▪ Though the Programma 101 seems to be more powerful than the LOCI-2, clearly the Wang machine was on the scene first. Electronics reported the Programma 101 as the first in a family of related computers which Olivetti will be introducing.

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People

After 10 years of making laboratory oscilloscopes, Tektronix Inc., has decided to diversify. The company has set up a new, still-unnamed, division and has selected **C. Norman Winningstad,** a 40-year-old electronics engineer, as its director to handle research and production. Tektronix hopes to market new products in a year or so.

About four years ago the company developed a cathode-ray tube that stores signals for about an hour. Since that development, the company has designed new oscilloscopes that use its tube and started looking for other applications for the tube. The company decided to aim for two markets: office equipment and computers.

The storage tube, says Winningstad, could be used as a remote readout for a computer or in equipment that transmits printed data over telephone lines, displays the data and provides a permanent copy of the material. Research on both products is under way, Winningstad says.

The new division chief holds a bachelor's degree in electrical engineering from the University of California. He worked on bevatron instrumentation at the university's radiation laboratory before joining Tektronix in 1958.

"We've just opened the door," says **Col. Mitchel Goldenthal,** the new commander of the Army's Satellite Communications Agency (Satcom) at Fort Monmouth, N. J.

"We can expect a continuous research-and-development effort that will increase the capacity and efficiency of all satellite communications systems," Col. Goldenthal continues. He can be

There's Ed Maloney

inside every Bendix rectifier.

In today's semiconductor business, who still talks about the personal touch? Ed Maloney does . . . Sure he's got high-reliability rectifiers . . . and yes, he meets military specifications . . . and of course, he provides fast delivery on 300 different part numbers.

But . . . Ed says there's a lot more to it than that. As Manager of Silicon Rectifier Production, he firmly believes that personal integrity must be built inside every Bendix rectifier.

He watches 100% high temperature testing like a hawk; he's right on top of the smooth flowing process; he's checking into things from the crystal stage all the way to shipping.

You can't afford not to have a guy like this on your side. Place Bendix rectifiers in your equipment! You'll feel better with them inside.

TYPES MEETING MIL SPEC	AT 150°C	
	I AMPS	PRV VOLTS
USN1N1124A,26A,28A	1	200-600
USAF1N1199-1206	12	50-600
JAN1N1202,R,04,R,06,R	12	200-600
JAN1N1614,R-16,R	5	240-720
JAN1N4458,R,59,R	5	960, 1200

Bendix Semiconductor Division
HOLMDEL, NEW JERSEY

THE Bendix CORPORATION

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sure of an increased R&D effort since he also was named Satcom's acting project manager, which makes him responsible for this research and development. Satcom develops and tests ground facilities to be used in military satellite communications systems.

"Satcom's work will not stop when the worldwide network now under development becomes operational," says the 44-year-old commander. "I look for tremendous growth in tactical systems." The need, he explains, is for highly reliable, portable ground stations to provide communications between a command-and-control center and a field commander—no matter where the commander might be.

A native of New York City, the colonel is a graduate of West Point; he received masters' degrees in mechanical engineering from Texas A&M University and in international affairs from George Washington University.

The vacuum tube is still the workhorse of the microwave business, but in another decade it will face tough competition from solid-state sources—unless better tubes are made, says **Curtis M. Hellenbrand,** recently named senior engineer at the tube division of Microwave Associates, Inc., of Burlington, Mass.

Hellenbrand, 43 years old, will supervise the company's new research and development program in crossed-field devices. The magnetron—an oscillator—is the grandfather of this species, but the industry push now is for crossed-field amplifiers—second- and third-generation tubes with more bandwidth, higher gain and lighter weight.

"More output power per pound, in other words," says Hellenbrand.

Immediate demands for new amplifiers come from the electronic countermeasures area, but Microwave Associates feels that an increased capability in crossed-field devices will give the company an opportunity to expand generally in the market for high-power tube systems.

NEW!

CEC announces the first low cost, three-in-one portable direct-writing recorder

CEC's new solid-state DG 5511 introduces engineering and performance advantages never before offered by any recorder in its price range.

This portable, 2-channel, thermal writing recorder is so versatile it provides the capability formerly achieved only through multiple instruments. The DG 5511 features *two* plug-in signal conditioners for a wide range of voltage inputs. *No* preamp is needed for high level signals. Due to its all-modular design, users may convert from high level signal inputs to low level inputs by a simple change of plug-in attenuator/amplifier units.

In addition, the DG 5511 is remarkably easy to use with its unique snap-in, front chart-loading and convenient push-button selectable chart speeds.

Frequency response is equally outstanding—d-c to 70 cps; flat to 125 cps at reduced amplitude. And its wide signal range (25 millivolts to 500 volts full scale) makes the DG 5511 readily adaptable to telemetry and computer readout. And of particular importance to industry is the fact that the DG 5511, being a true portable, may be used virtually anywhere there is a power source and wherever there are unknown forces such as vibration, pressure or temperature to be measured. Consequently, the DG 5511 is certain to be a "must" instrument for every conceivable application from foods and pharmaceuticals to chemicals, construction and heavy equipment.

Features:

- Portable
- Rugged and compact
- Lightweight
- Low cost
- Versatile (3 in 1)
- High performance
- Snap-in chart-loading
- Excellent frequency response
- Push-button chart speeds
- All solid state

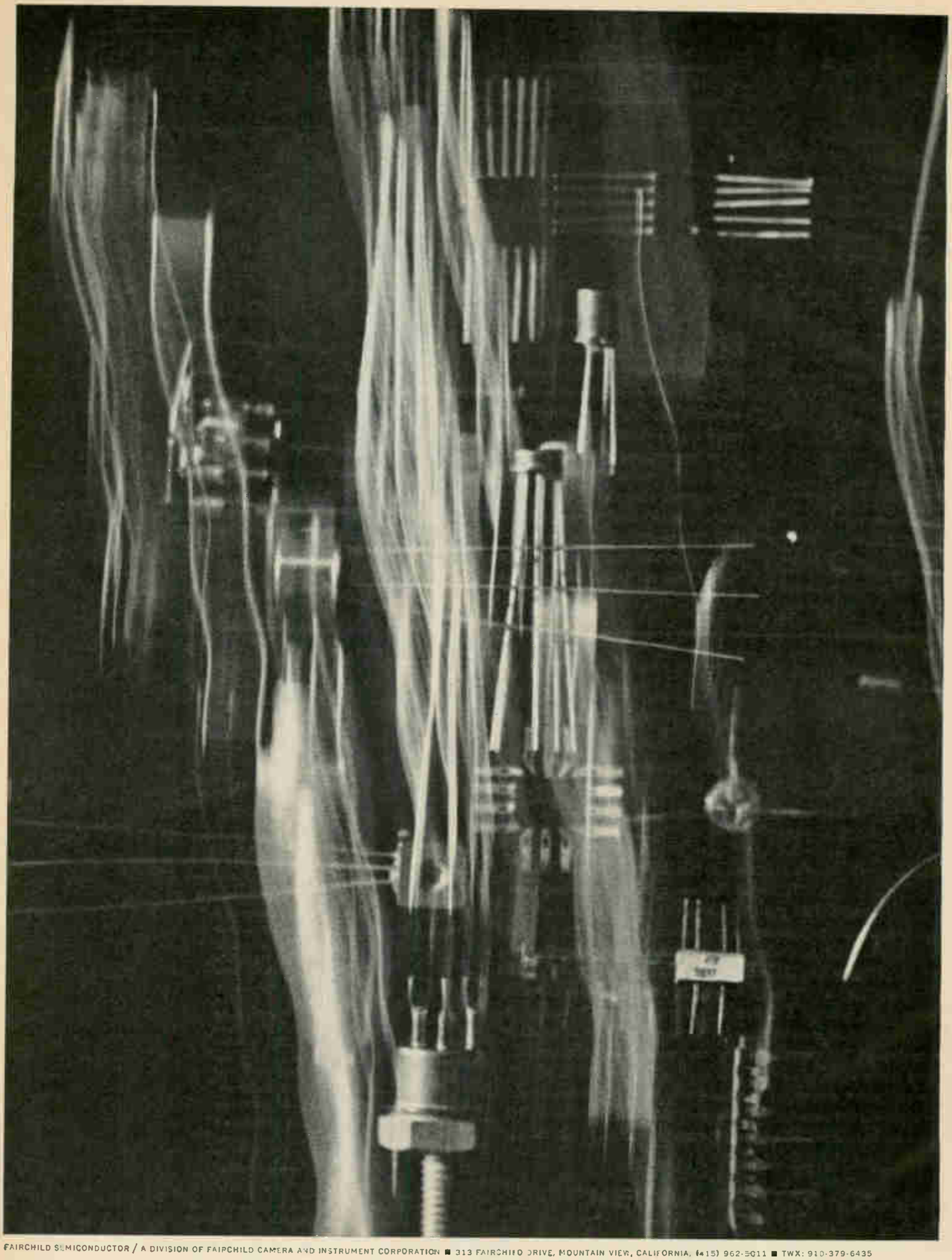
A wide range of accessories and operating supplies is available.

What about service? CEC backs its instruments with the largest, best equipped sales/service organization in the field today.

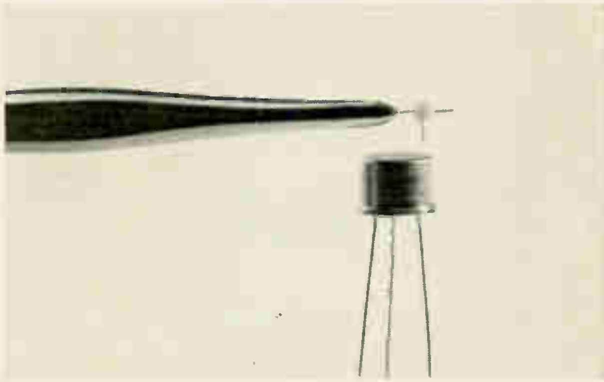
For a desk top demonstration of the DG 5511, contact your nearest CEC Field Office, or write for CEC Bulletin 5511-X8.

CEC
Data Recorders Division
CONSOLIDATED ELECTRODYNAMICS
A SUBSIDIARY OF BELL & HOWELL/PASADENA, CALIF. 91109
INTERNATIONAL SUBSIDIARIES: WOKING, SURREY, ENGLAND AND FRIEDBERG (HESSEN), W. GERMANY

Circle 11 on reader service card



Below: a Hermet next to a TO-5. Both are transistor packages; both are hermetically sealed; both are readily available. But, there is a difference:



You can get TO-5 packaging anywhere. You can get the Hermet only from Fairchild. The standard Fairchild line includes some very special packages: Cerpak, Flatpak, Dual in-line, matched duals, TO-50, TO-51, and Hermet.

Hermet: 80x80x60 mils. Gold over kovar leads. Hermetically sealed. Accommodates all Fairchild transistors except power devices.

FAIRCHILD SEMICONDUCTOR

Circle 13 on reader service card

Meetings

Electromagnetic Sensing Symposium, University of Miami, American Geophysical Union University of Miami, Coral Gables, Fla. **Nov. 22-24.**

International Conference on UHF Television, IERE; London, **Nov. 22-23.**

Nuclear Electronics Conference, International Atomic Energy Agency; Bombay, India, **Nov. 22-26.**

Symposium on the Interaction of Space Vehicles with an Ionized Atmosphere, AAS, School of Environmental and Planetary Sciences, University of Miami, Deauville Hotel, Miami Beach, **Nov. 26-27.**

Ultrasonics in Medicine Conference, AIUM; Lima, Peru, **Nov. 26-27.**

Digital Equipment Computer Symposium, DECUS; Stanford University, Stanford, Calif. **Nov. 29.**

Joint Computer Conference, AFIPS, Las Vegas, **Nov. 30-Dec. 2.**

Sonics and Ultrasonics Symposium, IEEE; Hotel Sheraton, Boston, **Dec. 1-3.**

Vehicular Communication Conference, G-VC/IEEE; Sheraton-Park Hotel, Washington, D.C., **Dec. 2-3.***

Integrated Circuit Design Seminar, Integrated Circuit Engineering Corp; Marriott Motor Inn, Philadelphia, **Dec. 6-10.**

Analytical and Measuring Instruments and Laboratory Apparatus Show, Bureau of International Commerce; U.S. Trade Center, London, **Dec. 7-17.**

International Conference on Radiological Protection in the Industrial use of Radioisotopes, Societe Francaise de Radioprotection; Centre de Conferences Internationales, Paris 16, **Dec. 13-15.**

ASSET/Advanced Lifting Re-entry Technology Symposium, Flight Dynamics Lab; Wright-Patterson Air Force Base, Dayton, **Dec. 14-16.**

American Association for the Advancement of Science, AAAS; University of Calif., Berkeley, **Dec. 26-31.**

International Symposium on Differential Equations and Theory of Systems, AFOSR, Brown University and the University of Puerto Rico; University of Puerto Rico, **Dec. 27-30.**

Astrodynamics Symposium, American Astronautical Society; University of California, Berkeley, Calif. **Dec. 29.**

American Society of Tool and Manufacturing Engineers Meeting, ASTME; Statler Hilton Hotel, Boston, **Nov. 30-Dec. 1.**

Solid State Physics Conference, Institute of Physics and The Physical Society; Renold Building, Manchester, England, **Jan. 4-7.**

Sealab II Symposium, Navy; Statler Hilton Hotel, Washington, D. C., **Jan. 11-12.**

Conference on Electronics in Publishing, American University; International Inn, Washington, D.C., **Jan. 17-20.**

National Electronic Representatives Association Marketing Conference, ERA; Riviera Hotel, Palm Springs, Calif., **Jan. 26-30.**

International Symposium on Information Theory, AFOSR, IEEE; University of California, Los Angeles, **Jan. 31-Feb. 2.**

Integrated Circuits Seminar, IEEE, Basic Sciences Committee; Stevens Institute of Technology, Hoboken, N.J., **Feb. 2.**

Call for papers

International Symposium on Generalized Networks, Polytechnic Institute of Brooklyn, AFOSR, ONR, ARO; Hotel Commodore, New York, Apr. 12-14. **Jan. 1** is deadline for submission of papers on network theory and applications to the Symposium Committee, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, N. Y. 11201.

Automatic Control Conference, AIAA, ASME, ISA, IEEE and AIChE; University of Washington, Seattle, Aug. 17-19. **Jan. 3** is deadline for submission of papers on control system theory, applications and components to the society of the author's choice. All papers should be marked "For 1966 JACC".

* **Meeting preview on page 16**

Astrodata's New Astrolock-loop FM Subcarrier Discriminator*

Stability

Within ±0.01% of center frequency for 24-hours after a 5-minute warm-up.

Linearity

Better than ±0.02% of full bandwith, best straight line.

The Astrodata Model 402-201, all solid-state FM subcarrier discriminator utilizes the new Astrolock phase-frequency detector, crystal-referenced, FET chopper-stabilized VCO, and current mode loop filter, which are proprietary developments of Astrodata, Inc.

This completely new and different type of locked-loop discriminator gives performance exceeding that of both conventional phase-locked-loop and pulse-averaging types of discriminators.

The new crystal-referenced, FET chopper-stabilized VCO provides state-of-the-art performance in stability and linearity, without a temperature controlled oven.

The Astrolock detector, with its composite phase-frequency characteristic, assures positive lock-in at any signal level within the 66 db dynamic range. True locked-loop performance is provided for deviations up to ±40%, with specified linearity. A quadrature detector mode of operation, selected by a switch on the front panel, provides correlation detection for extremely low S/N signals.

The Model 402-201 introduces a new method of tape-speed compensation in which the reference frequency is processed in the frequency domain. As a result, tape speed compensation is perfect at any fixed frequency from lower bandedge to upper bandedge, and is better than 30 db for intelligence frequencies up to a modulation index of 4. Deviations of more than ±3% anywhere in the band can be accommodated. No adjustments are necessary.

With this new Astrodata Tape Speed Compensation system, the over-all stability for a given data channel is that of the data discriminator alone, whereas in a conventional system the over-all stability is the sum of the stabilities of both the data discriminator and the reference discriminator.

A complete line of accessories is available for use with the Model 402-201. Channel Selectors and Low Pass Filters are provided for all standard IRIG and Constant Bandwidth center frequencies up to 300 kc. Six discriminators and one common power supply mount in a rack adapter which occupies a panel space of 7-in. x 19-in.

For complete technical information on Astrodata's unique Astrolock-loop FM Subcarrier discriminator and full line of telemetry components, call your local Astrodata engineering sales representative or write to us directly.

ASTRODATA INC.

P. O. Box 3003 • 240 E. Palais Road • Anaheim, California 92803

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Meeting preview

IEEE in Washington

Frequency-crowding in land mobile communications will be the subject of a panel discussion at the Vehicular Communications Conference, sponsored by the Institute of Electrical and Electronics Engineers (IEEE) in Washington on Dec. 2 and 3.

The panel will include members of the advisory committee for land mobile radio services, which has been studying frequency-crowding for two years under the auspices of the Federal Communications Commission. Allocating frequencies too close together creates interference for police cars, fire trucks, ambulances and so on and is worsening. James E. Barr, chief of the FCC's safety and special services bureau, will be the moderator at this discussion.

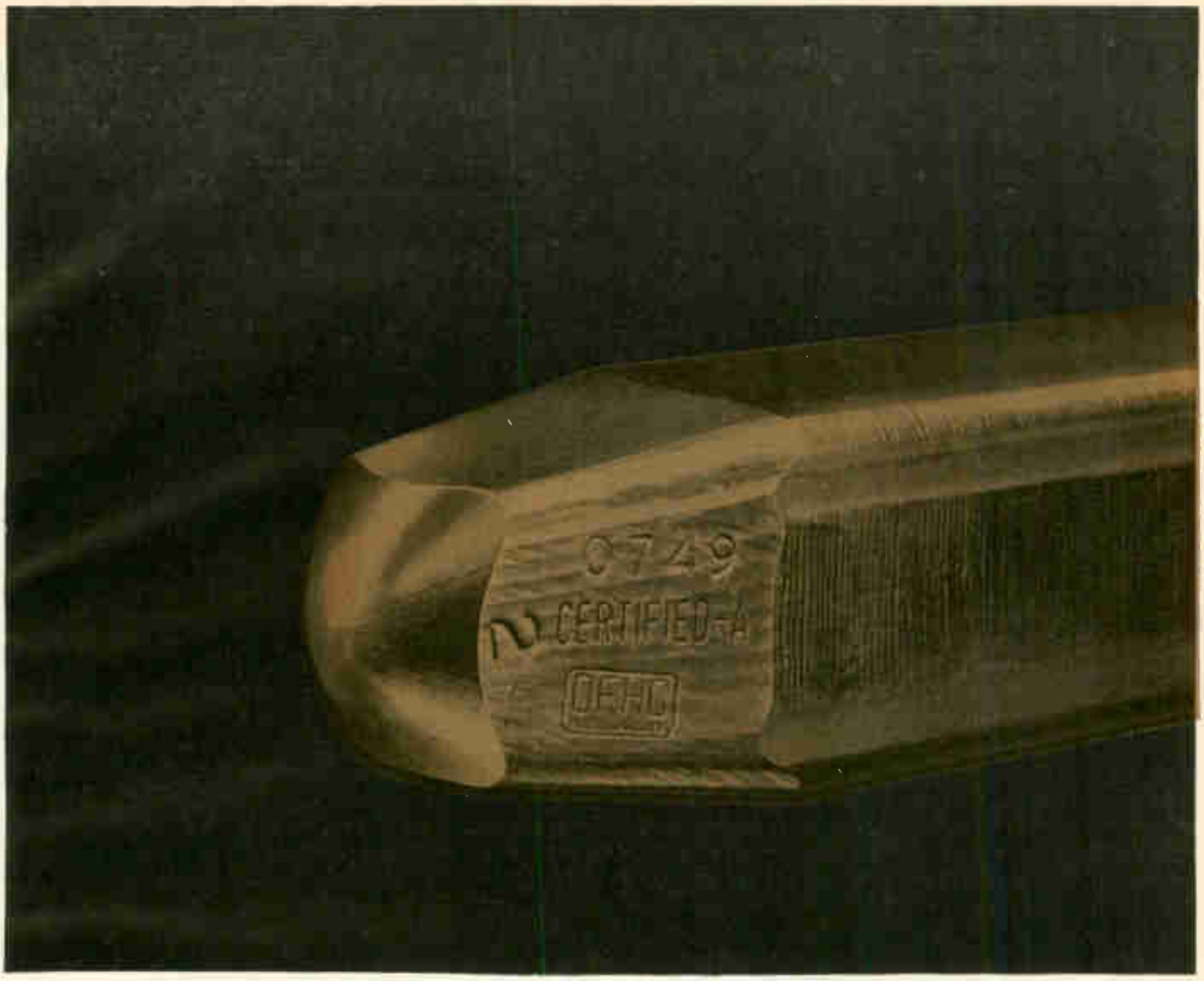
Four sessions. Fourteen papers will be presented during the four sessions. R.D. Carlton of the Minnesota Mining and Manufacturing Co. will discuss the use of thermoelectric generators to provide power to repeaters for mobile communications systems.

John W. Battin of Motorola, Inc. will examine the problems in achieving high reliability in solid-state vehicular communication sets.

S.J. Matyckas of the Radio Corp. of America will follow with a paper on solid-state mobile transmitters and discuss overlay transistors [Electronics, Aug. 23, 1965, p. 71] in a transmitter's radio-frequency output power stage. He will also describe design considerations necessary to obtain maximum reliability performance, such as preventing antenna-load mismatch which could destroy the transistors in the output stage.

J.H. Eakin of the Farinon Electric Co. will deliver a paper on intermodulation control of mobile transmitters. A paper by R.T. Myers and T.A. McKee of the General Electric Co. will discuss using computers as a tool to improve receiver design.

Sen. Everett M. Dirksen (R, Ill.) will be guest speaker at the conference banquet on the evening of Dec. 20.



sometimes, the best is too good

The OFHC brand says this copper is the best—the purest and most uniform copper available in commercial quantities. The "CERTIFIED" stamp guarantees that impurities *total less than one-hundredth of one percent*. OFHC's extreme purity of 99.99+% and structural uniformity give it some truly unconventional properties.

For some copper applications, OFHC is too good; its superior properties simply are not required.

For many other applications, OFHC is the *only* copper that can give you top performance. It's worth a hundred times the few cents per pound premium it costs . . . which usually becomes insignificant when you relate it to the total end-product cost.

We suspect there are still many applications ideal for OFHC where it has not been tried—probably because of the slight extra initial cost. However, the properties inherent in 99.99+% pure copper often turn a slightly higher initial cost into a *lower overall cost*.

Chances are that you'll be able to improve your product's performance...and increase its profitability at the same time because of the ease with which OFHC can be worked. Interested?

Yours for the asking...

...technical information and assistance on putting OFHC to work for you. Just contact the AMAX Oxygen-Free Copper Products Group.

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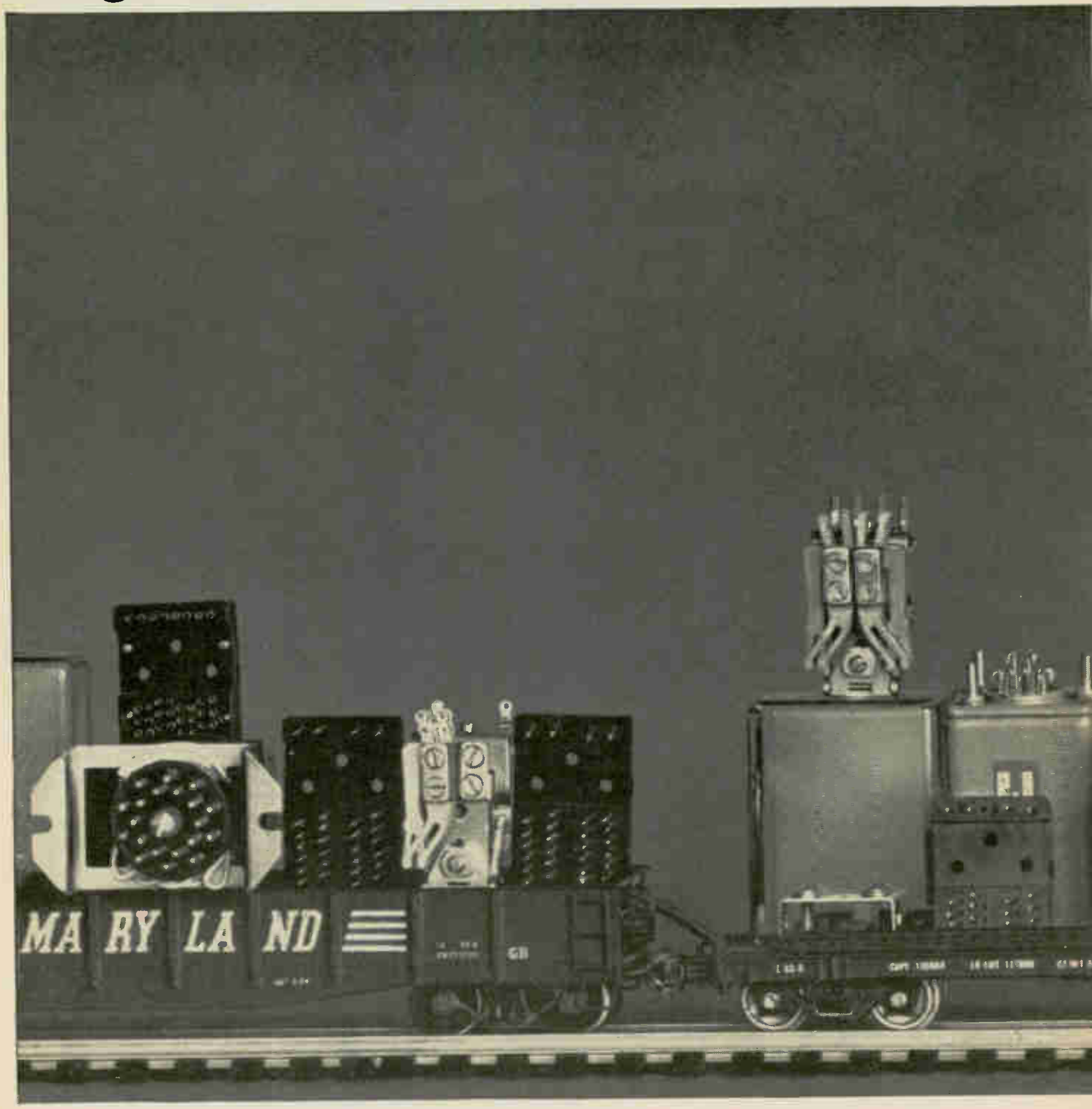
Try to find a connection



The growing popularity of AE's Class E Relay as the "workhorse of the industry" has set off a demand for a wide variety of mounting techniques.

Now AE can accommodate virtually every type of circuit connection or mounting used in electrical and electronic equipment designs.

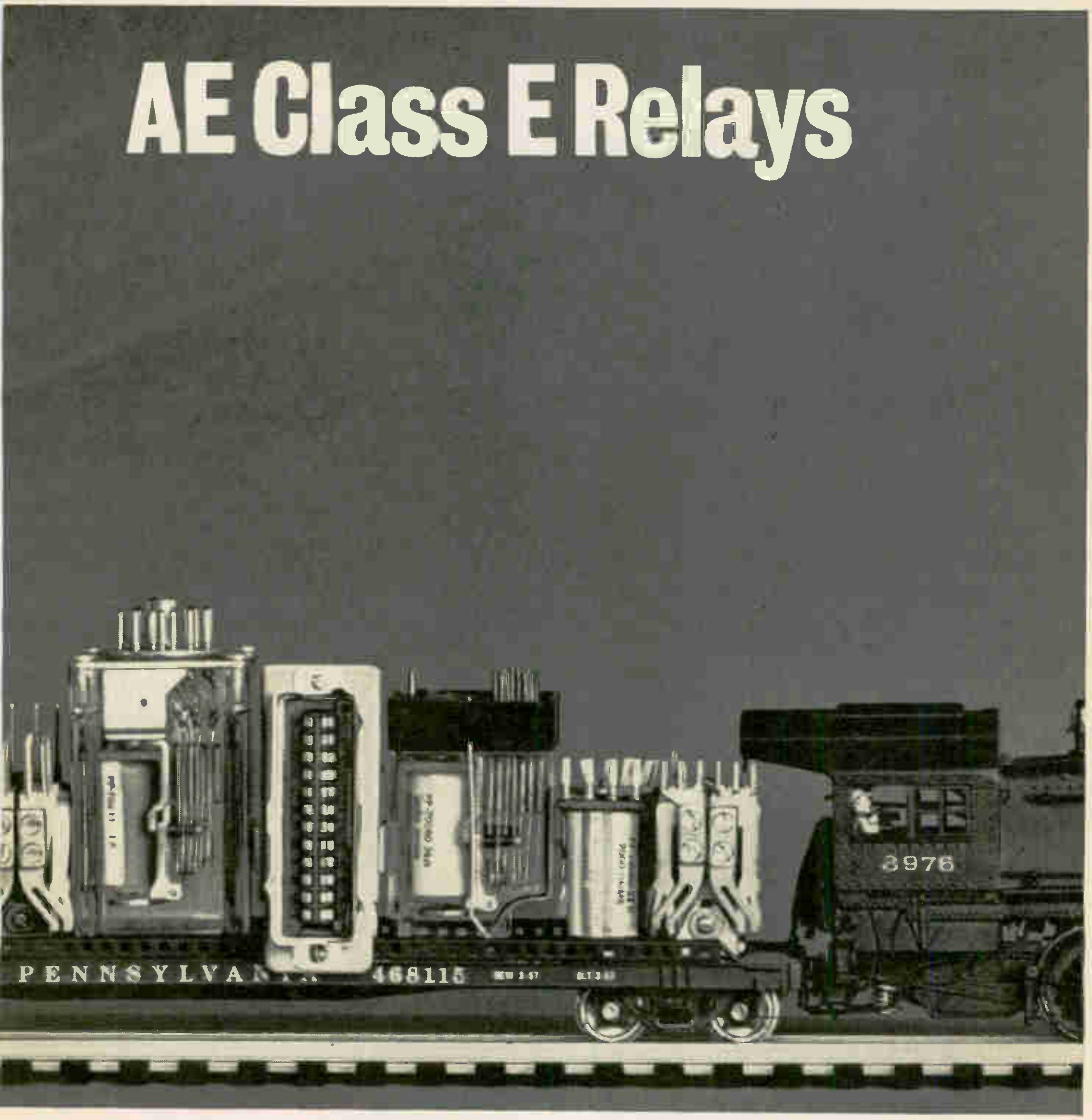
Wherever designs call for "wiring in," AE Class E Relays are available with solder-type, wrapped-wire, taper-tab and printed-circuit terminals.

AE has also developed special sockets for chassis or printed-wiring board mounting, that accommodate Class E Relays with PC or taper-tab terminals. And prewired types with octal plug-in bases.

Where extra protection is required, AE Class

you can't make with

AE Class E Relays



E Relays are available in hermetically sealed enclosures with either hook terminals or plug-in headers. Or plastic dust covers that snap on to the chassis- or printed-circuit type of socket.

For full information on the limitless variations in mounting and connections for AE Class E Relays, ask for Circular 1942-C. Write to the Director, Relay Control Equipment Sales, Automatic Electric Company, Northlake, Ill. 60164.

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SUBSIDIARY OF
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Circle 19 on reader service card

Sigma relay of the month

DPDT relay with 100 mw sensitivity has mechanical life of 1 billion operations.

The Sigma Series 42 is designed for a wide range of general purpose applications—from alarm and control systems to demand meters and timing circuits. It combines sensitivity and long mechanical and electrical life with stability, high insulation between circuits and high coil overload capacity. Check all of its features and ratings:

Long mechanical life—1 billion operations—due to pivotless hinge construction where the motion is rolling rather than sliding, thus reducing wear.

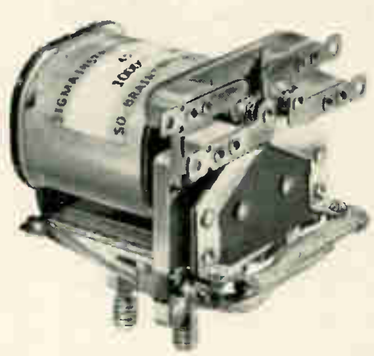
Long life under load—1,000,000 operations—due to small armature mass that reduces bounce, and controlled contact wipe that prevents circuit induced sticking.

100 mw sensitivity—minimizes coil load in circuits with limited load handling ability.

High stability—due to beryllium copper contact springs and return springs.

High circuit insulation—due to glass alkyd contact base.

High coil overload capacity—handles control voltages 4 to 6 times rated coil input.



Test the U. L. listed Series 42 for yourself—free—against the type you may now be using. Just send for the Sigma Series 42 bulletin and a free relay redemption certificate.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design / Braintree, Mass. 02185

Circle 21 on reader service card

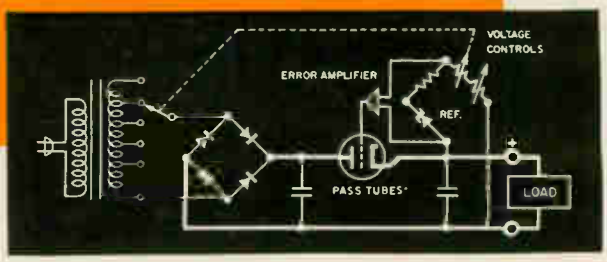
IN HIGH VOLTAGE POWER SUPPLIES

KEPCO HYBRID CIRCUITRY

MAKES THE DIFFERENCE!

Model HB 6AM

REAR VIEW



KEPCO HB GROUP

REGULATED DC SUPPLY

TRADITIONAL QUALITY, NOW AT EVEN LOWER PRICES

Kepco Hybrid circuitry utilizes vacuum tubes as series pass regulators, with a solid state error amplifier. The combination provides high voltage, high power, full range regulation, stability and reliability. A tapped input transformer ganged with the panel range switch provides optimum performance within predetermined ranges. Packaged in a 3½" high, space saving design.

- Voltage or current regulated
- High resolution 10-turn vernier voltage control; 5 voltage bands
- Kepco pioneered hybrid regulator
- Voltage or current programmable
- Kepco Bridge† Regulator
- 2 auxiliary 6.5V AC, 6 amp unregulated outputs

†Applicable Patent Nos. furnished on request

0.01% REGULATION and STABILITY

MODEL	DC OUTPUT RANGE		OUTPUT IMPEDANCE OHMS MAX.			PRICE
	VOLTS	MA.	DC to 100 CPS	100 CPS to 1 KC	1 KC to 100 KC + μH	
HB 2AM	0–325	0–200	0.2	0.08	0.2+0.5	$295.00
HB 4AM	0–325	0–400	0.1	0.08	0.2+0.5	330.00
HB 6AM	0–325	0–600	0.06	0.08	0.2+0.5	365.00
HB 8AM	0–325	0–800	0.05	0.08	0.2+1.0	395.00
HB 250M	0–250	0–1000	0.025	0.08	0.2+0.5	495.00
HB 525M	0–525	0–500	0.08	0.08	0.2+0.5	435.00

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Editorial

Surprise for consumer firms

Many specialists in consumer electronics were jolted last month when word leaked out that the Admiral Corp. will use an integrated circuit in its color television sets next year [Electronics, Nov. 1, p. 25]. The experts had been declaring with assurance that the use of IC's in consumer products was 5 to 10 years away.

Admiral's decision has stirred many consumer-electronics companies to reconsider IC's—and not a minute too soon. The Japanese are already hard at work adapting IC's for consumer products. IC's will make their debut in Japanese products by the end of 1966 and will be used broadly by the end of 1967. Many of these Japanese products can be expected to compete with American equipment.

Japanese efforts in integrated circuitry trail those in the U. S. Serious study in Japan started only in 1964, stimulated by IBM's announcement of the System 360 computer with some integrated circuitry. But the Japanese are working hard to catch up. Since the consumer field is by far the most important segment of Japan's electronics industry, that's where the strongest research efforts are being made. Also, by borrowing heavily from U. S. technology, the Japanese have short-cut the schedule required to develop digital devices for computers, and have completed much of that work.

Today, nine Japanese companies are active in integrated circuits, and their productive capacity is far more than the Asian computer business can absorb. The Nippon Electric Co. alone expects to be producing 500,000 IC's a month by the end of 1966.

Many integrated-circuit producers are also big names in Japanese consumer electronics—Hitachi, Ltd., NEC, Toshiba (Tokyo Shibaura Electric Co.), Mitsubishi Electric Corp. and Matsushita Electric Industrial Co. Their chief interest is in selling consumer products, but they have to justify their big investments in IC facilities. Of the companies that supply their own semiconductor devices, only the Sony Corp. and the Sanyo Electric Co. have not yet gone heavily into integrated circuits. Soon Sony may change its tune. Though its newest product, an electronic calculator, to be introduced by the end of the year, is made of discrete components, the second generation is already being designed for integrated circuitry.

Thus Admiral's decision to go to integrated circuits comes at a good time for U. S. companies. It forces others to take IC's seriously now.

Dubious 'boom'

After reading his obituary in a San Francisco newspaper, Mark Twain quipped, "The report of my death is grossly exaggerated." Just as exaggerated is the report of a boom in color television in Japan, published earlier this month in the respected New York Times.

The truth is that not many color-tv sets are being made in Japan and even fewer are sold. And this situation is not likely to change much in the next two or three years.

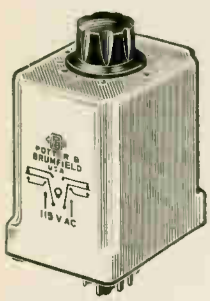
According to the Electronic Industry Association of Japan, which collects production figures, only 80,000 color-tv sets have been built in Japan since production started around 1960. Twenty thousand of these sets, the association adds, are so obsolete as to be unusable. That hardly constitutes a boom in a country that can turn out 500,000 black-and-white sets a month.

With a price of $575 per set, and with only four hours of color-tv programing available daily, color sets are not luring many purchasers. Moreover, there is a recession in Japan these days; almost all the consumer-electronics companies are looking abroad for business.

Production of color-television sets in Japan is so scanty that some companies assemble them in the engineering department because there isn't enough volume to justify a production line. Only Toshiba (Tokyo Shibaura Electric Co.) and the Sanyo Electric Co. have relatively large volume—as much as 2,000 sets a month. Most of Toshiba's production, which reached reasonable proportions only last spring, is going to Sears, Roebuck and Co. in the United States. Sanyo started exporting last month and hopes to be shipping 2,000 color sets a month soon.

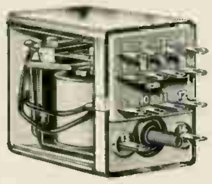
Output of the Sony Corp.'s color-tv sets with the Chromatron tube has been so slow that the company has restricted sales to metropolitan Tokyo and Osaka. Mechanical difficulties continue to limit production of the Chromatron tube to pilot-plant proportions—about 200 tubes a month. The Yaou Electric Co. is having similar problems with its Colornetron tube, and production is under 200 a month.

These P&B relays are immediately available at factory prices from your electronic parts distributor



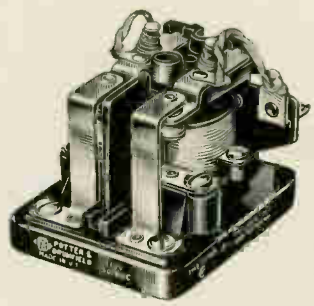
CD-38

SOLID STATE TIME DELAY—You get excellent timing characteristics in these knob-adjustable solid state relays. Timing range: 0.6 to 60 seconds. AC or DC models. Internal DPDT relay rated at 10 amperes, 115V AC resistive. For continuous duty over temperature range of −40°C to +55°C.



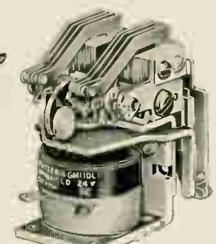
KHP

COMPACT FOUR-POLE RELAY—Small, rugged 4PDT relay designed to meet exacting requirements of data processing, computer and process control applications. Rated at 3 amperes at 30V DC or 115V AC resistive. Solder terminals. Special sockets have printed circuit or solder lug terminals. Also available hermetically sealed.



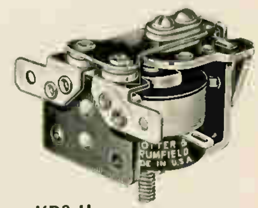
PR

POPULAR 25 AMPERE POWER RELAY—Compact, heavy-duty power relay listed by U/L and CSA. Screw terminals and rugged construction suitable for industrial application requiring reliability and long life. AC or DC models.



GM

VERSATILE IMPULSE/SEQUENCING RELAY—Unusual single-coil relay can be used to latch, step, count and switch in sequence. Switching occurs during drop-out for greater reliability. AC or DC models. Contacts rated for 3 amperes. Can also be furnished with uni-directional printed circuit boards having 10 or 12 switch positions.

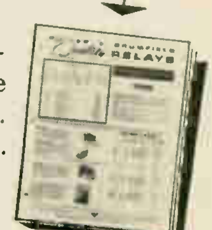


KR3-H

SMALL RELAY SWITCHES 20 AMPERES—Three KR3-H relays will fit in space required for most other 20-ampere relays. Mechanical life exceeds one million operations and twin contacts are rated at 20 amperes at 115V AC, 60 cycles resistive or 28V DC, 1 HP 115/230V 60 cycles. Contact terminals will accept ¼" quick-connects or solder connections. Contact arrangement: SPST-NO-DB.

...and there are 60 other types to choose from!

Chances are, you'll save both time and money when you order standard P&B relays from an authorized distributor. You'll get speedy service at factory prices. Your P&B distributor has available more than 60 basic relay types totalling 627 coil voltages and contact arrangements. All are shown in our new Stock Catalog 100 . . . free from your electronic parts distributor. Ask for a personal copy today.



POTTER & BRUMFIELD

Division of American Machine & Foundry Company, Princeton, Indiana
Export: AMF International, 261 Madison Avenue, New York, N.Y.

Electronics Newsletter

November 15, 1965

C-w laser 'better than radar' for low-angle tracking

An automatic tracking system using a continuous-wave gas laser has demonstrated high accuracy in field tests. At the Northeast Electronics Research and Engineering Meeting (Nerem) in Boston this month, E.L. McGann of Sylvania Electric Products, Inc., reported on a 10-milliwatt helium-neon laser that tracked a foot-long rocket with accuracy of 100 microradians during powered flight and 25 microradians during the coasting stage.

For tracking missiles in early launch phase, the laser is claimed to be superior to radar in precision and in ability to do low-angle tracking. C.J. Peters, manager of electro-optical projects at the Sylvania Applied Research Laboratory, says the tracking laser's accuracy "is comparable to the best data collection system at Cape Kennedy—that is, the camera systems." Laser systems will also be explored with a view to target tracking for ground-to-air and ground-to-satellite communications links.

The system also tracked the approach of an aircraft from a 10-mile distance at an altitude of 10,000 feet against a bright sunlit sky.

GaAs in parallel delivers 200 watts

By connecting two samples of bulk semiconductor material in parallel to form a pulsed gallium-arsenide microwave generator, a record output of over 200 watts at about 1.5 gigacycles has been achieved. Daniel G. Dow, Charles H. Mosher and Arthur B. Vane of Varian Associates, predicted that in a couple of years these Gunn-effect oscillators will have 10 kilowatts of peak power at L band, 1 kilowatt at S band, and 100 watts at X band. Efficiencies were reported at 5% to 10% and circuit tuning was estimated at 10% to 25% of bandwidth.

British to fight 'brain drain'

A British recruiting team will tour the United States next year, attempting to lure British scientists and engineers back home. The British hope to reverse the "brain drain" that has been bringing almost 6,000 foreign scientists a year to the U.S. over the past few years.

Concern by the British has been intensified since the new U.S. immigration law that takes effect Dec. 1 admits persons on a skills basis rather than on the previous country-quota basis; this, they feel, may swell the number of foreign scientists and engineers coming here.

TI to introduce microwave IC's

The first experimental microwave integrated circuits are being developed by Texas Instruments Incorporated for introduction at the convention of the Institute of Electrical and Electronics Engineers next March in New York. One circuit is a 4-stage power amplifier with a 2-watt output at 2.25 gigacycles. It contains four transistor chips alloyed on a substrate to thick-film passive components. Both ceramic and silicon substrates are being evaluated.

Project MOL remains secret

Advocates of secrecy on the manned orbiting laboratory (MOL) project apparently have carried the day—for a while, at least. "There is no plan at this time to change the press policy on MOL," Secretary of the Air Force Harold Brown said in Los Angeles earlier this month. The present press policy on MOL is one of almost complete silence, [Electronics, Oct. 4, p. 65]. Brown said MOL would be treated as any other military space venture: not even the launches would be announced. Brown said this secrecy probably would hold for the first MOL launches. A statement will be released after the flights, he said. Asked if the Air Force would never release information on MOL, such as on instrumentation, Brown replied, "Never is a long time."

At a briefing in Washington, a high Air Force official said a **review of MOL policy probably would be conducted after definition studies are completed** by the Douglas Aircraft Co., the prime contractor for MOL.

Siemens and Bosch may work together

Two of West Germany's biggest companies, **Siemens & Halske AG and Robert Bosch GmbH,** are **considering coordinating their production efforts.** Each company would remain independent, but each might drop or deemphasize a product line in which the other is stronger, and become a supplier of parts for the primary producer.

Siemens, with sales last year of $1.7 billion, is Germany's biggest electronics company. Bosch, whose 1964 sales totaled $712 million, is a major producer of electronic and electrical products.

H-P makes bid with low-cost wideband recorder

The Hewlett-Packard Co. is making its debut in the instrumentation tape recorder market **with a 1.5-megacycle-bandwidth machine that sells for $20,000, about half the cost of comparable ones, the firm says.**

The 14-channel instrument **has six electronically controlled speeds.** The machine has been designed for medium-size scientific and industrial laboratories; most machines with a 1.5-Mc bandwidth are too expensive for this market, John Young, general manager of Hewlett-Packard, says. **The company achieved the low price by extensive use of machine-tool operations, rather than hand-machining.**

Varactor diodes amplify, oscillate

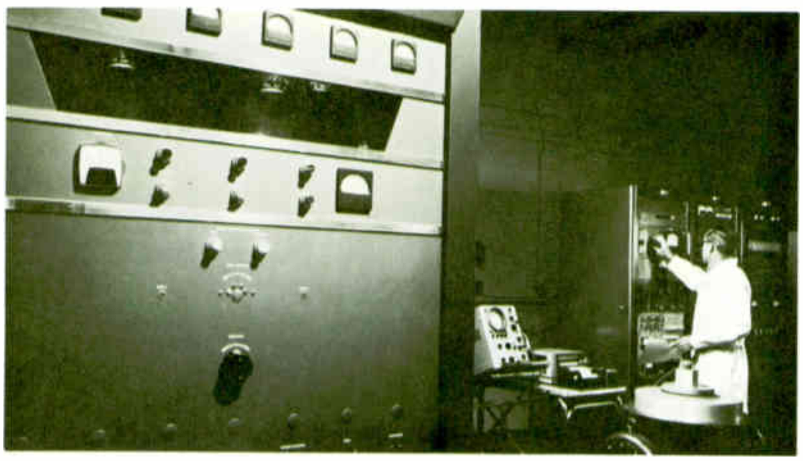
Commercially available **varactor diodes have been operated as X- and ku-band oscillators** at **relatively high powers.** The work was done by Vincent Higgins, Frank Brand and Joseph Baranowski of the Army Electronics Command at Fort Monmouth, N. J. Using epitaxial diffused gallium arsenide, the researchers biased the diodes into the avalanche region and got 25 milliwatts of continuous-wave power at 13 to 14 gigacyles and 16 mw at 8½ to 10 Gc; efficiency was better than 5%, the researchers say. The operation of the diodes was apparently similar to the mechanism of the Read diode, a device that depends on avalanche and transit-time effects. Frequencies between 7.6 and 48 Gc were also obtained.

Gallium-arsenide varactor diodes obtained from the Army group have shown amplification in tests at Bell Telephone Laboratories.

Addenda

The Fairchild Camera & Instrument Corp. plans to go into the memory products business with a line of monolithic semiconductor "scratch-pad" assemblies, ferrite memory cores, wired memory core planes and "stacks" of core planes. . . . A computer that keeps track of a patient's condition during neurosurgery has been developed by the Mayo Clinic and the International Business Machines Corp. for St. Mary's Hospital in Rochester, Minn. Medical personnel inside the operating room can operate the computer's simplified controls without extensive training.

BOURNS TRIMPOT®
ADJUSTMENT POTENTIOMETERS

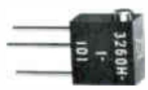


THERE MUST BE A REASON

why Bourns sells more Adjustment Potentiometers than all others combined. The answer is simply *better value*. This short-form catalog not only shows the excellent specifications and wide choice you have with Bourns adjustment potentiometers, but also describes *why* Bourns' quality, delivery and service are the best in the industry. This TOTAL VALUE philosophy saves you money in the long run by cutting your procurement problems to a minimum. In short, when the performance *must* match the promise, remember— TRIMPOT means Bourns — Bourns means Quality.

ADJUSTMENT POTENTIOMETER SHORT FORM CATALOG NO. 12 OCTOBER, 1965

HIGH-PERFORMANCE WIREWOUND

Model	DIMENSIONS H W L	TERMINALS ①	ACTUAL SIZE	RESISTANCE TOLERANCE (%) ①	POWER (WATT) @ 70°C	MAX. TEMP. (°C)	ADJ. TURNS	HUMIDITY ③ (MIL SPEC)	STD. RESISTANCES ③ Ω	PRICE ② 1 - 9	10 - 24	25 - 49
220 SUB-MINIATURE HIGH TEMPERATURE (RT 10)	5/16 x 3/16 x 1	L , W		±5	1.00	175	15	Yes	10 -10K 20K-30K	8.64 10.26	8.00 9.50	7.20 8.55
224 HIGH TEMPERATURE (RT 12)	5/16 x 3/16 x 1 1/4	L , S , P		±5	1.00	175	22	Yes	10 -10K 20K-25K 50K	7.02 8.64 9.18	6.50 8.00 8.50	5.85 7.20 7.65
									100K	11.34	10.50	9.45
3000 MICRO-MINIATURE HIGH TEMPERATURE	5/16 x 5/32 x 3/4	P		±10	0.50	175	15	Yes	50 -10K 20K	9.72 10.80	9.00 10.00	8.10 9.00
3010 HIGH TEMPERATURE (RT 11)	5/16 x 9/32 x 1 1/4	L , P		±5	1.00	175	25	Yes	10 -10K 20K-25K 50K	7.02 8.64 9.18	6.50 8.00 8.50	5.85 7.20 7.65
									100K	11.34	10.50	9.45
3070 HIGH RESOLUTION	5/16 x 5/16 x 1 1/16 3/8 x 5/16 x 1 1/16	H P		±5	1.5	175	10	Yes	100 -25K 50K	9.00 11.00	8.34 10.19	7.50 9.17
	5/16 x 5/16 x 1 1/16 7/16 x 5/16 x 1 1/16	S PANEL L MOUNT							100 -25K 50K	9.80 11.80	9.08 10.93	8.17 9.83
3250 SUB-MINIATURE SQUARE HIGH TEMPERATURE (RT 22)	3/16 x 1/2 x 1/2	L	 	±5	1.00	175	25	Yes	10 -10K 20K-25K 50K	6.71 7.56 10.01	6.22 7.00 9.27	5.59 6.30 8.34
	7/32 x 1/2 x 1/2	P, W							10 -10K 20K-25K 50K	7.23 7.97 10.53	6.69 7.38 9.75	6.02 6.64 8.78
3260 MICRO-MINIATURE 1/4″ SQUARE	1/4 x 1/4 x .17	H		±5	0.2	175	11	Yes	10 - 1K 2K- 5K 10K-20K	7.50 8.25 10.50	6.95 7.64 9.72	6.25 6.88 8.75
3280 MICRO-MINIATURE SQUARE HIGH TEMPERATURE	13/64 x 3/8 x 3/8	L, P, W	 	±5	1.00	175	25	Yes	10 -10K 20K-25K 50K	7.56 9.18 9.72	7.00 8.50 9.00	6.30 7.65 8.10
3300 MICRO-MINIATURE SINGLE-TURN HIGH TEMPERATURE	3/8 x 1/4 x 5/16 5/16 dia. x 3/16	W P	  	±5	0.50	175	280°	Yes	10 -10K 20K	5.94 7.56	5.50 7.00	4.95 6.30
	5/16 dia. x 15/32	S							10 -10K 20K	8.91 10.53	8.25 9.75	7.43 8.78

BOURNS TOTAL VALUE / Always your *best* value in potentiometers

EXCLUSIVE RELIABILITY PROGRAM

The Bourns Reliability Assurance Program is the only one of its kind in the potentiometer industry. Its primary goal is reliability! This program frequently requalifies all standard models to assure conformance with published specifications. Free test data is also made available, saving you the time and expense of quality verification. Conducted in addition to NPC-200-3 and MIL-Q-9858A quality control, it makes Bourns potentiometers the most thoroughly inspected and tested units available.

SUPERIOR QUALITY CONTROL

One-fifth of all Bourns production employees work in quality control or reliability monitoring. This is one of the highest personnel ratios of QC employees and inspectors in the electronics industry. All standard Bourns products undergo extensive in-process and 100% final inspection for all electrical characteristics.

HIGH-PERFORMANCE NON-WIREWOUND

	DIMENSIONS H W L	TERMINALS (1)	ACTUAL SIZE	RESISTANCE TOLERANCE (%) (4)	POWER (WATT) @ 70°C	MAX. TEMP. (°C)	ADJ. TURNS	HUMIDITY (5) (MIL SPEC)	STD. RESISTANCES (3) Ω	PRICE (2) 1 - 9	10 - 24	25 - 49
3001 MICRO-MINIATURE HIGH TEMPERATURE RESISTON (7) ELEMENT	5/16 x 5/32 x 3/4	P		±20	0.20	150	15	Yes	20K-1 Meg	11.02	10.20	9.18
3011 HIGH TEMPERATURE RESISTON ELEMENT (RJ 11)	5/16 x 9/32 x 1 1/4	L , P		±20	0.25 @ 50°C	150	22	Yes	5K-5 Meg	7.37	6.83	6.14
3012 HIGH TEMPERATURE PALIRIUM (7) ELEMENT	5/16 x 9/32 x 1 1/4	L , P		±10	1.00	175	25	Yes	2K-1 Meg	7.13	6.60	5.94
3051 HIGH TEMPERATURE RESISTON ELEMENT (RJ 12)	5/16 x 3/16 x 1 1/4	L , S , P		±20	0.25 @ 50°C	150	22	Yes	5K-5 Meg	7.37	6.83	6.14
3052 HIGH TEMPERATURE PALIRIUM ELEMENT	5/16 x 3/16 x 1 1/4	L , P		±10	.1.00	175	25	Yes	2K-1 Meg	7.13	6.60	5.94
3053 HIGH TEMPERATURE PALIRIUM ELEMENT	5/16 x 3/16 x 1 1/4	L P, S		±15 (2Ω) ±10 (5-200Ω)	0.50	175	25	Yes	20-200 2-5 10-200	7.13 11.02 7.13	6.60 10.20 6.60	5.94 9.18 5.94
3251 SUB-MINIATURE SQUARE HIGH TEMPERATURE RESISTON ELEMENT (RJ 22)	3/16 x 1/2 x 1/2 7/32 x 1/2 x 1/2	L P, W	 	±20	0.50 @ 50°C	150	25	Yes	20K-1 Meg	8.22	7.61	6.86
3281 MICRO-MINIATURE SQUARE RESISTON ELEMENT	13/64 x 3/8 x 3/8	L, P, W	 	±20	0.5 @ 50°C	150	25	Yes	20K-1 Meg	7.94	7.35	6.62
3301 MICRO-MINIATURE SINGLE-TURN HIGH TEMPERATURE RESISTON ELEMENT	3/8 x 1/4 x 5/16 5/16 dia. x 3/16 5/16 dia. x 15/32	W P S	  	±20	0.25	150	260°	Yes	10K-1 Meg 10K-1 Meg	6.24 9.36	5.78 8.66	5.20 7.80

MOST ADVANCED PRODUCTS

As the pioneer in adjustment potentiometers, Bourns has set the standards for an entire industry—in new products, in product improvements, in materials, in processes. Innovations such as the RESISTON® carbon and PALIRIUM® film elements and the virtually indestructible SILVERWELD® termination demonstrate that Bourns is constantly pushing the standards higher.

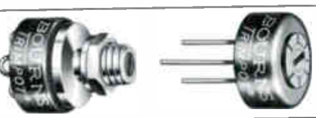
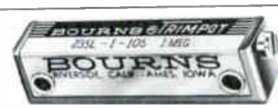
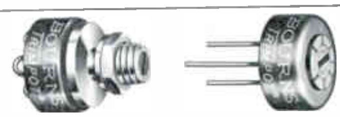
LARGEST SELECTION

Bourns offers the world's largest selection of adjustment potentiometers and an extensive line of precision potentiometers, relays and micro-components. This single-source capability means less shopping around, avoidance of costly specials.

NOTES:
(1) Key to terminal types L = Insulated stranded leads. S = Solder lugs (includes panel mounting bushing on Models 3367S, 3368S, 3300S & 3010S only). P = Printed circuit pins. W = Uninsulated wires (edge mounting 3250, 3251, 3280 & 3281)
(2) Franchised local distributors quote factory prices to 500 pieces. Contact factory for prices in high quantities.
(3) The following resistances are standard if they fall within the limits listed Wirewound — 10, 20, 50, 100, 200, 500, 1K, 2K, 5K, 10K, 20K, 25K, 50K, 100K. RESISTON, RESISTALOY — 5K, 10K, 20K, 50K, 100K, 200K, 500K, 750K, 1 Meg., 2 Meg., 5 Meg PALIRIUM — 2, 5, 10, 20, 50, 100, 100K, 200K, 500K, 750K 1 Meg. Other resistances available on special order
(4) Closer tolerances available on request, except commercial models
(5) All models are sealed against sand and dust.

(Continued)

GENERAL PURPOSE

	DIMENSIONS H W L	TERMINALS ①	ACTUAL SIZE	RESISTANCE TOLERANCE (%) ①	POWER (WATT) @ 70°C	MAX. TEMP. (°C)	ADJ. TURNS	HUMIDITY ⑥	STD. RESISTANCES ③ Ω (MIL SPEC)	PRICE ② 1 - 9	10 - 24	25 - 49
WIREWOUND												
200 GENERAL PURPOSE	5/16 x 1/4 x 1 1/4	L, S, P L		±10	0.5	125	25	Steady State	10 -10K 20K-25K 50K 100K	4.86 6.48 7.56 9.18	4.50 6.00 7.00 8.50	4.05 5.40 6.30 7.65
236 GENERAL PURPOSE	23/64 x 19/64 x 1 11/32	L, S, P L		±10	0.80	135	25	Yes	10 -10K 20K-25K 50K 100K	7.02 8.64 9.18 11.34	6.50 8.00 8.50 10.50	5.85 7.20 7.65 9.45
260 HIGH TEMPERATURE GENERAL PURPOSE	5/16 x 1/4 x 1 1/4	L, S, P L		±10	1.00	175	25	Steady State	10 -10K 20K-25K 50K 100K	5.94 7.56 8.10 9.72	5.50 7.00 7.50 9.00	4.95 6.30 6.75 8.10
3367 SUB-MINIATURE SINGLE-TURN	1/2 dia. x 15/64 1/2 dia. x 35/64	P S		±5	0.50	105	285°	Steady State	10 -20K 10 -20K	4.86 5.67	4.50 5.25	4.05 4.73
271,3,5 COMMERCIAL TRIMIT ⑦	5/16 x 1/4 1 1/4	L, S, P		±10	0.50 @ 25°C	105	25	No	50 -10K 20K	3.19 4.32	2.95 4.00	2.66 3.60
3067 COMMERCIAL E-Z-TRIM⑦	23/64 x 9/32 x 1	S, P		±10	0.50 @ 25°C	85	15	No	50 -20K	1.85	1.71	1.54
3257 COMMERCIAL TRIMIT	.22 x 1/2 x 1/2	L P, W		±10	0.5 @ 25°C	105	25	No	10 -10K 20K	3.19 4.32	2.95 4.00	2.66 3.60
3307 COMMERCIAL SUB-MINIATURE	3/8 x 1/4 x 5/16 5/16 dia x 3/16	W P		±5	0.5	150	280°	Steady State	50 -5K 10K 20K	3.78 4.86 5.94	3.50 4.50 5.50	3.15 4.05 4.95
NON-WIREWOUND												
215 GENERAL PURPOSE RESISTON⑦ ELEMENT	5/16 x 1/4 x 1 1/4	L, S, P		±20	0.25 @ 50°C	125	22	Steady State	5K-5 Meg	4.86	4.50	4.05
235 GENERAL PURPOSE RESISTON ELEMENT	23/64 x 19/64 x 1 11/32	L, S, P		±20	0.25 @ 50°C	125	22	Yes	5K-5 Meg	7.02	6.50	5.85
3368 SUB-MINIATURE SINGLE-TURN RESISTON ELEMENT	1/2 dia. x 15/64 1/2 dia. x 35/64	P S		±20	0.25 @ 50°C	105	285°	Steady State	20K-1 Meg 20K-1 Meg	5.94 6.75	5.50 6.25	4.95 5.63
272,4,6 COMMERCIAL TRIMIT RESISTALOY⑦ ELEMENT	5/16 x 1/4 x 1 1/4	L, S, P		±20	0.20 @ 25°C	105	25	No	5K-5 Meg	3.78	3.50	3.15
3068 COMMERCIAL E-Z-TRIM RESISTON ELEMENT	23/64 x 9/32 x 1	S, P		±20	0.20 @ 25°C	85	15	No	20K-1 Meg	1.85	1.71	1.54

BOURNS TOTAL VALUE/Always your *best* value in potentiometers

BEST AVAILABILITY

The factory maintains a constant reserve of more than 500,000 units. Whatever you need in potentiometers, you can depend on Bourns for an off-the-shelf answer.

BEST APPLICATIONS HELP

Bourns provides a staff of 15 professional Application Engineers whose sole job is to give you technical assistance. Each of these specialists serves a specific geographic area. All are extremely able and anxious to help you cut time, corners and costs.

NOTES (Continued)

(6) Humidity-proof version available on special order. Contact factory for part number, price and delivery.
(7) BOURNS, TRIMPOT, TWINPOT, TRIMIT, E-Z-TRIM, RESISTALOY, RESISTON, PALIRIUM, SILVERWELD, KNOBPOT and QUAORATRON are registered trademarks of Bourns, Inc. Other products made by Bourns, Inc., are identified by trademarks which include: TRIMISTOR, TRIMM, MIL-E-TRIM, CARBOLON, PANLTRIM, MILISEAL, CLOCKPOT, TRIMR, MICROTRIM, RESISTRIM, TRIMPOT JR., B. LABPOT, INFINITRON, DIALPOT, and TRIMPONENT. Bourns, Inc. is the owner, of rights under the following listed United States Letters Patents relating to certain of its adjustment potentiometers: 2.706,230 / 2.777.926 / 2.805.307 / 2.831,949 / 2.873.337 / 2.882.375 / 2.922.976 / 2.935.716 / 2.945.198 / 2.946.975 / 3.010.092 / 3.018.459 / 2.898.569 / 3.089.110 / RE 25.412 / RE 25.725 / 3.107.336 / RE 25.510 / 3.124.779 / 3.124.955 / 3.139.601 Other patents pending. Certain Bourns products are under issued and pending foreign patents.
(8) End setting varies from 1 to 15% to account for lead resistance.

SPECIAL PURPOSE

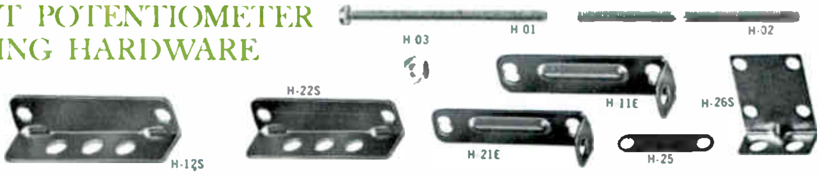
	DIMENSIONS H W L	TERMINALS ①	ACTUAL SIZE	RESISTANCE TOLERANCE (%) ④	POWER (WATT) @ 70°C	MAX. TEMP. (°C)	ADJ. TURNS	HUMIDITY ⑤ (MIL SPEC)	STD. RESISTANCES ⑥ Ω	PRICE ⑧ 1 - 9	PRICE ⑧ 10 - 24	PRICE ⑧ 25 - 49
WIREWOUND												
207 HIGH-POWER (2-WATT)	13/16 x 9/32 x 1 1/4	L		±10	2.00 @ 50°C	175	25	No⑥	100-50K 100K	10.26 11.88	9.50 11.00	8.55 9.90
3020 HIGH-POWER HUMIDITY-PROOF	21/64 x 1/4 x 1 1/4	L		±5	3.75	200	25	Yes	100-10K 20K-25K 50K	14.04 15.66 16.20	13.00 14.50 15.00	11.70 13.05 13.50
209 DUAL-ELEMENT TWINPOT ⑦	5/16 x 1/2 x 1 1/4	L		±10	0.5 (each element)	135	25	No⑥	10 -10K 20K-25K 50K	12.96 14.58 16.20	12.00 13.50 15.00	10.80 12.15 13.50
3030 HIGH-POWER (15-WATT) HIGH TEMPERATURE	1 1/16 x 33/64 x 1 17/64	L		±10	15 @ 25°C	265	25	No	10 -10K	14.58	13.50	12.15
3040 RADIATION PROOF ULTRA HIGH TEMPERATURE	3/8 x 19/64 x 1 1/4	W		±10	5.00	350	17	No	500-20K	27.00	25.00	22.50
ULTRA-RELIABLE												
224-500 WIREWOUND	5/16 x 3/16 x 1 1/4	L, P		±5	0.50	150	22	Yes	100-10K 20K	14.58 16.20	13.50 15.00	12.15 13.50
HIGH RELIABILITY												
3250-501 WIREWOUND	3/16 x 1/2 x 1/2 7/32 x 1/2 x 1	L P, W		±5	0.50	150	25	Yes	100-10K 20K	13.50 14.58	12.50 13.50	11.25 12.15

PANEL MOUNTING

Most models are available with the added convenience of panel mounting. Unique design permits quick factory conversion of "off-the-shelf" units. Clip brackets, mounting brackets and mounting screws are available for other mounting requirements.

Add to price of basic unit			
209	2.16	2.00	1.80
All others	.81	.75	.68

TRIMPOT POTENTIOMETER MOUNTING HARDWARE



H-01 —1 1/2", 2-56 machine screw
H-02 —2-56 Stainless steel rod stock (12" length only)
H-03 —2-56 Hex nut, stainless steel for use on H-01 and H-02
H-04 —1-72 machine screw, 1" long
H-05 —1-72 hex nut, stainless steel (for use on H-04)
H-12S — Stainless steel side bracket for models with 1" mounting centers
H 22S — Stainless steel side bracket for models with 3/4" mounting centers.
H 25 — Stainless steel stacking straps for models with 0 520" mounting centers
H-11E — Stainless steel end bracket for models with 1" mounting centers
H 21E — Stainless steel end bracket for models with 3/4" mounting centers
H-26S — Stainless steel side bracket for models with 0 520" mounting centers

LONGEST EXPERIENCE, RELIABILITY

Bourns—originator and sole manufacturer of the TRIMPOT® leadscrew-actuated potentiometer — has been making adjustment potentiometers longer than any other manufacturer. Bourns products have the longest reliability record, too, having performed successfully in virtually every major U.S. missile and space program. And the record continues: in today's worldwide markets, far more adjustment potentiometers bear the Bourns label than any other.

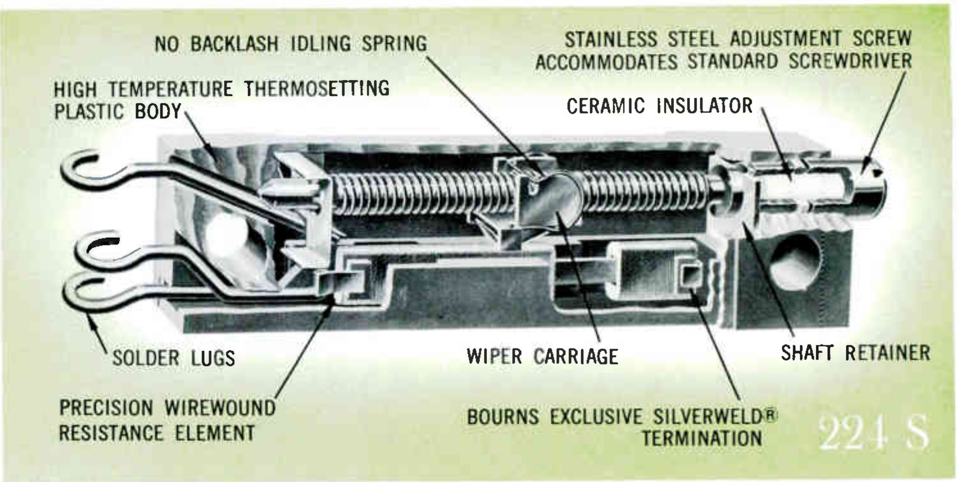
COMPETITIVE PRICES

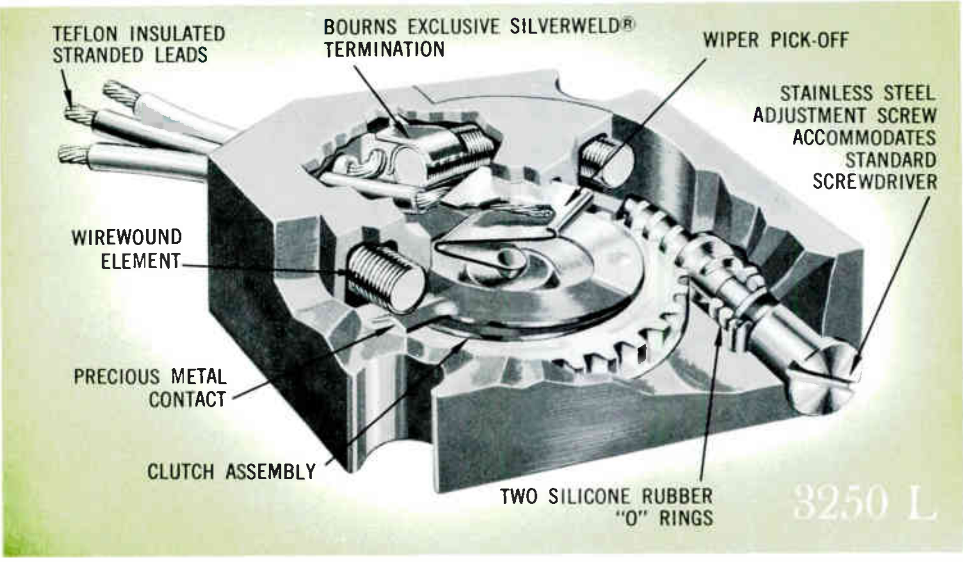
Depth of product line and high production efficiency allow Bourns to meet or beat the prices of competitors—despite its heavy extra expenditure for product reliability. Furthermore, Bourns "holds the line" on prices while continually upgrading its products. In those cases where a Bourns unit is slightly more expensive, you can be sure that the small extra cost means considerable extra value. It is a firm Bourns policy never to compromise quality for price.

BOURNS QUALITY DESIGN

insures BUILT-IN reliability and performance.

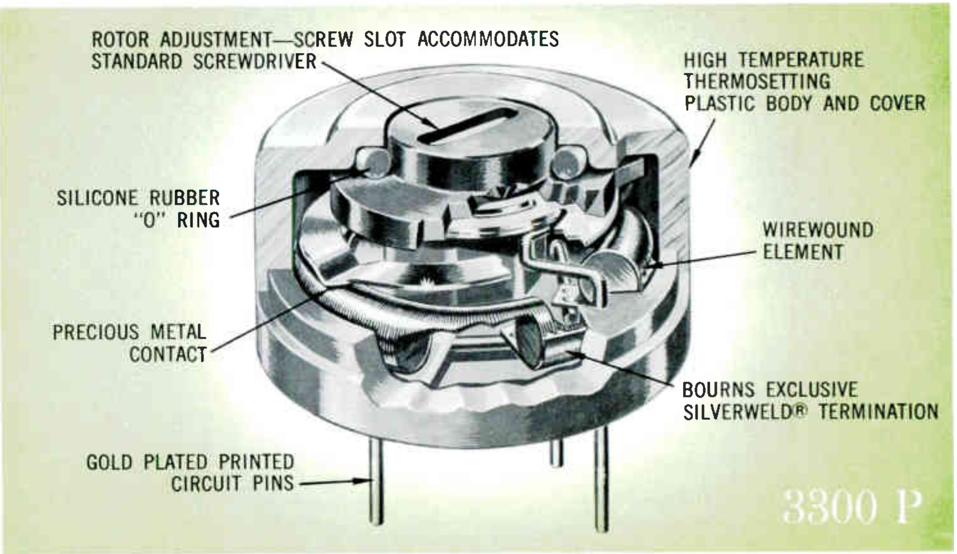
TRIMPOT® LEADSCREW ACTUATED POTENTIOMETERS were introduced by Bourns, Inc., in 1952 to meet the need of the aerospace industry for a rugged, high performance miniature adjustment potentiometer. These units pioneered such potentiometer qualities as small size, accuracy, multi-turn adjustment and stable settings, as well as rugged, sealed construction for reliable performance in severe environments.





BOURNS WORM GEAR ACTUATED POTENTIOMETERS, in the popular square configuration, were developed to add packaging versatility yet assure the same high performance and reliability as the TRIMPOT Leadscrew Actuated Potentiometer line. These units, in ½″ and ⅜″ sizes, available with stranded insulated leads or printed circuit pins, feature all-sealed construction, excellent resolution, and an exclusive clutch-action wiper which prevents damage from forced adjustment.

BOURNS SINGLE-TURN ROTARY POTENTIOMETERS combine many of the leadscrew actuated and wormgear actuated potentiometer features in micro-miniature and subminiature circular configurations. Available with solder lugs and printed circuit pins, these units operate up to 175°C, are encased in a lightweight, all plastic case, and have excellent shock and vibration stability. Micro-miniature types — smaller than a transistor—are available; while sub-miniature types combine high performance with nominal cost.



OTHER PRODUCTS BY BOURNS

Featuring the same exclusive TOTAL VALUE concepts.

PRECISION POTENTIOMETERS

MODEL NUMBER	SIZE (inches) DIA. — CASE LENGTH	NUMBER TURNS	RESISTANCE RANGE (ohms)	TR TOL. (%)	LINEARITY (%)	POWER (watts)	MAX. OP. TEMP. (°C)	HUMIDITY (MIL-R-12934C)
3400	1 13/16 x 1 3/4	10	100-1 Meg	±3	±0.15	5.0 @ 40°C	105	Yes
3410	2 x 5/8	1	50-100K	±3	±0.3	4.0 @ 70°C	125	Yes
3430	1 1/16 x 5/8	1	50-100K	±3	±0.5	1.5 @ 70°C	125	Yes
3440	3 x 5/8	1	100-500K	±3	±0.25	6.0 @ 70°C	125	Yes
3500	7/8 x 1	10	50-500K	±3	±0.2	2.0 @ 70°C	125	Yes (1)
3501	7/8 x 1	10	1K-500K	±5	±0.5	2.0 @ 70°C	125	Yes (1)
3510	7/8 x 9/16	3	20-100K	±3	±0.30	1.0 @ 70°C	125	Yes (1)
3520	7/8 x 11/16	5	25-250K	±3	±0.30	1.5 @ 70°C	125	Yes (1)
3530	7/8 x 1/2	1	25-50K	±3	±0.50	1.0 @ 70°C	125	Yes
3700	1/2 x 1	10	50-250K	±5	±0.25	1.0 @ 70°C	125	Yes
3507	7/8 x 1 1/8	10	100-250K	±5	±0.50	2.0 @ 25°C	105	No
3707	1/2 x 1	10	100-100K	±5	±1.0	1.0 @ 40°C	105	No
3450	2 x 2 1/4	10	100-1 Meg	±3	±0.15	5.0 @ 70°C	125	Yes
3460	2 x 5/8	1	50-100K	±3	±0.3	4.0 @ 70°C	125	Yes
3480	7/8 x 9/16	1	50-100K	±3	±0.5	1.5 @ 70°C	125	Yes
3490	3 x 5/8	1	100-500K	±3	±0.25	6.0 @ 70°C	125	Yes
3550	1 x 1 9/16	10	50-500K	±3	±0.20	2.5 @ 70°C	125	Yes
3551	7/8 x 1 9/16	10	1K-500K	±5	±0.5	2.0 @ 70°C	125	Yes
3560	7/8 x 1 3/64	3	25-100K	±3	±0.25	1.5 @ 70°C	125	Yes
3570	7/8 x 1 3/16	5	25-250K	±3	±0.25	2.0 @ 70°C	125	Yes
3580	7/8 x 5/8	1	25-50K	±3	±0.5	1.0 @ 70°C	125	Yes
3750	1/2 x 1 3/16	10	50-250K	±5	±0.25	1.0 @ 70°C	125	Yes
3600	3/4 x 1	10	100-250K	±5	±0.5 (2)	1.5 @ 25°C	125	Yes
3640	1 1/4 x 1 1/2	10	100-500K	±3	±0.1 (2)	2.5 @ 25°C	125	Yes

(1) Std. models exceed humidity cycling requirements of MIL-STD-202, METHOD 103. Optional models are available meeting moisture resistance requirements of MIL-STD-202, METHOD 106.
(2) Standard dial accuracy, including linearity.

RELAYS AND TIME DELAYS

	Model 3100	Model 3101		Model 3900	Model 3907	Model 3908
Size:	.2″ x .4″ x .6″	.2″ x .4″ x .6″	Time delay range:	0.1 - 200 seconds	0.1 - 200 seconds	0.1 - 200 seconds
Max. Oper. Temp:	125°C	125°C	Nominal voltage:	20 to 30 VDC	20 to 30 VDC	20 to 30 VDC
Contacts:	SPDT; Rating 1.0 amp resistive, 26.5 VDC	DPDT; Rating 1.0 amp resistive, 26.5 VDC	Life (min.)	10^5 cycles	10^6 cycles	10^5 cycles
			Output	DPDT Relay	SPST NO—Solid State	DPDT Relay
Coil resistances:	50Ω to 2000Ω	65Ω to 2000Ω	Contact rating:	1 ampere resistive at 26.5 VDC.	0.05 ampere resistive at 26.5 VDC, 120°C; 0.150 amp at 25°C	1 ampere resistive at 26.5 VDC.
Pick-up sensitivity	100 milliwatts	160 milliwatts				
Vibration:	40 G standard, 3000 CPS	40 G standard, 3000 CPS				
Shock:	150G	150G	Ambient temp. range:	−55 to +120°C	−55 to +120°C	−40 to +85°C

TURNS-COUNTING DIALS

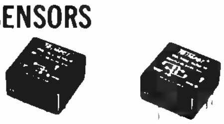
Easy-to-read vernier dials requiring only 1″ of panel space are available for all Bourns precision potentiometers (except KNOBPOT® units, which incorporate their own readout).

New 10-TURN H-351 SERIES TURNS-COUNTING DIAL, only ½″ dia. x ⅝″ long. Clockface readout; continuous, full-gear engagement.

MODEL 3660 LABPOT™ PRECISION POTENTIOMETER

A compact, dial-readout precision potentiometer designed as a convenient tool for a variety of laboratory applications. Incorporates Bourns' exclusive KNOBPOT® potentiometer for high readability through its unique "clock-dial" face. Portable, lightweight, yet remains firmly in place when in use. Large five-way binding posts permit easy hookup of any kind of leads. Fused for protection against burnout. An extra fuse is provided inside for added convenience.

VOLTAGE SENSORS



	Model 3910	Model 3917
Trigger voltage range:	0 to 1000 VDC	0 to 1000 VDC
Supply voltage:	20-30 VDC	20-30 VDC
Life:	10^5 operations	10^6 operations
Output:	DPDT relay	SPSTNO—solid state
Contact rating:	1 ampere resistive at 26.5 VDC	0.05 ampere resistive at 30 VDC
Ambient temp. range:	−55 to +105°C	−55 to +105°C

MICRO COMPONENTS

	Resistor	Capacitor	Inductor	Transformer
Range	1K-200K	10 pf to .12 mf	0.1 Hy-66 Hy	400 CPS-250K CPS
Tolerance	±1% — ±10%	±10% & ±20%		
Temp Range	−65° to +150°C	−55° to +150°C	−65° to +130°C	−65° to +130°C
Rating	0.07Watt at 100°C	200 WVDC		50 MW at 1 KC
Size	0.1″ x 0.03″ x 0.05″	Variable	0.250″ Cube	0.250″ Cube
Environmental	MIL-R-10509D	MIL-C-11015C	MIL-T-27B	MIL-T-27B

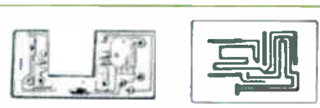
QUADRATRON® EXPONENTIAL RESISTOR

Model 4100A-1-010

Bourns new QUADRATRON exponential resistor generates a multitude of nonlinear mathematical functions when used as an input or feedback element with DC operational amplifiers. Multiply and divide, and obtain square, square root, sine, cosine, and many other functions.

CUSTOM FILM HYBRID CIRCUITS

Now you can get custom micro-circuits from Bourns for virtually any application! Our total capability — conductive, resistive, capacitive and magnetic — can satisfy your custom circuit needs at lowest possible cost! Standard flat-pack configurations eliminate special tooling and insure rapid delivery.



BOURNS
FACILITIES & CAPABILITIES

Bourns TRIMPOT Division and corporate headquarters are housed in an ultra-modern 100,000-square-foot facility in Riverside, California. Named one of the "top ten" plants of 1963 by FACTORY MAGAZINE, it is specifically designed for full-scale production of electronic components. A controlled air system provides dust-free environmental conditions throughout the entire manufacturing area. A separate molding department, with many high-speed presses produces virtually all of the Division's plastic parts and cases for maximum control and quality.

The new Ames, Iowa Plant, currently under construction, incorporates all of the advanced features of the Riverside Facility, including a controlled air system, movable partitions and high intensity lighting. This 75,000-square-foot plant will greatly increase Bourns TRIMPOT Division manufacturing capability. Bourns wholly-owned subsidiary, Bourns (Canada) Ltd., provides the Division with still another manufacturing facility to serve the expanding Canadian market.

BOURNS

All Bourns potentiometers are individually inspected and tested for *all* key physical and electrical specifications. Your final quality guarantee is the Bourns Reliability Assurance Testing Program—the most stringent in the potentiometer industry. Random samples are selected from stock and checked for stability and performance under extreme conditions of cold, humidity, shock and vibration—each condition at the limit of published specifications. Load life and rotational tests are also performed. This unique reliability program is your final guarantee that Bourns components meet or exceed published standards of performance and reliability.

BOURNS, INC., TRIMPOT DIVISION • 1200 Columbia Ave., Riverside, Calif. 92507 • Telephone (714) 684-1700, TWX 714-682-9582

Trimpot® & Precision Potentiometers·Relays·Microcomponents: Transformers, Inductors, Resistors & Capacitors·Microcircuits

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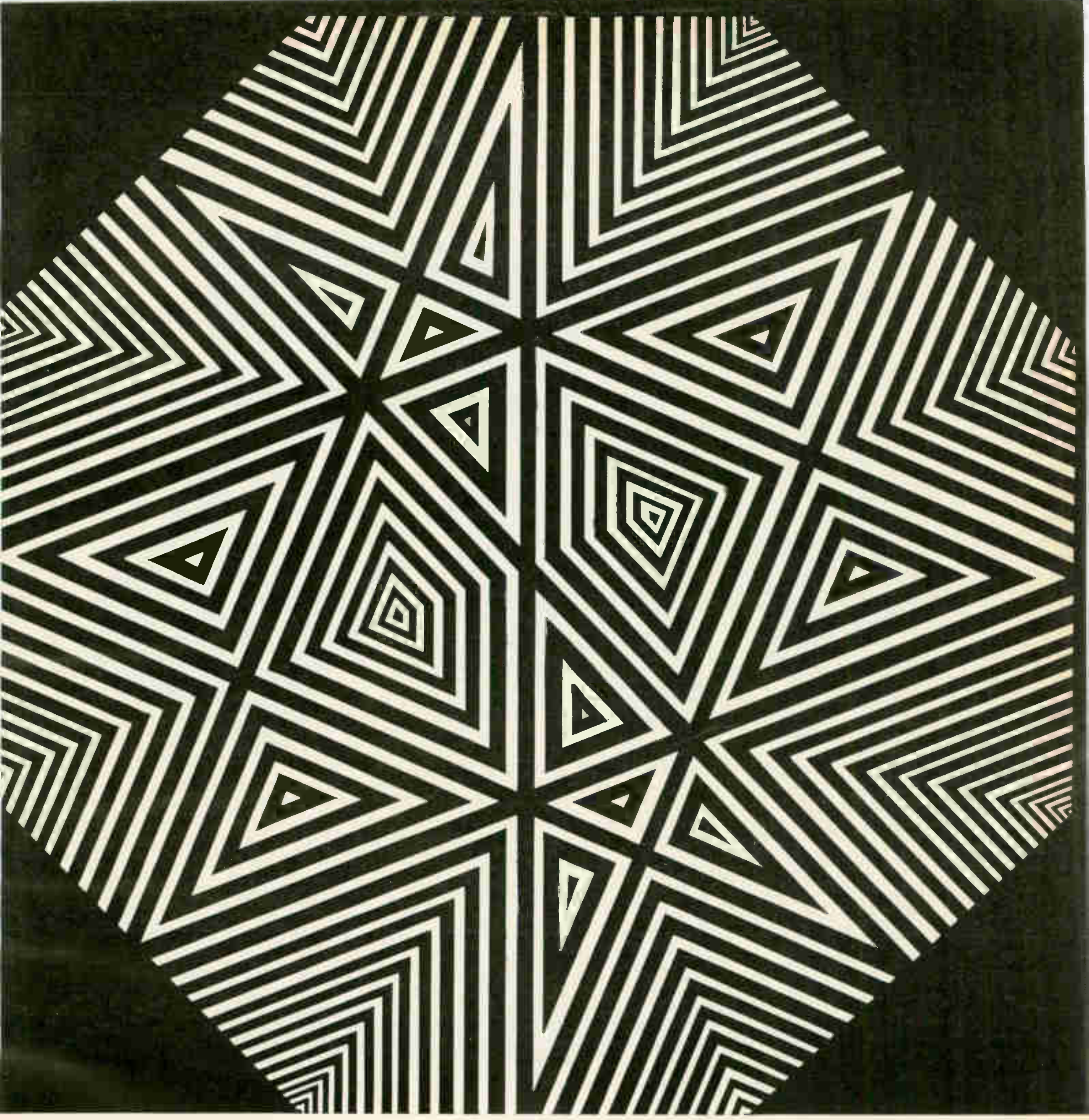

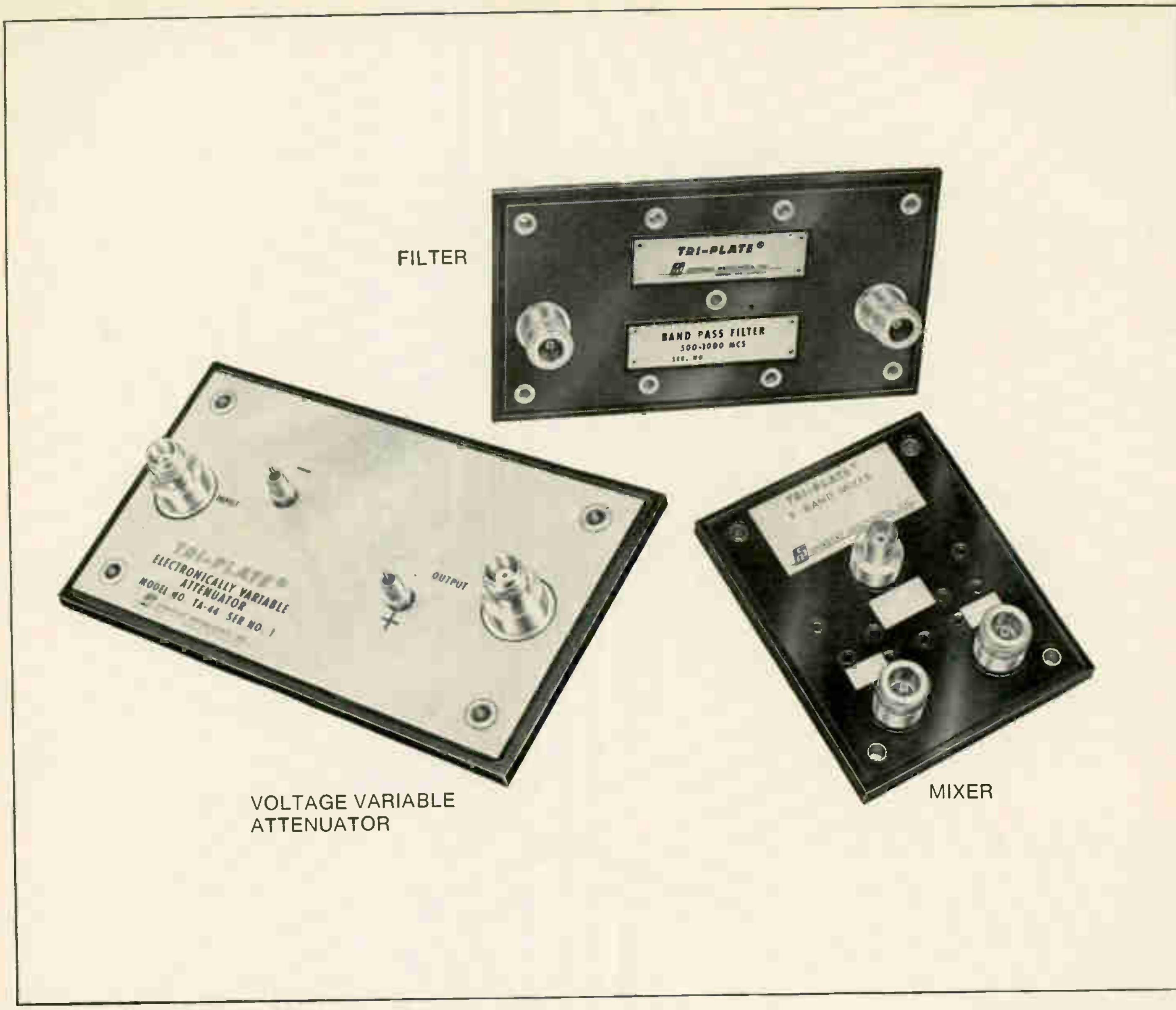
FILTER
TRI-PLATE®
BAND PASS FILTER
500-1000 MCS
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ELECTRONICALLY VARIABLE
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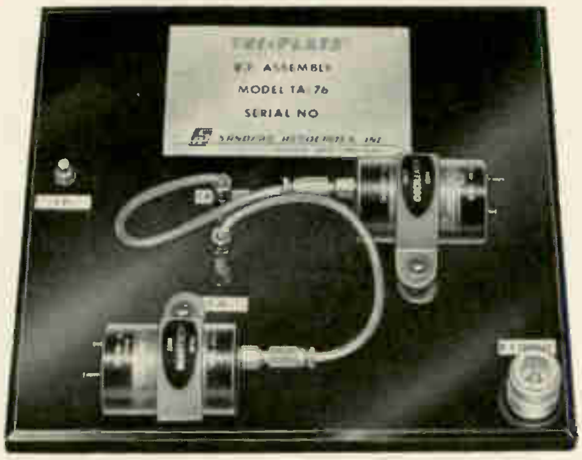
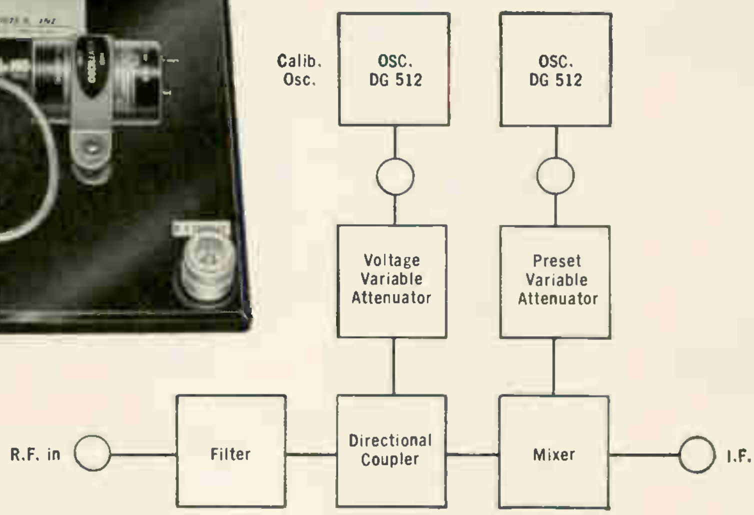
ATTENUATOR
MIXER





INTEGRATED ASSEMBLY
(R.F. front end assembly
for a radar receiver)
All units shown half size

is this...

(Specify Sanders for microwave components or complex integrated packages)

components and designed to perform the same function. By combining all elements in a single, integrated assembly, interface problems are eliminated and high overall system performance is assured. The unique package has a bandwidth of 10% and maintains a VSWR of 1.3 max. as compared to a 1.5 max. for a system where all necessary microwave components are connected. Conversion loss is only 8db as compared with the 9.5 max. in the component system. The noise figure drops to less than 9db into 1.5db preamp; it would be 11db in a conventional cable-connected microwave system.

Whether it's sophisticated microwave components or totally integrated microwave packages, Sanders TRI-PLATE strip transmission line techniques incorporate all necessary solid state elements including both active and passive functions, plus greater reliability and operating economy.

Which do you need? To get the most qualified recommendation on the best method to solve any microwave packaging problem, consult Sanders. Call or write today for complete details on Sanders TRI-PLATE techniques and integrated assemblies, plus comprehensive data sheets on solid state switches and mating drivers. Sanders Associates, Inc., Microwave Products Dept., Nashua, New Hampshire 03060.

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CREATING NEW DIRECTIONS IN ELECTRONICS

Specialized RFI Test Equipment

The vast experience of Electro International, Inc. in radio frequency interference control is clearly evident in these high performing, reliable units. Many have solid state circuitry—all have been designed to military and commercial standards. For detailed specifications on instrumentation ready to solve your RFI problems, call collect: Electro International, Inc., (301) 263-2661.

PREAMPLIFIERS

AP-501R — LOW NOISE TUNABLE VHF PREAMPLIFIER

Circle 286, Reader Service Card

Covering the frequency range from 30 to 300 mc, this preamplifier is designed to satisfy low noise requirements in narrow band applications. Price: $1500.

Frequency Range	30-300 mc, 2 bands
Gain	23 db (nominal) minimum (±2 db)
Noise Figure	4.5 db maximum (less than 3.5 db below 250 mc)
Bandwidth (3 db)	Band A, 30-70 mc, 2 mc Band B, 55-300 mc, 4 mc at 55 mc at 300 mc
Input and Output Impedance	50 ohms (nominal)

AP-502R — LOW NOISE TUNABLE UHF PREAMPLIFIER

Circle 287, Reader Service Card

For low noise requirements in narrow band applications, this preamplifier covers the frequency range from 300 to 1000 mc. Price: $1700.

Frequency Range	300-1000 mc
Bandwidth	3.5 mc at 300 mc 15 mc at 1000 mc
Gain	26 db (nominal) ± 3 db
Noise Figure	4.0 db at 300 mc 8 db at 1000 mc
Input and Output Impedance	50 ohm VSWR > 1.2:1

ARP-300S — LOW NOISE REMOTELY TUNED PREAMPLIFIER

Circle 288, Reader Service Card

150 KC — 30 MC

Designed to increase the sensitivity of receivers using remote rod antennas and which require a 50 ohm input in the 150 kc — 30 mc range. Price: $1020.

Tuning Range	150 kc to 30 mc
Input and Output Impedance	50 ohms
Calibrate Input	50 ohms impedance. Accepts narrow band CW generator or impulse generator

AMPLIFIERS

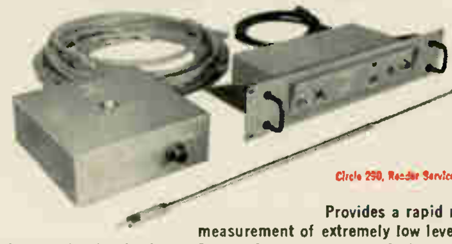
AW-203 & AW-203-1 — WIDEBAND AMPLIFIER GROUP

Circle 289, Reader Service Card

Used in the detection of low level radiated or conducted wideband interference or as a high gain, low noise, video amplifier. Price: $1455.

Gain	80 db
Gain Control	Continuously variable output control plus compensated input step attenuation of 0, 10, 20, 30, 40 db
Bandpass (3 db)	500 cps to 6 mc or greater with load shunted by 60 pfd or less
Input and Output Impedance (10 kc)	50 ohms
Highpass Filter Cutoff Frequency	Approx. 5 kc and 25 kc
Noise Figure	6 db

AW-204 — TRANSISTORIZED WIDEBAND AMPLIFIER



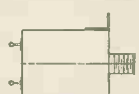
Circle 290, Reader Service Card

Provides a rapid means for remote measurement of extremely low level radio frequency interference in the 14 kc to 30 mc frequency range. It is used in conjunction with standard RFI meters and a calibrated signal source such as an impulse generator and employs the signal substitution method for calibration. Price: $750.

Frequency Range	14 kc to 30 mc (2 bands) 14 kc to 2 mc 2 mc to 30 mc
Input and Output Impedance	50 ohms

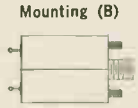
POWER LINE FILTERS (r-f suppression) 130v, 60 cps

Circle 291, Reader Service Card



Mounting (A)

Mounting (B)



Mounting (C)

TYPE	CURRENT RATING (Amperes)	INSERTION LOSS DB	INSERTION LOSS FROM	INSERTION LOSS TO	CASE SIZE** WIDTH (Inches)	CASE SIZE** LENGTH (Inches)	CASE SIZE** DEPTH (Inches)	NOTE
FPA-1000.5-A1 (*)	½	40	0.150 MC	1 KMC	1¾	2¼	1	
FPA-1000.5-B1 ( )	½	60	0.150 MC	1 KMC	1¾	2½	1	
FPA-1000.5-C1 ( )	½	80	0.150 MC	1 KMC	1¾	3½	1	
FPA-1000.5-D1 ( )	½	60	0.100 MC	1 KMC	1¾	2¼	1½	
FPA-1000.5-E1 ( )	½	70	0.100 MC	1 KMC	1¾	2½	1½	
FPA-1000.5-F1 ( )	½	100	0.100 MC	1 KMC	1¾	3½	1½	
FPA-1001-F1 ( )	1	60	0.300 MC	1 KMC	1¾	3½	1½	
FPA-1003-G1 ( )	3	60	0.300 MC	1 KMC	2¼	2¾	1½	
FPA-1005-K1 ( )	5	60	0.300 MC	1 KMC	3	3½	1½	
FPA-201 ( )	1	70	0.150 MC	1 KMC	2 5/16	2 11/32	1⅜	
FPA-203 (C)	3	60†	0.150 MC	1 KMC	3 1/16	3 9/16	1 9/16	(C) MTG. ONLY
FPA-205 (C)	5	60†	0.150 MC	1 KMC	3 1/16	3 9/16	1 9/16	(C) MTG. ONLY

**Not including mounting brackets, terminals and connectors † 80 db at 0.400 kc to 1 kmc

* ( ) Letter assigned according to method of mounting desired by customer.

COMPLETE LITERATURE with detailed specifications available on request.

RADIO FREQUENCY INTERFERENCE CONTROL AND TEST SERVICES AVAILABLE

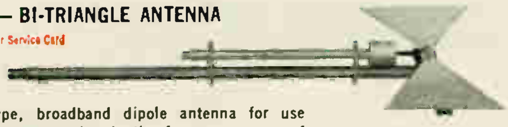
Wherever your problem exists, call for quick reaction estimates.

By Electro International, Inc.

ANTENNAS

BTA-901 — BI-TRIANGLE ANTENNA

Circle 292, Reader Service Card

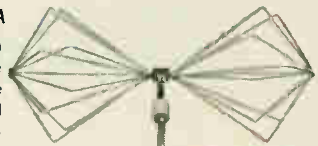


Bow-tie type, broadband dipole antenna for use with receivers operating in the frequency range of 300 to 1000 mc. The antenna is fitted with a broadband balun which permits it to operate efficiently over its frequency range without tuning. Price: $125.

Frequency Range	300-1000 mc
Impedance	50 ohm unbalanced (type N fitting)

BCA-902 — BI-CONICAL ANTENNA

Bi-conical, broadband, dipole antenna for use with receivers operating in the frequency range of 88 to 350 mc. The antenna is fitted with a broadband balun which permits it to operate efficiently over its frequency range without tuning. Price: $160.



Circle 293 Reader Service Card

Frequency Range	88-350 mc
Impedance	50 ohm unbalanced (type N fitting)

ANCILLARY EQUIPMENTS

ET-1A/SA & ET-1A/E — SUBAUDIO DETECTOR GROUP

Circle 294, Reader Service Card

Provides a means of detecting low level electric and magnetic fields in the subaudio frequency range. The instrument is used in two modes—electric and magnetic field input. Price: $1630.

Gain: Electric Field Position Magnetic Field Position	50 db (nominal) 75 db (nominal)
MDS: Electric Field Position Magnetic Input Position	40 db above 1 uv/meter or less Less than 32 db above 1 microampere turns/meter
Bandpass	3-45 cps
Magnetic Input Impedance	Approx. 10 ohms or less

RG-3 — INTERFERENCE RASTER GENERATOR

Circle 295, Reader Service Card

Used as an aid in determining the sources of signals interfering with computers, voice and digital communications and telemetry. Price: $1365.

Video Bandpass (3 db)	5 cps to 5 mc/s
Video Gain	40 db
Input Impedance (1 kc)	100 K ohms
Output Impedance (1 kc)	50 ohms at Z axis output
Gain Control	Continuously variable gain control plus compensated input step attenuator of 0, 10, 20, 30, 40 db
"Z" Output Dynamic Range (1 kc)	30 volts pk-pk or greater
Video Amplifier Modes	Normal or inverted, linear or compressed
Low Pass Filter Cutoff Frequencies	5 mc, 500 kc, 50 kc, 5 kc, 500 cps, 50 cps
High Pass Filter Cutoff Frequencies	5 cps, 50 cps, 500 cps, 5 kc, 50 kc, 500 kc
Pulse Stretcher	Selectable bipolar, 40 microsecond discharge time constant

HF-1 — POWER LINE IMPEDANCE STABILIZATION NETWORK

Circle 296 Reader Service Card

Specifically designed to present a high impedance to line-conducted r-f interference in the measurement of interference levels present on the power supply line or terminal equipment under test. Reflecting a high impedance (relative to 50 ohm) the HF-1, when used with any 50 ohm RFI detection system, precludes the possibility of inaccuracies in RFI power line conducted measurements. Price: $180.

Frequency	4 mc - 1 gc	Maximum Current	8 amps
Line Voltage, DC	200 volts max.	Maximum Insertion Loss	— 15 db
Line Voltage, AC (60 cps)	220 volts max.		
Output Impedance		50 ohms (unused output must be terminated with 50 ohms)	

LF-1 — POWER LINE IMPEDANCE STABILIZATION NETWORK

Presents a high impedance to line-conducted r-f interference in the measurement of RFI levels present on the power supply line of terminal equipment under test. Reflecting a high impedance (relative to 50 ohm) the LF-1, when used with any 50 ohm RFI detection system, effectively precludes the possibility of inaccuracies in RFI power line conduction measurements. Price. $295.

Circle 297, Reader Service Card

Impedance (into AC output on either BNC)	50 ohms nominal
Line Voltage, DC	200 volts, max.
Line Voltage, AC (60 cps)	220 volts, max.

LK-1 — LOW LEVEL KEYER

Assists in isolating the sources of radio interference from teleprinters and similar data handling equipments under test. Price: $290.

Voltage Requirements	105-125 vAC, 60 cps, 40 watts

Circle 298, Reader Service Card

BG-7 — BAUD GENERATOR

Pulse pattern generator for bench or screen-room testing of communications equipment such as demodulators, data processing equipment, low level teleprinter keyers, paper tape punches, etc., at speeds less than 60 wpm to over 100 wpm. Other clock frequencies and ranges are also available. The BG-7 can be used as a DC square wave generator or keyed tone generator. Price: $750.

Circle 299 Reader Service Card

KEYED DC OUTPUT

Baud Length	Baud length continuously adjustable to cover range of printer speeds from below 60 wpm to above 100 wpm.
Baud Sequence	7 or 8 baud cycle, each baud individually adjustable for mark or space condition. Total of 128 combinations possible. (7 & 8 bauds switched together, i.e., double stop for teleprinter. Double stop optional—switch selected.)
Voltage Level	Variable 0 to + 10 volts, 0 to — 10 volts, and + 10 to — 10 volts.
Output Impedance	600 ohms (nominal)
Keyed Tone Output Frequency	Internal, selectable 1 kc and 10 kc (nominal) External, 5 cps to 80 kc

Prices and data subject to change without notice.

The BIG "E"

ELECTRO INTERNATIONAL, INC.

For discussion on complete product line, contact representative in your area or Electro International, Inc., Box 391, Annapolis, Maryland 21404, TEL 301—263-2661, TWX 301—267-8275

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New PAR Lock-In Amplifier Measures Signals in the Presence of Noise by Crosscorrelation

Transistorized Lock-In Amplifier — Model HR-8

The PAR Model HR-8 Lock-In Amplifier represents a significant advance in signal processing equipment for experimentalists who must measure low-level signal intensities in the presence of noise. It employs the theoretically optimum technique for signal recovery, and can be incorporated into a large class of experiments in which the signal of interest is, or can be made periodic, and in which a reference voltage related in frequency and phase to the signal can be obtained. The Model HR-8 first amplifies and bandlimits the input signal and then crosscorrelates it with the reference signal, suitably phase shifted and shaped. The crosscorrelation of input and reference signals yields a DC output voltage proportional to the signal of interest, while the crosscorrelation of the reference and noise results in no net DC voltage. The system can also be described as a continuously integrating, highly sensitive, phase conscious voltmeter, the response of which is "locked" to that particular frequency and phase at which the signal information has been made to appear.

Technical Features:

Frequency Range: 1.5 cps to 150 KC continuously tunable in 5 ranges.

Time Constants: 11 values in 1-3 sequence extending from 0.001 to 100 seconds. Single or double section RC filtering.

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Type A: Differential 10 megohm input.
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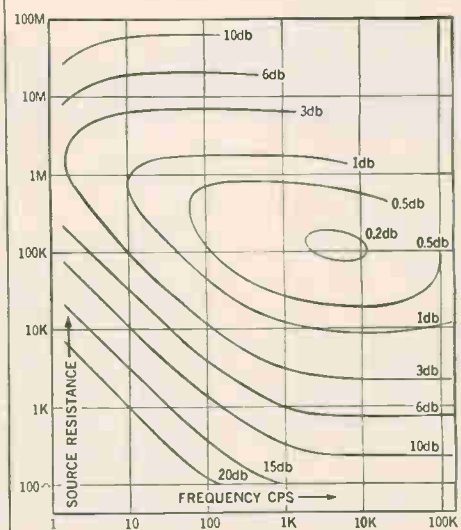

Contours of constant noise figure for a typical PAR Type A preamplifier plotted to show dependence on frequency and source resistance at 300° K. Amplifier operated single-ended.

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Electronics Review

Volume 38
Number 23

Missiles

Orbiting bombs

The best argument for producing satellite-killer missiles was paraded through Red Square on the anniversary of the Bolshevik Revolution. It was a 115-foot "orbital missile," called the Scrag, whose warhead, the Russian military declared, "can deliver its blow on the first or any other orbit around the earth."

On Sept. 17, 1964, President Johnson announced that the United States had two operational satellite killers: one a derivative of the Army's Nike-Zeus and the other stemming from the Air Force's Thor. The President had said that both weapons had proven their effectiveness, but neither has so far been ordered into production.

This Iron Maiden rocket, encased in a cylindrical pod, can be launched from its own self-propelled transport. Weapons paraded in Red Square showed Soviet emphasis on mobility and longer range. The Russians also displayed a 115-foot "orbital missile."

Tracking danger. The satellite interceptors would use the North American Air Defense Command's elaborate space detection network, which is operated by the Navy and Air Force. The Air Force scans the sky with large, land-based radars throughout the United States; the Navy with radars on board ships as well as a large interferometer system on land.

The Russian boast caught United States officials by surprise. Back in September, 1963, Soviet Foreign Minister Andrei Gromyko proclaimed his government's intention to refrain from orbiting nuclear or mass-destruction weapons. And President Kennedy followed suit the next day, with a similar announcement. Then, in October of that year, the United Nations approved a resolution that bars weapons in space, and both the U. S. and Russia signed the ban.

Offense or defense. The question for the United States, then, is whether to concentrate on defensive weapons—satellite killers—or to orbit a bomb of its own. As recently as last Aug. 25, a Pentagon official, during a press briefing on the manned orbiting laboratory (MOL), repeated the U. S. position against orbiting a weapon of mass destruction. MOL, it was emphasized, was to be a space platform limited to experiments and surveillance.

While the orbiting missile was the big news of the parade, other Russian weapons—many shown for the first time—rumbled over the cobblestones in an impressive display.

The emphasis on mobility and longer-range solid-fuel rockets indicates that the Russians are phasing out of their arsenal stationary liquid-fuel missiles—even those in hardened underground sites.

Another new missile was a small, intercontinental solid-fuel model that looks like Russia's operational Scamp missile.

Mobility. Two tactical missiles, the Frog and the Scud, were displayed; they are capable of carrying nuclear weapons hundreds of miles. Both appear to have been lengthened, to 75 feet from 60 feet, indicating an increase in their range and destructive force.

Both missiles were hauled on fast-moving carriages. This was interpreted as evidence of Russia's desire for more missile mobility.

One new weapon that was shown relied heavily on electronics. The weapon, a 50-caliber antiaircraft gun, carried on a vehicle, has its own built-in radar to search out its target. One analog computer, needed for the fire control system, will be used in each vehicle to aim the weapon system's four guns. This is the kind of weapon that has knocked United States planes out of the sky over Vietnam.

Consumer electronics

Pay 'phone

Next year, some shoppers will be able to pay bills by telephone. In a preliminary version of the "pay-by-'phone" technique, a chain of six department stores in Delaware will collect for purchases by telephone, but the 'phones will be set up in the stores.

The computer-operated system

set up by the Bank of Delaware, Wilmington, uses plastic identification cards and the Bell System's new touch-tone 'phones. A slot in these 'phones accepts perforated cards coded with frequently called numbers.

Back-to-back. The bank issues a perforated plastic identification card to a depositor. When he makes a purchase, he presents this card to a store clerk who inserts it and the store's identification card, back-to-back, in the phone slot. The cards automatically dial the bank's computer, which notes the identity of the customer and the store. The clerk next presses numbered buttons on the face of the phone, as if it were a cash register, to record the dollar amount of the purchase.

Automatically, the bank's computer deducts the amount of the purchase from the customer's account and credits it to the store's account.

The principle behind the telephone-computer technique isn't new. But similar systems currently in operation are internal: clerks at a bank branch can get data or transact business through the bank's central computer via telephone.

Other banks are also moving into this new area of paying bills by phone. The Wells Fargo Bank of San Francisco and the Manufacturers National Bank of Detroit, for example, which currently use the internal system, plan to adopt the external system soon.

Development work on the bill-paying scheme is being conducted by the International Business Machines Corp. and the American Telephone & Telegraph Co.

Military electronics

Long-term gamble

"We're not going to participate in project-definition competition again; the amount of money you spend, compared with the chance of winning, isn't worth it."

Speaking is F. Edward Rushlow, a vice president and director of marketing of the Giannini Controls Corp. Rushlow is not alone in his complaint. Many businessmen are unhappy because they say the definition phases of major military contracts are becoming too long and too costly.

The long round. The study phase for the giant cargo plane, the C-5A, for example, took about 18 months before development contracts were awarded. In the final round of competition, the three airframe and two engine competitors who were still in the running required 240,000 pages to present their proposals. Thirty copies of each proposal had to be submitted and the paper alone weighed 35 tons. More than 400 Air Force personnel spent five months reading and evaluating this mass of data. Furthermore, the competing companies spent some $15 million each in the contest, and received only $7 million each from the government.

In the contract-definition phases for the manned orbiting laboratory (MOL) and the integrated helicopter avionics system (IHAS), the basic story is the same.

Loud complaints. Subcontractors —and most electronics companies are subcontractors—are the most vociferous in their complaints, because their risks are greater and their resources usually more limited than contestants for a prime contract. In addition, the government doesn't help underwrite their participation in the competition as it does for prime contractors.

Most executives don't go as far as Rushlow of Giannini. They think the definition concept is good, from both the government's and the contractor's standpoint. But they feel, as does Sidney Sternberg, vice president and general manager of Electro-Optical Systems, that the time has come to shorten and simplify the procedure.

The Defense Department is aware of these criticisms and is concerned about them, although it does not agree they are all valid. It is considering asking industry associations to form a study group to look into the complaints and to suggest specific remedies.

The Pentagon uses the definition technique to pin down design details, technical risks, estimated costs and time schedules before embarking on a complex development program. With contractors performing definition studies on a competitive basis, the Pentagon is thus able to choose the one offering the best price, development plan and management concept. It also employs the highly controversial "technical transfusion" technique of taking the best features of the losers' proposals and wrapping them into the winning bid.

Why so long? Definition contests are growing longer because the government is increasingly cautious about beginning risky new developments such as MOL and because, as in C-5A, it is beginning to demand that contractors submit plans and bids not only for development, but also for production and provision of support equipment.

In a recent speech to the Electronics Industries Association's Systems Effectiveness Conference, Sternberg pinpointed some of the major problems:

As the competition goes through its various phases, government representatives "confer with each of the competing primes, and then rewrite the requirements, and confer with the primes again, giving guidance and evaluation results, and perhaps again submitting new requirements." As a result, "ideas generated vertically from prime to government soon drift horizontally —like cigar smoke in a crowded room—toward the other primes so that innovations developed privately by one soon become the common property of all."

Sternberg points out that the subcontractor's risk in contract definition is always going to be greater than the prime contractor's because the subcontractor has no assurance he is going to share in the final award of a hardware contract. The prime contractor may decide to reopen the subcontract competition or, as in the case of MOL, the government may insist that this be done.

Double jeopardy. But the likelihood of the subcontractor being placed in double jeopardy increases as the definition competition lengthens because prices and proposals tend to become outdated.

Robert Charles, assistant secretary of the Air Force, has said he will try to simplify the data and cost demands for contract definition under the "total package" procurement technique used on C-5A. Perhaps, he says, the Pentagon should seek less design detail and instead let the winning contractor achieve required performance level in his own way. And the Air Force could be satisfied with less cost data, he adds, since it is turning more and more to fixed-price incentive contracts.

Navy's A-7A makes its maiden flight over Dallas. The plane is being built under the Navy's first fixed-price contract.

On their toes

Representatives of Ling-Temco-Vought, Inc., and a handful of other military contractors breathed easier last week in Dallas after the A-7A Corsair II landed following a successful maiden flight. The contractors had been more concerned than usual because the multimillion-dollar contract for the light attack plane is the most demanding one ever awarded by the Navy. The order, the Navy's first fixed-price contract, calls not only for stiff performance specifications, but even stiffer maintenance specs.

So LTV has no choice but to be extra tough with its vendors. If the company fails to meet the demanding specs, the Navy can hit it with massive penalties.

He's out. Says an LTV spokesman: "We have a second tier of vendors waiting in the wings. If the first guy doesn't deliver (on time and within the specs) he's out."

To be sure these difficult specs are met, says Sol Love, LTV's project manager for the craft, the company was forced to avoid state-of-the-art equipment. Some 90% of the avionics is conventional, off-the-shelf gear.

The only exception is the classified forward-looking radar-television display system being provided by Texas Instruments Incorporated. But the system wasn't adopted without a struggle; LTV officials at first were against gambling on a development system. However, Texas Instruments officials convinced LTV engineers that not only is the display reliable, but a new radar system would give the prime contractor a big advantage over other competitors for the new Navy plane.

Under the maintenance specs, LTV had to guarantee that for each hour of flight, the A-7A wouldn't need more than 11.5 hours of maintenance man hours.

So far, LTV has contracts in excess of $221 million for 182 of the planes, and it's expected that the Navy will eventually order between 1,000 to 1,500.

Instrumentation

Deep-sea Geiger counter

An unusual underwater Geiger counter may help oceanographers discover why fish can't live in some parts of the ocean.

The Research Triangle Institute in Durham, N. C., is developing an "off-side" counter that will allow a chemical examination known as radio-release analysis to be used for continuous measurement of the oxygen content of water down to depths of 6,000 feet.

Lack of oxygen is believed to be one reason for the ocean's barren areas, a lack that is probably related to the absence of nutrients that would support plant life. Studies of the barren areas have been hampered by the lack of continuous measurement methods. Conventional sample-taking and analysis is a lengthy, difficult process.

Pollution gauge. Radio-release analysis may also perk up the waning industrial interest in Geiger counters, especially in view of a nationwide effort to control water pollution. The technique can be used to measure the pollution of rivers by sewage, since one measure of such pollution is a decrease in oxygen.

Oxygen in water flowing over an isotope of thallium, Tl-204, causes a chemical reaction that releases thallium ions. The ions and the water form a solution that emits beta particles. The solution's radioactivity is proportional to the amount of oxygen in the water.

For accurate analysis, water must be at ambient pressure, and conventional Geiger counters can't withstand deep-water pressures.

Eccentric tube. Research Triangle has built a sturdy, but eccentric, counter tube. The anode wire is off-center to allow room for a small, stainless-steel pipe that carries the solution of thallium and seawater through the counter. The counter works as well as the concentric ones that others make, although it is more difficult to calibrate, says Harold G. Richter, of Research Triangle's measurements and control laboratory.

Counting circuits will be in a protective container and connected to surface equipment by an armored cable. Like most of the institute's work on counters, the development is being sponsored by the Atomic Energy Commission. The institute is operated by three North Carolina universities.

Wrap-around counters. Richter and his coworker, Arthur S. Gillespie Jr., have designed even odder counters. One looks like a vacuum-cleaner's plastic hose. Increasing the length increases the counting capabilities. The hose was to be wrapped around pipes and other vessels for radioactive tracer measurements, but industry never adopted the idea.

Many of the hoped-for applications of beta detectors have been taken over by gamma counters, which are more sensitive, or by nonnuclear techniques that employ a change in dielectric constant rather than a radioactive tracer to detect the interfaces between liquids in a pipe.

Richter hopes for better luck with an unusual design for anti-coincidence counters. These sensitive instruments, usually a cluster of small cylindrical counters, reject counts caused by high-level radiation passing through the array. Low-level radiation that triggers only one counter is measured.

The same result can be obtained, Richter says, by arranging four triangular counters to form a square in cross-section. Such counters could be used to detect and compare low levels of radioactivity in gases channeled through each triangular section and they would be easy to make, Richter says.

Pollution control. Last winter, Richter and Gillespie experimented with radio-release analysis at the local sewage plant. They found it could determine whether there were harmful bacteria in the plant's outflow into a stream. If the oxygen content in the stream drops, it means that some harmful bacteria are victors in the war with "good" bacteria in the plant's digesting beds.

The two scientists say radio-release analysis may also be useful in monitoring food and beverage production by fermentation processes.

They are hoping for a chance to try it out in a brewery.

Advanced technology

What race?

Ask any laser researcher if he's involved in a race for the most powerful, most efficient continuous-wave laser, and he'll deny it. But a quick look at the flood of recent announcements indicates that not only is there a race, but the pace is feverish.

Only a few weeks ago the record output for a laser was 42 watts, from yttrium aluminum garnet (YAG). Since then, that level has been more than quadrupled, with Bell Telephone Laboratories—for the time being at least—holding the lead with 183 watts.

Here's the way the field shapes up:

The Radio Corp. of America reported 10 watts of c-w emission from double-doped YAG with an efficiency of 0.33%. Two weeks earlier the Linde division of the Union Carbide Corp. announced 42 watts, c-w, at 0.07% efficiency from a neodymium-doped YAG. YAG emits in the infrared at 1.06 microns.

Quasi c-w. Kumar Patel, Ping King Tien and James McFee of Bell Labs reported a 6.2%-efficiency carbon-dioxide, nitrogen and helium laser with c-w power of 106.5 watts; it is excited by a direct-current source. Then, using a-c as the pump, the researchers got 183 watts of quasi c-w at 7.4% efficiency. They used a plasma tube that is 2.3 meters long, 78 millimeters in diameter. Two frequencies were emitted—one at 10.5915 microns, the other at 10.6324 microns. Quasi c-w is the result of lasing only on the peaks of the a-c cycle, and the output looks like a continuous series of spikes.

At the Perkin-Elmer Corp., researchers J. Dane Rigden and Guido Moeller announced a 130-watt CO_2-N_2-He laser, also providing a quasi c-w output, with an efficiency of 8.2%. Another 40-watt device has an efficiency of 13.8%. The researchers used a plasma tube 6 meters long to get a spectral output of several wavelengths close to 10.6 microns.

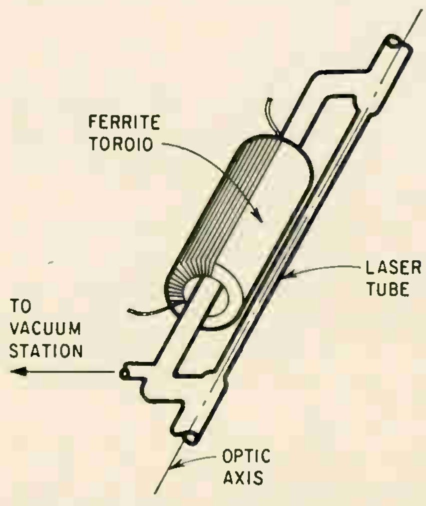
At the Raytheon Co., a 90-watt CO_2-N_2-He laser has been operated at about 7% efficiency. A ¾-inch plasma tube is used to give the continuous-wave output, and larger diameters are expected to increase power by a factor of five. This is a d-c pumped system.

Keep cool. The high efficiencies of such gas lasers make cooling of the discharge tube a negligible factor (fans or water jackets can be used for this purpose), and the only problem of any consequence is the limitations of available power supplies whose impedance matches that of the laser's.

Presumably, more input power is one sure way of pushing up output, and increasing tube diameter is another. However, beyond diameters of about 3 inches, the gas discharge is no longer uniform, that is, only portions of the CO_2 become excited enough to lase, and power begins to drop. It is estimated that diameters less than about 3 inches can only provide powers of up to 500 watts. More than that will probably come from folded tubes. Although such geometries would be expensive, they could probably get powers up to many kilowatts.

Lasing by induction

Gas-ion lasers are susceptible to all sorts of trouble: even the slightest impurities in the gas foul up the



Design of an experimental laser system developed by William E. Bell of Spectra-Physics. A ferrite toroid, wrapped around the ion gas laser tube, induces an alternating voltage in the tube, causing laser action.

metal electrodes, while sputtering of particles from the cathode contaminates the gas. In addition, only nonreactive gases can be used in the tube and current input must be limited to less than 50 amperes or the tube will be destroyed. A laser design that appears to get around all these shortcomings is being developed by William E. Bell, a physicist at Spectra-Physics, Inc., of Mountain View, Calif. The laser eliminates the troublesome electrodes, and produces an alternating voltage inside the gas tube by magnetic induction.

Double doughnut. Spectra-Physics' laser looks like two interlocked doughnuts; one doughnut is the gas-filled laser tube, and the other is a coil wound over a ferrite core. By driving the core with an alternating current, a voltage is induced in the tube. In every other respect, however, the design is like any other ion laser.

But, unlike a laser that uses electrodes, this one is regenerative; that is, ions are not lost at the cathode—since there is no cathode. Hence, ions excited by the induced voltage remain inside the tube. Efficiencies many times better than those achieved with lasers that use electrodes are expected, according to Bell.

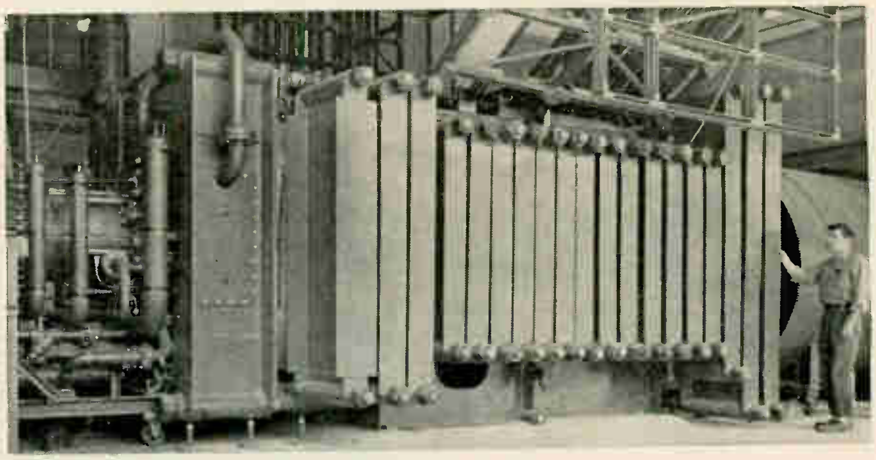
The design has several other advantages. Since almost any gas can be used in the tube, a wider variety of output frequencies can be produced.

In addition, Bell reported that he was able to operate a sulfur laser for several hours with no signs of cataphoresis or arc instabilities. Earlier attempts to lase with sulphur gas haven't been very successful because of the reactive nature of such a vapor.

Superpower generator

Some day the military may build a laser powerful enough to blast a hole through a mountain. If it does, the system will need a mighty power source—like the one Avco-Everett Research Laboratory is developing in Haverhill, Mass., on the shores of the Merrimack River.

"The long-range aim is hundreds and thousands of megawatts," says Thomas R. Brogan, director of the magnetohydrodynamic (MHD) generator program at this division of the Avco Corp.



Huge, rocket-powered generator produces 33.3 million watts. The generator is being developed for the Air Force by the Avco-Everett Research Laboratory.

Like many other laboratories, Avco-Everett is working on gas lasers, which offer promise of power outputs in the kilowatt range. There are indications that MHD generators may be able to pump 20 megawatts of short-duration power into a laser within a year or two. And, if laser efficiency levels do not improve significantly it will require input powers in the megawatt range to achieve kilowatt outputs.

Energy conversion. The MHD generator operates on the same principle as a conventional generator: an electrical conductor moving through a magnetic field generates a voltage. But instead of a rotating armature driven by a turbine, the MHD device drives a stream of high-temperature, ionized gas—a plasma—through a magnetic field. Thus a solid moving part is replaced by the plasma, and the turbine is eliminated. Electricity is produced by a direct energy-conversion process, which is simpler and theoretically more efficient.

Under a program funded by the advanced research projects agency of the Department of Defense, Avco-Everett developed a self-excited steady-state MHD generator driven by a rocket engine. The generator, called the Mark V, has achieved a record direct-current output of 31.3 million watts gross and 23.6 million watts net. The 7.7 million watt difference was used to energize the magnetic field.

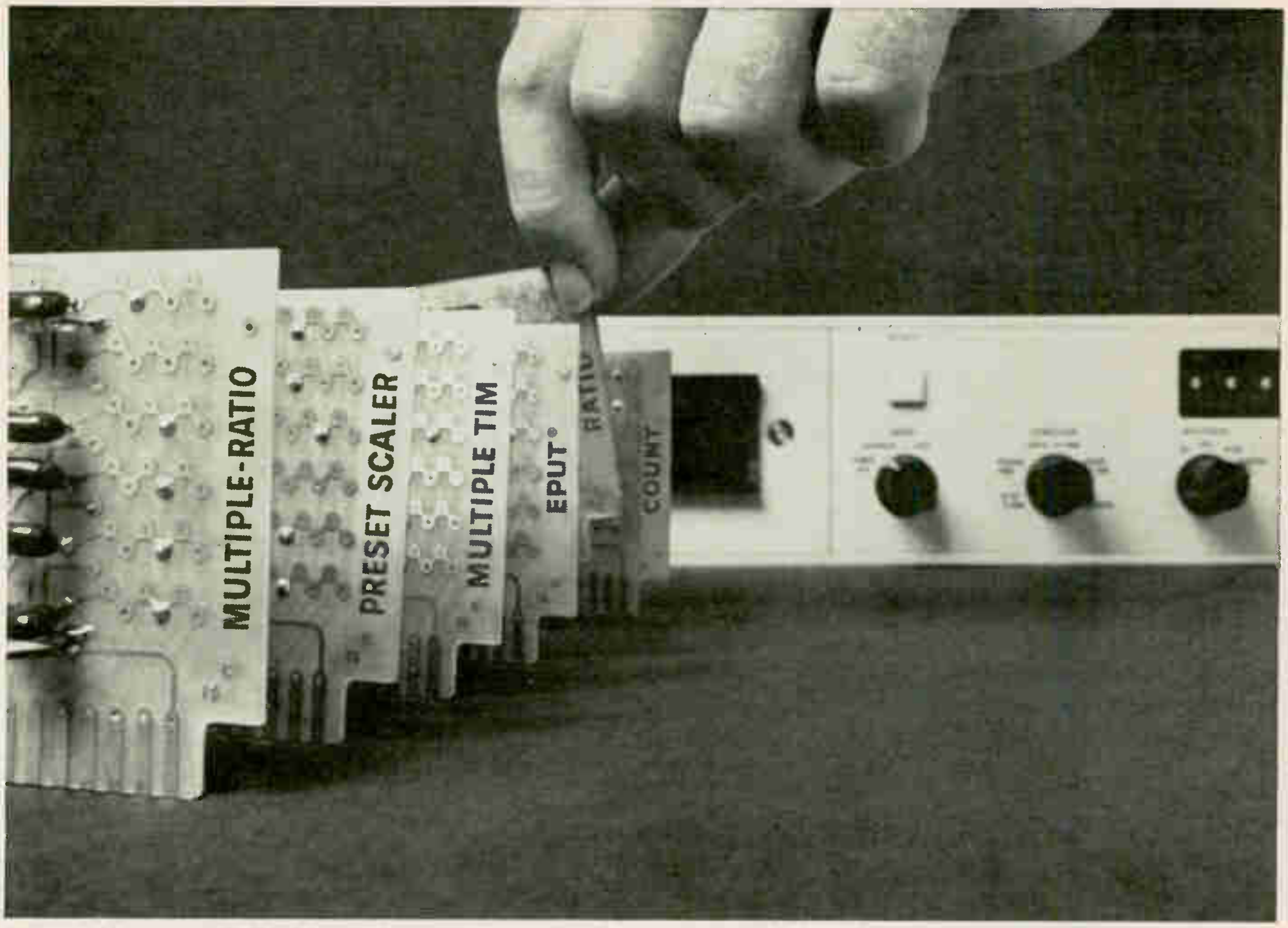
Next step in a program on which the government has spent $1.1 million so far, is to demonstrate experimentally the feasibility of producing repeated, short-duration impulses of high-energy usable electric power. This step is being funded by the Air Force's Aero Propulsion Laboratory at Wright-Pattterson Air Force Base in Ohio.

In the Mark V, the power is dumped into a resistor load, consisting of 50 water-cooled stainless steel tubes, one for each set of output leads. The Mark VI will be a power supply instead of a laboratory experiment. There will be only one set of output leads, so the power will be usable.

For what? The Avco engineers say they don't know yet. The anticipated 20 megawatts of net power which would be available for as much as three minutes would constitute a valuable power source for experimental superpower lasers.

'Demand power.' Short-duration, very high-power outputs, called "demand power," fill many commercial and military needs, according to Arthur Kantrowitz, Avco vice president and director of the Avco-Everett Lab. In addition to pumping high-energy lasers, demand power could fill emergency peak needs of generating stations, power high-energy radar systems and help to explore the possibilities of radiation-type weaponry.

The MHD generator in Haverhill



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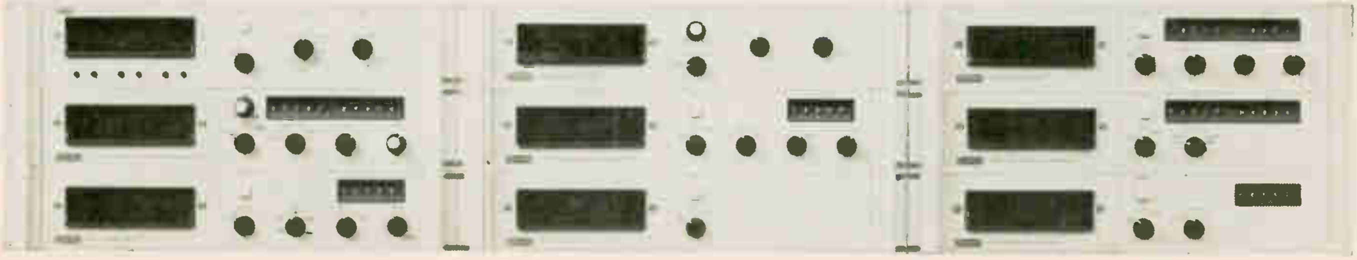

Circle 47 on reader service card

burns oxygen and jet fuels in a combustion chamber similar to a rocket engine to create electrically conducting gas which reaches a temperature of 5,000°F. Traveling at about 2,700 miles an hour, the plasma discharges from the burner into a channel where it interacts with the magnetic field to generate electric power. Usable power is tapped through the electrodes which make contact with the plasma in the channel.

The experience developed during Avco's preliminary program, says Brogan, "enables us to build rocket-driven generators to meet any ground-based power demands ranging from a fraction of a second to several hours."

Integrated circuits

RCA's ripple

About 25 companies now produce commercial quantities of integrated circuits and many are working round the clock to keep up with the burgeoning demand. Conspicuously missing from the roster of commercial IC producers has been the Radio Corp. of America, which has a hand in producing most every other electronic product, from consumer goods to industrial equipment. This week, the giant electronics company will take the plunge, with a line of 17 IC's but the plunge isn't expected to make more than a ripple in the IC market—at least not immediately. (For details on the circuit, see page 169.)

Although actual figures on RCA's present output of IC's, manufactured in Somerville, N. J., haven't been disclosed, it is known that the level is insufficient to meet in-house demands. Integrated circuit production was initiated specifically for the Spectra 70 computer series, but even then RCA had to turn to other companies, among them the Fairchild Camera & Instrument Corp., to supplement its needs for monolithic IC's for the computers.

RCA doesn't plan to remain a minor-league producer for long; expansion programs are currently under way to double output, the company says, although it won't discuss present production or the size of the new facilities.

Wrong signal? RCA's long delay in starting commercial production of IC's goes back to 1958. At that time, the Army's Signal Corps, together with RCA, was convinced that the future lay not in IC's, but in micromodules. Micromodules are 0.35-inch encapsulated square modules that contain a small number of microelements on stacked wafer-thin substrates. Each substrate is notched around its periphery to allow interconnections, which form a circuit.

RCA became prime contractor for the circuits, but then, 5½ years later, when the Army stopped funding the project, the company turned out a line of commercial micromodules, including monostable multivibrators, flip-flops, timers, differential amplifiers and power amplifiers. Sales were low, despite the Army's endorsement of the devices' performance and reliability. Finally, in 1964, RCA abandoned its micromodule production at Somerville, fastened its eye on IC's, and converted the New Jersey plant to produce the monolithic IC's.

RCA has a long way to go before it can overcome its competitors firm grip on the IC market. Full families of IC's were being produced by Fairchild and Texas Instruments Incorporated back in 1961.

Communications

Laser signal-detector

While some researchers are working on ways to boost the power of the laser, others are seeking methods for detecting even the weakest pulses. One research team in the latter group has developed a laser detector 100 times more sensitive than available instruments.

The detector, in which a pure germanium photoconductor senses light signals, has a noise-equivalent power of 10^{-15} watt; such a measurement expresses the power of a light signal modulated at one cycle per second, measured at the detector's input, which will produce a signal-to-noise ratio equal to unity at the detector's output; this is considered to be the minimum signal-to-noise ratio that can provide useful signal information.

Converting light. Developers of the detector, Henry Sommers and Edward Gatchell of the Radio Corp. of America labs at Princeton, N. J., say its bandwidth can be as large as 100 megacycles. The detector converts light signals into microwave signals.

Increased sensitivity, they explain, is achieved by applying to the crystal an electric field that oscillates at 10 gigacycles per second, extending the life of the minority carriers in the crystal and enhancing its gain. Reducing the size of the crystal also contributes to the increase in gain.

The photoconductor is mounted in a reflection-type microwave cavity. Reflection of the cavity's 10-Gc frequency depends on the conductivity of the photoconductor. A laser beam, modulated by altering its intensity, is focused on the photoconductor. Changes in the beam's intensity cause changes in the photoconductor's conductivity. In this way, the information on the light carrier leaves the cavity as sidebands superimposed on the microwave frequency, which are amplified and detected.

Exciting electrons. The technique for enhancing the detector's sensitivity is based on the use of the electric field to maintain the minority carriers, or holes, within the crystal. Light energy that hits a photoconductive crystal will excite some electrons into an unfilled energy band, causing a change in the crystal's conductivity. But when the light levels are low and the modulation frequencies high, the conductivity changes are hard to detect.

The high electric field enhances the detection of the high-frequency, low-power signal in this way:

Under the stress of a high electric field, the excited electrons can move easily. If the electric field were unidirectional, the minority carriers, or holes (assuming the crystal is an n-type material), would be quickly swept out of the crystal into the external circuit. Under these conditions the electron-hole pairs generated by the light would disappear and the detection process would be terminated. But with a rapidly alternating electric field, the minority carriers are not swept out of the crystal.

Longer life. The lifetime of the electron-hole pair is extended and depends on the recombination process within the crystal, rather than on the applied electric field. This permits a larger current to flow than is possible with a unidirectional field.

The RCA researchers trimmed the size of the crystal down to ½ by 1 by 1 mil. This contributes to the enhancement of the gain, because gain is a function of the ratio of the photoconductive time-constant to the free electrons' transit time. Photoconductive time-constant is the duration it takes a light-activated electron to recombine with a hole; transit time describes the duration required for a free electron to traverse the crystal.

Pulses quicken

Although pulse-code modulation, pcm, is only starting to gain a foothold in Europe's telephone networks (for details, see page 227), a second-generation system is being tested in the United States.

Bell Telephone Laboratories has developed a model of a pcm system that handles up to 3,456 voice channels simultaneously. Telephone voice, television, business data and other communications can be transmitted at one time.

A maximum of 24 voice channels can be transmitted by the currently operating telephone pcm system, where only channels transmitting data at 1.5 million bits per second are compatible. With Bell's high-speed system, varying data rates can be made compatible by, in effect, speeding up the slower ones. The experimental system operates at 224 million bits per second and uses synchronization technique called "pulse stuffing," which makes it possible to add or drop off data along the transmission route.

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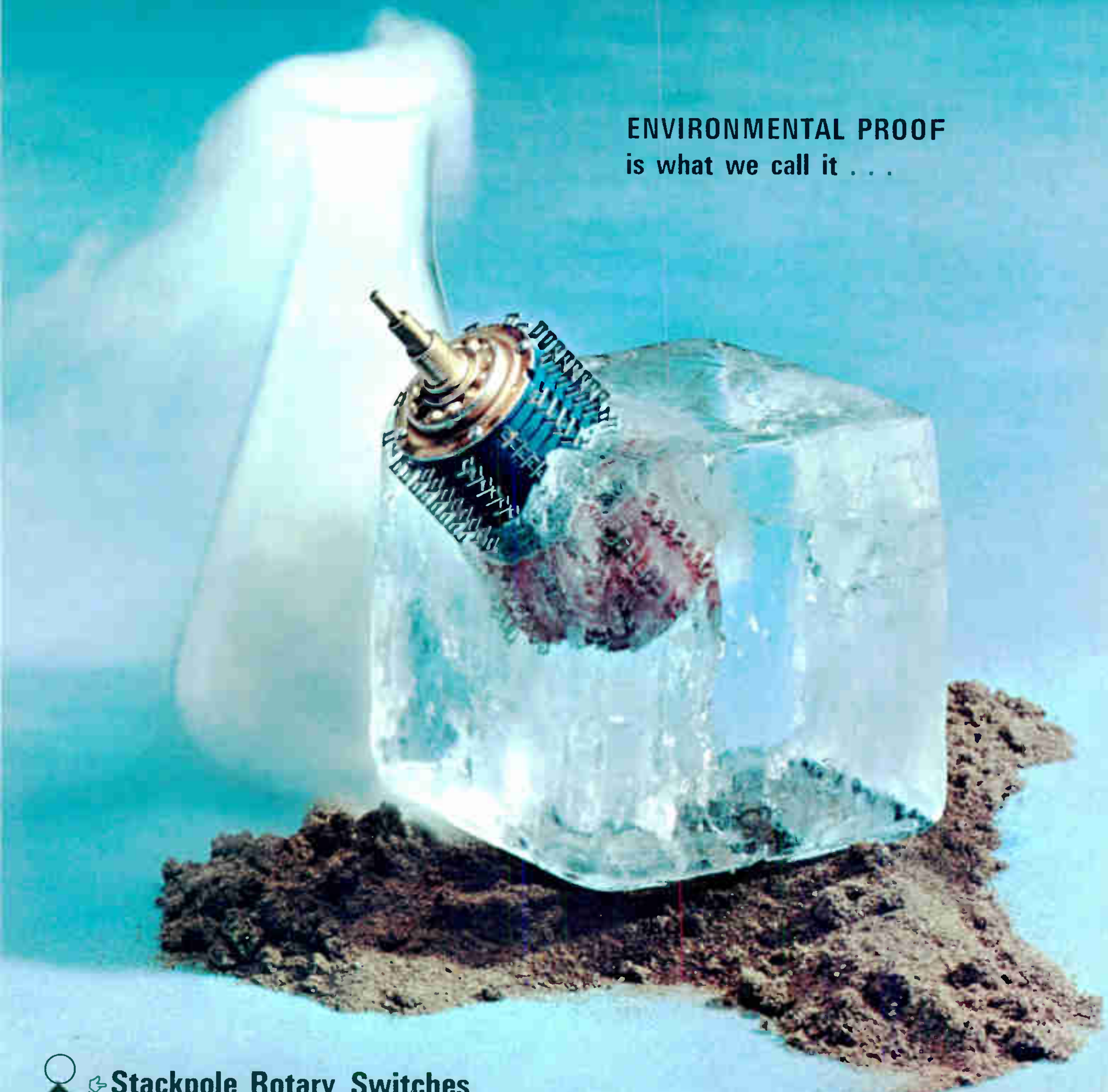

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Specially Designed to Guard Against
EXPOSURE–CONTACT CONTAMINATION–PRODUCTION DAMAGE

COMPETITIVELY PRICED — This completely enclosed, rugged switch costs no more than the open clip type.

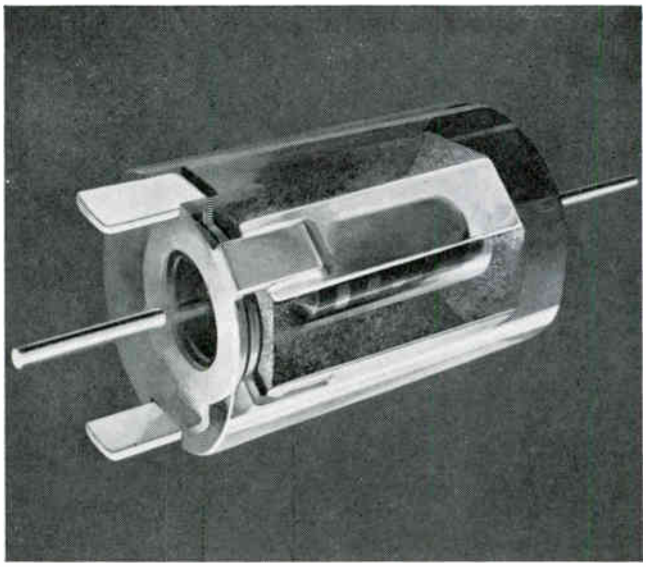
SAMPLES IN 3 DAYS—to your exact specifications. Send your drawing and prove it to yourself.

ORDERS IN 2 TO 3 WEEKS—On-time delivery of uniform, high quality production quantities to meet your schedule.

SEND YOUR DRAWING FOR A QUOTATION AND SAMPLE. Take advantage of Stackpole quality, price and service. For additional information and technical data write: Electro-Mechanical Products Division, Stackpole Carbon Company, St. Marys, Pennsylvania 15857. Phone: 814-834-1521. TWX: 510-693-4511.

STACKPOLE
ELECTRO-MECHANICAL PRODUCTS DIVISION

Get Fast Delivery on These TI Semiconductors From Weatherford

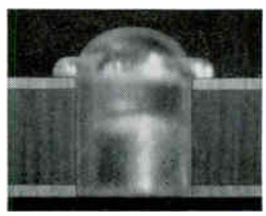


New TI temperature-compensated diodes offer improved temperature coefficients, greater voltage range

New Texas Instruments temperature-compensated diodes offer you greatly increased design flexibility for high-frequency crystals, differential amplifiers, digital voltmeters, and voltage-reference instrumentation. Units are available in 14 standard ratings from 3.3 volts to 12 volts. Maximum TC ratings are 0.005%/°C from −55° to +100°C. Temperature coefficients as low as 0.001%/°C are available depending upon voltage range. The new TI diodes provide temperature stabilization over a wide current range and are relatively immune to voltage fluctuations. Temperature is maintained within 1°C over a 10% voltage change. Call us for immediate delivery of TI's new TC diodes — TIXD746-759.

Sensistor® silicon resistors provide economical, reliable temperature compensation or measurement

Sensistor silicon resistors offer unique, high, *positive* temperature coefficients of + 0.7%/°C (nominal). Available to meet any packaging requirement, they are useful as temperature sensing or measuring elements and provide excellent compensation for the temperature characteristics of silicon transistors. Wide selection available in power ratings from 10 mw to 1/4 watt. Resistance values from 10 to 10,000 ohms.



LS-600 in 1/16″ PC board

Two TI light sensors give you high sensitivity, fast response

TI's LS-400 and LS-600 light sensors feature stability and uniformity of electro-optical characteristics. Typical light-to-dark current ratio is 100,000 to 1 — speed is fully adequate for all card and tape readers. Unique package design of the LS-600 allows assembly into printed circuit boards. Order now from our complete stock.

GET FULL INFORMATION ON THESE TI SEMICONDUCTORS!

Please send the TI brochures covering diodes, resistors and light sensors to:

(Please Print)

Name____________________

Position____________________

Company____________________

Address____________________

City________ State________ Zip Code________

☐ TC diodes ☐ Light sensors ☐ *Sensistor* resistors

New bulletins are available on TI temperature-compensated diodes, *Sensistor* silicon resistors and light sensors. For your copies, complete the coupon, check the information you desire, and send it to us at the address listed below.

R. V. WEATHERFORD CO.

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Who cares about component innovations?

At General Electric, engineering is the most important factor in electronics. This engineering excellence means you get the best in component reliability and performance.

Who cares if you improve your circuit designs?

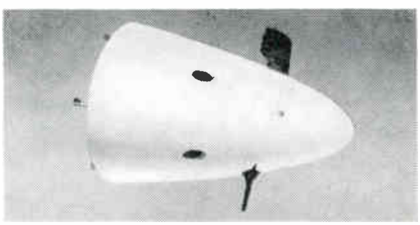
Constant attention to new and improved electronic circuit designs results in better quality, lower price, and new market growth for your business and ours.

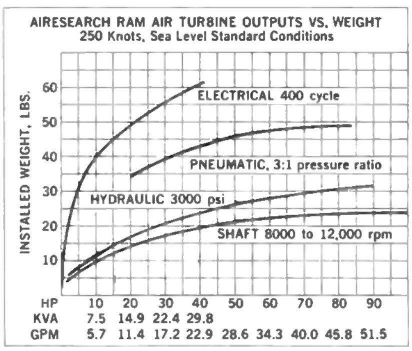
THINK RATS

No ordinary "rats," these.

These are airborne RATS — **Ram Air Turbine Systems** — built by Garrett-AiResearch for emergency or auxiliary electrical, mechanical and hydraulic power.

Maybe you've never considered using Ram Air Turbines as independent power sources. For example, did you know that Garrett-AiResearch RATS can supply electrical, mechanical, pneumatic, or hydraulic power for any externally-stored airborne system such as countermeasure pods, photo or sensor reconnaissance systems, chemical warfare equipment, special armaments such as Gatling-type guns, tow targets, refueling pods, and many others?





And are you aware that Garrett-AiResearch RATS offer great savings in weight and size over battery-powered systems and hot gas power units?

Garrett-AiResearch has built more than 10,000 RATS for a variety of applications. We offer units from ⅛ to 100 shaft horsepower. Our RATS have better power-to-weight ratios, less drag, instantaneous response, better sensitivity to acceleration and load change, and fine speed control. And they're available now for aircraft, drone and missile applications.

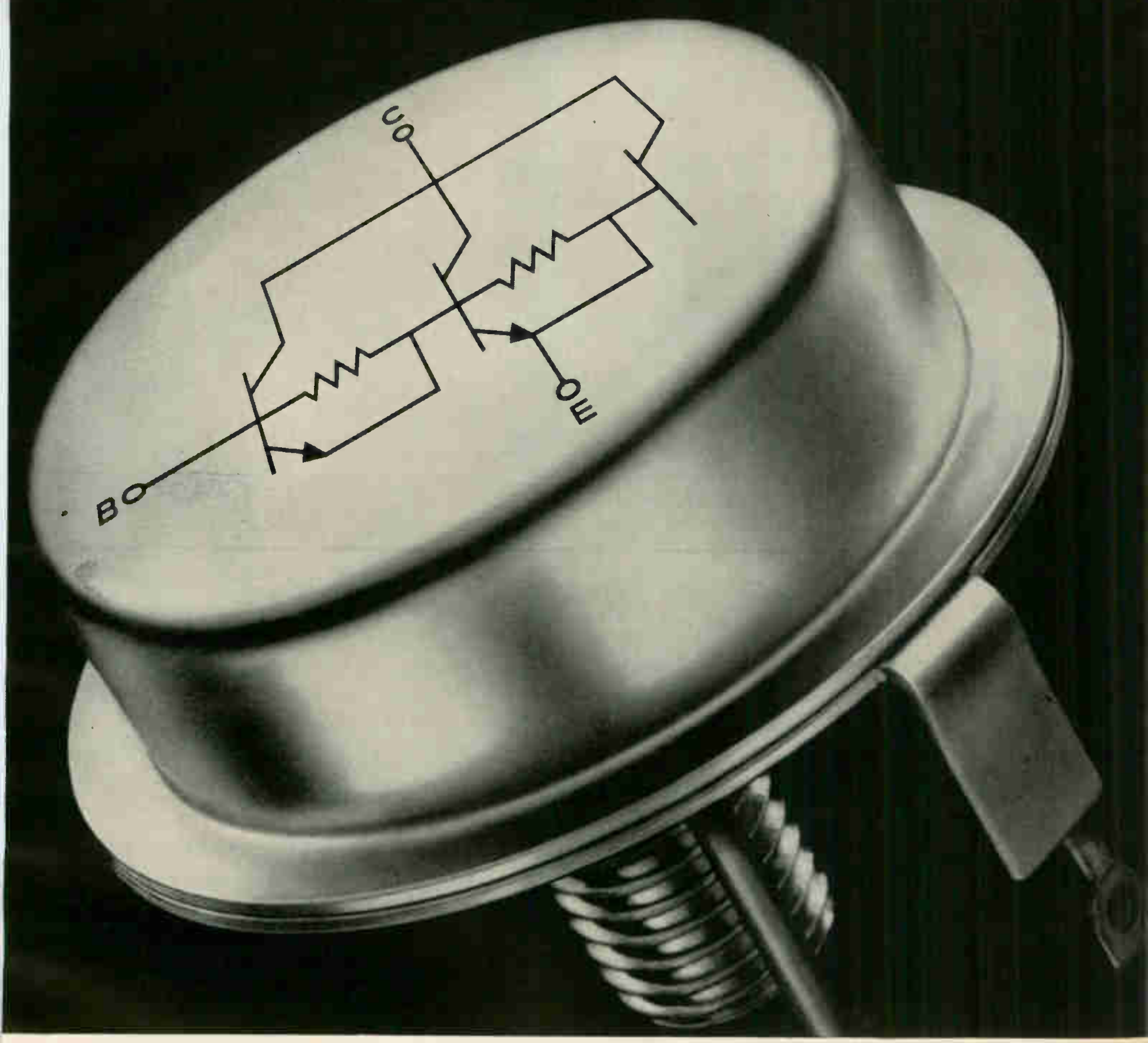
Our brochure has a lot more to say about RATS. Write, AiResearch Manufacturing Company, 9851 Sepulveda Blvd., Los Angeles, California 90009.

GARRETT

AIRESEARCH RAM AIR TURBINE SYSTEMS

 Circle 56 on reader service card

Inside story of the new look in series regulators



Westinghouse power integrated amplifiers eliminate a complete driver stage.

Save space, improve reliability, cut costs with Westinghouse power integrated amplifiers. Types 2N2233 and 2N3477 provide exceptionally high gain at high power levels—$h_{FE} = 400$ at 10 amps I_C, $V_{CE} = 200$ volts and $P_D = 150$ watts. Single and double ended packages provide complete design flexibility. Check these exclusive features:

- Hard soldered junctions eliminate thermal fatigue.
- Large emitter-base area puts an end to secondary breakdown.
- True monolithic construction stops runaway leakage.

SINGLE ENDED	DOUBLE ENDED	V_{CE}	h_{FE}
2N2226	2N3470	50	100 @ 10A
2N2227	2N3471	100	
2N2228	2N3472	150	
2N2229	2N3473	200	
2N2230	2N3474	50	400 @ 10A
2N2231	2N3475	100	
2N2232	2N3476	150	
2N2233	2N3477	200	

You can be sure if it's Westinghouse

And, of course, reliability is assured by the exclusive Westinghouse Lifetime Semiconductor Guarantee.* For full information call your Westinghouse salesman or distributor, or write to the Westinghouse Semiconductor Division, Youngwood, Pennsylvania.

*Westinghouse warrants to the original purchaser that it will correct any defect or defects in workmanship, by repair or replacement f.o.b. factory, for any JEDEC-type silicon power semiconductor during the life of the equipment in which it is originally installed, provided said device is used within manufacturer's published ratings and applied in accordance with good engineering practice. This warranty is applicable to devices of the stated types shipped after March 9, 1964, until further notice. This warranty shall constitute a fulfillment of all Westinghouse liabilities in respect to said products. This warranty is in lieu of all other warranties expressed or implied. Westinghouse shall not be liable for any consequential damages. SC-2050

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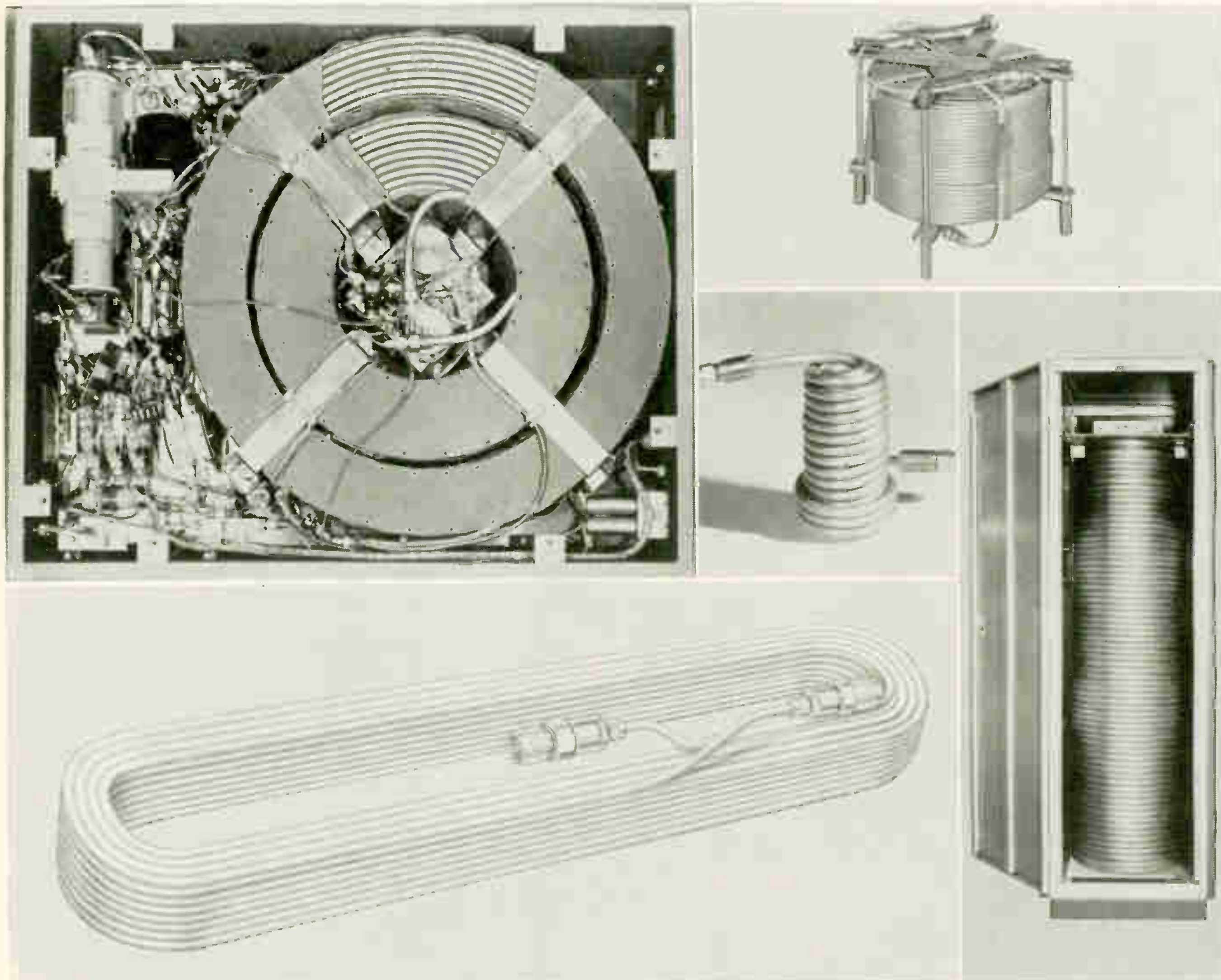


Coaxial cable delay lines. Big. Miniature. Plain, packaged or potted. Capable of accuracies up to ± .02 nanoseconds.

Combine the outstanding performance characteristics of Phelps Dodge Electronic's coaxial cables with a proprietary ability to bend to a radius of three times the sheath diameter to the center line of the bend. Add newly developed measuring and testing techniques to meet unheard-of accuracies. Result? The unique in coaxial delay lines.

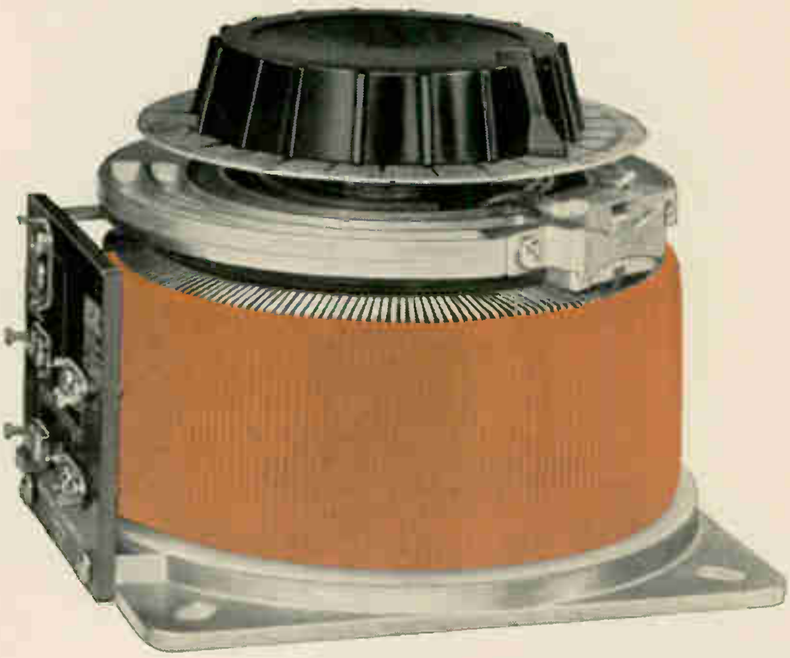
Here is broader band operation, less attenuation per nanosecond of delay and greater stability over wide temperature ranges. Here too, is great latitude in the specification of operating parameters, physical dimensions or, moisture, vibration, shock and temperature resistance. Packaging? Containers, shock mounting, standard rack panel mounting, strapping, potting and encapsulating. And, availability for operation at frequencies from 60 cps to 12 Gc, power from one milliwatt to many kilowatts, impedances of 50, 70, 75, 100 and 125 ohms.

Can we tell you more? Let us know your requirements, or write for Bulletin DL-2.

PHELPS DODGE ELECTRONIC PRODUCTS
NORTH HAVEN, CONNECTICUT

QUALITY, VARIETY SERVICE

...that's the story of "Ohmitran" v. t.® variable transformers



From Ohmite's tiny, exclusive, 1-amp VT1 to the husky VT20, a full range of single-unit ratings to 25 amps is available.

SATISFY yourself . . . eliminate irritating variable transformer difficulties with Ohmite's famed reliability and long service life. In any piece of equipment, an Ohmite component indicates that there has been no compromise with quality.

MEET virtually all your requirements from Ohmite's big selection. Single units start with a tiny (and exclusive) 1-amp model, extend through heavy-output models of 25 amps. For single and/or ganged models, voltage inputs begin below 40 volts, run to 480 volts. There are assemblies for 3-phase applications, too, plus models in stationary or portable cases—with meters if you like. Most are stocked for fast delivery.

EASE engineering headaches by taking advantage of Ohmite's ready-to-ship stock of standard units, or willing advice and service on units for special applications. Bone up on the broad aspects of Ohmite's complete variable transformer service by requesting *Catalog 500*.

RHEOSTATS • POWER RESISTORS • PRECISION RESISTORS • VARIABLE TRANSFORMERS • RELAYS
TAP SWITCHES • TANTALUM CAPACITORS • SEMICONDUCTOR DIODES • R.F. CHOKES

OHMITE

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3610 Howard Street • Skokie, Illinois 60076
Phone: (312) ORchard 5-2600

Circle 59 on reader service card

THE FINEST ASSORTMENT OF RACK/PANEL CONNECTORS AVAILABLE

The industry's largest supplier of rack/panel connectors . . . there's a CANNON® Plug designed to meet every conceivable plug-in application. Whether your requirements are microminiature, subminiature, or heavy duty standards, ITT Cannon Rack/Panel Connectors offer you the widest selection of shell sizes, styles, and layouts in use today.

Available with crimp snap in contacts, including the LITTLE CAESAR* Rear Release System, or solder pot versions . . . hermetic, printed circuit, nonmagnetic, environmentally sealed and custom engineered types.

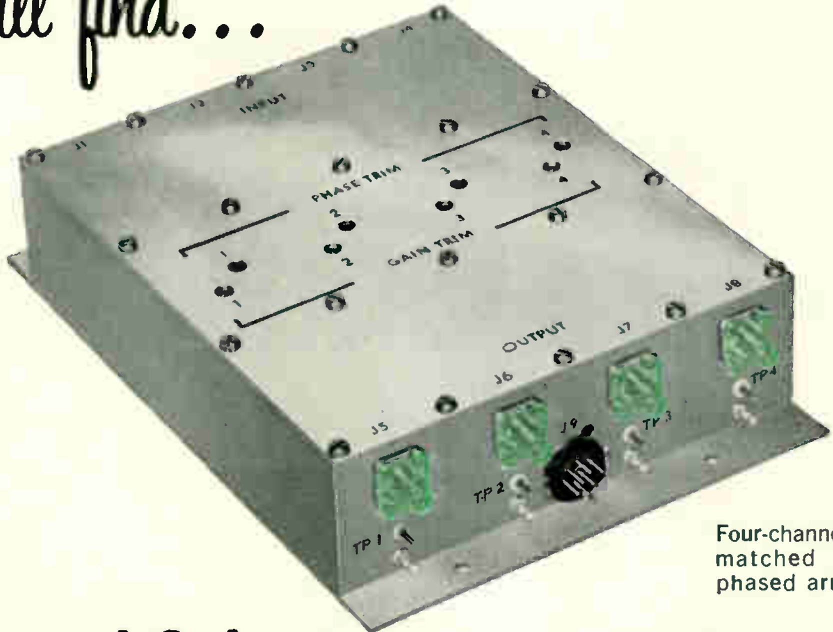
Also available with filter, high voltage, and coaxial contacts. ITT Cannon Rack/Panel Connectors are offered in single, two-gang, four-gang and shell-less styles. When you specify rack/panel plugs from ITT Cannon, the world's largest and most experienced manufacturer of electrical connectors, you are assured of the utmost in reliability and space utilization. For more information, write to: ITT Cannon Electric, 3208 Humboldt Street, Los Angeles, California. A division of International Telephone and Telegraph Corporation.

CANNON® PLUGS

*TRADEMARK OF ITT CANNON ELECTRIC

ITT CANNON

Best match you will find...



Four-channel phase and gain matched IF Amplifier for phased array radar.

LEL's Phase and Gain Matched IF Amplifiers

Doing anything in phase and gain tracking? LEL's line of IF Preamps and Postamps is really matchless where phase and gain match is concerned. Whatever the requirement...X-band monopulse receivers, phased array receiver systems or other similar applications, you'll appreciate the *match accuracies* achieved by these solid-state, precision performers. They're versatile too...can be set up in multiple channels for closer tracking. Wide choice of center frequencies and bandwidths are available. Here is a set of typical specifications:

MIXER–PREAMPLIFIERS

Operating Range	500 mc to 40 Gc
IF Center Frequency	60 mc
Bandwidth (3 db)	20 mc
Gain (RF-IF)	24 db
Gain Reduction	30 db
Maximum RF Input Signal for linear output	−10 dbm
Output Impedance	50 ohms
Noise Figure (IF)	3 db
Power Required	Supply: 15 ma @ +20 VDC AGC: 0 to +10 VDC
Phase Match (as compared to another similar unit operated off a common AGC bias)	±2° (max)
Gain Match (as compared to another similar unit operated off a common AGC bias)	±0.5 db (max)

POSTAMPLIFIERS—Dual-Channel

Center Frequency	60 mc
Bandwidth (3 db)	20 mc
Gain (IF)	50 db
Gain Reduction	40 db (min)
Maximum Input Signal for linear operation	−15 dbm
Maximum Output Signal for linear operation	0 dbm
Input Impedance	300 ohms
Output Impedance	50 ohms
Noise Figure	4 db
Power Required	Supply: 70 ma @ +20 VDC AGC: 0 to +10 VDC
Phase Match	±2.5° (max)*
Gain Match	±1.0 db (max)*

**These data are maximum variations within temperature range of −55°C to +80°C and over the full specified gain control range.*

In a typical application for an X-band monopulse receiver, using three channels and a common AGC bus, phase tracking is ±2° and gain tracking is ±1 db for 100 db of gain. For applications such as this or for phased array receiver systems, multiple channels may be built in a common chassis, enabling even closer tracking. A volume of about 15 cubic inches is required per channel.

Put LEL leadership to work in your system with performance proved IF Amplifiers...send for complete details today.

LEL DIVISION
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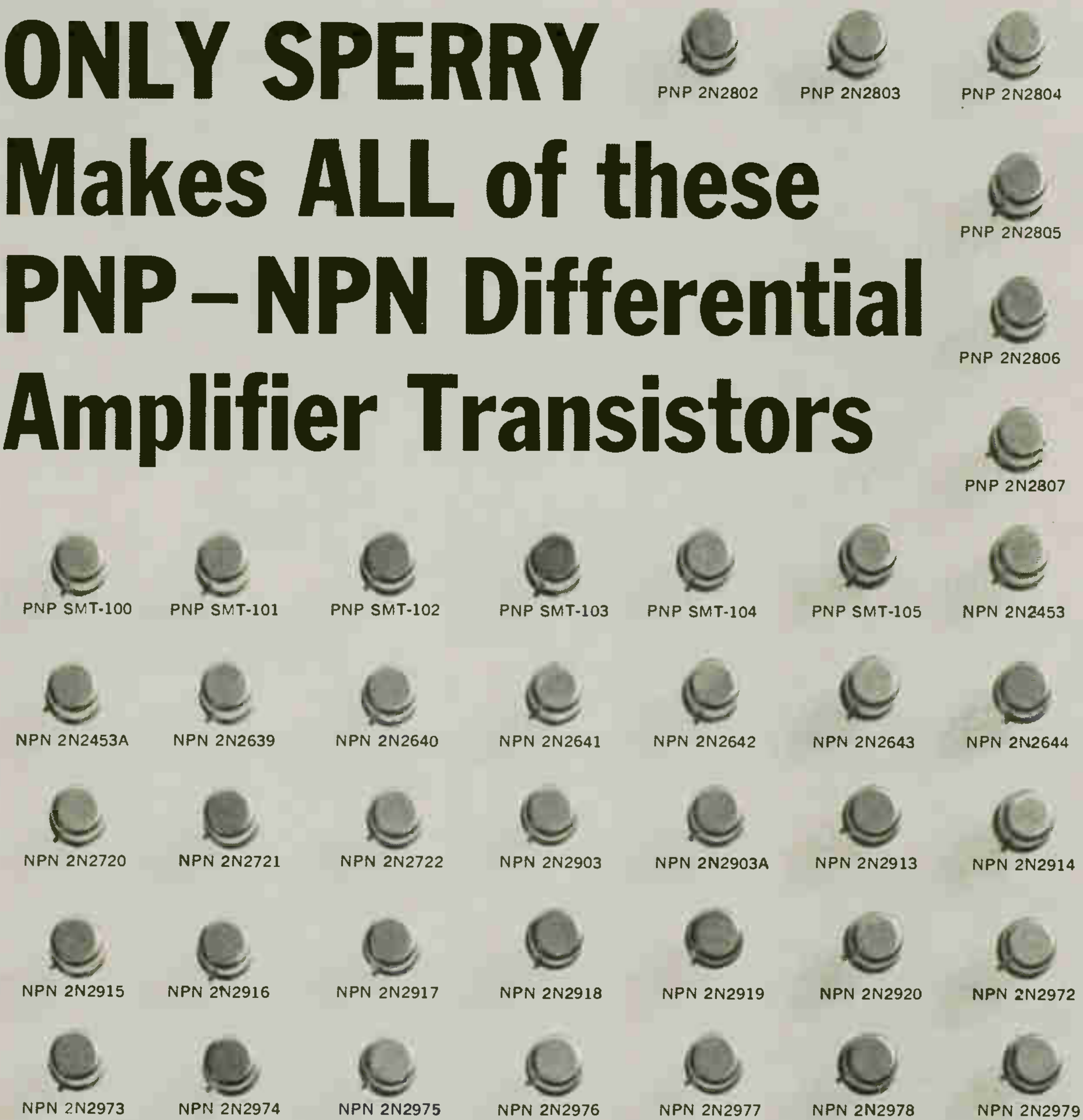
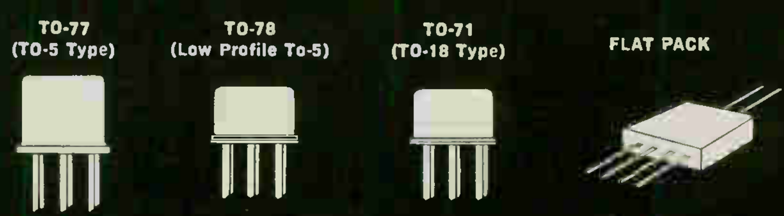
AKRON STREET COPIAGUE, L. I., NEW YORK 11726
(516) Amityville 4-2200 / (516) PYramid 9-8200 / TWX Code 516-691-5085

ONLY SPERRY Makes ALL of these PNP–NPN Differential Amplifier Transistors



AND IN ANY OF THESE FOUR PACKAGES TOO!



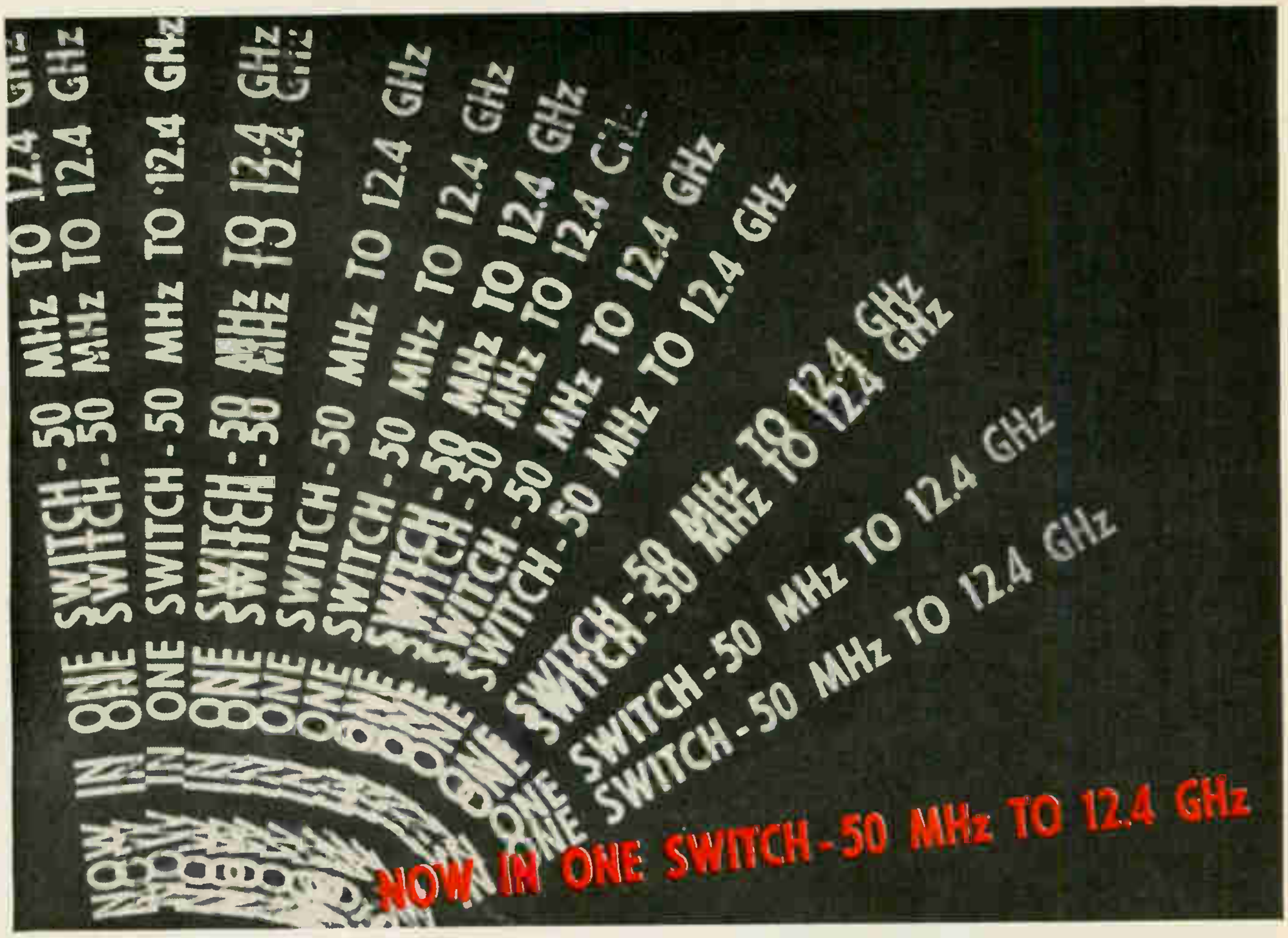
ONE HUNDRED SIXTY-FOUR COMBINATIONS NOW AVAILABLE.

Chances are which ever differential amplifier transistor you need, you can get it from Sperry and in the package you want. Get complete information today– Contact SPERRY– ☐ **SPERRY SEMICONDUCTOR, Norwalk, Connecticut 06852.**

SPERRY

DIVISION OF SPERRY RAND CORPORATION

Sperry Europe Continental, 7 Avenue de l'Opera, Paris 1, France



specify microwave switches—variable attenuators by hpa

The hpa 3500 Series of microwave switches is ideal for ECM receiver switching, low-power antenna switching in phased arrays and pulse modulation. As variable attenuators, the hpa 3500's can be used for power leveling and signal modulation applications. Availability of alternate connectors and bias polarities provides significant flexibility of choice in switching, attenuation and modulation applications. All units operate over the broad frequency range 50 MHz to 12.4 GHz with high isolation and low insertion loss. Price of all four units, $275 each.

For more information about these single-pole, single-throw devices, write today for complete specifications.

DEVICE SPECIFICATIONS FOR 3501, 3503, 3504, 3505

Frequency (GHz)	.05–0.5	0.5–1.0	1.0–2.0	2.0–4.0	4.0–8.0	8.0–12.4*
Insertion loss (V_{bias}=20v) Max.		0.4 db	0.5 db	1.0 db	1.0 db	1.5 db
Typ.	0.5 db	0.2 db	0.3 db	0.7 db	0.7 db	1.0 db
Isolation (I_{bias}=50 ma) Min.		25 db	30 db	40 db	45 db	45 db
Typ.	25 db	28 db	35 db	45 db	50 db	50 db

VSWR
- Switch ON (Max.) .... 2:1†
- Switch OFF (Typ.) 50:1

RF impedance switch ON 50Ω

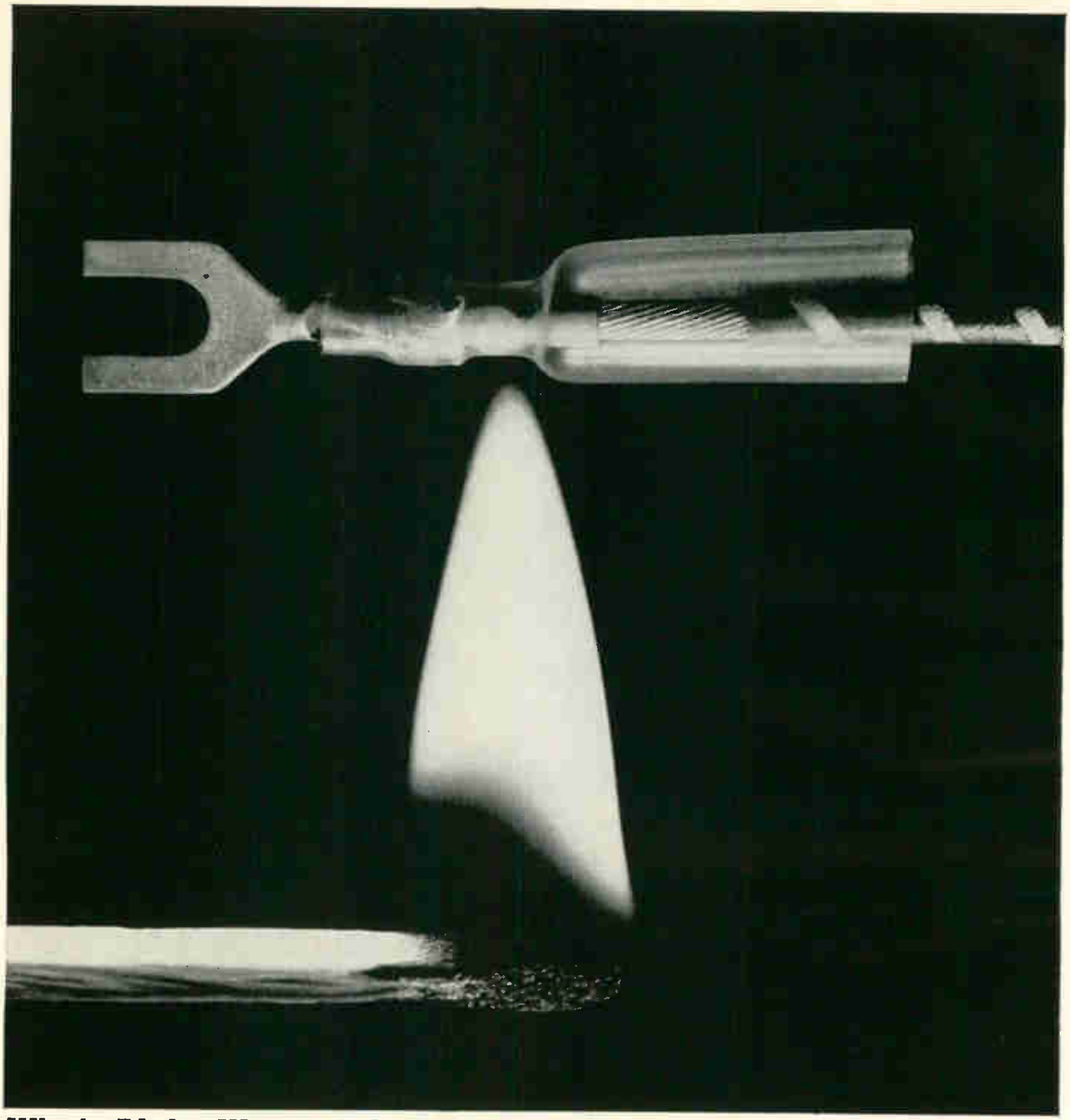
Typ. RF switching characteristics
- ON .... 300 nsec
- OFF .... 100 nsec

	RF terminal	Bias polarity OFF
3501	TNC	Positive
3503	N	Positive
3504	TNC	Negative
3505	N	Negative

*Useful to 15 GHz
†In either direction—no preferred switch orientation
Data subject to change without notice. Prices f.o.b factory.

hpa **hp associates** 620 PAGE MILL ROAD, PALO ALTO, CALIF. 94304, (415) 321-8510
An Affiliate of Hewlett-Packard Company

Circle 65 on reader service card



Who's Alpha Wire to take all the fun and guesswork out of heat shrinkable tubing?

In seven seconds, the diameter of this insulation tubing will shrink from .093" to precisely .045" and give you a tight mechanical bond. Without splitting. Without crushing.

You get predictable, controlled shrinkage. Alphlex FIT® irradiated tubing ends all the guesswork.

It won't melt at elevated temperatures (up to 350° C). Or split when shrunk over irregularly shaped objects.

It resists stress and solvents. Even the longitudinal shrinkage is controlled (usually no more than 5%).

How do you use it? For insulating. Encapsulating. Splicing. Connecting. Jacketing. Capping. We have a type and size for every job.

Why does Alpha Wire get involved with irradiated tubing? Because we believe that making the best wire in the business is only half the story. The other half is being sensitive to your application problems.

Until now, heat shrinkable tubing was one of them.

Alpha Wire Headquarters: Elizabeth, New Jersey 07207. Write for our new 108-page catalog.
A Division of Loral Corporation

No need to scrap reliability for low price ...get both with DALE METAL FILM RESISTORS

LOW NOISE CONSTRUCTION. Maximum for standard resistance range: 0.10 micro-volt per volt over a decade of frequency. Low and intermediate values: below 0.05 micro-volt per volt. Terminating band of low-resistance metal alloy is deposited in same vacuum as metal film element resulting in *oxide-free*, low-noise contact area between film, terminating band and press-fit cap.

CONTROLLED T.C. Ten standard T.C. codes from 0 ± 150 ppm/°C to 0 ± 25 ppm/°C available in operating temperature range of −55°C to +175°C. Close matching between pairs or sets available.

GOOD HF CHARACTERISTICS. Low reactance gives excellent stability at high frequencies. Non-helixed or laterally adjusted units supplied for extremely critical applications above 100 mc.

SPECIAL REQUIREMENTS. Special terminals, special matching, special pre-conditioning, special networks and mountings can be quickly supplied by our Special Film Products Department.

WRITE FOR CATALOG A

DALE ELECTRONICS, INC.
1300 28th Avenue, Columbus, Nebraska
Also Sold by Dale Electronics Canada, Ltd., Toronto, Ontario, Canada

MFF Epoxy coated. Meets electrical and environmental requirements of Char. B, C, D, E; MIL-R-10509E, but is dimensionally smaller.

MFH Hermetically sealed in ceramic tube. Meets requirement G; MIL-R-10509E.

MF Transfer molded in epoxy. Meets all requirements of Char. B, C, D, E; MIL-R-10509E.

DALE TYPE	MIL TYPE	125°C RATING	RESISTANCE RANGE	DIMENSIONS (L×D.)
MF 50	RN 50 Proposed	1/20 watt	49.9 Ω to 60K Ω	.140x.065
MF 1/10	RN 55	1/10 watt	49.9 Ω to 200K Ω	.250x.093
MF 1/8	RN 60	1/8 watt	30 Ω to 550K Ω	.406x.140
MF 1/4	RN 65	1/4 watt	30 Ω to 1 Megohm	.593x.203
MFS 1/2	RN 70	1/2 watt	49.9 Ω to 2 Megohms	.750x.250
MF 1	RN 75	1 watt	49.9 Ω to 6 Megohms	1.093x.375
MF 2	RN 80	2 watts	100 Ω to 15 Megohms	2.188x.375

Tolerance: ±1% standard; ±.5%, ±.25%, ±.1% available.

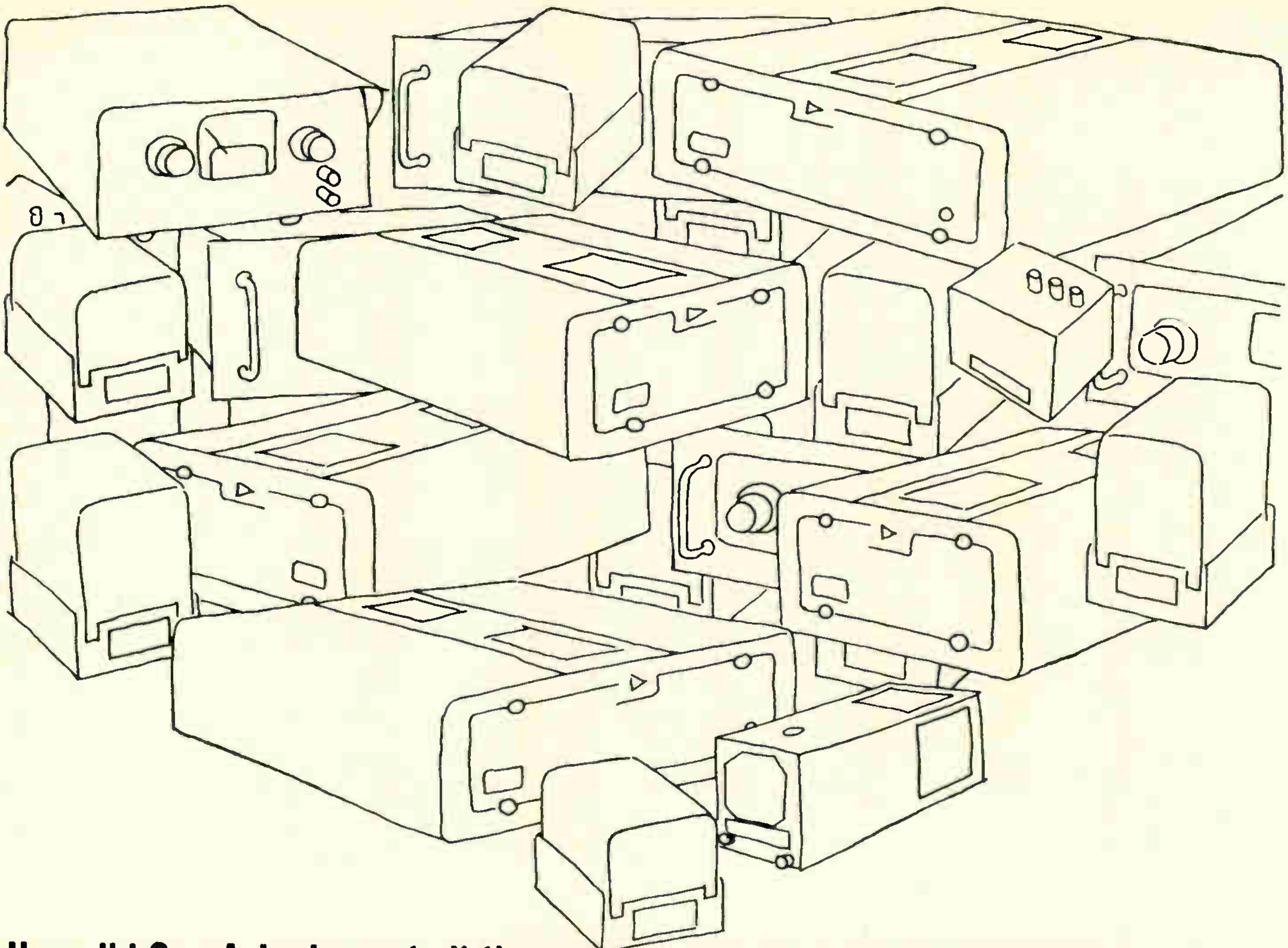
ENVIRONMENTAL SPECIFICATIONS*

Dale MF resistors are manufactured to the environmental specifications of MIL-R-10509E. Characteristics D, C or E apply depending on T.C. Code specified at purchase.

DALE T.C. CODE	Applicable Char. of MIL-R-10509E
T-1 (100 P.P.M./°C)	D
T-2 (50 P.P.M./°C)	C
T-9 (25 P.P.M./°C)	E

*Specifications for MFF and MFH are similar, but vary dimensionally.

Circle 67 on reader service card



How did Con Avionics get all those power supplies in that itty-bitty catalog?

We have an itty-bitty Short Form catalog because most engineers find it easier to work with. Especially when it's supplemented by our comprehensive data sheets.

And we have a lot of power supplies because Con Avionics makes the widest variety of ac-dc modules for systems. Once you've got our handy little catalog, in fact, you really don't need any others.

Take our HS series for example. Until we made these units, most engineers thought you had to buy expensive wide-range lab supplies foı high current systems applications.

That's changed now. Because an HS power supply will do anything a lab supply will do in a system, but cost about $100 less per unit. They come in rack or half-rack size, are self-cooled (you won't need systems space for heat dissipation) and operate in ambients up to 75°C. The new modules are unconditionally guaranteed for five years, are built completely with silicon transistors and have an amazing M.T.B.F. of 35,000 hours.

How we packed all this quality into the supplies and still can make them available for $100 less than lab supplies is described in the data sheet we can send you.

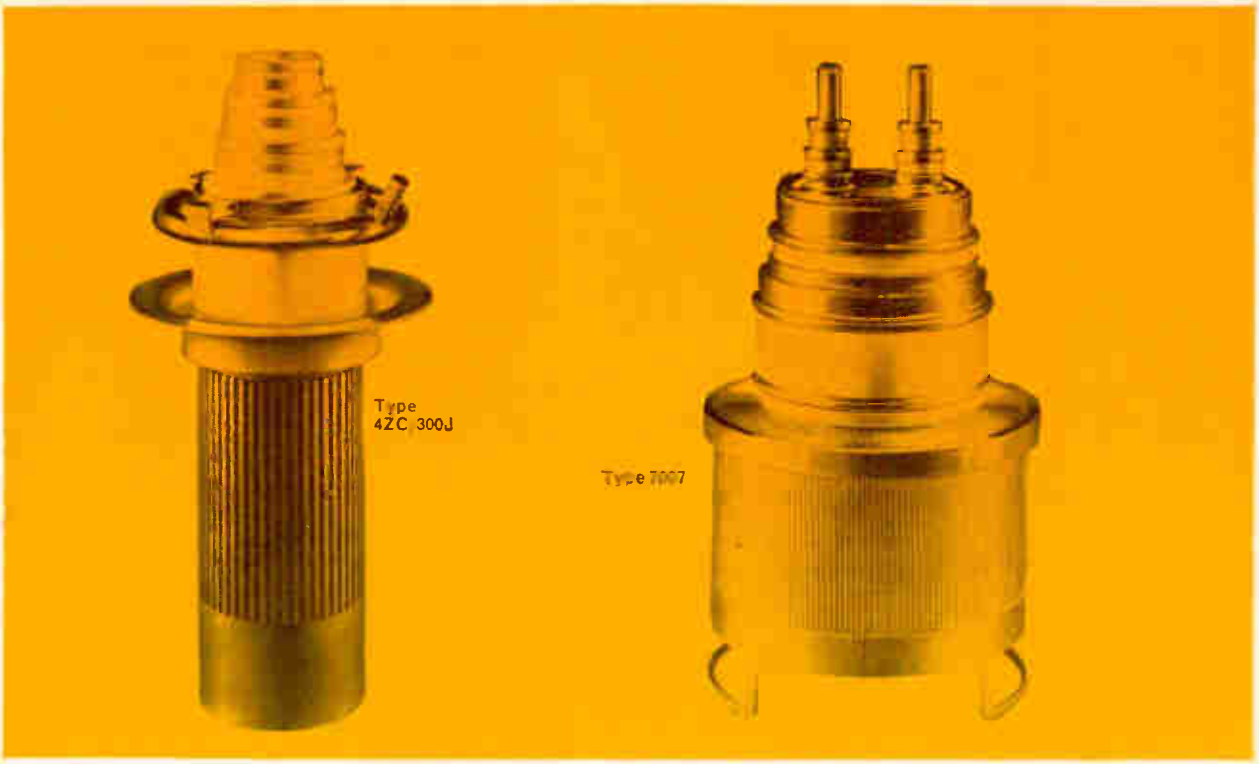
But not in the catalog. It wouldn't fit.

PARTIAL SPECIFICATIONS

Input: 105-125 VAC, 47-63 cps
Regulation: (Line and load combined) ±0.05%
Ripple: 1 mv RMS max.
Response time: 25 microseconds
Temperature Coefficient: 0.015%/°C or 18 mv/°C., whichever is higher
Temperature: 75°C max.
The entire voltage range between 5.5 vdc and 51.0 vdc is covered in twenty-six models. Currents range from 8.0 amps to 46.0 amps. Wattages from 104.5 to 816.

CONSOLIDATED AVIONICS A DIVISION OF CONDEC CORPORATION

800 Shames Drive, Westbury, Long Island, New York/(516) ED 4-8400



High performance power tetrodes

STC has introduced a new power tetrode with extremely linear performance over a wide range of characteristics. It yields 60 kW peak envelope power in Class AB_1 and has a maximum anode rating of 14 kV at operating frequencies up to 30 Mc/s. The tube is available with two alternative forms of cooling: vapour-cooled 4ZC/300J will dissipate 40kW and forced-air-cooled 4JC/300J, will dissipate 30 kW.

ABRIDGED DATA (Type 4ZC/300J)
Maximum Ratings

	4JC/300J	4ZC/300J
Eb (kV)	14	14
Pp (kW)	30	40
Pg2 (kW)	1·2	1·2
Pg1 (kW)	1·0	1·0

Typical Power Output Performance

Class AB_1 (Peak envelope power)	60 kW	60 kW
Class C. Unmodulated/FM	71 kW	106 kW
Class C. Plate and screen modulated	42 kW	54 kW

Another tetrode in the STC range is the Type 7007 which is a direct replacement for the USA Type 7007. This tube is intended primarily for use as a power amplifier, especially in Class B television service. It has an anode dissipation of 12 kW and may be operated at full ratings up to 220 Mc/s.

ABRIDGED DATA (Type 7007)
RF Amplifier. Class B Television Service.
Maximum Ratings

Eb	7·5 kV
Ec2	2·0 kV
ib	4·0 A
Pi	24 K
Pg2	400 W
Pp	12 kW
Pg1	400 W

Typical Operation in Grid Drive & Cathode Drive Circuits
Po approx.

Synchronising level*	12·0kW
Pedestal level*	6·8 kW

*Standard USA negative modulation technique.

For full information, write for data sheets to STC Valve Division, Brixham Road, Paignton, Devon, England.

USA enquiries for price and delivery to ITT Electron Tube Division, Box 100, Easton, Pennsylvania.

Standard Telephones and Cables Limited
Subsidiary of International Telephone and Telegraph Corporation

ITT

65/8MS

Circle 69 on reader service card

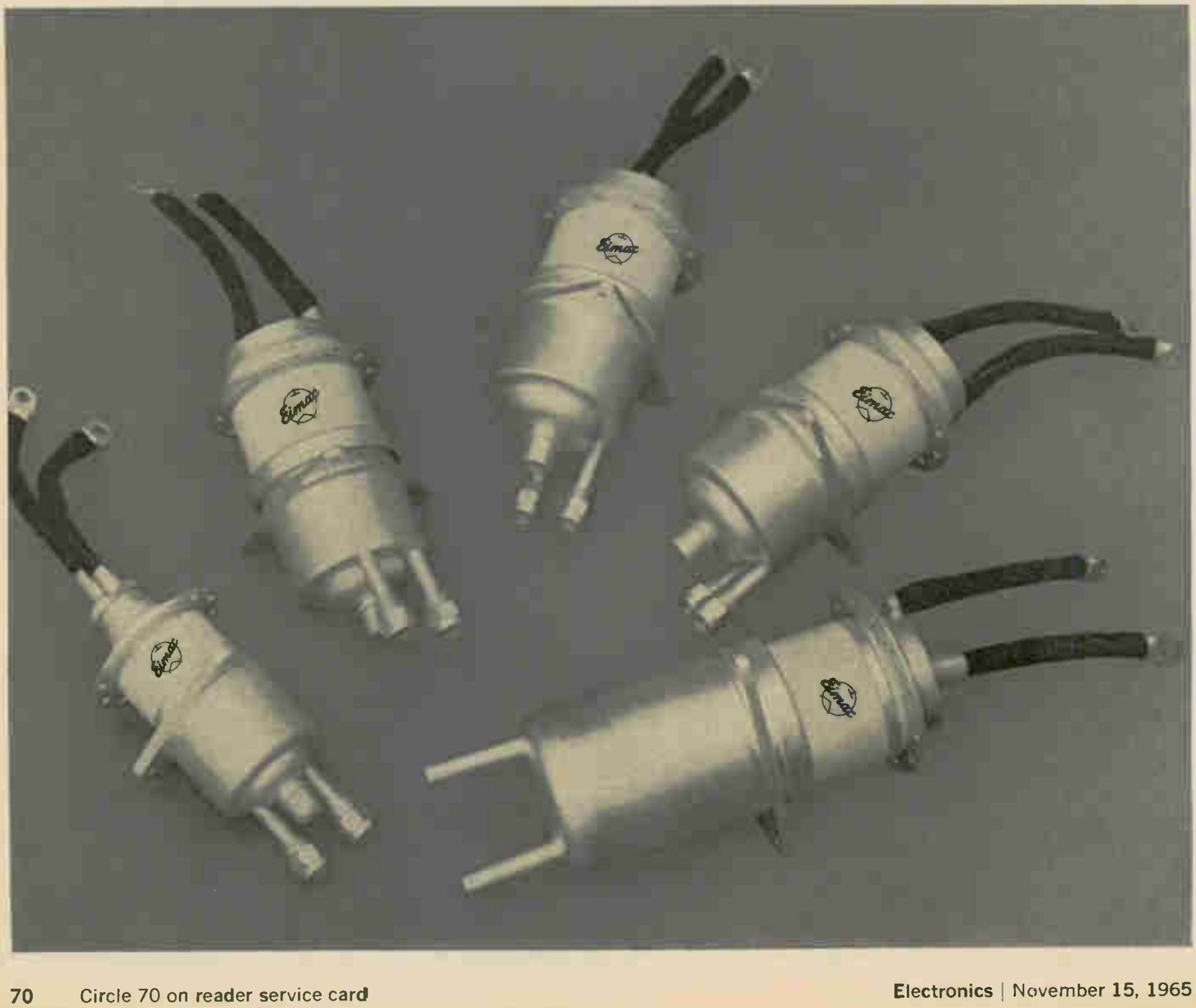
EIMAC introduces new family of rugged triodes for industrial heating

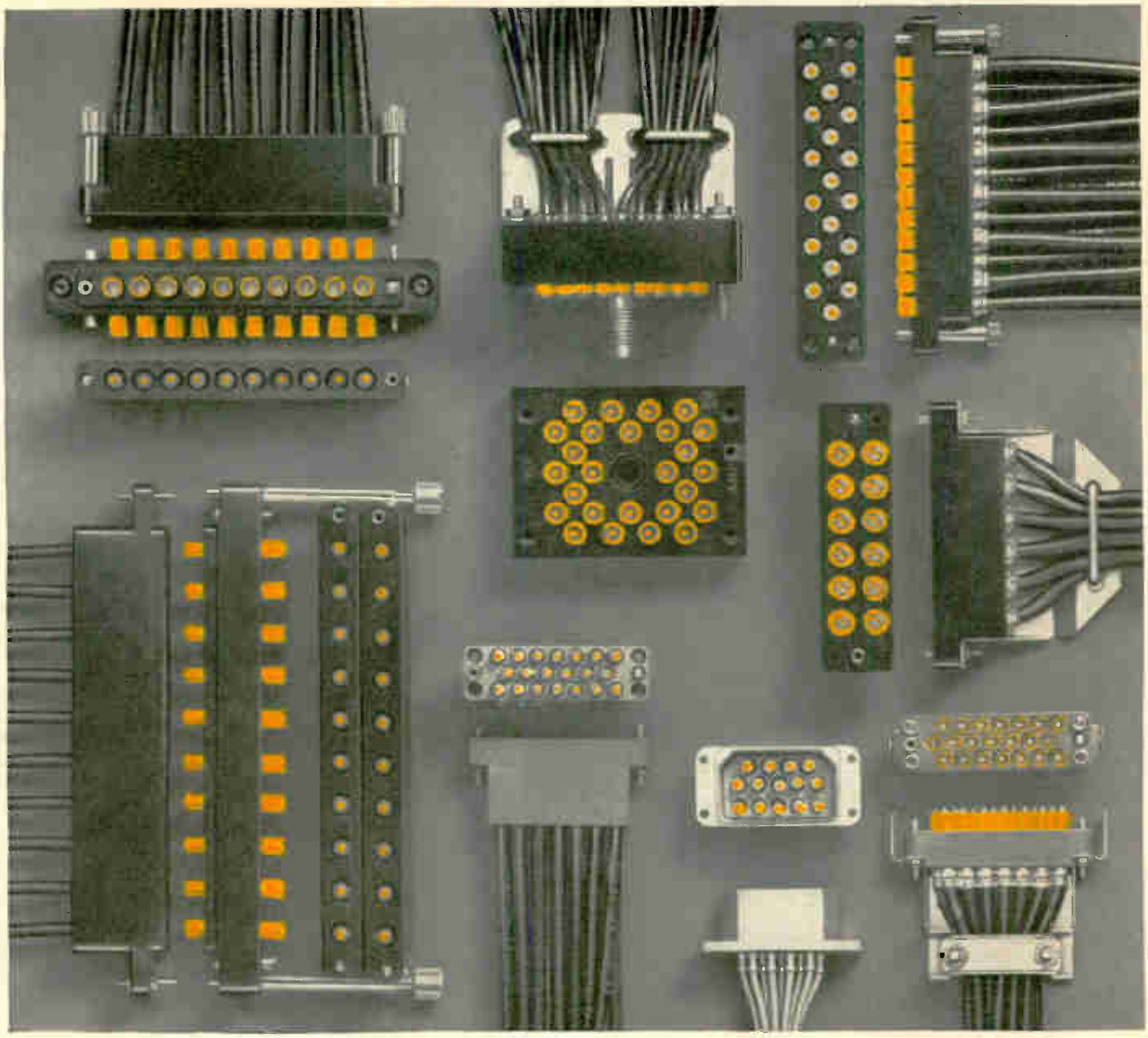
From Eimac comes a new family of water-cooled triodes designed especially for induction and dielectric industrial heating service. The tubes feature a new cast silicon-bronze cooler design with constant cross-section spiral water channels. This design insures uniform anode cooling with minimum water flow and back pressure. For example, the 3CW20,000H3 requires only 4 GPM water flow at 3.5 psi for 20 kW plate dissipation. The new tubes feature filament connecting leads—no sockets are required—and have grid flanges for low inductance connection to the grid. This new industrial family is rated at full power to 90 Mc, with reduced ratings to 140 Mc. All include anode tabs for ease of mounting into industrial machinery plus rugged, high-dissipation grids for industrial oscillator service. Write Power Grid Product Manager for additional technical information, or contact your nearest Eimac distributor.

CHARACTERISTICS

	Plate Dissipation (kW)	Filament Voltage (Volts)	Input Power (kW)	Useful Output (kW)
3CW5,000H3	5.0	7.5	30	15.5 to 22.5
3CW10,000H3	10.0	7.5	40	25.0 to 30.0
3CW20,000H3	20.0	6.3	60	42.0 to 45.0
3CW30,000H3	30.0	10.0	80	55.0 to 60.0
3CW40,000H3	40.0	13.0	120	75.0 to 90.0

EIMAC — San Carlos, California
a division of Varian Associates





Economy and reliability do come in one package

AMP's full line of COAXICON★ connectors give you both the low cost and the high reliability you need for your coaxial cable circuits.

Reliability comes from AMP's formidable engineering and manufacturing know-how combined with finest quality materials.

Economy comes from AMP's simplified tooling and assembly procedures.

This is one of the most comprehensive coaxial connector lines on the market and still growing. You can find just the connector you want in the Standard, Twin Standard, Miniature and Subminiature lines—including the new T and Y configuration connectors.

And no matter which size you choose, you'll get all the benefits of AMP's unusual COAXICON contact. Both the inner conductor and the outer shield of your cable are simultaneously terminated with just one precise, controlled crimp. Contacts then snap quickly and securely into housing through AMP's special retention spring.

So get the reliability you need, the economy you want for all your coaxial cable requirements . . . from AMP. Get the full story today.

★Trademark of AMP INCORPORATED

AMP INCORPORATED
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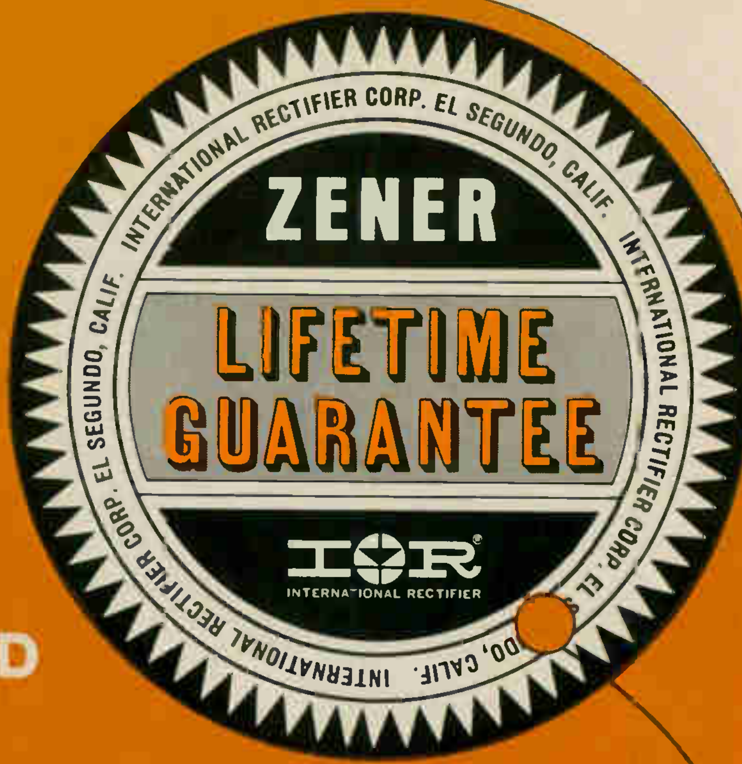
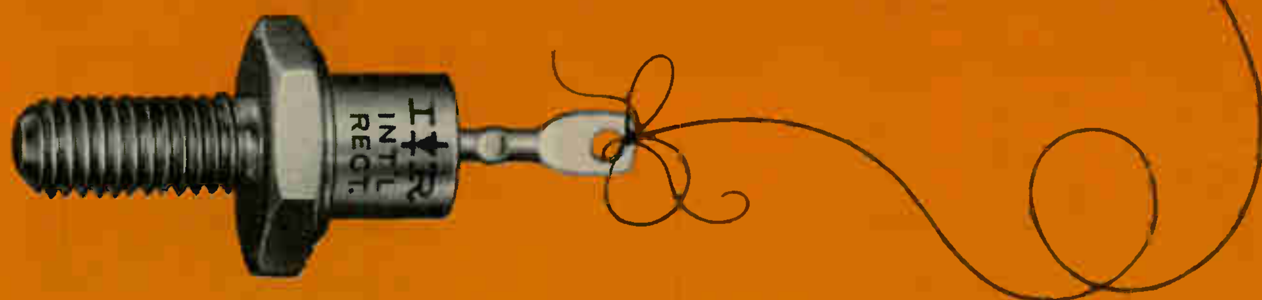
GUARANTEE

THE ULTIMATE ASSURANCE OF QUALITY AND RELIABILITY





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Washington Newsletter

November 15, 1965

Navy will test streamlined plan for ship contracts . . .

The Navy will test a new streamlined contract procedure for building and buying ships, patterned after the Air Force system for acquiring planes. **The new plan opens a broad, new market to electronics, aerospace and other companies with systems-development experience, even if they have never built a ship.**

The system will be tried first in purchasing a new class of vessels, to be known as fast-deployment cargo ships (FDL's). Contractors will compete for design and development in a contract-definition phase, then a single contract will be written covering follow-on construction, maintenance and repair. Traditionally, the Bureau of Ships has designed vessels, and shipyards have built them, on a job-shop basis.

The proposed changeover, pushed by Defense Secretary Robert S. McNamara, is already leaving scars within the Bureau of Ships. In protest against the plan, the bureau's chief, Rear Adm. William Brockett and the chief deputy, Rear Adm. Charles Curtze, decided to retire.

. . . opening door to electronics, space companies . . .

The FDL prime contractor will have to be a company experienced in systems design and management rather than one solely engaged in ship construction. For this reason, the award may go to an aerospace concern or to a combination aerospace-shipyard team because the shipbuilding industry is relatively weak in design and systems-approach experience.

Companies supplying electronics for the FDL's will do business with a system prime contractor and with the new office of the project manager, Rear Adm. Nathan Sonshein. **The project manager will be empowered to cut through the organizational structure of the Bureau of Ships to push through changes or speed-ups in parts of the contract.** This is the first time such a procedure has been ordered for a surface ship, although it has been used in the procurement of Navy missiles, such as the Polaris, and the fleet of nuclear submarines.

. . . and favoring automated ships and shipyards

The FDL program affects the electronics industry in two other respects:

- The vessels themselves will be relatively simple craft. **They will use state-of-the-art navigation and communications.**
- The Navy hopes to automate the operation of the ships as much as possible to reduce crew size. In addition, because the craft will be built in volume, **the Navy will favor the bidder that offers automated shipyard operations to cut production time and costs.**

Pentagon increasing 'breakout' buying

The Defense Department will increase "breakout" buying of electronic and other components. Under breakout buying, the government itself may buy a component common to several weapons systems rather than allow the prime contractors to buy it; the government is able to buy in volume and thus at a lower price.

The Defense Department has adopted the policy after months of controversy during which the General Accounting Office pressed for more breakout buying and prime contractors sought to limit it.

Washington Newsletter

Money-back clause produces revenue

The first two applications of a clause in research-and-development contracts, pioneered by the Federal Aviation Agency, have put $158,000 back in the U.S. Treasury. The "recovery of development costs" clause provides that a company developing a product with financial aid from a government agency must return the development money should the product be sold commercially.

The patents panel of the White House's Federal Council for Science and Technology recommends the clause to those departments—Commerce; Interior; Health, Education and Welfare; Agriculture—where the results of R&D are most likely to enter the consumer market.

But even the Air Force, at the insistence of the FAA, has written development-repayment clauses into its contracts for the Lockheed C-5A and the older C-141 Starlifter. The FAA is joint sponsor of these projects with the Air Force. And Air Force-NASA-FAA contracts written on the supersonic transport carry repayment clauses.

FCC to probe Western Electric charges to Bell

An investigation of the sales and pricing practices of the Western Electric Co. is in the making. It will be part of an inquiry by the Federal Communications Commission, that may take two years or more, into the giant American Telephone & Telegraph Co. and associated Bell System companies. Public hearings start next spring.

Implicit in the FCC investigation order is the question of whether Western Electric is making fair charges to sister Bell System companies for equipment and services. Western Electric is the manufacturing arm of AT&T.

Pentagon steps up contract activity

Several weapons programs heavily dependent on electronics are closer to production as the result of recent decisions by the Pentagon.

The Boeing Co. and the Martin Marietta Corp. have been named finalists in the contract-definition competition for the short-range attack missile (SRAM) to be used on late-model B-52's and on a possible strategic bomber version of the F-111. The McDonnell Aircraft Corp. and North American Aviation, Inc., were eliminated. Boeing and Martin will submit final proposals next spring.

The Lockheed Aircraft Corp. has won the development contract for the Army's advanced aerial fire support system, a high-speed armed helicopter. The aircraft will have an integrated avionics system, called IHAS; a good prospect is the system being developed for Navy helicopters by the Teledyne Systems Corp., a subsidiary of Teledyne, Inc.

The Navy wants the Defense Department to start production of IHAS soon, even though the system is still in the early development stage. Parallel development and production would avoid costly retrofitting of helicopters that are to be produced in increasing quantities as a result of stepped-up procurement for Vietnam.

The Army should be choosing soon between the Radio Corp. of America and the Hughes Aircraft Co. for development of a new air defense missile known as Sam-D. Joint Army-Navy studies, of how to obtain as many common components as possible between Sam-D and a contemplated new Navy air defense missile known as ASMS, have been compiled and submitted to the Pentagon.

BEEP BEEP BEEP BEEP BEEP BEEP BE

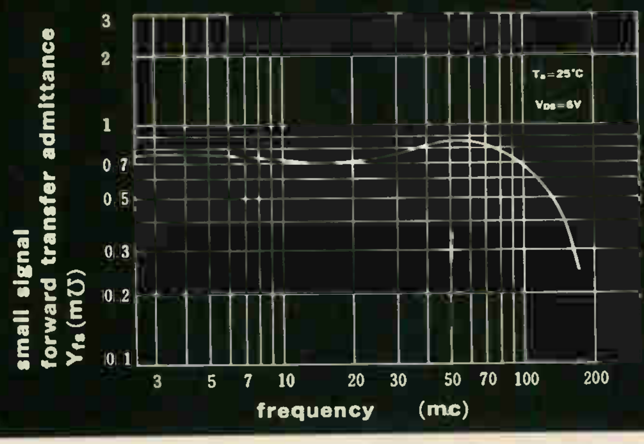
3SK11 ac amp. — 3SK12 Switching — 3SK13 dc amp.

MOS N-CHANNEL TYPE

This family utilizes a hermetically sealed four-lead package which is similar in shape to the JEDEC TO-18.

ELECTRICAL CHARACTERISTICS (T_a=25°C)		3SK11			3SK12			3SK13			
		min	typ	max	min	typ	max	min	typ	max	
V_{DSX}	(I_D=10μA, V_{GS}=−10V)	20	—	—	20	—	—	20	—	—	volts
I_{DSS}	(V_{DS}=6V, V_{GS}=0)	0.5	2.0	6.0	0.5	2.0	8.0	0.5	2.0	6.0	mA
V_{GS}	(V_D=50μA, V_{DS}=6V)	—	—	−8	—	—	−8	—	—	−8	volts
Y_{fs}	(V_{DS}=6V, V_{GS}=0, f=1kc)	400	750	1500	300	750	—	400	750	1500	μ℧
I_{GSS}	(V_{DS}=0, V_{GS}=−6V)	—	—	1.0	—	—	50	—	—	1.0	pA
C_{is}	(V_{DS}=0, f=1mc)	—	3.6	—	—	3.6	—	—	3.6	—	pF
$R_{DS(on)}$	(V_{DS}=0.1V, V_{GS}=0)	—	—	—	—	0.6	2.0	—	—	—	kΩ
$R_{DS(off)}$	(V_{DS}=0.1V, V_{GS}=0)	—	—	—	50	—	—	—	—	—	MΩ
t on	(V_{DD}=6V, R_L=100Ω, R_{gs}=50Ω)	—	—	—	—	—	50	—	—	—	mμs
t off		—	—	—	—	—	50	—	—	—	mμs
ΔI_{DSS}*	(V_{DS}=6V, V_{GS}=0, t=0.5 hour)	—	—	—	—	—	—	—	+0 −20	—	μA
NF	(V_{DS}=6V, I_D=0.5 mA, f=1kc, R_g=10MΩ)	—	6	—	—	—	—	—	6	—	db

*Initial Drift



MAXIMUM RATINGS (T_a=25°C)
V_{DSX} ....20 volts
V_{GSX} .... +2 −20 volts
$V_{GS(peak)}$ ... ±20 volts
I_D....................10mA
P 100mW
T_{ch} ....150°C
T_{stg} ......−55~150°C

Now you know what the Hitachi Field Effect Transistors are all about.

HITACHI
Tokyo Japan

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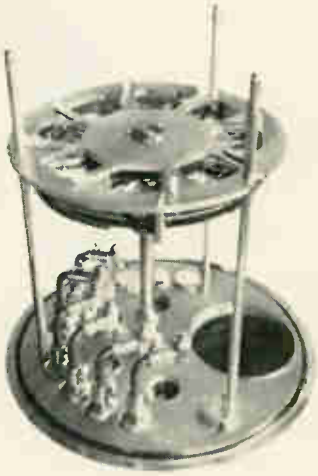
3 NEW PRODUCTS

for improving your thin film evaporation



EIGHT-POSITION MASK SUBSTRATE CHANGER

- Accuracy of registration
- Unrestricted sequencing of coating steps
- Ease of operation

These and many other features have been built into this changer which has been designed and developed from Bendix' background of many years in thin film microcircuit fabrication. Models are available either to be mounted in the BBV BA 510 coater, or self-contained on a feed through collar for use in any 18" coater. Eight 2" x 2" (or smaller) substrates, eight masks and eight source positions may be combined and sequenced in any order.

THIN FILM CONDUCTANCE RATE MONITOR

- Higher sensitivity
- Greater convenience
- Wider range

This monitor has a decade resistance which may be preset at any value from 1 ohm to 10 megohms. A test glass exposed beside the substrate is continuously monitored as its conductance changes from zero to 100% of the conductance corresponding to the preset resistance. As this change is displayed on the conductance meter, a second meter simultaneously shows the rate-of-change of conductance. Accurate control can be maintained over both final film conductance and the rate of increase which allows the evaporation process to be standardized.

Coupled with an automatic shutter (available in the BBV BA 510) this unit provides push button control of start (or stop) of film deposition, display of change and rate of change, automatic shutter trip at 100% conductance plus indication of post-deposition drift and exposure-to-air effects.

MULTI-SOURCE ELECTRON BEAM EVAPORATOR

- Six water-cooled crucibles
- Full 3 KW output
- Solid state power supply
- Water-cooled gun
- Variable high voltage and filament current

These features are among those which make the BBV Multi-Source Electron Beam Evaporator the most versatile and dependable electron bombardment source available. The gun, power supply, and control unit are combined into a complete system with cables, flow switch, automatic water valve and vacuum interlock. Safety and convenience are built in, with the capability for evaporating any metal or alloy, including tungsten, refractory oxides or carbides under contamination-free conditions.

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ANOTHER ANALOG FIRST FROM NEXUS

NOW
LOW COST OPERATIONAL AMPLIFIERS
TO MEET WIDE RANGE OF ENVIRONMENTS AND RELIABILITY

COMMERCIAL SQ-10	**PREMIUM Q-10**	**MILITARY Q-10 (M)**
$24 unit price*	**$39 unit price***	**$59 unit price***

*Much less in quantity

There are now three new Nexus low-cost operational amplifiers designed to meet the requirements of commercial, industrial and military users. Models SQ-10, Q-10 and Q-10(M) are available at low, low prices, especially in OEM quantities. This means greater design freedom . . . the ability to match the amplifier closely to specific performance and economic requirements.

All these Nexus amplifiers are moderately high-gain units primarily designed for closed-loop operation with negative feedback in most analog configurations. They may also be used open-loop as voltage crossing detectors, etc. All three models provide up to 0.1 megohm differential input impedance (10 megohms common mode). They also provide input offset temperature coefficients typically $\pm 20 \mu v/^{\circ}C$ and $\pm 2 na/^{\circ}C$.

The Commercial SQ-10, fully encapsulated, offers a quality and reliability that is comparable to that of many premium amplifiers. The Premium Q-10 which features metal-can, hermetic-seal transistors, can withstand storage temperatures of $-65^{\circ}C$ to $+125^{\circ}C$. The third, the MIL-type Q-10(M), was expressly designed to fill the stringent requirements of military users and contains MIL/QPL parts throughout. And for the customer who needs them fast, off-the-shelf availability insures rapid delivery of all orders.

For excellent d-c stability, small size, high reliability, versatility and low price too, your best buy in solid-state operational amplifiers is NEXUS.

Be sure to write today for full details on the NEXUS SQ-10, Q-10, and Q-10(M).

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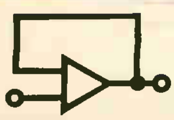

D CASE K CASE L CASE Q CASE QB CASE

WANT TO SAVE MONEY BY USING GUDEBROD LACING TAPE? . . .

YOU DO IT HERE!

Harness tying may be a relatively minor operation. But it also can be a major cost drain. Lacing tape is one of the smallest costs in the harnessing operation but with Gudebrod Tape you can save dollars in making harnesses. Knots tie easier, workers say they almost tie themselves, knots stay tied, the harness workers can go right on with the harnessing without having to go back for re-tightening. Workers like to use Gudebrod Tape. You cut harnessing time—you have fewer rejects. All of this works for you in saving money on cable harnesses—that's why it pays to specify Gudebrod Lacing Tape, the original flat braided tape. Prove these statements in your own harnessing department—give Gudebrod Tape a comparative test.

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When you need help on knots, on spacing, on the type of tape to use—Gudebrod is your one best source for information. We have over 200 different lacing tapes in stock, for temperatures up to 1500° F. or down to −100° F., burn proof tapes, tapes that do not outgas in vacuum, color coded tapes, cut lengths, tapes of nylon, Dacron*, Teflon*, spun glass, silica fiber. Ask for a copy of our Product Data Book.

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GUDEBROD BROS. SILK CO., INC.

FOUNDED IN 1870

Electronics Division

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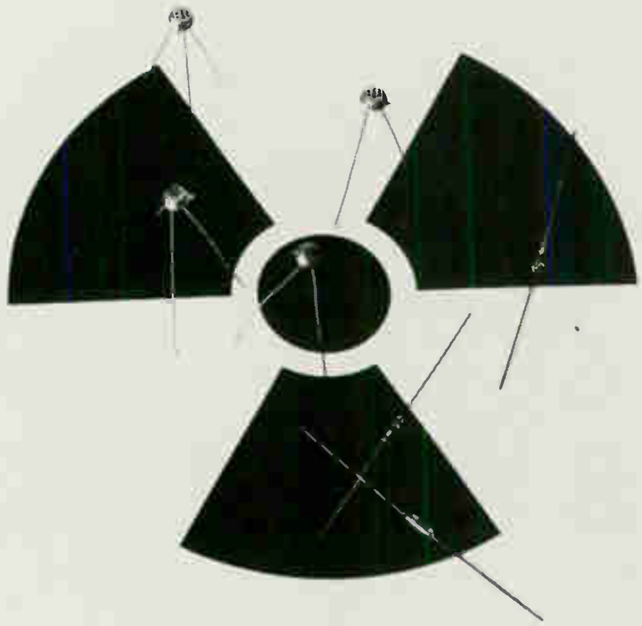

radiation resistant.

FT40 transistor: Amplifier or high speed switch. h_{FE} of 10 or better after radiation exposure of 1×10^{15} nvt. Guaranteed.

FRR 300 diode: V_F less than or equal to 1.0V @ I_F = 100mA, PRV=300V after radiation exposure of 5×10^{14} nvt. Guaranteed.

FAIRCHILD SEMICONDUCTOR

In distributor stock or write for complete data.

Look who stepped out of the Great Seal to wear a CMC Crusading Engineers' medal. Think he looks proud? You should see us! **He's on the first and only solid-state counter fully militarized to meet Mil Specs.**

If you want the safety of a counter providing full Mil Specs reliability at a price surprisingly close to a commercial counter, then check these specs: 0 to 100 Mc frequency range; oscillator stability of 1 part in 10^9; meets or exceeds MIL-E-16400, including appropriate temperature, humidity, vibration, shock, and RFI specs; built-in time interval measurement. Three militarized plug-ins available: 500 Mc heterodyne converter, 3 Gc heterodyne, and a 15 Gc transfer oscillator.

It may take some time, but you can probably expect copies of this counter from our creative competition at high-powered H-P and big, bad B. But they'll be copying the instrument originated and designed by CMC. State-of-the-art development of a fully militarized solid-state counter isn't the first or last technological coup for CMC. Add to it the first all solid-state counter, first all-silicon solid-state counter, first 10-line-per-second low-cost printer, first dual plug-in counter, and numerous others.

Write today for a complete spec sheet on our new Model 880 so you can compare when and if the others arrive on the market. And remember, we won't give you the bird, we'll give you a medal.

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- light dimmers
- space heaters
- computers (tape drive control)
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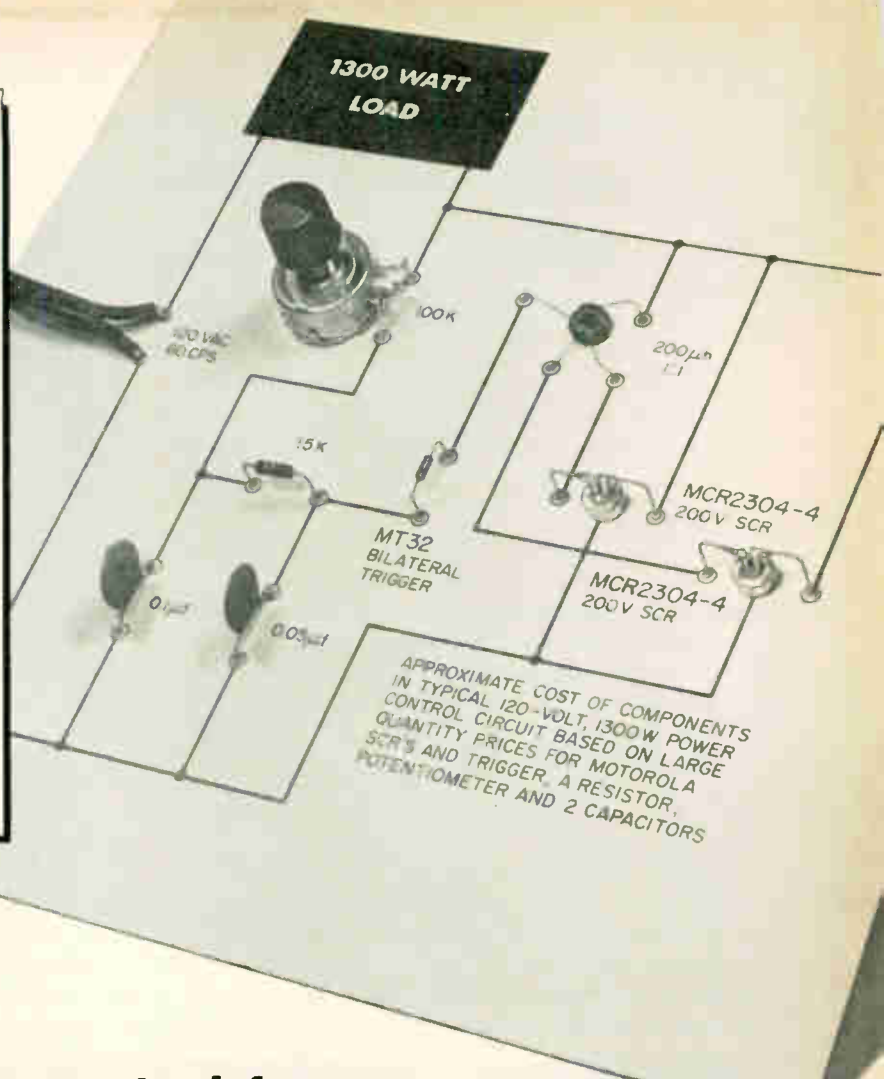
- motion picture projectors



You can add solid state reliability plus continuous power control for less than $2.50 in total component cost...

Continuing development of the Elf® thyristor – Motorola's popular low-cost 8-ampere SCR – has opened up unlimited areas for stepless control of 120- and 240-volt operated electrical equipment. Now the Elf truly satisfies the current and power requirements of virtually every product using continuous control of motor speed, heat or light . . . retains all the safety features essential to reliable SCR circuit operation in these products . . . yet costs little more than non-hermetically-sealed devices having only a fraction of its current-handling capability.

Without waste, wear and repair . . .

common to expensive electro-mechanical switches and controls, the midget-sized "Elf" SCR's give you these design advantages:

- high power handling capability at elevated temperatures – 5 amperes (AV) at 75°C, case
- minimum power loss — low 1.3-volt forward voltage drop (max.) @ 5A @ T_J = 25°C
- mounting versatility – 12 different hermetic cases (plus reverse polarity)
- immunity from false triggering due to noise – a realistic 10mA (typ.) gate firing level
- current surge protection – 100 amperes for 1 cycle, 60 cps, minimizes chances for damage from transients

Get symmetrical firing characteristics . . .

with the MT32, bilateral trigger – a versatile companion in value that replaces neon lamps, unijunction transistors, and other thyristor triggering devices requiring complex circuitry.

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Call your Motorola distributor for off-the-shelf engineering units . . . And for ideas that can help accelerate your thinking about electrical control designs, write for our set of "applications unlimited" thyristor circuits and device data sheets.

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P.O. BOX 955, PHOENIX, ARIZONA 85001

If you're working with 0.100 to 20 amps, our new Series JA circuit breaker will save you space, weight, and money over this other OEM model

The hydraulic-magnetic breaker shown above has long been the most popular OEM type on the market. But now the big buy is the little Heinemann Series JA that you see down below.

The JA is one-third smaller in volume than the other breaker. And one-third lighter in weight.

And it costs less.

On a standard series-trip model you save about ten percent. On special-function models (relay-trip, shunt-trip, etc.) you save even more.

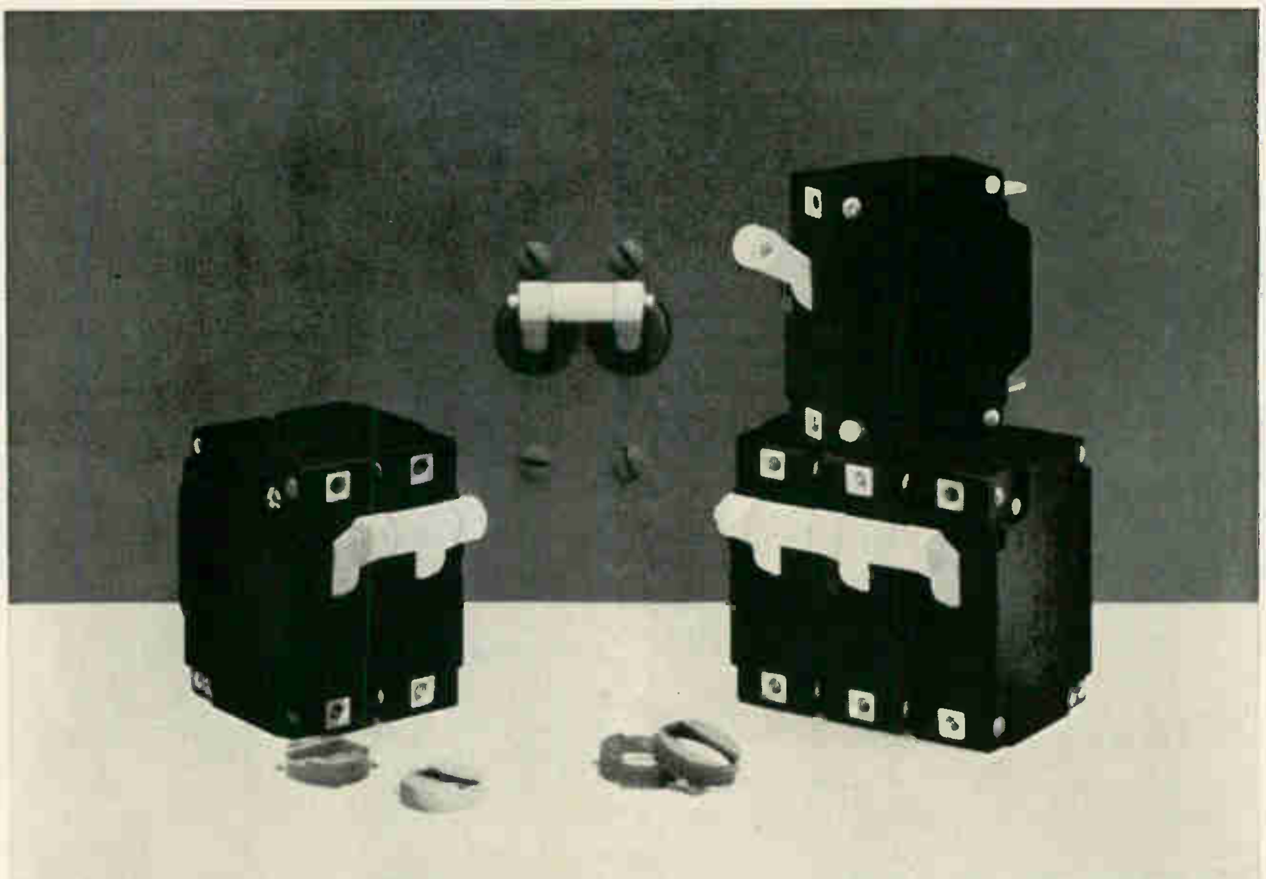
The JA is also easier to install. Its round boss eliminates the need for the square-cornered panel cutout the other breaker requires. Drill or punch a few holes and you're all set.

"Universal" terminals further expedite things. The JA will accept quick-on or soldered connections directly or, with snap-on adapters, screw-type connections. Whatever method you're tooled for is "go."

The JA is better looking, too. It comes with a neat white switch handle, and you can, as an option, dress it up with snap-on color-coding boss caps.

In performance capabilities, the JA is thoroughbred Heinemann all the way. That means precisely calibrated, temperature-stable trip-points and nominal current rating. Choice of time-delay or instantaneous overload response characteristics. And a number of unique functional options.

The smaller, lighter, less expensive, better-looking Series JA circuit breaker is available in single- and multi-pole models rated for standard maximum voltages of 250 vac, 60 or 400 cycles, or 50 vdc. Our new Bulletin 3350 will give you detailed technical data. Write us for a copy.



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SA3243

WHICH BRANCH

OF THE PNP SILICON TRANSISTOR FAMILY TREE

P N P

ARE YOU CONCERNED WITH?

P N P — LOW LEVEL LOW NOISE

$I_{CBO} < 1$ nA

h_{FE} (10 μA-5V) 100-300

NF 3 db

2N2603
2N2604
2N2605
2N3544
2N3548
2N3549

P N P — MEDIUM POWER

BV_{EBO}, $BV_{CEO} > 60V$

h_{FE} (.1mA to 100 mA) >100

$t_{TOT} < 100$ N SEC

2N2485A
2N2486A
2N2904A — 2N2907A
2N3502 — 2N3505

P N P — INTEGRATED CHOPPERS

$BV_{EE} > 50V$

$V_O < 50 \mu V$

$I_{EEO} < 1$ nA

3N90 — 3N95
3N114 — 3N119

P N P — DIFFUSED EPITAXIAL

BV_{CBO}, BV_{CEO}, $BV_{EBO} > 50V$

$h_{FE} > 50$

$I_{CBO} < 10$ nA

2N328A
2N329A
2N2944
2N2945
2N2946
2N3857
2N3058 — 2N3065

P N P — DIFFERENTIAL AMPLIFIERS

$h_{FE} > 100$

$\frac{h_{FE1}}{h_{FE2}}$ 10%

$V_{BE1}\text{-}V_{BE2} = \pm 3$ mV

NS7200
NS7201
2N3502
2N3503
2N3504
2N3505
2N3800 — 2N3811

NSC-130

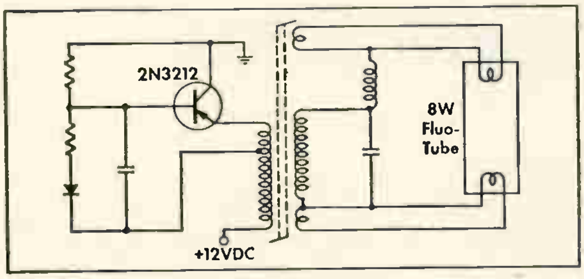
Whichever branch of PNP's you are concerned with, before you specify a brand CHECK THE NSC LINE. Write for spec sheets on any of these devices—or better yet, the NSC Composite Catalog.

NSC

NATIONAL SEMICONDUCTOR CORPORATION
DANBURY, CONN.

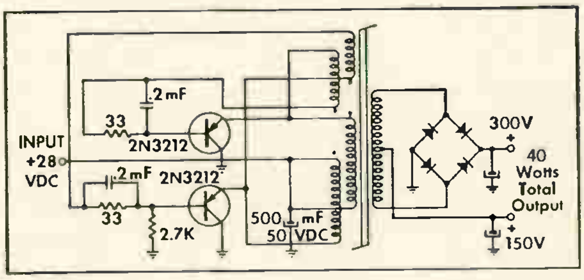
HOW TO CRAM BIG POWER INTO A LITTLE SPACE

Consider this family of miniature Nu-Base† transistors. Delco Radio's 2N3212, 13, 14 and 15 in the TO-37 case. They'll help you pack high current, high voltage, and fast switching in a small circuit package. And our SPAC‡ process gives them excellent parameter stability over a wide range of environmental conditions.

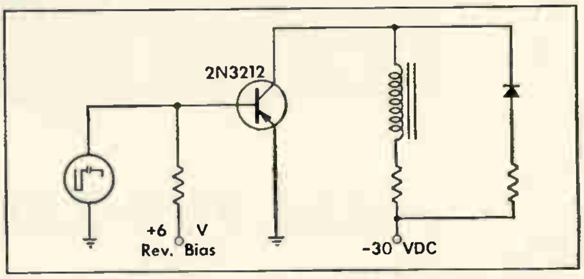


Battery-operated fluorescent light supply: A basic transistorized blocking oscillator forms the heart of this 8-watt portable fluorescent light.

Each of these Delco devices is rated 5 amperes, maximum continuous collector current. Their VCEO ratings, shown on the chart, make them especially useful where high voltages and high currents are encountered. In switching applications, they combine relatively low saturation resistance and high speed for excellent efficiency and reliability.



40-watt DC to DC converter gets an efficiency of 90 percent from the low saturation resistance of the miniature Delco 2N3212.



Print-out hammer driver: The high gain of this miniature TO-37 Nu-Base transistor enables it to switch 7 amperes of collector current at short duty cycles (10-15%).

In Delco Nu-Base construction, the husky element has built-in protection from current "hot spots" to assure freedom from secondary breakdown over the operating range.

These units will dissipate over 5 watts at 71°C case temperature, and operate over a range of −65° to 110°C. They lend themselves easily to automatic insertion.

Get in touch with one of our sales offices or your Delco semiconductor distributor. More data, prices and application information on this big little transistor will soon be on its way.

TYPE	2N3212	2N3213	2N3214	2N3215
Vcbo	−100	−80	−60	−40
Vceo @ Ic=20ma	−80	−60	−40	−30
hFE @ 3A	30-90	30-90	30-90	25-100
Vce (sat.) @ Ic=5A	−0.5v	−0.5v	−0.5v	−0.5v
Vce (sus.) @ Ic=3A	−80	−60	−40	−30
Conditions for Vce (sus.)	Pulse Width=1.4ms Duty Cycle =4% Inductance =6mh			

Operating temperatures=110°C max., −65°C min.; max. storage temperature=125°C.

†Delco's name for drift field non-uniform diffused base construction.

‡Surface Passivation and Ambient Control.

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Model	Voltage	Current (ma)	Regulation Line (%)	Regulation Load (%)	Stability Per Hr. (%)	Stability Per Day (%)	Calibration Accuracy (%)	Max. Ripple (rms)	Resolution	Price
412B	0-2,100	0-30	0.001	0.001	0.005	0.02	0.25	500 μv	5 mv	$ 410
405B	0-3,100	0-30	0.001	0.001	0.005	0.02	0.25	1 mv	5 mv	$ 525
408B	0-6,000	0-20	0.001	0.001	0.005	0.02	0.25	1 mv	5 mv	$ 665
410B	0-10,000	0-10	0.001	0.001	0.005	0.02	0.25	1 mv	5 mv	$ 975

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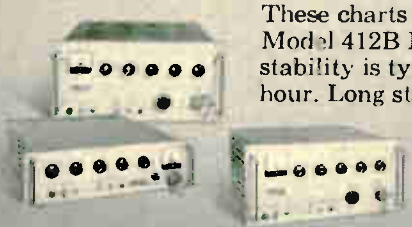

These charts show the short and long term stabilities of the new Fluke Model 412B Precision High Voltage Supply. Notice that the short term stability is typically ±0.0005%/hour compared to a spec of ±0.005%/hour. Long stability is specified as ±0.02% per day compared to an actual ±0.005% for more than 12 hours for this unit. Foreground shows Model 412B. Background shows left to right Model 405B, Model 408B, and Model 410B.

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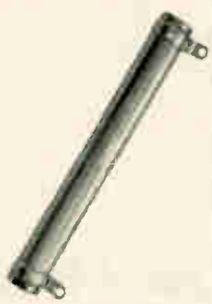

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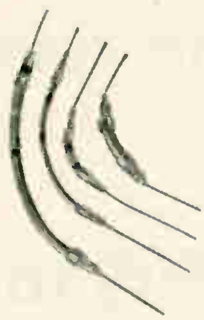

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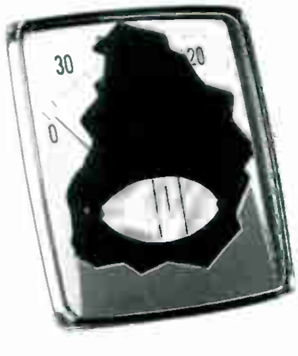

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These advantages apply not only to core meter magnets, but to other precision applications as well, such as a-c and d-c motors, hearing aids, controls and speedometers. Innovator: Magnetic Materials Sect., Edmore, Mich.

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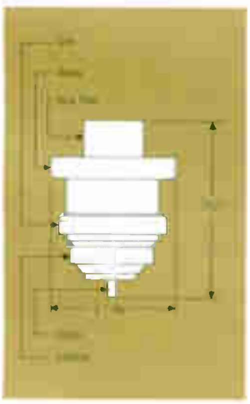
These sample triodes were equipped with unique grid structures to maintain extremely close grid-cathode spacing. They also employed high-current-density cathodes (up to 2 amps/cm² CW). Result: Gm's of 300,000 to 750,000 micromhos, 5-KW pulsed output with duty cycles as high as 7%, and gain-bandwidth products never before obtained using gridded tubes.

Y1430 Developmental CW Triode



PERFORMANCE CHARACTERISTICS*

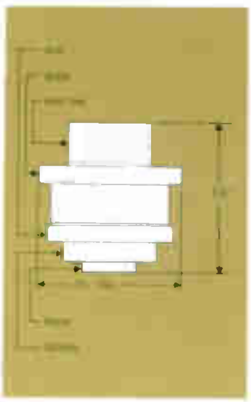
Typical Electrical Data

Heater voltage	30 volts
Heater current	0.5 ampere
Amplification factor	200
Grid-plate transconductance (at I_b=1.0 amp)	300,000 μmhos
Interelectrode capacitance:	
Grid-plate	4 $\mu\mu$f
Grid-cathode	20 $\mu\mu$f
Plate-cathode	0.2 $\mu\mu$f

Typical Operation (at 1.3 Gc) at RF Power Amplifier

D-c plate voltage	2100 volts
D-c grid voltage	—8 to —40 volts
D-c plate current	0.57 to 0.76 amp
D-c grid current	approx 0.03 to 0.22 amp
Driving power	approx 5 to 50 watts
Power output	approx up to 1000 watts

Y1498 Developmental Pulsed Triode



PERFORMANCE CHARACTERISTICS*

Typical Electrical Data

Heater voltage	60 volts
Heater current	0.6 amp
Amplification factor	200
Grid-plate transconductance (at I_b=3.0 amp)	500,000 μmhos
Interelectrode capacitance:	
Grid-plate	5.7 $\mu\mu$f
Grid-cathode	65 $\mu\mu$f

Typical Operation (at 1.3 Gc) at RF Power Amplifier

D-c plate voltage	3400 volts
D-c grid voltage	—6 volts
D-c plate current	5.0 amps#
D-c grid current	approx 1.8 amps #
Driving power	approx 200 watts #
Power output	approx up to 5000 watts #

#For duty cycle of 0.07 and pulse length of 500 microseconds.

*Based on data obtained on tubes manufactured by the General Electric Company for the U.S. Army Electronic Command, Ft. Monmouth, N. J., under their contract #DA-36-039-AMC-03215 (E).

While these two developmental tubes are not yet available for purchase, General Electric is prepared to discuss the basis and timing on which they *can* be built. Their development, furthermore, has enabled G.E. to provide similar characteristics in many microwave tubes already available. Such advantages include:

- high-frequency performance (through Ku band)
- highest triode efficiencies at S, C, and X bands
- excellent tolerance of shock and vibration (such as 20,000-G impact and 48-G RMS at 2,000 cps, 3 minutes each plane)
- 3-to-4-second warmup (to 90% of rated I_p)
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Innovator: Tube Department, Owensboro, Kentucky.

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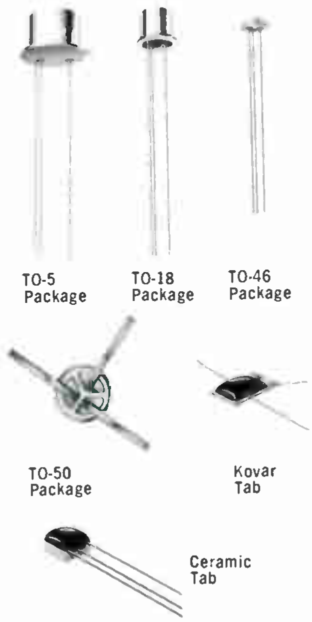
Whether you're looking for a special kind of core driver, amplifier or switch, you can forget about packaging problems when you specify from G.E.'s Large Geometry Line transistors. These NPN units come in six different package configurations (shown here) and three separate series groupings. There's a 38-model series for general purpose amplifier and some switching applications, a 32-model series—all with extremely low collector saturation voltages, and a 10-model series—excellent for core driver applications with good switching characteristics as well. Innovator: Semiconductor Products Department, Syracuse, New York.



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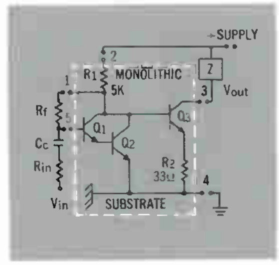
. . . and you can order quantities in either a TO-5 or flat pack configuration. D-c biasing and adjustable gain by means of feedbacks are achieved simultaneously in audio amplifier applications using a single volume control. If desired, positive feedback can be externally applied to result in many unique, non-linear applications of the astable, bistable and monostable types.



4JPA113 silicon monolithic circuit (TO-5 configuration, 5 leads)

The 4JPA113 multi-purpose unit is fabricated within a 27x29-mil silicon chip using planar epitaxial techniques. This 3-stage direct-coupled integrated circuit features a typical open loop current gain of 60,000 and open-loop frequency response of 250 kc. And it can be operated from supply voltages up to 15 volts. You'll find this low-cost unit excellent for pulse-shaping, pulse-sawtooth or sine-wave oscillators, relay drivers with bistable or monostable control, and many other amplifier applications. Innovator: Semiconductor Products Department, Syracuse, N.Y.

*in quantities of 100–999 in TO-5 package.

Circle No. 257

Want more prices?

Technical facts?

Application help?

Ask your G-E engineer/salesman for full price details on any or all components described on these pages. Ask him for free literature, or send for it yourself by circling the appropriate numbers on the Reader's Service Card. Write or call any local or regional G-E Electronic Components Sales Office for the application help you may be seeking. Or, for other assistance, write us at Section 285-09, General Electric Company, Schenectady, N. Y. 12305.

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When this headline was current news... digital recording tapes had a packing rate of 200 bpi.

Today, 800 bpi is standard; improvement in tape and base is the reason.

In analyzing the sensational development of EDP over the past decade, most of us naturally talk in terms of improvement of hardware. But when you stop to examine them, the contributions made by tape manufacturers have been quite remarkable.

The tape of today *looks* like the tape of 1954 . . . but think of the differences: improved oxide coatings to increase total capacity, reduce fluctuations in performance; much stronger binders to reduce dropouts and flaking, lengthen tape life; smoother surfaces to give longer, error-free wear; thinner coatings and better production controls to guarantee reel-to-reel uniformity.

Working hand in hand with the tape manufacturers during this time has been Du Pont. Improvements in the uniformity, stability and overall reliability of the base of MYLAR* have played a vital role in making possible the sophisticated tape in use today. Continuing cooperation of research and development facilites assures continuing improvements in the future. Your guarantee of the most advanced tape is the manufacturer's brand and a base of MYLAR polyester film.

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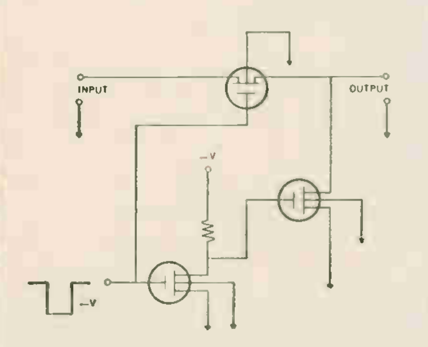

MOSFET CHOPPER AMPLIFIER

Type	DESCRIPTION (All Units P-Channel Enhancement Mode)	Y_{FS} (Typ.) µmho	BV_{DSS} (Min.) Volts	R_{ON} (Typ.) Ohms	C_{GD} (Typ.) pF	I_{DSS} (Typ.) nA
MEM511	MOSFET WITH INTEGRATED ZENER PROTECTION	2500	30	250	1.5	0.1
MEM517A	POWER MOSFET	12,000	30	25	10	1.0
MEM520	MOSFET WITHOUT INTEGRATED ZENER PROTECTION	2500	30	250	1.5	0.1
MEM550	DUAL MOSFET	1300	30	500	1.1	0.1
WRITE FOR FULL DATA AND SPECIFICATIONS						

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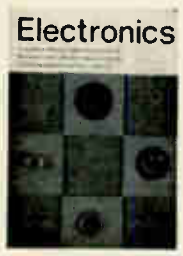
Technical Articles

What's new in semiconductor emitters and sensors: page 98



Operating at an increasing variety of wavelengths, from infrared far into the visible spectrum, optoelectronic components are finding new applications, including indicating lamps that are free of catastrophic failure. For the future there may be semiconductor arrays for displays bright as today's television sets. On the cover are some of Texas Instruments' semiconductor materials, produced by epitaxial techniques, and two emitter diodes that serve as indicator lights. The orange disk is gallium phosphide; the red one, gallium arsenide phosphide.

Six routes to noninductive tuned integrated circuits: page 114

Since inductance for integrated circuits is still limited to small magnitudes, the designer frequently has to simulate the effect of inductance. Six methods are available. Three of them employ resistor-capacitor networks; one uses RC notch filters; another, RC circuits in the forward transmission path, and one has negative impedance converters.

Solid state multipliers for servosystems: page 120

Because it is based on the magnetoresistive phenomenon, or the Hall effect, a new analog multiplier has higher resolution and is simpler and more rugged than the conventional wire-wound servo potentiometer.

Error-control systems get the message across: page 125

As the application of digital communications grows, the problem of detecting and correcting errors increases even faster. Without coding, noise and interference cannot be distinguished from the digital signal. In this article, the first of a series, a team of specialists examines the factors that produce errors and ways to combat them.

Coming November 29

- **Special report: Time-sharing computers**
- **Variable persistence in an oscilloscope**
- **More on packaging integrated circuits**

What's new in semiconductor emitters and sensors

New materials and manufacturing methods produce components that operate at an increasing variety of wavelengths from infrared far into the visible spectrum

By Edward L. Bonin and J.R. Biard
Texas Instruments Incorporated, Dallas, Texas

With the introduction of new materials and the improvement of production methods, semiconductor optoelectronic devices have advanced from specialized laboratory devices to a fast-growing segment of the component industry. Until recently, junction emitter outputs were confined to the region of infrared; now semiconductor emitters operate at a variety of wavelengths far into the visible spectrum.

The two basic elements in optical coupling are the emitter, or light source, and a sensor, or light detector. Currently, semiconductor junction emitters are made principally from gallium phosphide, gallium arsenide and gallium arsenide-phosphide. Junction detectors are usually made from silicon.

Light sources: infrared and visible

Two kinds of semiconductor pn light sources are available: those which emit infrared light and those which emit visible light. The infrared-radiation diodes are made from gallium arsenide; visible-light diodes are currently being fabricated from either gallium phosphide or gallium arsenide-phosphide.

Also under development are light sources which combine gallium arsenide with either gallium phosphide or gallium arsenide-phosphide. Either visible-light material provides a low absorption layer for transmission of the infrared emission from the gallium-arsenide diode.

Infrared light sources

By far the most popular combination in semiconductor optoelectronics is the gallium-arsenide infrared light emitter, and the silicon photo sensor.

Gallium-arsenide light sources are available for low-power applications where the detectors are placed only a few thousandths of an inch away, or for high-power applications where the coupling distances may be in tens of miles.

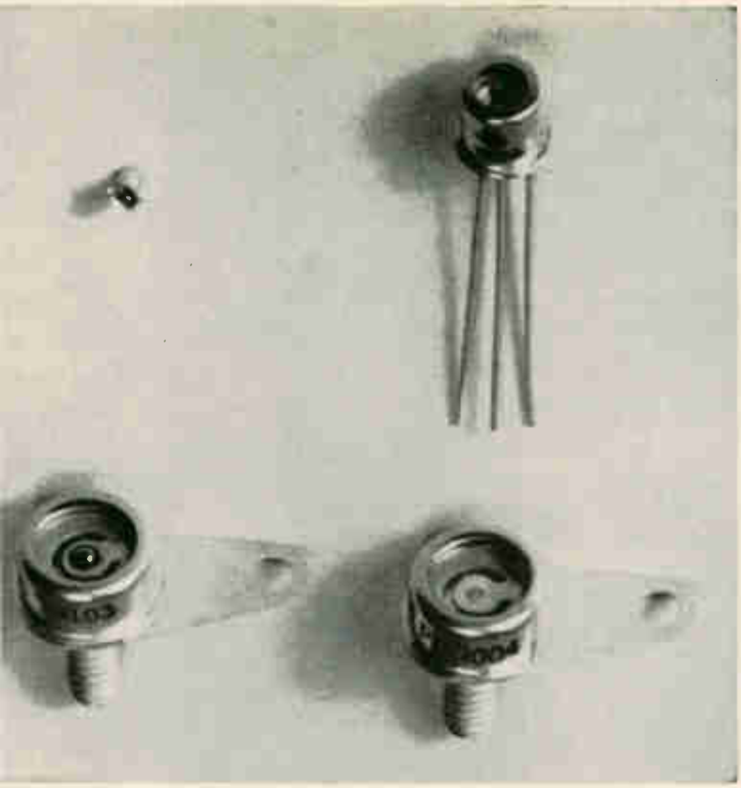
Four representative gallium-arsenide light sources are shown on page 99. The TIXLO1 package (upper left) is small enough so that 100 can be mounted in every square inch of printed circuit board. This density would allow 50 TIXLO1 packages and 50 LS600's to be mounted in source-sensor coupled arrays; the LS600 is a silicon-detector diode housed in the same type of package as the TIXLO1. Typical mounting arrangements for TIXLO1-LS600 pairs on printed boards are shown in the lower photograph on page 99.

Other light sources shown in the top photograph on page 99 are the TIXLO2 (upper right), which comes in a case similar to the Jedec TO-18. the TIXLO3 (lower left) and the PEX1004 (lower right). Both the TIXLO3 and the PEX1004 are packaged in cases with TO-5 dimensions, but modified to include windows, 6-32 threaded studs and mounting tabs.

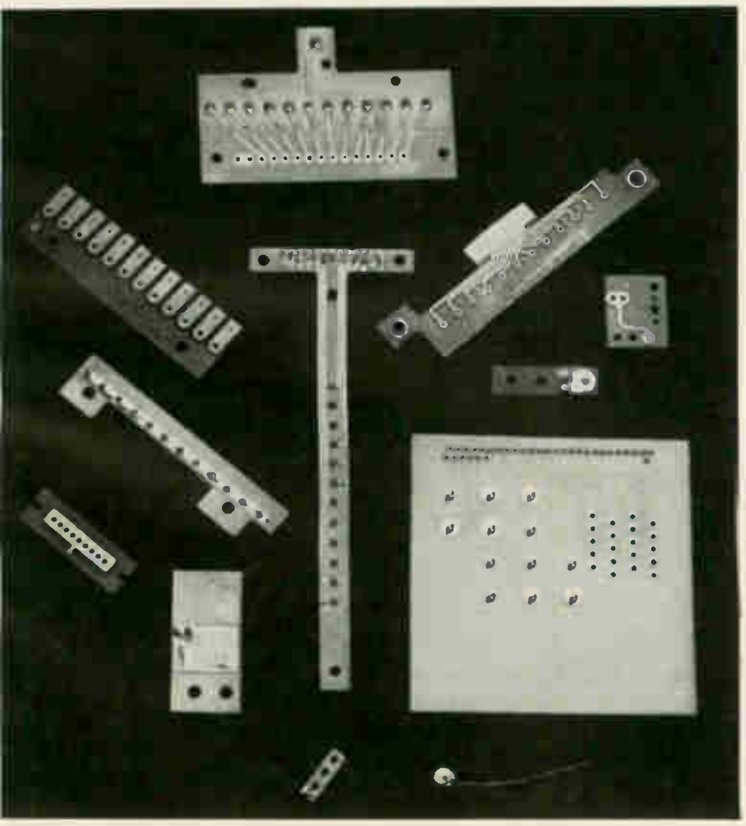
Design data

In working with semiconductor light sources, the equipment designer needs such information as output power or photon emission rate, photoemission spectrum. bias requirements, emission speed of response, size of the emitting region, and output emission angle from the package.

Typically, the emission spectrum of a gallium-arsenide source is in the near infrared range, as shown at the right for a TIXLO1. At 25°C, the wavelength of peak emission for a flat-geometry TIXLO1 is about 0.9 micron. The peak emission occurs at about 0.92 micron for TIXLO3's built with hemispherical geometry. A gallium-arsenide



Typical gallium-arsenide light sources. The miniature TIXL01 (top left) permits high mounting densities. The medium-power TIXL02 (top right) comes in a package similar to the Jedec TO-18 case. Two bottom units, are the TIXL03 (left) and the PEX1004.



Various mounting arrangements for TIXLO1 light sources and LS600 light detectors on printed circuit boards. Mounting densities of 100 devices per square inch are possible using TIXL01-LS600 pairs.

diode has a relatively narrow spectrum of about 300 angstroms at 25°C (10^4 angstroms = 1 micron).

Gallium-arsenide light sources are slightly sensitive to changes in temperature. The wavelength of peak emission increases about three angstroms for every one-degree rise in temperature. Increases in temperature cause spectral width to increase.

Typical power outputs for gallium-arsenide sources range from a few hundredths of a milliwatt for the TIXLO1 to the tens of milliwatts provided by the TIXLO3. The set of curves on page 101 illustrates the output power levels obtainable for gallium-arsenide light sources at various forward-bias currents. The source diode's power capabilities are determined by the physical geometry of the gallium-arsenide pellet as well as by the type of package.

Fabrication methods

Three basic geometries used in building gallium-arsenide emitters are the etched-flat, planar and hemispherical. These are shown on page 101. The flat geometry (left) for the TIXLO2 is typical with etching. The processing begins with the diffusion of p-type impurity into an n-type slice of gallium arsenide. The diffusion depth is about 0.3 mils. One side of the semiconductor material is then lapped and etched until the width is reduced to about 3 mils. Next, the slice is cut into wafers about 50 mils square. Contact-lead wires are then soldered across the n-type surface, the wafer is soldered to a TO-18 header, and the emitter is cleaned by electrolytic etching.

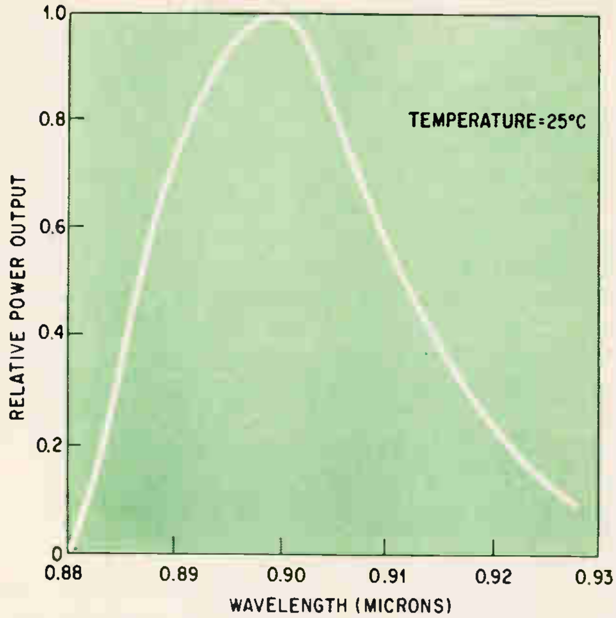
The rate of photon emission of an unpackaged TIXLO2 is proportional to the cosine of the emission angle with the optical axis as a reference. This is shown in the sketch on page 101. After the TIXLO2 is in its case (a Jedec TO-18 structure containing a window), the output angle is limited by the window to about 30° from a line perpendicular to the emission surface.

Semiconductor light sources may also be produced by planar diffusion. With this technique etching is not required and the pn junction is not exposed, an advantage of this process. Also, because contact metals can be applied using photoresist techniques, fabrication is simpler and the cost is lower. Examples of semiconductor light sources built with planar construction are TIXLO1 and the PEX1004.

The relationship between the rate of photon emission and the cosine of the emission angle, described previously for the etched flat structure, also applies to the planar device.

The package of the TIXLO1 includes a lens that focuses the light into a beam angle of 20°; beyond 10° at either side of the center point the emission intensity is below 50% of the intensity at the optical axis. The PEX1004 uses a flat lens, which projects a 120° beam through the package's aperture. The TIXLO1 has a 10-mil-diameter emitting junction; the PEX1004's emitting-junction diameter is 7 mils.

The efficiency of devices with flat geometries



Emission spectral curve for gallium-arsenide sources is narrow. However, wavelength at which they reach peak emission is about the same as that at which silicon detectors reach their peak response capability. The above curve is for the TIXL01.

Semiconductor optoelectronics: some applications

Optoelectronic coupling is especially useful in data processing systems in the transmission of either a-c or d-c signals between subsystems where ground plane noise may be present. Ground plane noise is attributable to spurious signals generated by large circulating currents flowing in circuits that have a common ground. Light coupling between the subsystems eliminates the common ground, thereby getting rid of the ground plane noise.

Here are some other applications for optoelectronics: object counters, punched-tape readers, card readers, position indicators, object orienting equipment, optomechanical programers, recognition equipment, and precision motor-speed controllers.

Also, because high voltages may be applied between the terminals of the light source and those of the detector, they may be used in current-measuring equipment for high-voltage transmission lines, in bias-control circuits for cathode-ray tubes, and in linking computer subsystems operating at wide differences in potential.

Semiconductor optoelectronic devices have also been used in a voice-modulated communications system that was operated in daylight over several miles. Optical beams were several degrees wide.

Semiconductor light sources have also been used to transmit video signals successfully.[1] In one experiment, conducted by the Lincoln Laboratory of the Massachusetts Institute of Technology, video signals from the tuner of a television receiver and also from a vidicon tube were fed to a gallium-arsenide-diode driver circuit. The infrared output from the diode was focused by a lens and picked up by a multiplier phototube 275 feet away.

The designer can resort to semiconductor light sources and detectors in separate packages,[2] to both devices in a single package,[3, 4] or to integrated circuits[5] that include both devices as well as other components.

is limited primarily by the differences between the refractive indices of the gallium arsenide and of air. Photons are generated in the vicinity of the pn junction and can be considered to be traveling in all directions in straight paths within the semiconductor material. Those photons that leave the semiconductor material are bent away from a line normal to the surface. In gallium arsenide, the only photons emitted are those that strike the emitting surface at less than about 16°, measured within the semiconductor material. All other photons are reflected at the surface.

Improving efficiency

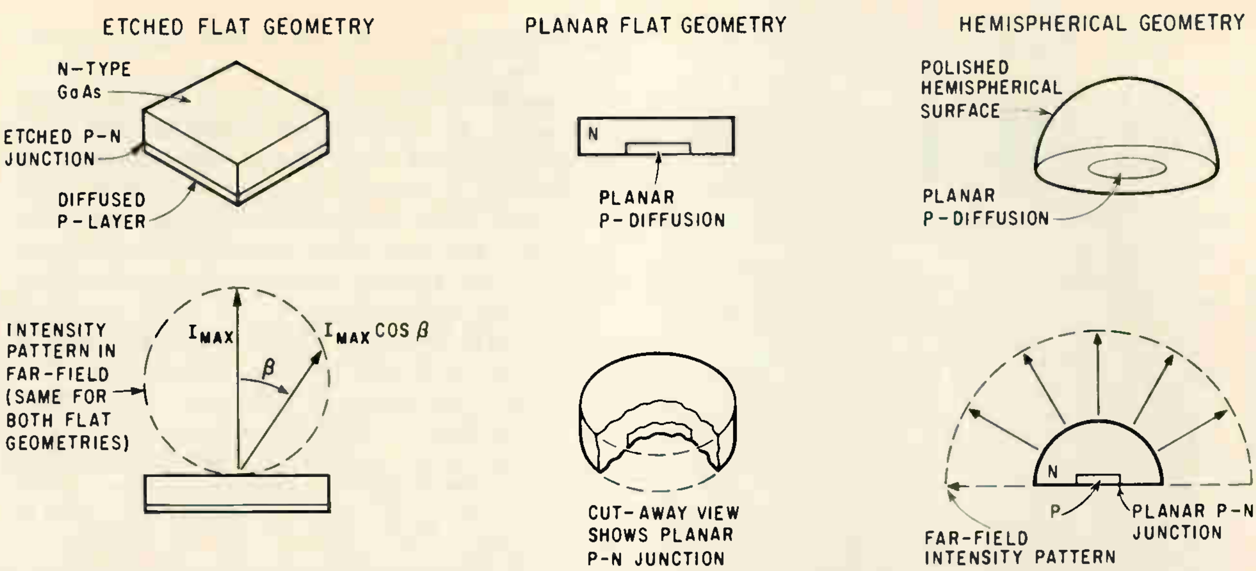
The barrier effect of the differences in refractive indices has been counteracted by a hemispherically shaped emitting surface[5] as revealed on page 101 at the top right. The hemispherical shape is produced by grinding and polishing operations. The ratio of the diameter of the hemisphere to the diameter of the diffused pn-junction region is the same as the ratio of the refractive index of gallium arsenide to that of air—about 3.6 to 1. In this case, all photons reaching the outer surface of the hemisphere make an angle of less than the critical value—that is, less than 16° with a line normal to the surface. Thus, total internal reflection of photons is impossible. By coating the hemispheres with an antireflective transparent oxide, the emission of light rays within the critical angle is increased.

For uncoated hemispherical units, the emission efficiency is typically 10 times that of flat-geometry units. Were it not for increased absorption within the thicker gallium-arsenide materials used for hemispheres, the improvement would be in the vicinity of 26 times.

The hemispherical shape affects both the pattern of light emission and the size of the emitting area. For unpackaged units, the emission is intense over approximately the 180° emission angle, indicated by the dotted lines in the diagrams at the top of page 101. The modified TO-5 package which contains the TIXL03, a hemispherical-geometry device, limits emission to about 60° from the normal. Because of spherical aberration produced by the hemisphere, the emitting area is effectively magnified to at least 7.8 times the pn-junction area. Effective size of the hemispherical geometry is especially important when additional lenses are in the optical path, as it determines the size of the ultimate image. For the TIXL03, the diffused junction has a diameter of 20 mils, centered at the base of a 72-mil-diameter hemisphere.

Forward biasing

All three pn-junction light sources described are biased in the forward-conduction direction with a regulated-current source. With a conventional voltage supply such as a battery, a resistor should be placed in series with the light-source diode; to protect the diode, the voltage drop across the resistor should be about twice that across the forward-biased diode. Maximum rated currents and



Geometries used to construct gallium arsenide light sources. At left is the etched flat geometry used for the TIXL02. The planar geometry shown in the center is used in building the TIXL01 and PEX1004. The hemispherical geometry of the TIXL03 is at right. The dotted lines show the light-intensity patterns before packaging of the wafers.

typical forward voltages at a case temperature of 25°C are 50 milliamperes and 1.2 volts for the miniature TIXLO1, 1.0 ampere and 1.6 volts for the TIXLO2, and 2 amperes and 1.6 volts for the TIXLO3 power source.

Response for the pn-junction gallium-arsenide sources described is relatively fast, with rise and fall times at 25°C ranging from about 3 nanoseconds for the TIXLO3 with 2-ampere pulses to 30 nanoseconds for the TIXLO2 and 100-milliampere pulses.

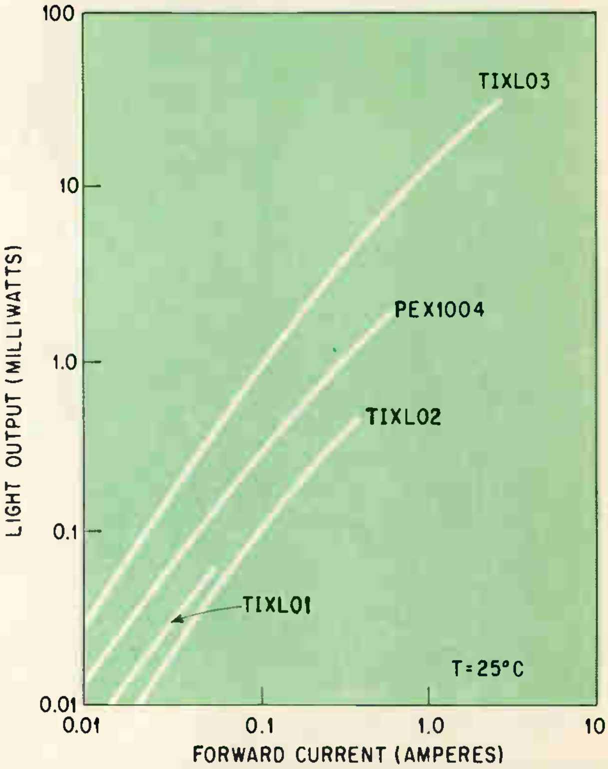
Both the system requirements and device-technology limitations must be considered in deciding which geometry is best for a specific application. For example, hemispherical sources can be made with diameters of 30 to 90 mils, while planar and flat-geometry dimensions can be as small as 2.5 mils. If lens restrictions are such that the source diameter must be smaller or larger than 30 to 90 mils, a flat type of geometry is required. In general, for a given effective size and a given bias current, the hemispherical source provides the greatest possible coupling distance that can exist between the source and the detector.

Current density

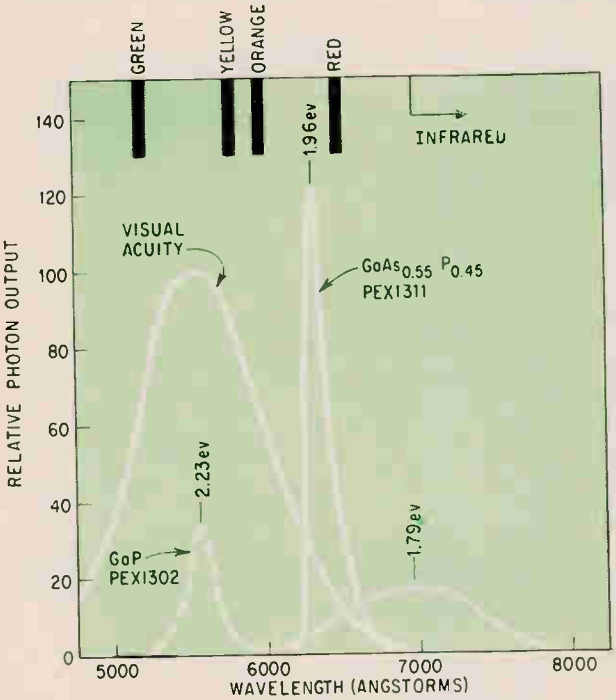
One important consideration is the current density at the pn-junction, because of its possible effect on device reliability. For the same effective size of a source, the actual size of a junction is larger for a flat-geometry source than for a hemispherical source. Thus, for the same current density and same effective size, the flat geometry may be preferred from a reliability standpoint. However, the bias current may also be excessively large for the flat-geometry unit; a further limitation may be the problems of thermal mounting for the gallium-arsenide wafer.

Visible light sources

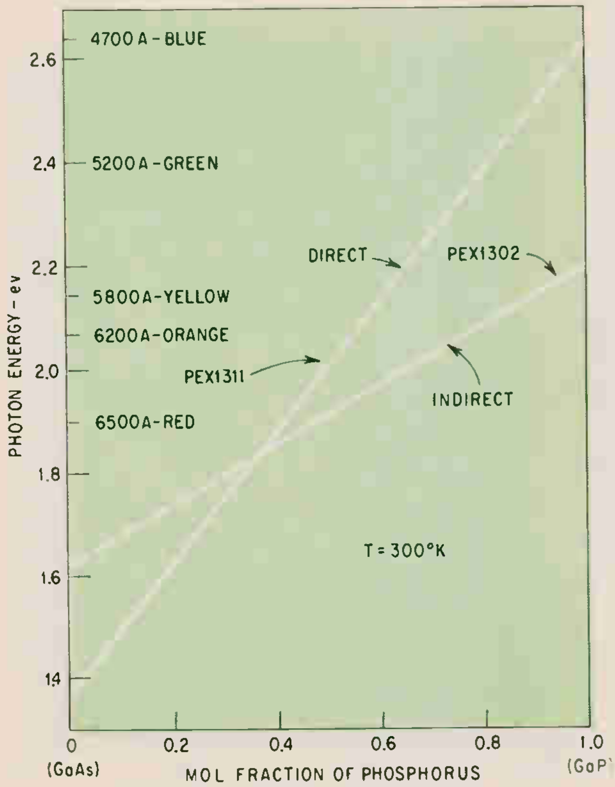
Visible light sources have been produced from gallium phosphide and gallium arsenide-phosphide, using single-crystal material of high purity. Gallium-phosphide light sources provide green or green-yellow light; gallium arsenide-phosphide



Output power curves for typical gallium-arsenide light sources. Power capability is determined by the device's internal geometry and by the package used.



Spectral output curves for visual-light emitters compared with eye-response curve. The gallium-phosphide source has two peak emission points, at 5,650 angstroms and at 7,000 angstroms for the PEX1302. By adjusting the doping concentration in the region of the junction, the amplitude of the peaks can be changed.



Photon energy vs. mol fraction of phosphorus. Increasing the percentage of phosphorus in gallium arsenide-phosphide raises the photon energy level obtainable from the semiconductor material.

sources emit red, orange or yellow light depending on the compositions used.

Examples of visible-light sources are the PEX-1302 and the PEX1311. The PEX1302 is made from gallium phosphide, with planar construction. It is circular with a junction diameter of 7 mils. Both the n- and p-type contacts are on the bottom of the wafer, and the yellow-green light exits from the top n-type surface. The emitter is mounted on a modified TO-5 header.

The PEX1311 uses a 26 by 26-mil rectangular wafer made from 55% gallium arsenide and 45% from gallium-phosphide. It has mesa construction. with a wire contact on the top n-type surface. The n-type layer is the exit surface for the red light emitted by the diode. A p-type layer covers the bottom of the wafer and is soldered to a TO-18 header.

Optical characteristics

The spectral output for typical PEX1302 and PEX1311 emitters and the standard visual-acuity curve are compared at the left. The PEX1302 has two emission peaks. at 5,600 and 7,000 angstroms. as shown in the diagram. Since the eye has greater response at 5.600 angstroms than at 7.000 angstroms. the source light appears to be yellow-green. The typical output power for the PEX1302 is 1.5 microwatts at 25°C with a 200-milliampere bias current. By adjusting the doping levels in the junction region. the relative amplitudes of the two peaks can be changed and the source diode's color can be made to appear orange or even red. The spectral output curve for the PEX1311 contains a single peak in the vicinity of 6,320 angstroms.

The curve at the left compares the approximate photon energy with the concentration of phosphorus in a gallium-arsenic-phosphorus ternary system. By adjusting the arsenic-to-phosphorus ratio. any wavelength can be obtained from the 5.600-angstrom green radiation provided by the PEX1302 gallium-phosphide diode to the 9.200-angstrom infrared radiation of the TIXL03 gallium-arsenide diode.

The peak red-light output of the PEX1311 is about five times greater than the peak green produced by the PEX1302. However. since the visual-acuity capability drops off at high wavelengths. the two sources appear about equally bright when operated at the same current density. The brightness of the PEX1302 green-light emitter at 200 milliamperes is about 3.300 foot-lamberts at 25°C. A current of 200 milliamperes corresponds to a current density of about 700 amperes per square centimeter.

Applications for visible-light emitters

Visible light emitters are useful as small indicator lamps. Because of their rugged construction. mechanical stability and relative freedom from catastrophic failure, they are much more desirable than small incandescent lamps, particularly in high-vibration applications. In addition, their small forward-voltage drop makes them ideal for solid-state circuitry.

The ability to select any wavelength of emission between 5,600 and 9,200 angstroms and the relatively narrow line width of the band-edge emission make gallium-arsenide-phosphide light emitters valuable in process control and other monitoring applications where line sources of spectral purity at specific wavelengths are significant.

One of their most promising application is in aerial photography. Depending on the optical system, the 1.5-microwatt output of the PEX1302 is sufficient to expose all common types of color film. Film marking in oscilloscope photography or in microscope photography can be carried out easily with present visible-light sources such as the PEX-1302 or the PEX1311.

Photodetector characteristics

Type number	I_L (ma)	H (mw/cm²)	V_L (volts)	I_D (μa)	V_D (volts)
1N2175	0.4	9+	±10	0.01	±50
LS400	5.0	9+	5	0.01	30
LSX515	(trigger)	10	10	1.0	10
LS600	2.0	20	5	0.01	30
LSX900	0.008	20	30	0.3	50
TIXL51	0.09	20	5	0.07	30
TIXL52	0.025	20	5	0.05	30
TIXL53	0.01	20	5	0.03	30

+ Measured with CS7-69 filter.

Types of photo sensors

Discrete silicon pn-junction detectors can be divided into two functional categories: photovoltaic and photoconductive. Photovoltaic sensors are power converters; they convert light energy directly into electrical energy. Solar cells, for example, are photovoltaic sensors, because they require no external bias and, under illumination, a voltage is developed across their terminals.

Photoconductive sensors require external bias. The amount of conduction increases with the intensity of illumination. The current available from a photovoltaic detector depends on the total light collected; thus, the output is proportional to the area illuminated. To meet the power requirements of most applications, photovoltaic sensors generally have a total active area 10 to 100 times that of photoconductive sensors. Two silicon photovoltaic sensors are shown at the right.

Dual and miniature photovoltaic units are also available commercially. The LS221, a dual photovoltaic sensor, is designed to operate with relatively high load resistances. In typical applications, the voltage output represents the imbalance of light on the two junctions. The output at 25°C is a minimum of 250 millivolts for a 10,000-ohm load with one of the junctions illuminated. The maximum imbalance voltage with both junctions illuminated is 50 millivolts; the illumination intensity in this case is 280 foot candles.

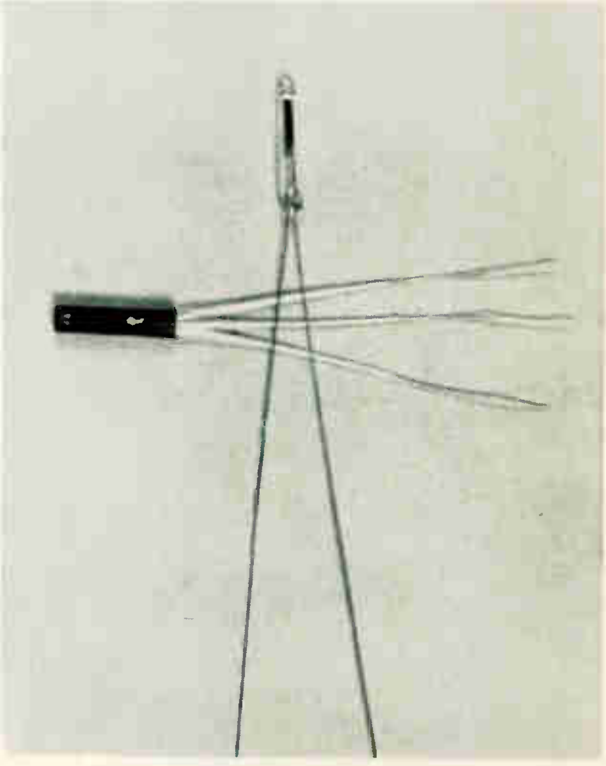
An example of a miniature solar cell is the LS2222. It typically supplies 290 microamperes to a 1,000-ohm load for 1,250 foot-candles of illumination.

When semiconductor photoconductive sensors are provided with constant illumination, they become constant-current sources. The output current varies little as the bias voltage changes. In contrast to the silicon junction devices, photoconductive sensors that use films of such materials as cadmium sulfide and cadmium selenide are in effect, light-sensitive resistors, because the bias current is approximately proportional to the applied voltage under constant *illumination*.

Because they have smaller areas and therefore smaller capacitances than do photovoltaic sensors, pn-junction photoconductive sensors are usually capable of faster response. These sensors also usually offer greater output for a given sensitive area. Typical silicon photoconductive sensors are shown at the bottom of page 104.

Specifying a sensor

One method for specifying the sensitivity of a photoconductive sensor is to measure its output while the sensor is subjected to light from a tungsten lamp operated at a filament (color) temperature of 2870°K. Typical filament temperatures for testing photovoltaic sensors are 2500° and 2800°K. For specifying some types of photoconductive sensors,



Two types of silicon photovoltaic sensors. The detector at left is a dual type. Its voltage output represents an imbalance of light on the two junctions. The other detector is a miniature solar cell.

the light is also transmitted through a type CS7-69 filter made by the Corning Glass Works. The emission spectrums of the lamp, measured 2870°K both with and without filtering, are shown in the curves on page 106. The specification of an illumination spectrum for detectors, instead of outputs for intensities, is necessary because the sensitivity of pn-junction sensors varies widely with spectrum.

The table on page 103 lists sensitivities at 25°C for several photoconductive devices. Note that for the LSX515, a thyristor, the illumination given is that typically required for triggering the device to the conductive state. Another important parameter is the dark current I_D, which flows with no illumination. Typical values of I_D at 25°C for applied voltage V_D are also given.

Sensor characteristics

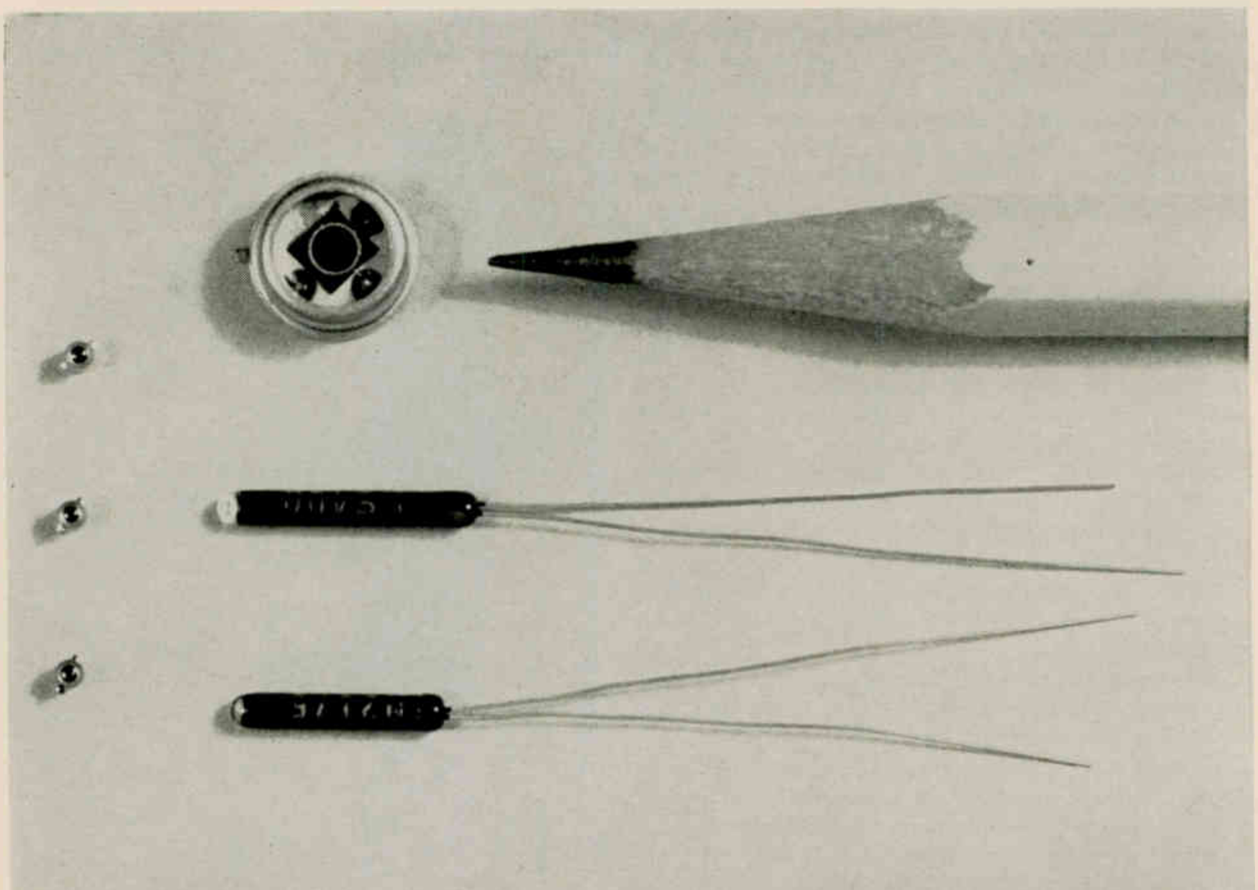
Typically, fall times are greater than rise times for general-purpose sensors. For the 1N2175, these rise and fall times are 2 and 45 microseconds respectively, and for the LS400 and LS600 they are 1.5 and 15.0 microseconds. These values apply for a series load resistance of 1,000 ohms. Because of the sensor's capacitance, its switching time increases with load resistance.

A laser light detector, the LSX900, has a minimum capacitance of 1.7 picofarads with high reverse bias. Response times (in the nanosecond range) generally are determined by the product of this capacitance and the load resistance. With sizable load resistances, the capacitances of devices such as the TIXL51, TIXL52 and TIXL53 become important for high-frequency response; respective values are typically 110, 40 and 24 picofarads. These sensors have relatively large areas—with diameters of 0.100, 0.050 and 0.030 inches respectively—since they are intended for high-sensitivity requirements of recognition and long-range communications equipment.

In such applications another parameter, designated as D*, is of interest because of its relation to maximum range and beam angle. It is given by the expression:

$$D^* = \sqrt{A \Delta f} / [NEP]$$

where A is the sensitive area of the detector, Δf is the modulation bandwidth, and NEP (or noise equivalent power in watts) is the rms value of the minimum light energy necessary to give a signal-to-noise ratio of unity. For the TIXL51, TIXL52 and TIXL53, values of D* are typically 8.0×10^{11}, 1.3×10^{11} and 2.2×10^{10} $(cm \times cps)^{1/2}$ respectively. These values were measured at 25°C with zero bias voltage. An unfiltered tungsten lamp was used at 2800°K, with the light chopped at 1,000 cps,



Photoconductive pn sensors. The detectors (all in the same package) in a column at the left are the LS600, the LS515 and the LS900. At the right (from bottom to top) are the IN2175, the LS515, a thyristor unit and the LS900, a laser light detector.

New process increases purity of light-emitter materials

Epitaxial technique creates new capabilities for junction light-emitting diodes

By Paul C. Goundry

Materials and Controls Division, Texas Instruments Incorporated, Dallas, Texas

A new epitaxial process is producing single-crystal gallium phosphide, gallium arsenide, and gallium arsenide-phosphide in purities and forms previously not available.

These materials, in turn, are creating new capabilities for diffused-junction light-emitting diodes and for optoelectronics in general. Light sources fabricated from gallium arsenide emit infrared radiation, diodes made with $GaAs_xP_{(1-x)}$ emit infrared, visible red, or visible orange light depending upon the compositions selected. The high-purity gallium phosphide provides a material from which visible green-light emitters are being produced.

With the prior processes, it was not possible to obtain films of high-purity gallium phosphide, difficult to obtain uniform compositions of gallium-arsenide phosphide, and difficult to obtain thick films of the gallium-arsenide phosphide or gallium arsenide. It was not uncommon for a supposedly uniform layer of gallium arsenide-phosphide, having a thickness of 20 mils, to contain 33% gallium phosphide at its top layer and 23% at the bottom layer.

The older way

In the older process, chunks of gallium arsenide are placed at one end of a horizontal heated tube, and over them are passed a gas stream of hydrogen that also contains some arsenic trichloride. A reaction occurs at the hot gallium-arsenide chunks, and vaporized chlorides of gallium are transported downstream by the moving hydrogen gas. At the other end of the tube, because the temperature is cooler, gallium arsenide is deposited epitaxially on gallium-arsenide substrates. A similar process is employed to obtain gallium arsenide-phosphide layers, except that phosphorus trichloride is added to the input gas stream.

The most serious fault of this method is the difficulty of obtaining thick deposits and maintaining the composition uniform throughout the layer. The production of highly pure gallium phosphide by this method is not possible because of the presence of the gallium arsenide.

The new way

Some details of the new process cannot be disclosed yet. However variations in gallium-phosphide concentration from the top to the bottom of a 20-mil layer of gallium arsenide-phosphide are in the vicinity of only 1%.

Using the new method, epitaxial layers of high-purity gallium arsenide-phosphide gallium arsenide, or gallium arsenide-phosphide with thicknesses up to 35 mils are deposited on gallium-arsenide substrates. Layers with thicknesses greater than 35 mils can also be obtained with high uniformity if applications should come along that require them.

If the layers are 10 mils or greater in thickness, they are self-supporting and the gallium-arsenide substrate can be removed. For layers thinner than 10 mils, the substrates are usually retained.

Examination by infrared reflectance and X-ray analysis show, for example, that the thick gallium arsenide-phosphide layers, after the substrates have been removed, exhibit the same composition on both sides; there are no detectable variations between the initially deposited material(bottom surface) and that finally deposited (top surface).

Gallium phosphide

Gallium phosphide is a transparent orange material with an energy gap of 2.24 electron volts at 300°K. Typical properties for the undoped n-type material are:

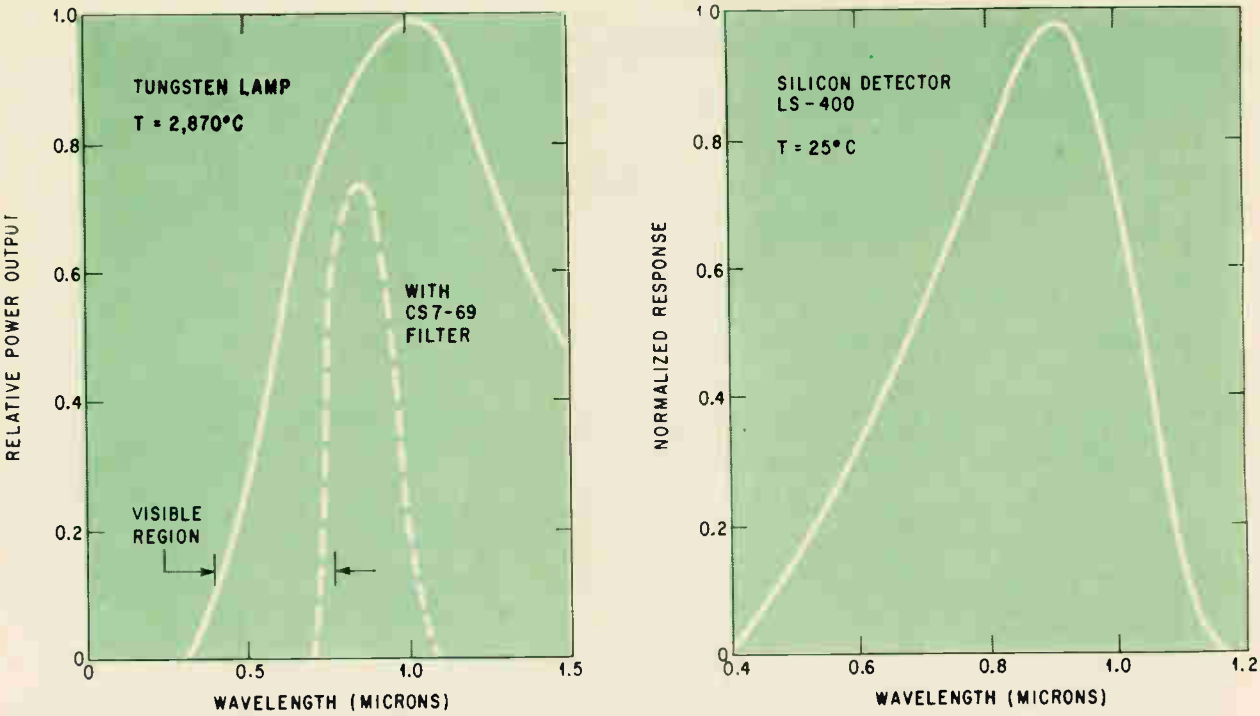
	at 300°K	at 77°K
Hall mobility (cm^2/v-sec)	150	660
Carrier concentration (cc^{-3})	3×10^{17}	7×10^{13}
Resistivity (ohm-cm)	0.1	130

Diffused-junction diodes made from this material emit visible green light at 5650°A. Tellurium is the n-type dopant used; p-type doping is accomplished with zinc. The p-type gallium phosphide is heavily doped with zinc to $3 \times 10^{18}cc^{-3}$ and exhibits a Hall mobility of 50 cm^2/v-sec at 300°K. This data for both n-type and p-type gallium phosphide indicates that the quality of this material is superior to any previously reported gallium phosphide.

Key data

The new capabilities for producing controlled compositions of gallium arsenide-phosphide [$GaAs_xP_{(1-x)}$] permit the manufacture of single-crystal material with energy-gap values between the 1.35 ev of gallium arsenide and the 2.24 ev of gallium phosphide. Thus $GaAs_{0.73}P_{0.27}$, which appears red when viewed by transmitted light, exhibits an energy gap of about 1.75 ev. Typical Hall mobility for this undoped composition at 300°K is 2,400 cm^2/volt-sec at a carrier concentration of $3 \times 10^{17}cc^{-3}$. Similarly, $GaAs_{0.16}P_{0.84}$ has a Hall mobility of 110 cm^2 volt-sec and a carrier concentration of $3 \times 10^{17}cc^{-3}$ at 300°K.

Of particular interest in optoelectronics applications is the production of special multilayer structures of gallium phosphide, gallium arsenide-phosphide and gallium arsenide. For example, a layer of gallium arsenide-phosphide or gallium phosphide 15 to 20 mils thick can be deposited over epitaxial gallium arsenide layers to form pn light-emitting junctions. The thick gallium arsenide-phosphide or gallium phosphide overlay provides a wider band-gap window for the infrared-junction emission of the gallium arsenide material. Furthermore, the entire structure is monolithic. Transmission for gallium phosphide extends from 0.535 to 21 microns. By comparison, gallium arsenide and $GaAs_{0.53}P_{0.47}$ exhibit band edge values of 0.9 and 0.63 micron.



Tungsten lamp's output is often used a a standard for mea suring the sensitivity of light detectors. It is sometimes used in conjunction with a narrow spectrum filter. At the right, the response curve for a silicon detector is given for comparison with the tungsten-lamp curve.

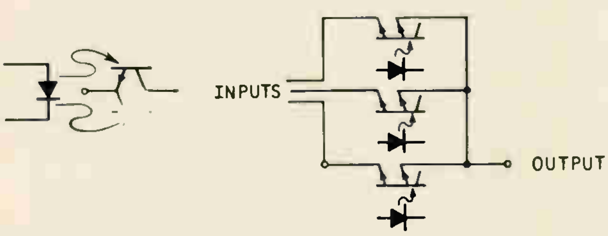
50% duty cycle; amplifier bandwidth was normalized to 1 cps.

General-purpose sensors such as the 1N2175, LS400 and LS600 have packages of small cross-section which permit their arrangement in compact sensor arrays. In addition, the LS600 is designed to fit into a $\frac{1}{16}$-inch-diameter hole in a standard $\frac{1}{16}$-inch-thick printed circuit board.

Source-sensor combinations

Packages containing a gallium-arsenide light source and a silicon photo sensor are commercially available in four-terminal devices and in integrated circuits. Representative of these single-package devices are the PEX3002 and the SNX1304. In the PEX3002, the sensor portion consists of two silicon photo transistors connected as shown in the circuit diagram below. The light source is a 30-mil-diameter gallium-arsenide hemispherical structure. When the gallium-arsenide diode is energized, the impedance between the transistor terminals changes from a high to a low value. To minimize the on-impedance, the transistor is designed to have high current gain for operation in the inverted mode. The on-impedance at 25°C is typically 30 ohms for a diode current of 100 milliamperes.

The voltage developed across the transistor terminals can be adjusted conveniently to 15 microvolts by varying the position of the light source relative to the detectors. This offset voltage determines the limiting value of the signal that can be commutated in the circuit shown on this page. When the gallium-arsenide sources are sequentially energized, the common output becomes a sequential sampling of all inputs. This type of circuit[3] is used in applications such as telemetry systems for satellites and missiles, in monitoring hundreds of environmental and circuit parameters, and in monitoring experimental test results. The maximum input signal is determined by the transistor's emitter-base breakdown voltage, which is typically 8 volts.



Gallium-arsenide source and two silicon photodetectors are contained in the PEX3002. In the circuit at the right, the device is used for sequential sampling of multiple signals in a multiplexing circuit.

Integrated circuits

The first integrated circuit to use a source-sensor pair[5] was the SNX1304. The sensor consists of a silicon photodiode included in a single silicon chip. The chip includes the detector diode and a feedback amplifier circuit. The gallium-arsenide source has a diffused junction about 10 mils in diameter, and is attached directly to the sensor by the high-refractive-index glass. Normal response times for the sensors that are not part of IC's vary from about 2 to 40 microseconds, and are a function of the charging time of the sensor capacitances.

Because of the feedback arrangement in the

SNX1304, the change in voltage across the sensor as the device is turned on or off is small; thus the capacitance charges quickly. Total rise and fall times are about 0.5 microsecond. The current requirement of the gallium-arsenide diode is typically 5 milliamperes. The output using a 6-volt supply is typically 4.8 volts for zero input and 0.3 volt with input current applied.

Functionally, the SNX1304's performance is analagous to that of a pulse transformer, with the added feature of having the response extended to direct current. Called the OPA, for Optoelectronic Pulse Amplifier, the device can be used with other commercially available integrated circuits. The SNX1304 is packaged in a standard 1/8 x 1/4 x 1/32-inch flat-pack (Jedec TO-89). The SNX1304 is used as a buffer between computer subsystems where circulating currents caused by the common connection of subsystem grounds may cause excessive noise. Another application is as an output device at the end of a long transmission line, since the connection of a ground to the end of the line can generate extraneous noise.

The microelectronics branch of the Air Force Avionics Laboratory at Wright-Patterson Air Force Base, Ohio, sponsored much of the development of light-coupled integrated circuits and four-terminal devices.

A look at the future

Avalanche-multiplication photodiodes are now being developed. Particular attention is being paid to the p-i-n (p layer, intrinsic layer, n layer) diode, a semiconductor device that works on the avalanche-multiplication principal.

A p-i-n photodiode, biased into the avalanche breakdown region, improves the signal-to-noise ratio of a detected photo signal; this is accomplished by the multiplication of carriers by impact ionization, with the bias voltage adjusted close to breakdown. Improvements in the performance of the avalanche-multiplication photodiode may result in a solid-state sensor with sensitivity and response speed exceeding that of the multiplier phototube. The multiplier phototube now has the greatest gain-bandwidth of available sensors.

Smaller headers are being developed that will allow higher-density packing of discrete visible-light sources while maintaining the desirable hermetic seal and ruggedness of the TO-5 and TO-18 headers.

With improved material-processing techniques, the quantum efficiency can be expected to increase for both the gallium-phosphide sources and the gallium arsenide-phosphide sources. At present, the quantum efficiency of the PEX1302 green emitter is only about $3 \times 10^{-4}\%$ at 25°C, whereas the PEX1201 gallium-arsenide infrared emitters exhibit quantum efficiencies as high as 7% at 25°C.

Further extension of the planar process used on the PEX1302 should make it possible to build large high-density monolithic arrays of visible-light emitters. Such arrays, coupled with silicon integrated circuits, will be useful in film annotation, alphanumeric character displays and small television-type displays, with brightness and quality at least as good as in 1965 commercial television sets.

Gallium-arsenide infrared light emitters probably will continue to dominate the applications in which optical coupling performs an electronic function. On the other hand, semiconductor emitters of visible light can be expected to play an increasing role in information display.

Development is under way in many laboratories on semiconductor pn-junction lasers with an efficiency of at least 0.1%, with input of less than 1 watt for continuous operation over a temperature range of −55° to +125°C. Such devices could be competitive with noncoherent sources in discrete source-sensor pairs and in integrated devices.

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J.R. Biard, as manager of TI's gallium-arsenide program, directs the development of optoelectronic devices.

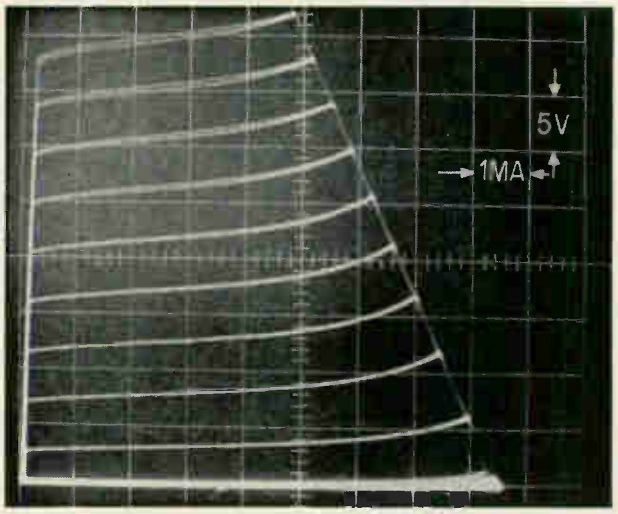
Circuit design

Designers' casebook

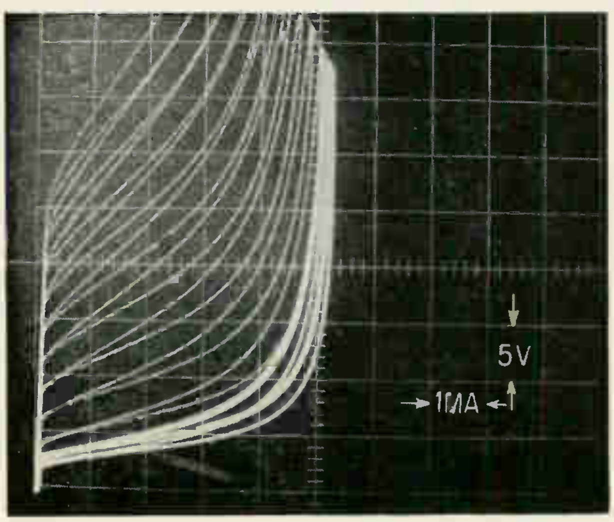
Designer's casebook is a regular feature in Electronics. Readers are invited to submit novel circuit ideas, packaging schemes, or other unusual solutions to design problems. Descriptions should be short. We'll pay $50 for each item published.

Local feedback improves transistor characteristics

By Stephen B. Gray
Sylvania Electronic Systems, Waltham, Mass.



Collector characteristics for germanium transistor are improved by the feedback path. These characteristics resemble those of a more expensive silicon transistor.



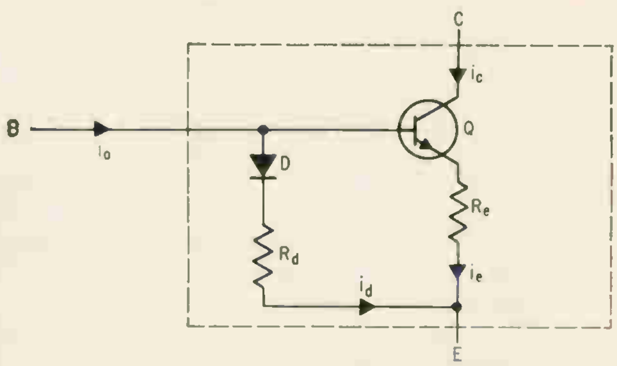
The characteristics of an expensive, high-quality silicon transistor can be simulated by a three-terminal circuit containing a high-gain germanium transistor using local feedback. These characteristics are collector curves that are nearly flat out to the breakdown voltage; low leakage; and adjustable current gain over a wide range of temperatures, current levels and collector voltages.

In the circuit shown below, assume that the transistor has high current gain (100). Diode D is made of the same semiconductor material as the transistor, and compensates for the transistor's base-emitter voltage drop. The voltages across both resistors, R_d and R_e, are assumed to be equal; hence the input current is constrained to be approximately i_eR_e/R_d. Therefore, the circuit gain is determined mostly by a stable, adjustable ratio of two resistor values, $R_e/R_d = r$.

If the current gain of the circuit is defined as $h = i_e/i_o$, and if the transistor's current gain is β, it is easy to derive $h = r\beta/(r + \beta + 1)$, which for large β reduces to $h \approx r$. Stability improvement for large β is found to be

$$\frac{dh}{h} = \frac{d\beta}{\beta} \cdot \frac{r}{\beta}$$

For $\beta = 200$ and $r = 10$, the circuit gain is $h \approx 9.5$



Feedback path between base and emitter improves the collector characteristics of an inexpensive germanium transistor.

◄ Collector characteristics for an unstabilized germanium transistor, 2N1605. Incremental base-current step for each characteristic curve is 0.005 milliampere. Curves represent nine base current steps, but when the characteristics were photographed, curve-splitting—due to the effects of heating and stray capacitance—occurred.

and the stability improvement factor is r/β or 20. This means that if β changes by 20%, the circuit's current gain varies by only 1%.

With this feedback, nearly ideal characteristic curves are obtained. The photograph at the left, bottom, shows the characteristics of a typical low-cost germanium transistor, 2N1605, whose leakage and breakdown characteristics make it useless for linear circuits rated beyond 25 volts.

The photo at the left, top, shows the characteristics of the synthetic transistor consisting of the same 2N1605, but degenerated by $R_e = 100$ ohms and $R_d = 1K$. This circuit has a current gain of about nine and is useful to over 40 volts. The lower leakage and higher voltage are results of the feedback path between base and emitter.

Note that the characteristics for the synthetic transistor resemble those of a silicon transistor.

Unijunction tranistor turns off latching relay

By Dennis P. Lynch

Naval Ordnance Laboratory, Silver Spring, Md.

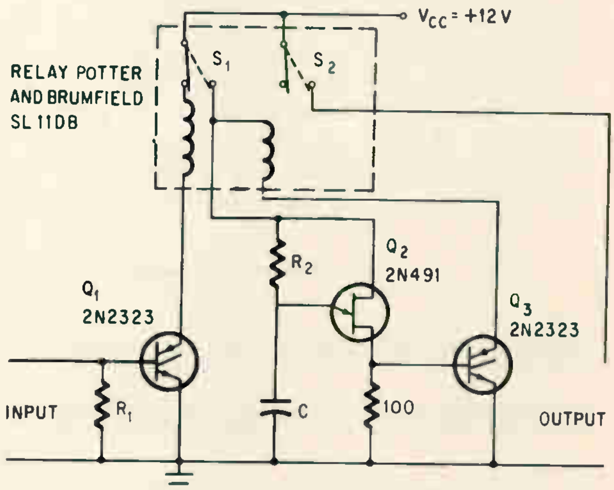
Transient pulses can be detected by the switching circuit at the right. The circuit has a preset on time, which is determined by the unijunction transistor relaxation circuit.

An input pulse applied at the gate of silicon controlled rectifier Q_1 turns it on and switches the double-pole, double-throw, latching relay. With the relay in the latched condition, one pole applies 12 volts to unijunction transistor Q_2 and charges capacitor C through R_2. The other pole connects 12 volts to the output terminals.

After time $T \simeq R_2C$, the voltage on the emitter of the ujt reaches its peak point $V_p = \eta V_{cc} + 0.7$ (where η is the ujt's intrinsic standoff ratio, 4.7 to 6.8 for a type 2N491 ujt), and Q_2 conducts, providing a trigger pulse for scr Q_3. When Q_3 conducts, the relay returns to its previous condition, removing the 12 volts from the output terminals.

In the active state, the circuit does not dissipate any power, since the only current that can flow is through scr Q_1 in its off state, and this current is essentially zero.

As a pulse or transient detector, the circuit's 12-volt output operated an inverter circuit, which powered a high-voltage flashtube for visual monitoring.



Unijunction transistor circuit determines output pulse length. Latching relay is turned on by input pulse, remains on until ujt reaches its peak point voltage.

Low-cost adjustable regulator consumes little power

By J. D. Wells*

Sperry Microwave Electronics Co., Clearwater, Fla.

Stability in vacuum-tube instruments is often affected by heater voltage variation; but regulating this voltage is unattractive because the required low-voltage, high-current circuits need large capacitors, and frequently have considerable power loss.

The circuit on page 110 provides close regulation of rms heater voltage yet requires little space and consumes little power. Inexpensive components may be used for currents up to several amperes.

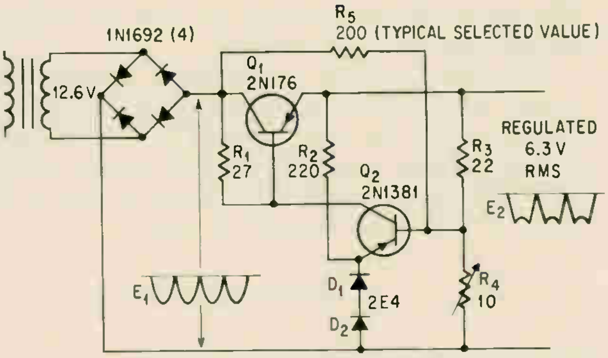
Operation is similar to that of a zener clipper-regulator. Input voltage E_1 is applied to the circuit from a full-wave rectifier. When E_1 is near zero only Q_1 is on, but as the base voltage at Q_2 increases to the forward drop of reference diodes D_1 and D_2, Q_2 conducts and the entire circuit operates as a conventional regulator. Output voltage E_2 appears as a flat-topped, full-wave, rectified sine

* Now with the Martin Co., Orlando, Fla.

wave. Output voltage is adjusted with R_4.

With simple clipping alone, a change in input voltage would change the area under the output waveform, resulting in a change in the rms value of the a-c voltage. To prevent this, resistor R_5 depresses the "flat-top" portion of the output waveform in proportion to the input change. Effective rms output regulation can be held to 0.2% or better with the proper value for R_5. Almost any low-cost silicon rectifier can be used for the reference diodes if the dynamic impedance is reasonably low near the knee of its forward characteristic. Peak inverse voltage rating is not a problem since no reverse voltage ever appears across D_1 and D_2.

Power is dissipated in Q_1 only when the peaks are absorbed; the transistor is turned on for the remainder of the cycle. The clipping ratio is decided by the permissible output ripple, the allowable dissipation in Q_1, and the range of input variations. A clipping ratio of 2:1 is easily controlled for the usual 105- to 125-volt line variation. This approach could also be used in a current clipper.



As input voltage rises, compensating resistor R_5 depresses the top of the output waveform so that the effective rms output remains unchanged.

Reduced loading improves accuracy of cascaded pots

By A. Paul Brokaw

Arthur D. Little Inc., Cambridge, Mass.

Cascaded potentiometers are used in a variety of applications, such as analog computers and process controls to provide a simple means of performing multiplication. Unfortunately, the conventional method of cascading potentiometers shown at the left in the diagram below results in an output which is only an approximate product of the potentiometer shaft rotations. In order to minimize the error, the output potentiometer, R_y, must be much larger than R_x. As a result, any load connected across the output must have a very high impedance if the accuracy of the cascaded circuit is to be maintained.

The circuit at the right provides an output which is exactly proportional to the shaft rotation product, and therefore considerably increases the accuracy. The circuit is driven with a current I_1 provided by a constant-current generator. The output voltage is given exactly by

$$V_o = I_1 R_1 R_3/(R_2 + R_4)$$

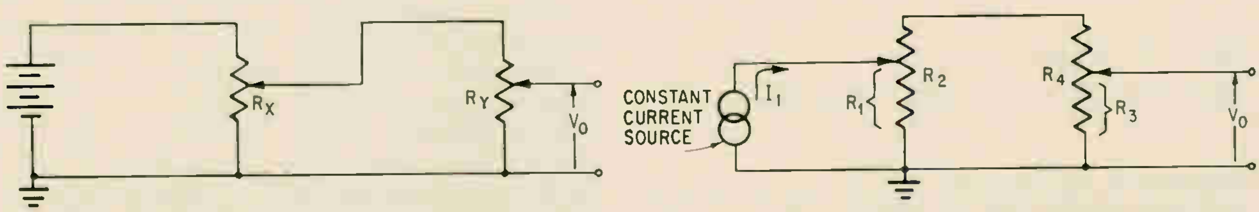
If $R_3 = K_4 \theta_4 R_4$ and $R_1 = K_2 \theta_2 R_2$ then

$$V_o = I_1 \theta_2 \theta_4 [K_2 K_4 R_2 R_4/(R_2 + R_4)]$$

where K_2 and K_4 = constants associated with potentiometers R_2 and R_4 and, θ_2 and θ_4 = angles through which the shafts of potentiometers R_2 and R_4 have been rotated.

Since $K_2K_4 R_2R_4/[R_2 + R_4]$ is a constant, V_o is proportional to the product of I_1 and the shaft angles θ_2 and θ_4.

The maximum output impedance as seen from the terminals AB is $(R_2 + R_4)/4$, and occurs when $R_o = (R_2 + R_4)/2$. Impedance of the instrument used to measure V_o should be at least 100 times higher than the maximum output impedance for measurements accurate to 1%. As a compromise between power drain and output voltage level, R_2

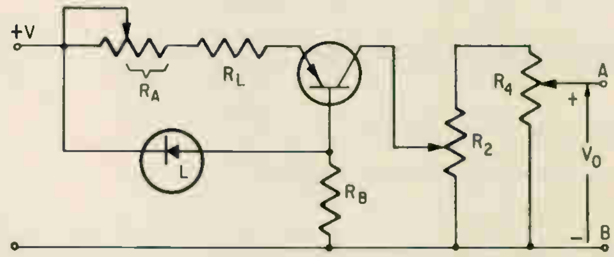


Conventional cascaded potentiometer on the left has an output which is approximately proportional to the product of the shaft rotations. The improved circuit on the right has an output which is exactly proportional to the product.

should approximately equal R_4 in most practical cases.

If the signal for the cascaded potentiometers is obtained from an operational amplifier, as in an analog computer, it is relatively simple to change from voltage to current feedback to provide a high impedance source of current I_1.

In the absence of an operational amplifier, constant current I_1 may be generated by the transistor circuit at the right. In this circuit, the low impedance of the zener diode effectively results in a common base configuration. The collector current is proportional to $(V_2 - V_{BE})/(R_L + R_A)$ where V_2 is the zener breakdown voltage and V_{BE} is the transistor base-to-emitter voltage. R_A is used to trim the maximum value of the output voltage, V_o. As an alternative, since I_1 is inversely proportional to $R_L + R_A$, the shaft angle of R_A could be used as an inverse multiplier of V_o. However, R_L should be retained to limit the emitter current to a safe value.



Constant-current to drive the potentiometers is provided by a common-base transistor amplifier.

If the supply voltage, V, is well regulated, the zener diode may be replaced by a resistor. The base voltage-divider circuit, consisting of the substituted resistor and R_B, should be kept at a suitably low impedance.

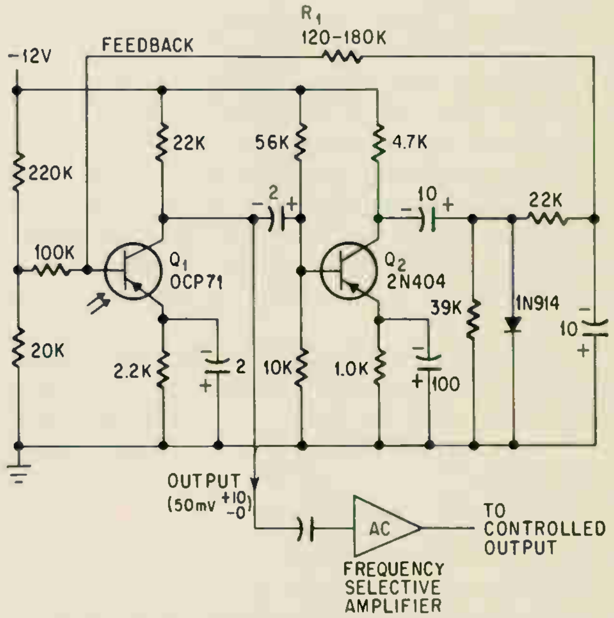
Photodetector gain control aids signal discrimination

By Peter H. Sydenham

Electrical Engineering Dept., University of South Adelaide, Australia

Light-controlled devices are used to open doors and protect dangerous areas around machine tools. Generally, some means of discriminating between an ambient source such as fluorescent illumination and the controlling-light source is required. The conventional technique is to chop the controlling source at some particular frequency and then include a frequency selective amplifier at the output of the detector. However, the undesired light source, though modulated at a different frequency, might have an intensity as much as 45 db greater than the controlling source. As a result, an extremely selective amplifier is required. The circuit at the right offers an economical method of eliminating the need for an excessively selective amplifier.

The circuit is an automatic-gain-control amplifier that keeps the output of the photodetector constant to within 2 db over an ambient-light-level variation of greater than 40 db. As a result the filter circuit must only discriminate between desired and undesired signals with a 2-db difference in amplitude. The signals, independently of their initial amplitudes, will have an amplitude at the output of the filter that is solely a function of its skirt selectivity.



Direct-current feedback to the photodetector reduces output variations due to varying ambient light levels. This reduces the selectivity requirements of the amplifier.

The output of the photodetector, Q_1, is amplified by Q_2 and converted to d-c in the half-wave rectifier circuit. The resulting direct current is fed back to the base of the photodiode to make the output constant over a wide range of illumination.

The feedback is controlled by resistor R_1. To suppress oscillation, R_1 may be increased. If desired, the 2-db variation may be reduced still further by using photodetectors having current gains (beta) greater than 80.

Crystal accurately controls avalanche pulse generator

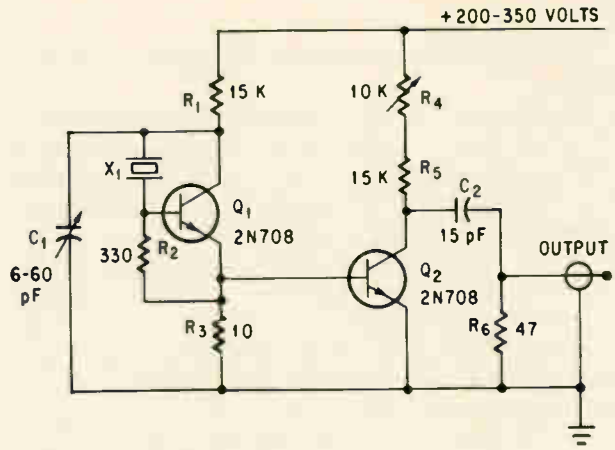
By J.N. Bridgeman,
Decca Radar Ltd., Cowes, England

An avalanche pulse generator can supply pulses of nanosecond duration at a relatively high repetition rate. If controlled by a crystal oscillator as in the circuit at the right, the pulses and its harmonics can be made very stable and can be used for phase locking ultrahigh- and microwave-frequency oscillators or for the generation of local oscillator signals at very high frequency and uhf.

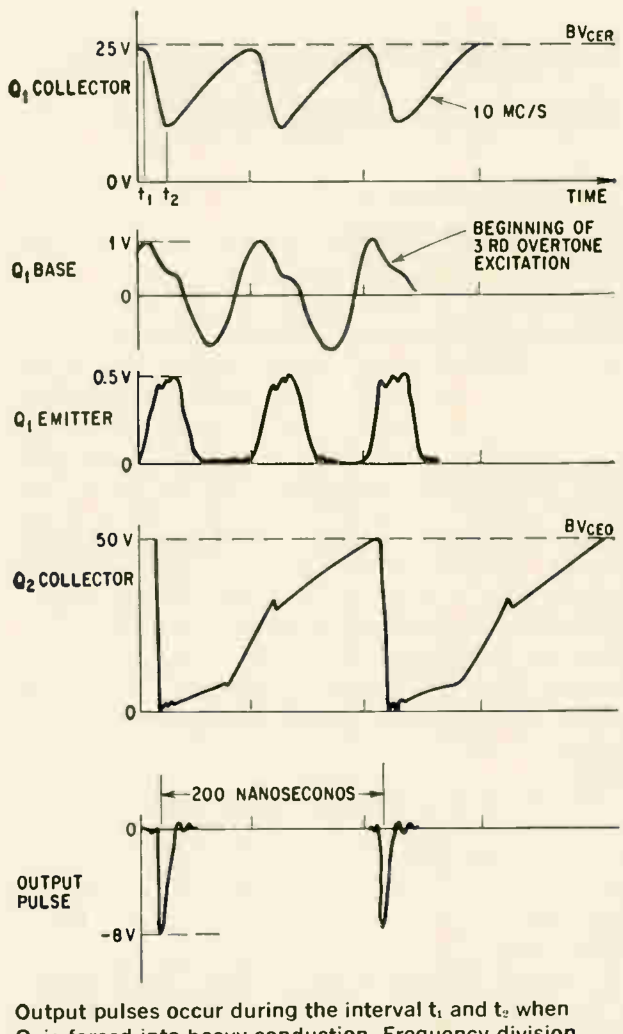
The transistors are type 2N708, but almost any high-frequency silicon switching transistor of mesa, planar, or planar epitaxial construction is suitable. Very high avalanche repetition rates are obtained with type 2N709 or 2N914 transistors. A transistor operates in the avalanche mode when the collector-to-emitter voltage is in the vicinity of BV_{ceo}, defined as the common-emitter breakdown voltage with the base open-circuited. This voltage is distinct from BV_{cer} which is measured with a resistor placed between base and emitter. Avalanche mode operation provides very high switching speeds and can supply much greater current outputs than obtained with conventional circuits. The effect occurs in reverse-biased pn-junctions as a result of impact ionization caused by mobile charge carriers. A similar phenomenon known as Townsend breakdown occurs in gases.

Transistor Q_1, which is part of the crystal oscillator circuit, operates with its collector voltage just below BV_{cer}. After an initial burst of avalanching when the circuit is turned on, the crystal, X_1, is excited into continuous operation and then controls the base of Q_1. A rapid increase in the collector current of Q_1 occurs when the base conducts on the positive half-cycle of the crystal output waveform, shown as the Q_1-base waveform in the diagram on the right. This corresponds to the portion of the collector voltage waveform between t_1 and t_2. The semilinear drop in collector voltage is delayed by the transistor propagation time so that the crystal is driven in the correct phase to maintain oscillation. On the negative half-cycle of the crystal waveform the transistor is cut off and the collector voltage rises towards the supply voltage with a time constant equal to $R_1 C_1$. When the collector voltage approaches BV_{cer}, Q_1 begins to conduct again and the cycle is repeated.

The avalanche transistor, Q_2, is triggered by the voltage developed across R_3 during the time interval between t_1 and t_2. The resistance of R_3 should be just large enough to trigger Q_2 when its



Crystal controlled oscillator, Q_1 accurately controls the pulse repetition frequency of Q_2. The crystal may be excited in its third and fifth overtones by reducing the value of C_1.



Output pulses occur during the interval t_1 and t_2 when Q_1 is forced into heavy conduction. Frequency division at the output is controlled by the time constant R_6C_2.

collector voltage approaches BV_{ceo}. This enables the avalanche stage to operate as a frequency divider. The output pulse is obtained by differentiating the collector waveform with the network comprising R_6 and C_2. To obtain large-amplitude pulses across R_6, the avalanche stage is adjusted to operate at a repetition rate of 5 Mc, and is triggered by every other cycle of the oscillator. Potentiometer R_4 is a fine adjustment, which may be required to lock the avalanche stage to the oscillator frequency.

To conserve d-c power, the supply voltage and resistor values could be lowered. However, any such reduction must allow the transistors to reach the breakdown voltage levels, BV_{ceo} and BV_{cer}. Also, the collector resistance of Q_2 must not be made too small or Q_2 will conduct continuously and burn out.

A wide range of repetition rates can be obtained by varying the time constant R_5C_2 to increase the frequency division of the avalanche stage, Q_2. However, this will be accompanied by an increase in the pulse width.

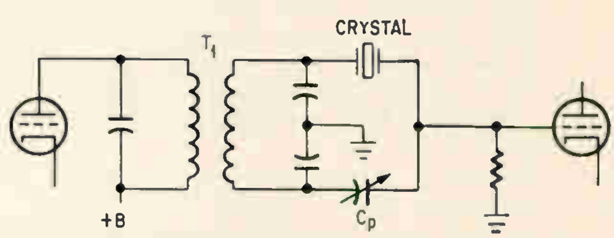
Capacitor C_1 may be used to change the frequency of operation of the crystal oscillator. When C_1 is decreased, both the fall and rise times of Q_1's collector voltage are increased and the crystal's third overtone is excited. The beginning of third overtone excitation is indicated on the base-waveform of Q_1. Further reduction in C_1 can result in excitation of the fifth overtone frequency. An increase in the supply voltage produces the same effect but tends to upset the operation of the avalanche stage, Q_2.

The circuit uses an AT-Cut crystal with a 10-Mc fundamental mode. With $C_1 = 60$ pf, the oscillator operates at 10 Mc. With C_1 reduced to 20 pf, the frequency changes to 30 Mc.

Remotely tuned crystal filter eliminates tuned transformer

By H. Olson

Stanford Research Institute, Menlo Park, Calif.

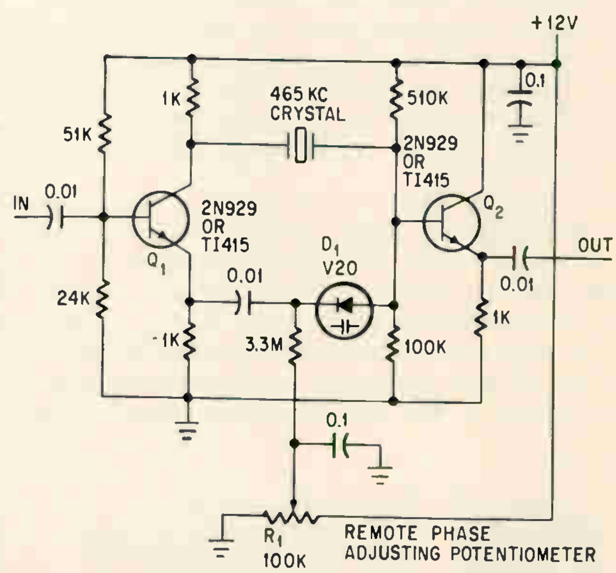


Conventional crystal—filter circuit must provide access to phasing capacitor.

A versatile, transistorized circuit remotely tunes single-crystal, intermediate-frequency filters used for radiotelegraph reception in communication receivers. In the conventional circuit shown above, such filters must be placed near the front of the receiver to provide access to the phasing capacitor, C_p. The problem of access to C_p represents a major restraint on the physical layout of the i-f stage and makes it difficult to add such a circuit to existing receivers. By using a voltage controlled tuning element the difficulty is circumvented.

In the transistorized version, the 465-kc crystal is phased by a varactor diode, D_1, under control of the remotely adjusted potentiometer, R_1. The circuit consists of a split-load phase inverter Q_1, and an emitter-follower output stage, Q_2. The phase inverter replaces the tuned transformer normally used to provide a balanced i-f signal with respect to ground.

The circuit may be used for any i-f in the range from 100 kilocycles to 1.6 megacycles per second by merely selecting a crystal which oscillates at the required frequency. If desired, the filter may be removed from the system by forward-biasing the varactor diode.



Phase inverter Q_1 substituted for the i-f transformer allows remote phasing by adjusting the potentiometer, R_1, which controls the bias on varactor, D_1. The circuit can be used over a wide frequency range.

Six possible routes to noninductive tuned circuitry

Inductance is nearly impossible to put into an IC, but the effect can be achieved using RC networks, digital filtering, acoustic resonators or semiconductor delay lines

By Vasil Uzunoglu

Applied Physics Laboratory
Johns Hopkins University, Silver Spring, Md.

When circuit designers began shifting from tubes to transistors, they also began to seek ways to do away with bulky transformers and coils. One approach was to use resistance-capacitance (RC) networks as substitutes for low-frequency inductance-capacitance (LC) circuits.

With the arrival of integrated circuits, the designers no longer have a choice. No practical method has been found for putting usable amounts of inductance into an integrated circuit, despite some qualified successes. Multilayer thin films, deposited on monolithic chips, can provide a few microhenrys of inductance; however, such small inductances are not adequate for operation at frequencies lower than a few megacycles per second. More recently, an electromechanically resonant field-effect transistor has been introduced [Electronics, Sept. 20, 1965, p. 84], but its ultimate utility is yet to be proved.

The engineer who wants to design a frequency-sensitive integrated circuit must find some way to duplicate the effect of inductance. There is no single perfect substitute for inductance, but at least six techniques are known; the choice depends on the requirements of the system being designed.

Three of these techniques employ resistor-capacitor networks. One uses RC notch filters in the feedback path; another, RC circuits in the forward transmission path; and the third, negative impedance converters. These methods have the same disadvantage: in some applications, particularly those in which high Q values (100 or larger) are needed, RC networks have a tendency toward instability. In such cases, three other techniques are possible: sampling (digital filtering), using acoustic resonators, and using semiconductor delay lines.

The choice of one of these six approaches depends on the specific requirement; it should be based on a careful evaluation of the specifications, and on the comparison of these requirements with the inherent advantages and disadvantages of each method.

Notch-filter feedback

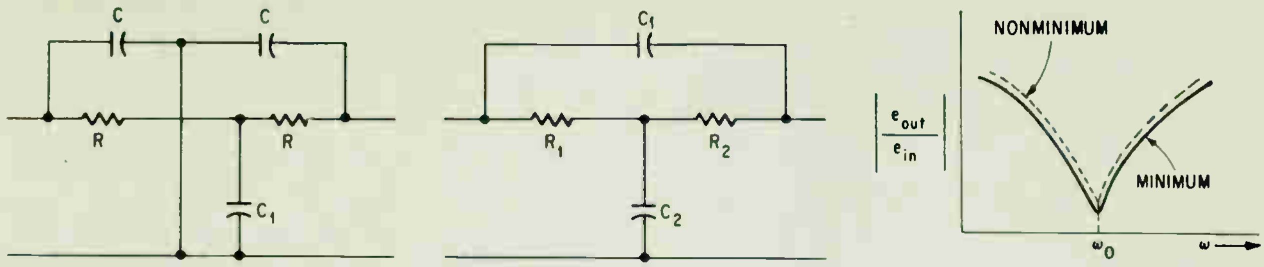
A notch-filter circuit is one whose gain-versus-frequency characteristic exhibits a steep drop or rise at resonance. A typical voltage-gain curve for a notch-filter circuit is shown on page 115. Also shown are two examples of notch-filter circuits: the parallel-T network and the bridged-T network.

Notch-filter circuits fall into two general categories: one called a minimum phase-shift type, the other called a nonminimum type. The minimum type exhibits a phase shift less than $\pm 90°$. The latter can produce shifts in phase from 0 to 360°. This is shown by the curves on page 115. Minimum-phase-shift circuits are usually fabricated with lumped elements, nonminimum types are made with either lumped or distributed elements.

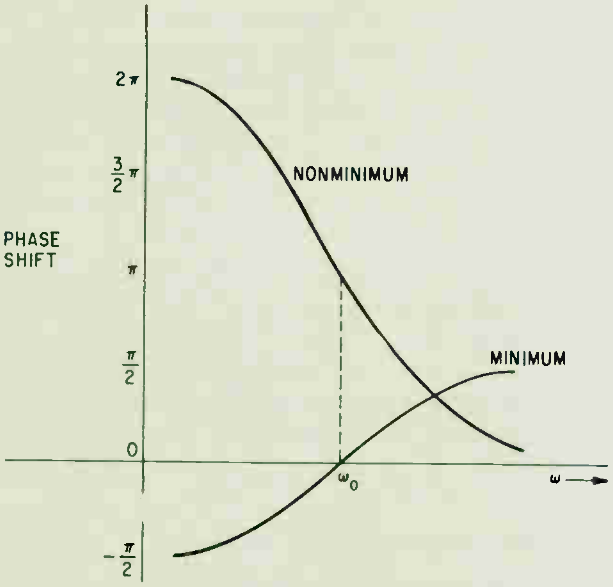
When high Q is desired, the nonminimum type is preferable, but such circuits can be unstable. For a high degree of stability, when lower Q can be tolerated, the minimum type is usually best. For

The author

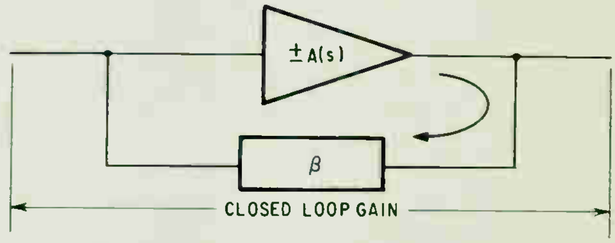
Vasil Uzunoglu's book, "Semiconductor Network Analysis and Design," was published last year by the McGraw-Hill Book Co. He holds six patents and has applied for six more. On Nov. 1 he joined the Arinc Research Corp. in Annapolis, Md., as a scientist in the devices research program.



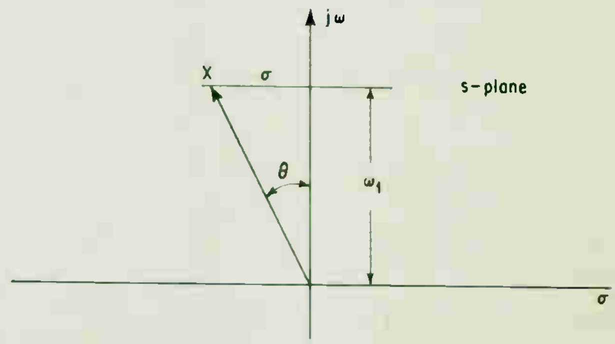
Two typical notch-filter **RC circuits** are the parallel-T at left and the bridged-T, center. The attenuation vs frequency relationships for minimum and nonminimum phase-shift networks are similar, as shown at right.



Phase characteristics for minimum and nonminimum phase-shift notch filters differ greatly, although attenuation characteristics are similar. The nonminimum circuit produces phase shifts from 0° to 360°; the minimum filter circuit exhibits shifts smaller than ±90°.



Simplified representation of an amplifier with a notch filter in the feedback path. The filter may be of either the minimum or nonminimum phase-shift type.



Pole plot for bandpass filter.

stable oscillator circuitry,[2] however, the nonminimum circuit is preferred because of the sharper phase shift with changes in frequency.

Either type of network can be constructed using a bridged-T arrangement. If a minimum phase-shift circuit is desired, lumped resistors are used for R_1 and R_2. For nonminimum phase shift, R_1 and R_2 should be distributed elements. Both minimum and nonminimum phase-shift networks can be realized with lumped elements using the parallel-T circuit but the nonminimum network requires more reactive (capacitive) components.

A nonminimum phase-shift circuit must have at least three capacitors.[1] However, the circuit can be designed so that the distributed resistors also contribute the required capacitance values.

A simple block diagram for an amplifier that incorporates a notch filter in the feedback path is shown on this page. Regardless of whether it is a minimum or nonminimum circuit, a notch filter must satisfy two circuit requirements: the required Q must be obtained, and the insensitivity to minor variations in operating conditions must be sufficient to prevent oscillations.

The closed-loop transfer function (gain including feedback) is given by:

$$A_T = \left|\frac{e_{out}}{e_{in}}\right| = \frac{A(s)}{1 + \beta(s)\,A(s)} \qquad (1)$$

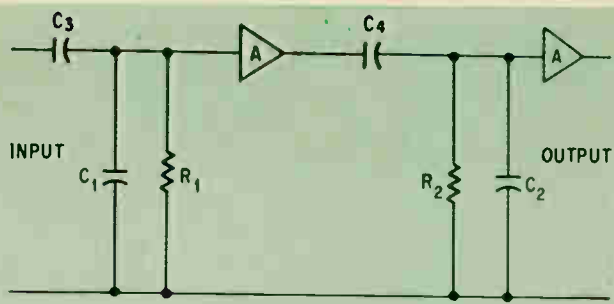
where A_T is the total closed-loop gain, e_{out} is the closed-loop output voltage, e_{in} is the input voltage, A(s) is the open-loop gain of the amplifier (gain without feedback), $\beta(s)$ is the feedback factor, $\beta(s) = \Delta e_{out}/e_{out}$, where Δe_{out} is the feedback voltage.

To achieve the required Q without oscillations, the amplifier design must satisfy the conditions that $|A(s)\beta(s)| \approx 1$ and the phase shift over the loop is approximately 360°. If the $|A\beta|$ is actually unity, and the phase shift 360°, oscillation would occur. Therefore, this product and phase angle should be approached but not actually reached.

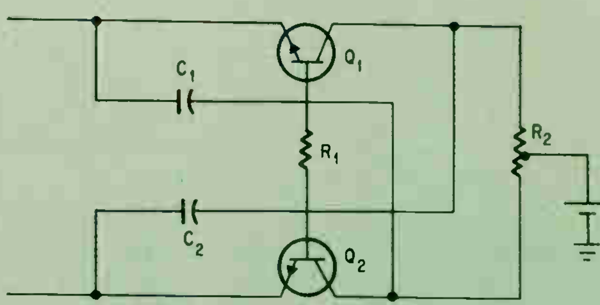
The sensitivity of the gain for a closed-loop system[1] may be defined as:

$$\frac{dA_T}{A_T} = \frac{1}{1 + A(s)\cdot\beta(s)} \cdot \frac{dA(s)}{A(s)} \qquad (2)$$

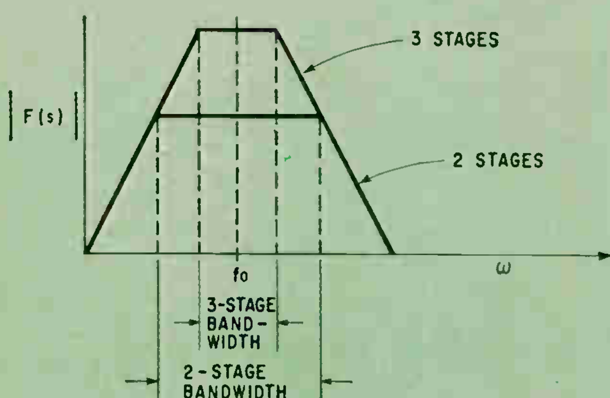
where dA_T is the variation caused by dA(s)



Two-stage circuit using RC networks in the forward transmission path. Adding stages increases gain and reduces bandwidth.



Basic negative-impedance converter circuit. Common base connections assure equal input and output current. Cross-coupling inputs to the outputs fulfills the second requirement: equal input and output voltages.



Effect of increasing number of stages of the amplifier is shown in Bode diagram for equation 4.

This equation shows that sensitivity—the inverse of stability—is a function of the open-loop gain A(s) and the feedback factor. It also shows that the effect of a change in open-loop amplification dA(s)/A(s) on the closed-loop amplification is reduced by the presence of the feedback circuit.

The sensitivity of the gain for a closed-loop system may also be expressed as:

$$\frac{(A(s) - A_T)A_T}{1 + (A(s) \cdot \beta(s))} \cdot \frac{d\beta(s)}{\beta(s)} \qquad (3)$$

where $d\beta(s)$ is a variation in the feedback circuit.

This equation shows that a variation in the feedback path has considerably more effect on the closed-loop gain than does a variation in the forward transmission path. This means that the designer must exercise considerable caution in adjusting the value of β to obtain the desired Q; otherwise oscillation may occur. In a pole-zero plot, the pole of A_T must be very close to the $j\omega$ axis if a high Q is required.

A pole plot for a bandpass-filter circuit is shown on page 115. The Q for the circuit is equal to $\omega_1/2\sigma$. As the pole approaches the $j\omega$ axis, Q becomes higher, but this condition also introduces instability. Any variations could cause the pole to move into the right-hand plane, causing oscillation.

Because variations in temperature or supply voltage, or gradual drifting of characteristics, can result in oscillation, they should be considered carefully in the over-all design. The higher the Q, the more important this consideration becomes. It has been shown by W. E. Newell[2] that the sensitivity of a pole in an active RC network is directly proportional to the circuit's Q; this is not the case, however, for a passive LC network.

One possible way to reduce the pole's sensitivity is to introduce a zero in the vicinity of the pole in the over-all transfer function. Even in this case, a stable location for the zero is not guaranteed. To achieve a Q of 100, using the pole-zero diagram on page 115, $\theta = \tan^{-1} Q/2 = \tan^{-1} 1/200$ or 0.3 degrees. With this value of θ, the zero will be very close to the $j\omega$-axis—too close for practical design consideration.

Forward-transmission RC networks

RC networks in the forward-transmission path provide stable operation with moderate Q's (10 to 20). A typical two-stage circuit is shown at the top of this page.

The transfer function for each state is expressed by:

$$F(s) = Ks/(s + p_1)(s + p_2) \qquad (4)$$

where K is the center-frequency gain, s is $j\omega$ and p_1, p_2 are poles in the complex plane for F(s).

Adding stages to the circuit increases the gain and reduces the bandwidth. If high gain is not essential, narrow bandwidth may be achieved by decreasing C_3 and increasing C_1.

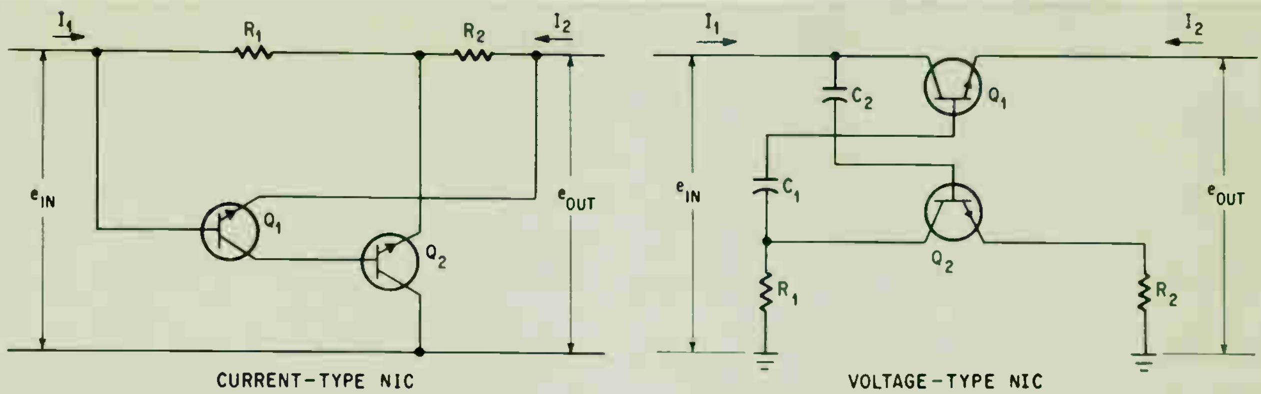
Negative impedance converters

A negative impedance converter is a coupling network that transforms the load impedance Z_L to its negative value at the network's input terminals.[1, 3-6] By placing a negative impedance converter between two RC circuits, the input impedance of the first RC circuit is transformed so that the entire network behaves like an LC circuit.

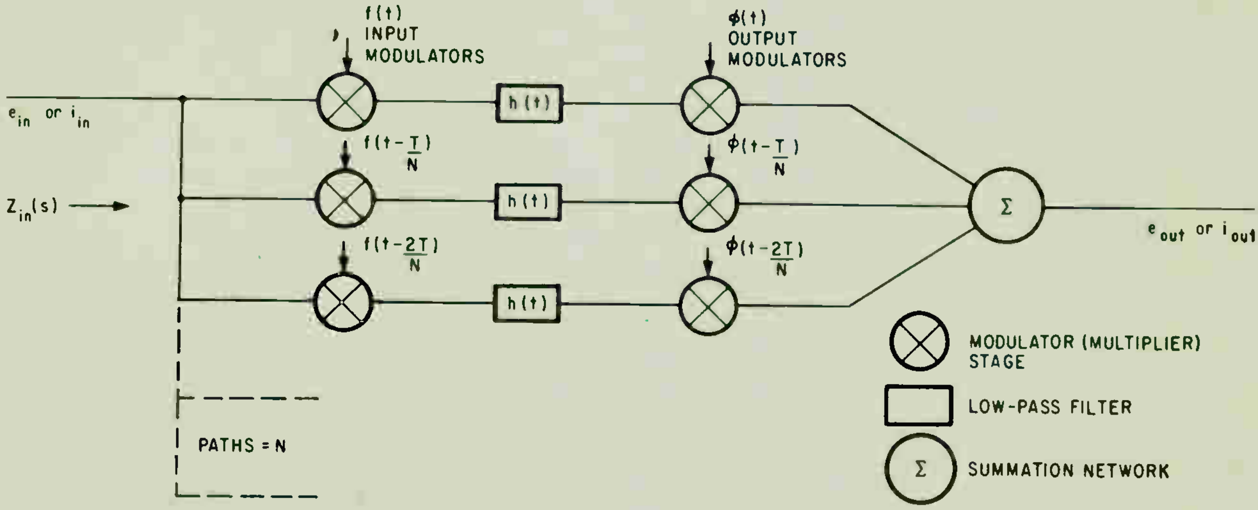
The relationship between the original and converted impedance is given by:

$$Z_{in} = -KZ_L \qquad (5)$$

where Z_{in} is the original impedance, K is the conversion efficiency constant, which is determined by the network elements, and Z_L is load impedance. In the ideal case, K would be equal to unity.



Two types of negative-impedance converter circuits. In the current-type circuit at left, input and output currents are made equal by varying the ratio R_1/R_2. The output-to-input voltage ratio of the voltage-type circuit at right is set approximately to unity by selection of R_1 and R_2.



Bandpass filter network using sampling (modulation) technique. This network provides stable operation and high Q but is more expensive than simple RC networks because of the additional components required.

The open-circuit voltage gain of the ideal negative-impedance converter is equal to the short-circuit current gain. This means that the input and output currents must be equal; the input and output voltages must also be equal in magnitude but opposite in sign. A network that meets these requirements is shown on page 116.

In this circuit, the transistors are arranged in common-base configurations so that the input and output currents will be equal. By cross-coupling the input of one transistor to the output of the other transistor, the input and output voltages are kept equal. To obtain a value of K that closely approaches unity, the transistors (Q_1 and Q_2) should be replaced by pairs of transistors in a Darlington configuration.

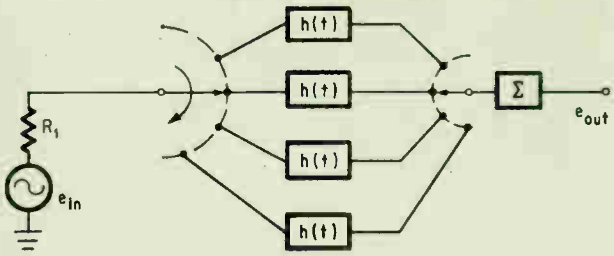
Two additional circuits that may be used as negative impedance converters are shown above. Since it is not possible to build circuits in which the input and output currents, also the input and output voltages, are exactly equal ($K = 1$), only one of these two conditions of equality can be obtained. The circuit at the left, a current-type negative-impedance converter, has its current ratio (I_2/I_1) set approximately to unity by varying the R_1/R_2 ratio. The input and output voltages are nearly equal because the emitter-to-base junction of Q_1 has very low impedance when Q_1 is conducting. In the voltage-type negative-impedance converter at the right, R_1 and R_2 are selected so that the ratio of the output to the input voltage is approximately unity. Because of the common-base transistor configuration, the input and output currents are almost equal.

Sampling or digital filtering

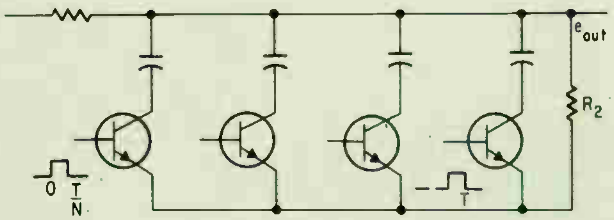
The first three techniques used RC networks in conjunction with active elements. As has been mentioned, active circuitry with RC networks is usually sensitive to small changes in operating parameters when high Q is required.

By using a sampling (modulation) technique,[7] the instability of a bandpass-filter circuit can be reduced substantially. However, this technique makes the circuitry considerably more complicated and, as a result, more expensive. An n-path network showing a use of this technique is shown on this page.

The input voltage or current (e_{in} or i_{in}) is multiplied (modulated) by $f(t)$, $f(t - T/N)$, $f(t - 2T/N)$,



Mechanical switching circuit for frequency filtering. Each filter represented by h(t) samples at a different time. The rejection of harmonics is improved by increasing the switching speed.



Electrical equivalent of the comb data-sampling circuit.

etc., where T is the period of the modulating function. The multiplied signal is then fed to a low-pass filter, h(t). The frequency difference between f(t) and e_{in} must lie within the bandpass limits of h(t). The outputs from the filters are multiplied again by functions $\phi(t)$, $\phi(t - T/N$, $\phi(t - 2T/N)$, in synchronism with f(t). The outputs from all branches are added up; this sum constitutes the final output. The entire operation simulates the functioning of a series-tuned LC network that passes a desired frequency and rejects all other frequencies.

Because the modulating signals are sinusoidal, the driving-point (input) impedance of the entire network can be represented by:[7]

$$Z_{in}(s) = K\frac{(s^2 + \omega_o^2)}{s} \quad (7)$$

where ω_o is 2π times the center frequency and K is a constant determined by the circuit elements. Equation 7 is also the expression for the impedance of an inductor in series with a capacitor.

If the modulating time function, f(t) is an impulse and if the input signal is supplied by a current source each modulator can be replaced by a simple switch. Then the input and output modulating signals are equivalent to a pair of rotary switches with N contacts as a common shaft that rotates at $1/T = \omega_o/2$ cycles per second. Each low-pass filter, h(t), must have a bandwidth much lower than f_o, the center frequency desired for the entire bandpass-filter network.

When only one passband is desired, the bandpass-filter circuit must have at least three h(t) sections to get rid of the harmonics (multiples of ω_o). A mechanical sampling section for eliminating harmonics[8] is depicted at the left. Each filter samples at a different time. As the switch's operating speed increases, the effectiveness of stopping the harmonics improves.

The extent of time during which the brushes remain on each contract is given by:

$$t_1 = T/R_1 \text{ and } t_2 = T/R_2 \quad (8)$$

where t_1, t_2 are contact times, R_1 is the source impedance, and R_2 is the load impedance.

An advantage of this technique is that the filter can be tuned at different frequencies without altering the system. The center frequency of the filter can be changed simply by changing the frequency of the timing source that controls the switching rate. With this method, it is possible to achieve Q's of 5,000 to 10,000 at a few hundred kilocycles per second. These values are much higher than those that can be obtained with any type of stable filter using RC networks.

Comb filters

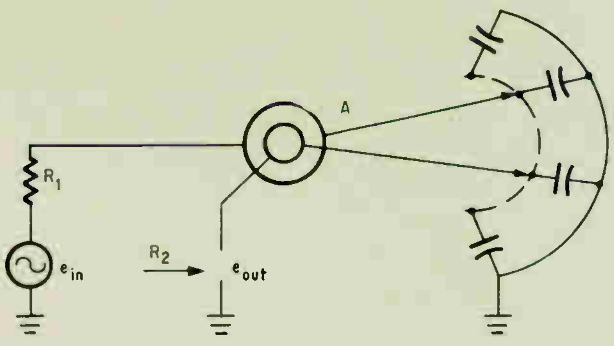
Besides its use as a very narrow bandpass filter, the same system can be used to build comb filters,[8] with bandpass centered at multiples of ω_o. In the simplified mechanical analog of a comb system, shown on page 119, t_1 is the time required by the brush to move from one contact to another. The input signal is applied through a high-value resistor to brush A (upper arrow on diagram). While A is in contact with the corresponding capacitor, the capacitor begins to charge, so that its potential approaches that of the input signal. However, the time constant of the RC network is much higher than the dwell time of the brush on one segment, so that it takes a certain time for the capacitor to charge; before the capacitor can build up an appreciable charge, the brush changes position.

If the signal frequency is a multiple of the frequency of rotation, the signal will have the same value each time the brush comes in contact with a given segment. Thus, after a certain number of revolutions, the potential across each capacitor will attain its maximum value; this means that the locus of charge on the capacitors is an indication of the input-signal level. However, this system prevents the buildup of random signals and signals that are periodic, or of signals that are periodic but whose frequency is not a multiplier of the rotational frequency. This suggests that such a sampling filter may be used in detecting weak periodic signals in the presence of noise.

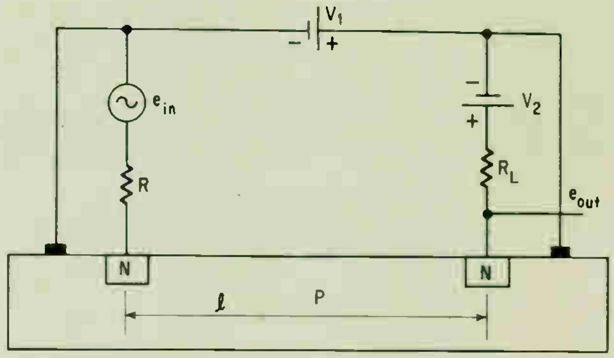
An electrical circuit equivalent of the mechanical data-sampling filter just discussed is shown on this page. This circuit was introduced by G. H. Danielson.[9]

Acoustic resonators

The acoustic-resonator technique requires mounting piezoelectric crystal onto a monolithic silicon chip. The installation is difficult, because the crystal must be positioned so that it is allowed to vibrate freely.



Mechanical analog of a comb filter. Here the mechanical rotational frequency of the switch fixes the location of the passbands, and the time constant (R_2 times the capacitor being touched by the brush) fixes the width of each band.



Semiconductor delay line. The time delay is a function of the distance between n-type silicon regions. The stability citerion of a circuit using a semiconductor delay line is similar to that of a network using an RC feedback circuit such as a notch filter.

When an electric wave is applied to the resonator, traveling acoustic waves are generated at the resonant frequency.[2] These traveling waves are reflected when they reach a boundary. If the resonator is well designed, the initial transmitted and reflected acoustic energy are added together, causing an intense standing wave. This acoustic wave is converted back to an electric wave at the point of application. At this point the electrical circuit sees the equivalent of a parallel circuit tuned to the resonant frequency. To achieve high Q, the losses must be minimized. The acoustic wave, as it bounces back and forth, is subject to high losses. The use of an acoustic resonator in microelectronic blocks is feasible if the supporting medium of either the resonator or substrate does not absorb the mechanical vibrations or permit leakage of the acoustic energy. Therefore, solid mounting of a conventional piezoelectric resonator is not possible. Piezoelectric materials such as cadmium sulfide and zinc oxide have been used for acoustic resonators.

Semiconductor delay lines

Semiconductors delay lines[1] are relatively easy to integrate because only one diffusion is required in their manufacture. Only resistive elements used; capacitors are eliminated. In the semiconductor delay line shown on this page, the distance between the two n regions determines the delay time and, therefore, the frequency.

Minority carriers are injected at the junction on the left and, being subject to an electric field, are diffused and drift to the right. When minority carriers are subjected to an electric field, they cause a phase shift ϕ which is given by:

$$\phi = \int_{\omega_1}^{\omega_2} t_0 d\,\omega$$

where t_0 is the time delay, ω_1 is the lower bandpass limit frequency, and ω_2 is the upper bandpass limit frequency. The delay is a function of the length of the semiconductor path, as noted above, also of the intensity of the electric field. If a delay line is inserted in the feedback path of an amplifier, it will cause a phase shift and attenuation, which will determine the closed-loop gain and phase.

The same stability relations discussed earlier in this article for an RC network placed in an amplifier's feedback circuit also apply if a delay line is substituted for the RC network.

In general, an RC notch filter in the feedback path provides poor stability unless the Q requirements are not formidable. RC networks in the forward transmission path provide good stability but poor Q values. With a negative impedance converter, both the stability and Q obtainable are somewhat better. All three methods have the disadvantage that they cannot provide high stability and a high Q simultaneously. Digital filtering can, but it has the disadvantages of complexity and associated high cost.

Acoustic resonators are a recent development. One big disadvantage of these is that fabrication of circuits containing such devices is difficult. Semiconductor delay lines can be made small and are relatively easy to integrate.

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Solid state multipliers for servosystems

Analog multipliers capitalize on magnetoresistance effect to eliminate errors inherent in servo potentiometers

By H.H. Wieder
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In analog computers that solve complex nonlinear differential equations, multiplication is usually performed by potentiometers whose wiper arms are positioned by computer servomechanisms. The accuracy of these servo-potentiometer multipliers is limited by the finite resolution of the wiper arm.

Being developed is a new type of analog multiplier, simpler and more rugged than the conventional potentiometer and accurate to within 1%. These solid state multipliers employ magnetoresistance, or the Hall effect.

Hall-effect multipliers generate an output voltage, v, proportional to the product of two independent variables, X and Y. The function X is proportional to the magnetomotive force generated by a current in the gap of an iron-core solenoid. The function Y is proportional to another current, transverse to X, flowing in the Hall-generator material. Thus, v = kXY where the scaling coefficient k is a complex function of the material from which the Hall generator is fabricated. In general, k is less than 1, and Hall multipliers thus require additional circuitry to adjust k to 1 or some multiple of 1.

Cause of it all

Magnetoresistance is caused by the short-circuiting of the Hall potential in a semiconductor element; in consequence, the resistance between the semiconductor's current electrodes increases as a nonlinear function of the applied magnetic field. There are some distinct advantages in using magnetoresistors rather than simple Hall generators for the construction of analog multipliers. The latter, although simpler in principle and essentially linear with X and Y, nevertheless require complex circuit compensation. In high magnetic fields, a compensation is required for incipient magnetoresistance effects which alter the linear relation between v and X. However, the resistance of matched magnetoresistors vary proportionally.

Magnetoresistive analog multipliers that are inherently precise, are possible due to advances in the technology of vacuum-deposition and crystallization of indium antimonide films[2,3]. The process has resulted in magnetoresistive configurations that have high initial resistance and a large magnetoresistive coefficient (magnitude of the resistance change as a function of the magnetic field).

Thin-film magnetoresistors

Magnetoresistors have been made in several different forms and shapes. The resistors are produced by vacuum-depositing and recrystallizing films of indium antimonide containing approximately 10% metallic indium. The recrystallization is performed by melting ($InSb + In$) films which had been previously deposited on a glass substrate in vacuum. Solidification of this liquid film leads to the formation of InSb dendrites with In filaments segregated between them.[2,3] The In filaments act as virtual electrodes for the InSb dendrites and, in the presence of transverse electric and magnetic fields, cause the shorting of the Hall field.

The large electron mobility, $\mu_e \cong 3 \times 10^4$ cm^2/

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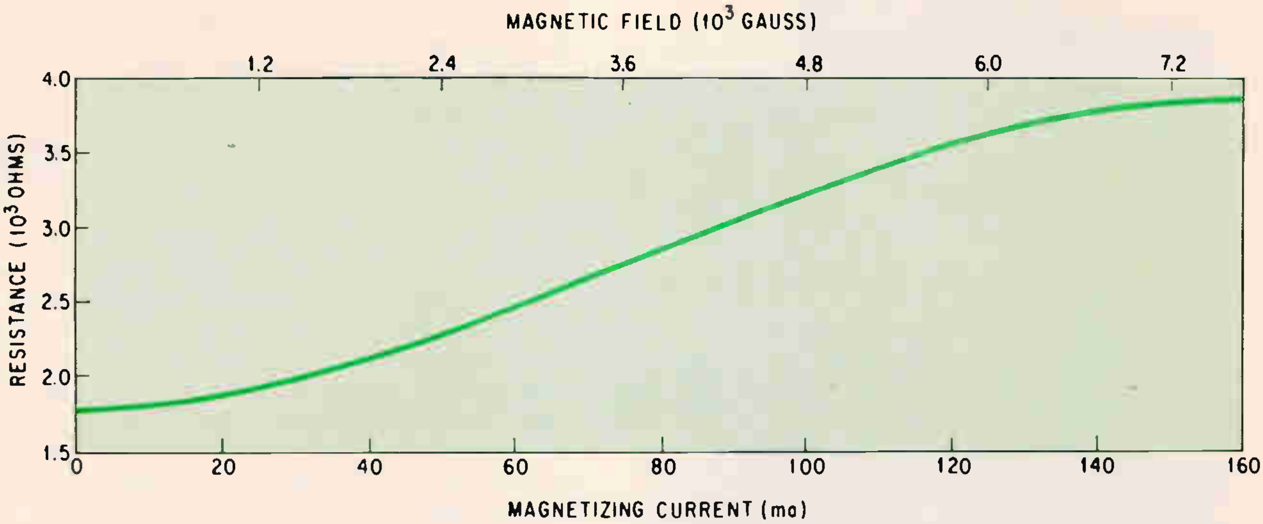


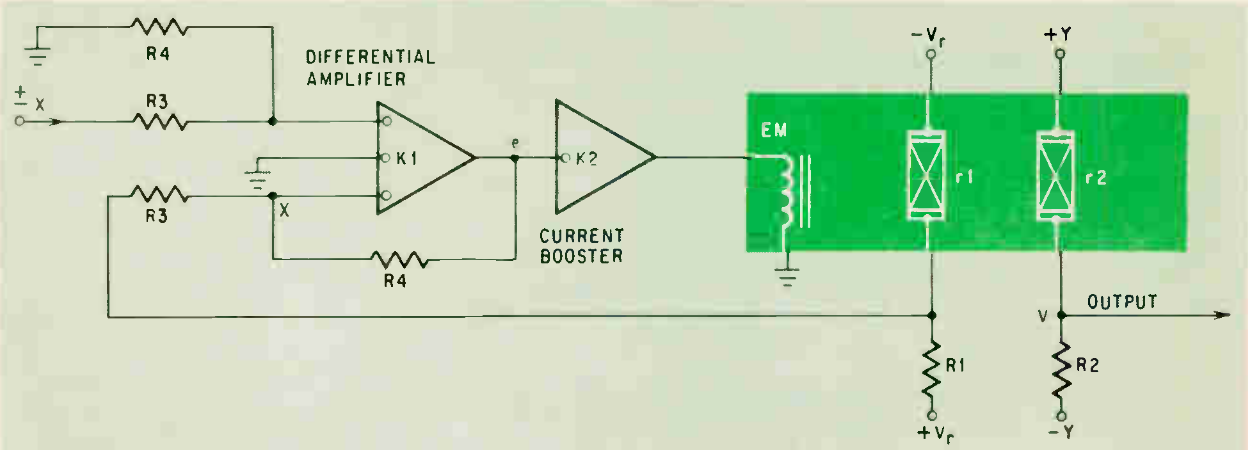
Magnetic field dependence of the resistance of one of the magnetoresistor elements is shown above; magnetizing current required to generate corresponding magnetomotive force is also shown for comparison. The value α is the ratio of the resistance of the magnetoresistor at some discrete magnetizing current level to that at zero current.

(volt-sec) and the electrostatic shorting of the Hall potential by the In inclusions cause a strong magnetic field dependence on the resistance of such films. The magnetoresistance coefficient ($\Delta\rho/\rho_0$ where ρ_0 is the initial resistance) in indium antimonide films is not dependent on its geometrical configuration. The electrostatic shorting caused by the In filaments is on a microscopic scale; hence magnetoresistor elements of arbitrary shape may be fabricated. Special electrode contours to induce large ($\Delta\rho/\rho_0$) are not necessary, as they are with bulk crystalline devices[4].

The InSb magnetoresistors discussed in this article were fabricated by standard photoetching techniques on recrystallized InSb films deposited upon glass substrates, with a nominal thickness of 1.1 micrometers. They were mounted between insulating, circular, ferrite plates of high permeability. Leads were attached to their terminals by means of adhesive silver paste. The initial resistances of the two magnetoresistor elements discussed in this article are respectively, r1 = 1756 ohms and r2 = 1930 ohms as measured with a precision Wheatstone bridge. The graph given above shows the magnetic field dependence of the resistance of one of these magnetoresistors; the other element has a qualitatively identical resistance variation with field.

Theory of a multiplier

The schematic below shows the design of a typical analog multiplier. It consists of two independent potentiometers each made up of a magnetoresistor element r, in series with a linear resistor R. The reference potentiometer has two equal input potentials $\pm V_r$ and an output x, applied to one of the input terminals of a differential amplifier with voltage gain K_1. The arbitrary input potential X is applied to its other input terminal. The amplifier output e, is fed to the input of a current booster amplifier with gain K_2. This furnishes the driving current for the solenoid of an electromagnet



Magnetoresistive analog multiplier: Magnetoresistors r1 and r2 are in the gap of electromagnet EM Resistors R_1 and R_2 are adjusted to match respectively r1 and r2; R_3 = 1000 ohms and R_4 = 1 megohm. V_r is a fixed reference potential. X and Y are variable input voltages whose product appears as the output voltage v.

Hall currents in semiconductors

The Hall effect works this way: if a conductor is placed in a magnetic field perpendicular to its axis, and if a current flows axially through the bar, a potential gradient is developed normal to both the magnetic field and the current. The potential gradient is at every point a function of the vector product of the magnetic intensity and the current density. One application of this is the Hall multiplier.

The Hall effect was first described by E. H. Hall in 1880. But Hall voltages are very small in conducting materials, so it wasn't until the advent of semiconductors that it could be more than a laboratory curiosity. One material in particular, indium antimonide (InSb), is able to generate comparatively large Hall voltages, and is used extensively.

When Hall currents in a semiconductor are shorted by a magnetic field, it causes an effect called magnetoresistance. J. M. Hunt first described the design of an analog multiplier using magnetoresistance in bismuth layers in 1960. Its main feature was the use of two interlaced magnetoresistive elements fabricated from electroplated bismuth, whose resistance is a function of a magnetic field controlled by an operational amplifier in a servo loop. Although the magnetoresistance coefficient of bismuth is small and the large, variable magnetic fields required limit the frequency response of such a multiplier, Hunt was able to show experimentally that replacing mechanical potentiometers by magnetoresistive elements, with their infinite resolution and freedom from dynamic anomalies, were capable of a multiplication with an accuracy of 0.077%—a marked improvement over servomultipliers in present use. However their efficiency was very low and circuit designers had to wait for better semiconductors.

EM, which provides a uniform and homogeneous magnetic field (H) acting identically upon both magnetoresistors. The follow-up potentiometer is connected to the independent input potential Y and its output is expressed by $v = Yr(H)$, where $r(H)$ is dimensionless and is defined by equation 3 below.

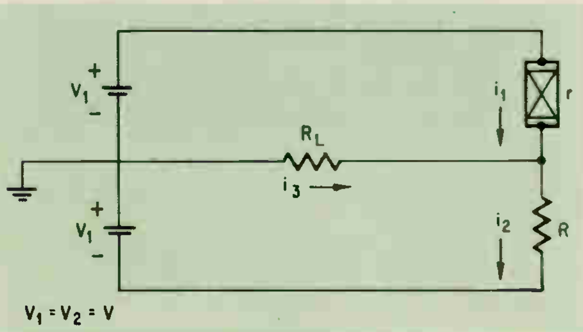
The differential amplifier output is $e = K_1 (X - x)$ and that of the current booster is a magnetic field $H (i)$ proportional to K_2e generated in the gap of the electromagnet by the current, i, or

$$H (i) \propto K_1K_2(X - x) \qquad (1)$$

The reference potentiometer output is given by $x = V_r r(H)$ and the feedback loop around the amplifiers constrains equality of the two inputs of the differential amplifier; thus, in the steady-state condition $x = X$, and the multiplier output is:

$$v = (1/V_r)XY \qquad (2)$$

In equation 2, it is assumed that the two magnetoresistive potentiometers exhibit perfect "tracking." This requires that both the initial resistances and the magnetoresistive coefficients of the magnetoresistors be identical. It also requires that the linear resistors which are in series with the magnetoresistors, be matched to eliminate intrinsic multiplication errors. The reference potential in equation (2) is obviously a scaling factor; for convenience, if X and Y are of the same order of magnitude, V_r may be chosen so that the multiplier output is in the same units as X and Y or in some convenient decimal scale.



Analysis of circuit diagram of a magnetoresistive potentiometer gives the output signal across R_L as a function of circuit parameters

The potentiometer circuit

Analysis of the circuit shown in the diagram at the bottom of the page (left) yields the expression

$$\frac{v_o}{V} = \frac{r - R}{r + R + (rR/R_L)}$$

For negligible loading of the potentiometer, $R_L >> rR$ and the equation above may be expressed as:

$$\frac{v_o}{V} = \frac{r - R}{r + R} = r(H) \qquad (3)$$

Expressing the maximum and minimum values of the magnetoresistor as r_M and r_m, respectively, the corresponding values of v_o are v_M and v_m, therefore:

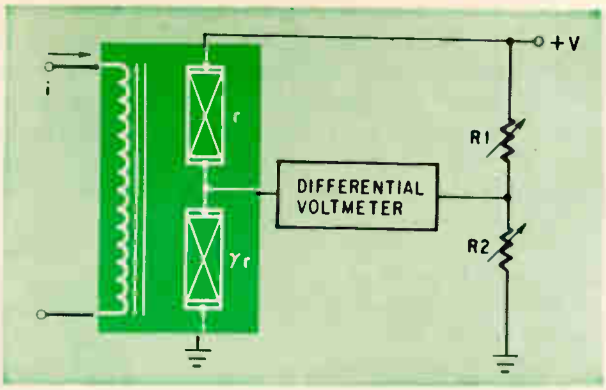
$$v_M = \left(\frac{r_M - R}{r_M + R}\right)V \text{ and } V_m = \left(\frac{r_m - R}{r_m + R}\right)V \qquad (4)$$

Let the initial resistance r_m of the magnetoresistor be equal to the linear series resistor R, that is, $r_m = R$, and let the highest available magnetizing current define a magnetoresistor value $r_M = \alpha\ r_m$, where α is a numeric coefficient. Equation 4 then yields

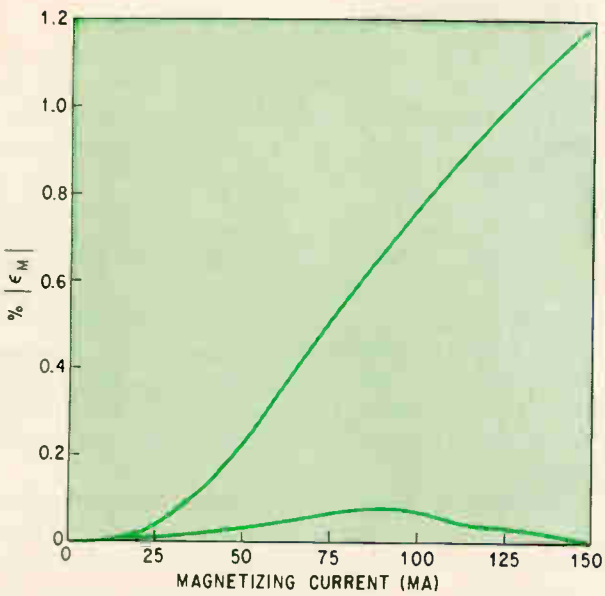
$$v_M = \left(\frac{\alpha - 1}{\alpha + 1}\right)V \qquad (5)$$

If the maximum available magnetizing current (i) through a magnetoresistor is approximately 100 ma, and we use the graph of magnetizing current vs. resistance on page 121, to calculate a value of 1.868 for α, v_M will equal 0.3026 V. The corresponding values for a bismuth magnetoresistor[5] of the same thickness subjected to the same magnetic field are $\alpha \cong 1.04$ and $V_M = 0.0196$ V. Defining a figure of merit, $z = v_M/V$, z (InSb) $\cong$ 15z (Bismuth).

The peak input potential V which may be applied to the magnetoresistive potentiometer is a function of joule heating. The power input that causes a 1% change in the conductivity of InSb films[6] deposited on glass substrates at +25°C is the order of 0.1 watts. Let $i = 2V(r + R)^{-1}$ for $i_3 \cong 0$ as shown in the schematic. The maximum input potential V_M that may be applied to the potentiometer in terms



Circuit to determine tracking error of interlaced magnetoresistors. The differential voltmeter is accurate to within ±0.02% for inputs above 0.1 v, and ±0.02% for inputs +2μ v to 0.1 v; R_1 and R_2 are precision decade resistor boxes.



Magnetic component of tracking error as a function of magnetizing current before and after (lower line) its partial compensation by means of a 0.112 megohm resistor shunted across r_2.

of the peak permissible power dissipation P_M is defined by the equation:

$$V_M \leq \left(\frac{R + r_m}{2}\right) \cdot \left(\frac{P_M}{r_m}\right)^{1/2} \qquad (6)$$

Thus $V_M \leq 13.2$ volts for $P_M = 0.1$ watts.

Tracking errors

The principle causes for multiplication errors are mismatch between the fabricated magnetoresistors; the difference in their magnetoresistance coefficients ($\Delta\rho/\rho_o$) as a function of magnetic field H (this leads to a multiplication error that varies with H); and differential electrothermal effects due to different potentials applied across the two magnetoresistive potentiometers and resultant differential joule heating.

These errors will be evaluated theoretically and experimentally since they have a direct bearing on the ultimate precision of the multiplier.

Suppose the reference potentiometer shown in the schematic on p. 122 is described in the steady-state condition in accordance with equation (3) as:

$$X = \left(\frac{r - R_1}{r + R_1}\right) V_r \qquad (7)$$

where X is the output of the reference potentiometer with input potential V_r, and with linear series resistor R_1. The instantaneous resistance r of the magnetoresistor is then obtained from equation (7)

$$r = \left(\frac{V_r + X}{V_r - X}\right) R_1 \qquad (8)$$

In similar fashion, the follow-up potentiometer output v, be given by

$$v = Y\left(\frac{\gamma r - R_2}{\gamma r + R_2}\right) \qquad (9)$$

where γ is defined as $\gamma = 1 + |\epsilon|$ and $|\epsilon|$ represents the absolute value of the sum of the tracking errors between the two potentiometers, Y is the input potential to the follow-up potentiometer and R_2 is its linear series resistance. For zero tracking error, let $|\epsilon| = 0$ and the linear resistor R_2 in the proceeding equation be replaced by R_1. This gives an output v_o, expressed by

$$v_o = Y\left(\frac{r - R_1}{r + R_1}\right) \qquad (10)$$

The simultaneous solution of equations 7 and 10 gives the output of the multiplier for perfect tracking in accordance with equation 2;

$$v_o = \frac{XY}{V_r} \qquad (11)$$

Let $\Delta v = v - v_o$; the fractional multiplier error may then be defined as $\eta = (\Delta v / v_o)$. From equations 9 and 10,

$$\frac{\Delta v}{Y} = \frac{2rR_1(\gamma - R_2/R_1)}{(r + R_1)(\gamma r + R_2)} \qquad (12)$$

Upon introducing the value of r from equation 8 into this equation

$$\Delta v = \left(\frac{YX}{V_r}\right) \cdot \frac{(V_r^2 - X^2)(\gamma - R_2/R_1)}{V_r X(\gamma + R_2/R_1) + X^2(\gamma - 1)} \qquad (13)$$

hence the fractional multiplier error is;

$$\eta = \frac{[(V_r^2/X) - X][\gamma - (R_2/R_1)]}{V_r[\gamma + (R_2/R_1)] + X(\gamma - 1)} \qquad (14)$$

The fractional error due to the original mismatch of the magnetoresistors can be compensated, in accordance with the equation 14, by choosing $R_2/R_1 = 1 + |\epsilon_o| = \gamma_o$.

The component of the tracking error dependent on the magnetic field can be evaluated by means of the circuit shown in the drawing at left by using a method similar to that of Hunt[1]. The voltage (v)

Typical tracking error for magnetoresistors

X(mv)	v(mv)	error %
0	0	0
25	24.9	0.40
50	50.0	0
75	75.0	0
100	99.6	0.40
125	125.1	0.08
150	149.3	0.47
175	173.9	0.46
200	199.1	0.45
225	224.0	0.44
250	249.1	0.36
300	300	0
350	349.8	0.06
400	399.4	0.15

detected by a high impedance differential voltmeter is:

$$v = V\left[\frac{r}{r+\gamma r} - \frac{R_1}{R_1+R_2}\right] \quad (15)$$

For $v = 0$, $\gamma = (R_2/R_1)$ hence the circuit may be used to select the values of R_1 and R_2 for compensating $|\epsilon_0|$. The magnetic field-induced error $|\epsilon_M|$ is calculated from equation 15 and the value of R_2 required to maintain $v = 0$ can be selected.

Such measurements were made on the magnetoresistive potentiometer assembly described here. The graph on p. 123 shows that $|\epsilon_M|$ is an increasing function of the magnetic field. If the error is small it might be compensated by the selection of a proper (R_2/R_1) ratio in midrange. However, the large $|\epsilon_M|$ values introduced large multiplication errors in accordance with equation 15.

A simple expedient for partial compensation of $|\epsilon_M|$ is to shunt r_2 with a suitable linear resistor. A carbon resistor of nominal value 112,000 ohms reduced $|\epsilon_M|$ to a maximum of 0.09% in the middle of the operational range. This error is independent of the magnitude, $|V|$, between 0.1 and 10 volts.

A prototype multiplier was assembled from standard components. The differential amplifier chosen, a Philbrick Model P-2, has a high input impedance, low drift and high common-mode rejection. It introduces negligible loading of the reference potentiometer. Its high open-loop gain and output are sufficient to drive the current booster, in this case a voltage-programed power supply (Lambda Electronics Model LH-124) with a voltage gain of unity and load regulation of about 0.015%. Its output provides the magnetizing current for the electromagnet.

The reference potentials were supplied by two matched mercury dry cells, $V_r = 1.352$ volts. Both magnetoresistive potentiometers were connected to these reference potentials. For this condition, it is evident from equation 2 that since $Y = V_r$, the multiplier output is $v = X$ for perfect tracking.

The results of such experimental measurements are shown in the table at left as a function of the input signal X. The maximum multiplication error is 0.47% and the mean error is 0.23%. The maximum calculated η by Equation 14 is 0.36% for $\gamma_o = (R_2/R_1) = 1.049$, $X = 150$ mv and $\gamma = 1.0958$. The discrepancy between the measured and calculated errors, $\Delta\eta = 0.12\%$ is ascribed to inherent errors in the adjustment of the amplifier balance and the null point of the power supply.

The total multiplication error η_t was determined by measuring the multiplier output as a function of X, with Y an arbitrary parameter with the range $0.1 \leq Y \leq 10$ volts. The results show the maximum error in this range is $\eta_t = 0.68\%$ and the mean error $\bar{\eta}_t = 0.31\%$. An order of magnitude estimate for the error introduced by the differential electrothermal effects is 0.1%.

Higher accuracies

As control over the fabrication processes improves, smaller tracking errors due to $|\epsilon_o|$ and $|\epsilon_M|$ will undoubtedly be obtained. New control techniques are presently under investigation. Differential electrothermal effects are bound to be larger in InSb than in Bi because InSb at room temperature is near its intrinsic conductivity region. These effects can be circumvented to some extent with heat sinks to improve heat transfer from the magnetoresistors. Alumina rather than glass substrates should lead to lower values of $|\epsilon_t|$. The high magnetoresistance coefficient of InSb is a distinct advantage if the available magnetomotive force must be limited to improve the effective frequency range of such a multiplier.

Magnetoresistors designed with the InSb films are not limited by geometrical considerations. High-resistance, noninductive elements may be fabricated either by using suitable masks during the evaporation process or by photolithographic techniques applied after recrystallization.

Thin film magnetoresistors deposited onto substrates less than 10^{-2} cm thick, produce a substantial increase in the efficiency of the magnetic circuit by decreasing the magnetic reluctance of the gap in which they are placed. The smaller mmf required to obtain significant changes in the effective flux suggest a variety of additional not necessarily restricted to analog multipliers.

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Acknowledgment

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Error-control systems get the message across

The growth of digital communications increases the need to detect and correct errors occurring during transmission. Factors that produce errors and means of combating them are described in this first article of a series

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Evn thoug lttrs ar mssng frm th wrds n ths sntnce it cn b ndrstd. The reader is using an error-control system based on the natural constraints of the English language.

Error control in digital communications is accomplished by adding constraints to the digital alphabet of 1's and 0's. The method by which such constraints are generated and added to a digital message is known as error-control coding. Error control through coding makes it possible to detect errors in a received digital message; to correct them, and to reconstruct the original message exactly despite the errors that may have been caused by the communications link.

All communications systems consist of three basic elements: a source where the information is generated and transmitted; a sink, or destination, where the information is received and used; and the transmission medium, or channel, that links the source and sink. The communications engineer's task is to match efficiently the source and sink within the limitations of the transmission channel, and to maintain the accuracy of the message.

There are a wide variety of disturbances in the transmission channel—random and impulse noise, fading, crosstalk, distortion, drop-outs or variable time delays—which can introduce errors in the message while in transmission. Fortunately, these errors can be reduced considerably by coding the message before transmission.

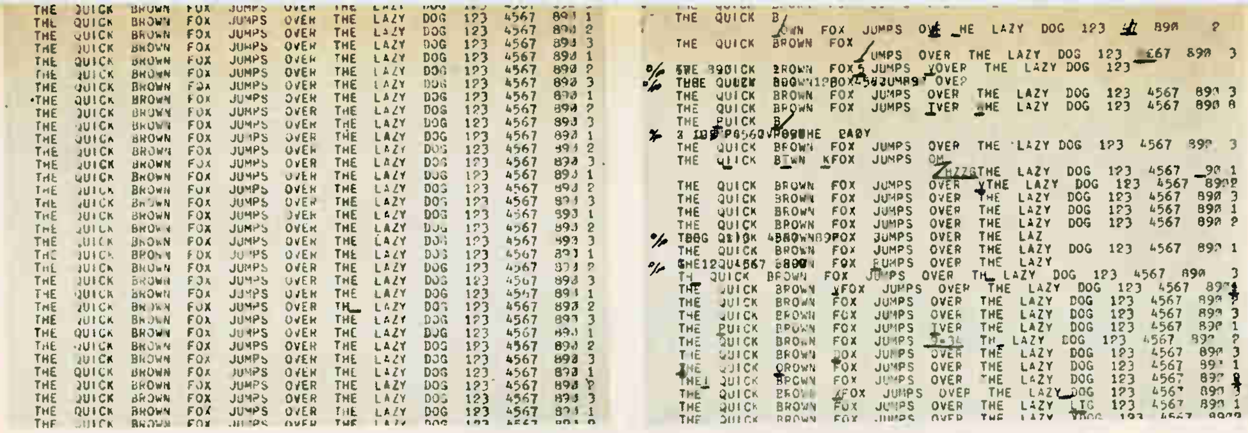
But the use of error-control techniques must be weighed against other methods of channel improvement, for example, increasing the effective radiated power for better signal-to-noise ratio, increasing the order of diversity, or using improved receivers.

Once error control is selected as the best method of upgrading the performance of a digital communications system, an appropriate code must be selected. Two considerations affect the selection of the most appropriate error-control code. The first involves the requirements of the user, the tolerable delays, error rates, data rates, channel efficiency, and other factors; the second deals with the characteristics of the transmission medium.

The behavior of typical channels depends on both the medium itself and the modulator-demodulator techniques (modems) applied in the channel. A simple description of a channel in terms of average error rate is inadequate, since most channels show a clustering of errors. Because their sources are varied, it is difficult to describe the occurrence of errors by theoretical analysis, and it is usually necessary to resort to an experimental study of a channel to derive a statistical description of the errors in it. The statistical description can be presented in the form of a series of probability distributions, or as a mathematical model.

Certain types of channel disturbances can't be corrected by improvements in equipment. For instance, no amount of increase in transmitter power or improvement in receiver sensitivity can remedy errors introduced by a chattering relay contact, or reduce errors caused by multipath propagation phenomena. When the basic capability of a system is close to its practicable limits, coding must be used to improve channel performance.

Economic advantages may be gained with error coding in certain cases, particularly where the sink terminates in a digital computer with spare capacity that can be assigned to the decoding process. Furthermore, a channel can be upgraded without modifying the system's internal components.



Comparison of teleprinter data transmitted with and without error coding over an intentionally degraded high-frequency radio channel. Symbol o/p in the margin of the error-filled copy means overprinting. Error-control equipment used in the test was Autospec, manufactured by the Marconi Co. of Great Britain. It uses a block code consisting of five information and five parity bits. Note the detected but uncorrectable error, indicated by a space, in the error-controlled copy.

I. Principles of error control

A typical one-way digital communication link that transmits coded information is shown in the block diagram below. The information source produces a message from the large set of all possible messages that might be transmitted over the link. Usually, the number of possible messages is so great that it becomes necessary to represent each message by a number of simpler messages in much the same manner as words, or letters of the alphabet, are simpler messages contributing to a more complex message—a complete sentence.

Each message, then, is represented by a unique sequence of simpler entities obtained in several successive steps. For example, the message may first be represented as a sequence of letters. Then, each letter may be represented by a sequence of still simpler entities such as the binary symbols 1 and 0. For the type of communications systems of concern here, the symbols leaving the information source are almost always in binary form, but this is a matter of convenience rather than necessity.

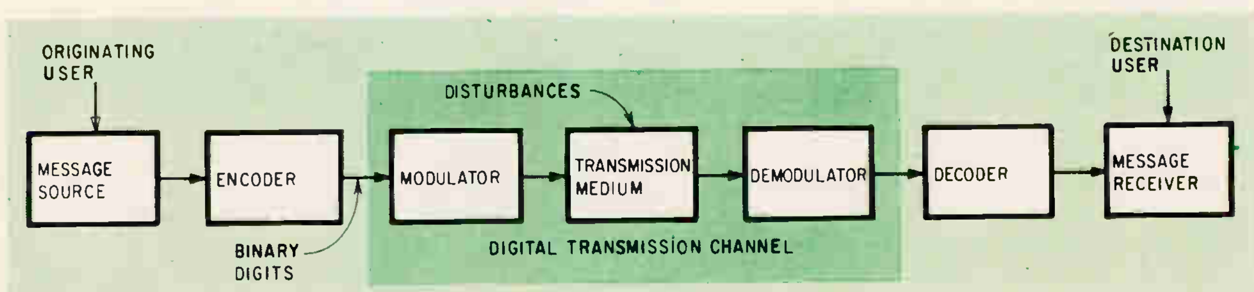
The stream of symbols leaving the information source may contain various intersymbol constraints that result from redundancy inherent in the particular form of the message. The intersymbol constraints in the English language make it fairly easy to reconstruct correctly a textual message that contains errors. If the constraints are strong, the redundancy is high (for example, the letter q is always followed by u in English text which means that it is not strictly necessary to transmit the u). Such constraints have two effects: the rate at which information can be transmitted is reduced because channel time must be allocated to the redundant symbols; and they provide the mechanism whereby isolated errors can be detected or corrected.

Unfortunately, the redundancy introduced by the natural constraints of a language is haphazard. While certain parts of a message may have high redundancy, others, for example a string of numbers, have very little. Error-control coding inserts a controlled redundancy into the message by introducing constraints between the symbols.

Introducing constraints

As an example of how a simple error-control encoder introduces these constraints, consider an information source generating a sequence of decimal digits, 125903766. An encoder might be designed to separate this message into blocks of three digits and append to each block a fourth, or check, symbol equal to the ordinary sum without carry (sum modulo 10) of the digits in the block. More simply stated, this means: add the three digits of the block; if the sum is 9 or less, use it as the check symbol; if the sum is greater than 9, use only the units digit of the sum as the check symbol.

The constrained sequence leaving the encoder would read **8**125**2**903**9**766 . The digits in color are the redundancies inserted by the encoder to establish the constraints. Because the transmission now is in the form of four symbols in a block of which only three represent the original message, the rate of information transfer is reduced and the



Digital communications system. Because the modulator and demodulator can also generate errors, they are included as part of the basic transmission channel.

Glossary

automatic repeat request (arq): When an error is detected at the receiver, a request for retransmission is initiated by this error-control method. Arq requires a return channel.

Baudot code: A teleprinter code containing five binary information symbols and two additional symbols, one indicating start and the other stop.

binary symmetric channel: A binary channel is one whose output can assume only the two discrete levels associated with the mark (1) and space (0) symbols. The binary channel is symmetric when the probability of a transmitted 1 being incorrectly received as 0 equals the probability that a transmitted 0 will be incorrectly received as 1.

block code: An error-control code structure in which each code word is a block containing a fixed number of symbols.

buffer: A storage device that accepts input symbols arriving at a variable rate and retransmits them at a synchronous rate.

coherent detection: A method of deriving additional information from the phase of the carrier.

correlation bandwidth: The width of the frequency band over which the correlation between the fadings of two transmitted tones is equal to or greater than some assigned value, often 0.5 or $1/\epsilon = 0.369$.

deterministic channel: A transmission channel whose output in response to given input signals is exactly predictable, as opposed to a random channel whose output is partly or wholly dependent on probabilistic phenomena.

differential phase shift keying (dpsk): A modulation scheme in which the information is conveyed by changes in carrier phase during one interval relative to the preceding interval.

diversity: A form of transmission using several modes, usually in space or in time, to compensate for fading or outages in any one of the modes. In space diversity system the same signal is sent simultaneously over several different transmission paths, which are separated enough so that independent propagation conditions can be expected. With time diversity, the same path may be used, but the signal is transmitted more than once, at different times. There are other forms of diversity, using different frequencies or different polarizations to provide the separate transmission modes.

Doppler shift: A shift in received frequency caused by relative motion between source and receiver.

Elliott model: One of several mathematical models proposed to describe the clustering of errors in digital transmissions over various media. The Elliott model is a generalization of the Gilbert model described below.

Gaussian noise: Unwanted electrical disturbances or perturbations described by a probability density function that follows a normal law of statistics.

frequency shift keying (fsk): A modulation process in which a 1 is indicated by transmitting a sine wave of frequency f_1 and a 0 is indicated by transmitting a sine wave of frequency f_2.

Gilbert model: One of several mathematical models proposed to describe the clustering of errors in digital transmission over various media.

incoherent detection: Detection wherein the information contained in the phase of the carrier is discarded.

intermodulation noise: Noise introduced in the channel of interest, by signals being transmitted on other channels.

M-ary modulation: As compared with binary modulation in which there are only two possible symbols, a mark or space, in M-ary modulation there can be M possible symbols.

matched filter: An optimum filter for separating a waveform of known shape from random perturbing noise.

modem: Modulator at the transmitter or demodulator at the receiver considered in error control, as part of the transmission channel.

Pareto model: One of several mathematical models proposed to describe the clustering of errors in digital transmissions over various media. The errors are assumed to be distributed according to a statistical distribution first discussed by Pareto in connection with economic models.

phase shift keying (psk): A modulation process in which a mark is indicated by transmitting a sine wave with phase ϕ_1 and a space is indicated by transmitting a sine wave with phase ϕ_2, both phases being measured relative to that of a reference sinusoid.

quantizing: Expressing an analog value as the nearest one of a discrete set of prechosen values.

Rayleigh distribution (fading): A statistical distribution describing the magnitude of a phasor composed of the sum of many component phasors randomly distributed in amplitude and phase. Fading of signals caused by cancellation and reinforcement of contributions received over separate paths often exhibits a Rayleigh distribution.

sequential decoding: A decoding process in which the computation of the intended symbol proceeds until a given confidence in the result is obtained.

sum modulo 2: Binary addition without carry, that is $0 + 0 = 0$; $0 + 1 = 1 + 0 = 1$; $1 + 1 = 0$.

sum modulo 10: Decimal addition without carry, for example, $6 + 5 = 1$.

threshold decoding: A decoding procedure so arranged that the decision on the symbol that was transmitted is based on a majority count of the parity check equations involving that symbol.

code is said to have an efficiency of ¾. However, any single error occurring in the information digits can be detected by checking the fourth digit.

This simple coding scheme is usually implemented in binary rather than decimal form; the message entering the encoder is composed of the symbols 0 and 1. But the same encoding principle applies. The encoder separates the sequence of binary digits into blocks and appends to each a redundant symbol that is the binary sum without carry (sum modulo 2) of the digits in the block.

A typical binary sequence might enter the encoder as 110111010110 and emerge as 11001111010-11100. Adding the redundant check symbol constrains the number of ones in each block of four digits to be an even number—an even parity code.

Other, more elaborate coding structures have been developed to correct and detect errors under specific channel conditions and some of them will be examined extensively in subsequent articles.

II. Media and modems

Constrained symbols are shown leaving the encoder and directly entering the transmission channel in the block diagram on page 126. In practice, discrete symbols cannot be applied directly to the transmission medium without modification. The change is performed by a modulator that generates an analog waveform for each of the symbols. If the constrained symbols are binary, a typical modulator might employ frequency shift keying (fsk), in which a sinusoid at frequency f_1 represent a 0 and frequency f_2 represents a 1. The signals are transmitted over the medium, which might be radio or cable link, and are reconverted at the sink by the demodulator in one-to-one correspondence with the symbols that entered the channel.

The modulator and demodulator, commonly referred to in combination as modems, as well as the medium, strongly influence the distribution of errors among the symbols. Since the transmission channel properly includes the modems as well as the transmission medium any discussion of a channel must include a description of the modem.

There is a tendency of certain modems to cause a clustering or bunching of errors when noise interference disrupts synchronization between the input bit stream at the transmitter and the output bit stream at the receiver.

Modems and types of channels

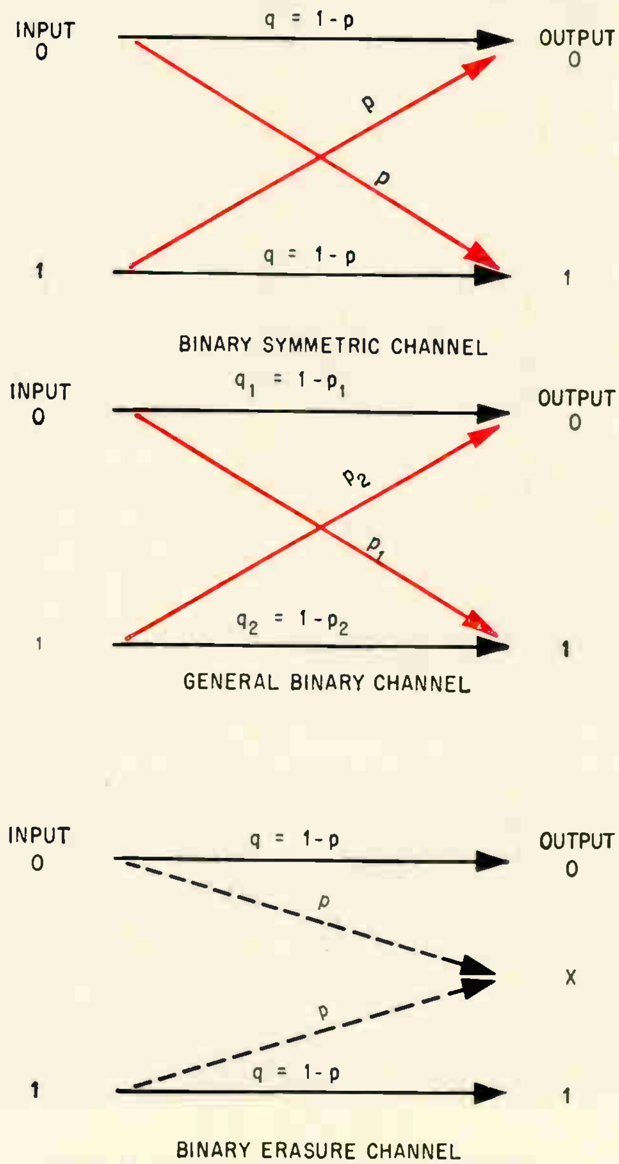
If the modem design dictates a strictly two-level output, and if there is reason to believe that with equal probability either level may be converted accidentally to the opposite level during transmission, then the channel is called a binary symmetric channel. In the top diagram at the right, the two levels are represented as 0 and 1 and the probability that each will accidentally undergo a transition from 0 to 1, or from 1 to 0, is equal to p.

A more general binary channel is shown by the middle diagram. Here the probability, p_1, that a transmitted 0 will be received as a 1, is not necessarily equal to the probability, p_2, that a transmitted 1 will be received as a 0. Such a situation may result with a modem and encoder that accept binary inputs but use multilevel transmissions over the channel before the signal is reconverted to binary symbols at the receiving end. With multilevel, or M-ary, transmissions the level of the transmitted signal represents one of M symbols.

At the output of some modems, it is possible to determine those symbols for which the decoding was ambiguous. The output may be a 0, a 1, or an X, indicating a poorly received symbol. This situation is represented in the bottom part of the diagram and labeled binary erasure channel. Although the erasure properties are shown as symmetric it is possible to have asymmetric erasure channels and even more general channels that combine the features of both the general binary and the erasure-type channels.

Easing error-control requirements

Any component of the basic digital communications system may influence the error performance of the system. For example, where selection is made from a large valume of data, it may be possible to reduce the data at the source instead of at the destination, thereby decreasing the demands on the transmission rate of the link. Or, if there is a high peak-to-average traffic load on the system (when transmitted information arrives in clumps



Binary Transmission channels are classified according to the probabilities that a binary bit will be received correctly or in error. For the symmetric channel, the probabilities are equal that either binary level will be correctly received, q, and incorrectly received, p. In the general binary channel, the probabilities that either binary level will be correctly or incorrectly received are not equal. The erasure channel indicates that either binary level could be correctly received, or received with some doubt as to whether it was correct.

with long dead-times between) the data may be stored and transmission delayed to reduce demand on the system's capabilities. These reductions can be traded off for improved error performance.

At the modulator, waveforms should be chosen to reduce the possibility of mistaking one for another in the presence of the expected type of noise. The demodulator performs a guessing or decision process which may depend on the use of matched filters, integrators or adaptive techniques.

Even the transmission medium itself offers many avenues of possible improvement in performance. Such possibilities include the selection of the most favorable medium and the introduction of diversity or redundant channels.

Error rate and efficiency

The decoding process need not be complex, if both high transmission efficiency and low error rate are not required. The communications engineer must judiciously develop a balance between efficiency, error rate and system complexity.

Assume that only the input and output terminals of a digital transmission channel are accessible, including the modems, and that a coder and decoder must be inserted in the positions indicated in the diagram on page 126. The channel will accept binary symbols at a fixed rate and deliver them to the decoder at the same rate. The channel has a maximum rate at which it can handle data; that rate is fixed by the number of binary symbols per second that the channel can pass and the probability of error in these symbols. This rate is referred to as the channel capacity C.

For the case of a binary symmetric channel that can deliver N binary symbols per second, with a bit error probability p, the capacity is

$$C = N\,[1+p\log_2 p+(1-p)\log_2(1-p)]\ \text{bits/second}$$

A fundamental theorem in information theory states that by properly encoding the input symbol stream, it is possible to transmit information at an average rate C without errors. For example, a channel capable of transmitting 1,000 symbols per second with a bit error rate, or probability of error, of 10^{-3} has a capacity

$$C = 1{,}000\,[1+10^{-3}\log_2 10^{-3}+(1-10^{-3})\log_2(1-10^{-3})] = 990\ \text{bits/second.}$$

At this rate, with proper coding, errorless transmission of information is theoretically possible. Thus, 1,000 symbols per second are transmitted, but 10 of these are redundant and the actual information transfer is reduced. For this example, according to theory, the loss in information rate necessary to permit errorless transmission is only 1.0%. For such a small price, why tolerate any errors at all?

The answer is found in the relationship between the output error probability, the channel efficiency, the delays introduced by the coding equipment and the complexity of the equipment. Reducing the error rate to extremely low values or operating at information rates that are very close to channel capacity are precluded by the complexity of the decoding equipment and by the intolerable delays that would be introduced by the equipment.

III. Practical error control

While it is difficult to establish a precise relation between equipment complexity, efficiency and error probability for the general case, some idea of the problems involved can be obtained from the following discussion.

For block codes, encoding starts by accepting information symbols in blocks of length k and appending redundant parity symbols to the block. Generally, this is not difficult. The difficulty is at the receiving end where the decoder must compare the received block of symbols with each of the 2^k possible input sequences and choose the one that most closely agrees. If k is large, the storage capacity at the decoder must be correspondingly large to remember each of the 2^k possible input sequences.

The length of the input block k, which provides a measure of decoder complexity, has been related to the probability of error at the decoder output for a particular code.[1] However, this relationship, which is typical of the general situation, is

$$P_e = K2^{-kB}$$

where

P_e = probability of error in output bit stream

k = number of information bits per block ($2^k = M$ = number of distinct code words)

C = error-free channel capacity in bits/second

R = information transmission rate in bits/second (here R represents only the information bits in a block, and not the check bits)

K = a slowly varying function of C and R, which is always approximately unity for practical purposes

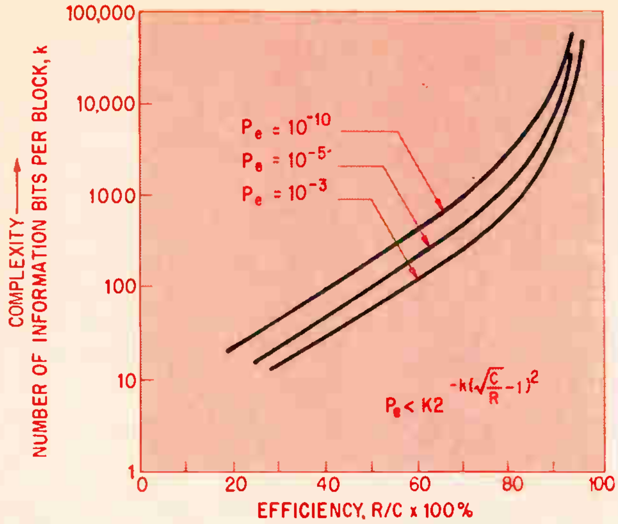
B = a function of channel capacity C and information transmission rate R as given below

$$B = \left(\sqrt{\frac{C}{R}} - 1\right)^2 \quad \text{for } 4 \geqq \frac{C}{R} \geqq 1$$

$$B = \frac{C}{2R} - 1 \quad \text{for } \frac{C}{R} \geqq 4$$

For reasonably efficient transmissions, attention is restricted to the case where $4 \geqq \frac{C}{R} \geqq 1$, so that at least one-fourth of the symbols transmitted contain information. Therefore, the probability of error P_e may be written as

$$P_e < K2^{(\sqrt{C/R}-1)^2}$$



Decoder complexity can be expressed as a function of channel efficiency. To approach 100% efficiency for a fixed error rate, P_e would require an extremely large number of information bits in each block of the code, and a complex decoder.

The set of curves shown in the graph above was obtained from this equation, assuming $K = 1$. From these curves it is apparent that decoder complexity increases drastically as one strives to approach channel capacity (100% efficiency) for a fixed error rate. Furthermore, the curves show that for a fixed efficiency, operation at low output error rates also demands high decoder complexity. The search for ways to overcome this equipment barrier has been a motivating force in the development of techniques such as sequential and threshold decoding, low density parity check codes and error detection with automatic request to retransmit information received in error.

Error rate and delay

The digital communications channel must transmit many kinds of messages including alphabetic and alphanumeric data (teleprinter), computer-to-computer data and digitized forms of speech, television and facsimile. Each of these categories is usually subdivided according to four parameters: message precedence, which specifies the maximum desired delay in message transmission; message length; message structure (in terms of transmitted block size and inherent message redundancy); and maximum allowable undetected bit error rate.

One common form of teleprinter transmission consists of 5-bit, Baudot-coded symbols with additional bits for start and stop. Assuming 6 characters per word, then each word would consist of 42 transmitted bits. A disturbance in the medium, producing an error in one bit, results in either a character error or a stop-start error, leading to a loss of synchronization.

The conversion factor relating bit error rate to its equivalent character error-rate is calculated to be less than 33 for this particular code. That is a bit error rate of 3×10^{-4} or 3 errors in 10,000 bits, will result in a character error rate no worse than 1 in 10^2, or 1 error in 100 characters. The number 33 was derived under the assumption that errors occur independently in the channel.

In setting the error rate requirement for teleprinter transmissions, it is necessary to keep in mind that errors can be introduced by the operators and terminal equipment. It is not profitable to specify undetected bit error rates which are more than 10 times greater than the error rate of the information source, simply because the improvement will not be discernible in the output error rate. Experience has shown that operator-caused character error rates may be greater than 1×10^{-3}.

Teleprinter messages may be strictly alphabetic or they may be alphanumeric. For alphanumeric messages, the inherent redundancy of a language cannot be used to reduce the undetected error probability, and a character error probability between 1×10^{-4} and 3×10^{-4} is usually demanded. This is equivalent to a bit error probability between 0.3×10^{-5} and 1×10^{-5}. For alphabetic text, the inherent redundancy of the language may be used to relax the resultant character error probability to somewhere between 1×10^{-3} and 3×10^{-3}, or a bit error probability between 0.3×10^{-4} and 1×10^{-4}.

A short-term correlation, or bunching of errors occurs in addition to long-term correlation for data transmitted over real channels. Unfortunately, there is no data available on the percentage distribution of errors for code words in error, when the code word length is 7 bits, as in Baudot code. It appears likely, however, that while maintaining the same character error rate, the requirement on average bit error probability may be relaxed by at least a factor of two due to the short-term bunching of errors; that is, error rates of 0.6×10^{-5} to 2×10^{-5} for alphanumeric information and 0.6×10^{-4} to 2×10^{-4} for alphabetic information may be specified.

By replacing the start-stop bits with a synchronous code, which defines each block of information, and regrouping the character blocks into n-bit word blocks, where the length of the word block is greater than the mean duration of an error burst, a further reduction in required bit error rate may be achieved.

A moderate amount of controlled redundancy may be added to long block words by an error-control code, thereby achieving the required undetected error rate even in the presence of channel errors occurring much faster than the required error rate.

In addition to the specification of error rate, the development of an error-control system for teleprinter transmission is also influenced by the following: maximum tolerable end-to-end delay (between transmitter input and receiver output), grade of service (percent of messages delayed more than a specified time); generated volume profiles (amount of information to be transmitted); and the statistical distribution of message lengths.

Computer-to-computer data

Data can be transferred from computer to computer on at least two distinct levels. The communication may be between the computer peripheral equipment, at the transmitting and receiving ends, where the information source is a punched card or magnetic tape; or it may occur directly between the arithmetic sections of the two computers. For communication between the peripheral equipment, the data may be transmitted conveniently in the start-stop mode; but, between the arithmetic sections, the data must flow continuously, and the source is constrained to operate on-line.

Data on a punched card can be represented by 80 characters, maximum, where each character consists of 8 binary bits. In present usage, redundant information for error control is already incorporated into the card format. On each card, 13.5% of all the bits represent redundant information. The data on the card is transmitted character by character.

There is little, if any, inherent redundancy in the computer data stream. It is implied in this discussion that the message is in the nature of accounting data, which has practically no redundancy per bit, as opposed to data representing points on a curve, which is highly redundant. Thus, any channel disturbance can cause the loss of one or more bits, which will not be recoverable at the receiver end.

With error control for punched card data, any single burst of errors up to 8 bits long can be detected and the information recovered by requesting the source to retransmit. Single, double or triple errors and most quadruple and even larger error patterns are detectable. The deliverable undetected error rate and its cost, in terms of data transmission efficiency, are a function of the channel characteristics. Under the assumption of independent error statistics, an average bit error rate on the channel of 1×10^{-4} results in a probability of about 6×10^{-14} that a card containing errors will be accepted. The transmission efficiency under this condition is 81%. About 5.5% of the transmitter cards are rejected because of detectable errors. For channels that are subject to burst errors, the channel efficiency increases, but this is because more cards with undetected errors will be accepted.

This leads to a consideration of the undetected error rate requirements for computer-to-computer communications. From these considerations, a designer can determine whether the previously described error control techniques are sufficient, or whether other, more complicated, error control procedures, must be applied. Again, as in the case of teleprinter transmission, it is useless to specify error rate requirements which are nearly equal to or greater than those of the contributing sources of errors, such as equipment failures. It is estimated that error rates from these sources are about 1×10^{-8} to 1×10^{-10}. Therefore the error rate requirement for computer-to-computer data transmission should be about 1×10^{-9} to 1×10^{-11}.

For computer-to-computer transmissions that must be on-line, error detection with automatic repeat request may not be employed unless the communication facility has a low error rate and sufficient buffering, or temporary storage, to absorb incoming data during disturbed channel conditions. Otherwise, with this type of system, a forward-acting error-control code is required to preserve the on-line function. And it is important to know the statistical distribution of channel outages in order to choose a forward-acting error control code that will provide the required undetected error rate economically. This is important because the cost of error-control equipment increases somewhat with the duration of bit outages that the equipment must handle. The duration of channel outages that can be economically accommodated is a function of the source bit rate.

Coders and decoders presently can handle a loss of 2,400 to 3,000 bits. At a transmission rate of 2,400 bits per second, this is equivalent to a maximum channel outage of 1 to 1.25 seconds.

Digitized voice signals

Analog voice signals are usually transmitted over a subchannel whose bandwidth is nominally 4 kilocycles per second. It has been estimated that the information content of the digital voice signal is as low as 50 bits per second. Direct digital encoding of an analog speech signal by sampling, quantizing, or pulse code modulation techniques requires a bandwidth of 56,000 bps. With fixed channel vocoding techniques, the bit rate required to transmit speed in digital form with adequate scores on intelligibility, articulation, and speaker recognition tests, has been reduced to 2,400 bps. There are other vocoding techniques, which will eventually reduce this bandwidth still further to 1,200 bps, and even to 300 bps but with markedly reduced quality.

The significance of digitized voice signals, whether at 1,200 bps or 56,000 bps, is their high inherent redundancy and, in consequence, low error-rate requirements. Tests to determine the loss of intelligibility of digitized voice transmissions show that an error rate of 2×10^{-2} is tolerable. In fact, over-all speech quality does not degrade significantly until the error rate exceeds 5×10^{-2}.

Error control is not required for present voice digitizing techniques and it probably will not be required until vocoding techniques have advanced to the point where digitized speech can be transmitted with a bandwidth of 300 bps.

Data rate

In addition to source requirements such as error rate, delay, and traffic loading, the error-control equipment must be capable of handling the data rate and message format of the source.

The data rate is an important factor in the selection of modems and on coding efficiency. Recent studies have shown that for data rates of 1,200 bps over typical voice channels subject to Rayleigh fading (for example, in tropospheric scatter communications) there is little difference between the performance of frequency shift keying (fsk) and differential phase shift keying (dpsk). Therefore, at 1,200 bps, the advantage lies with the fsk modems since they are cheaper. On the other hand, when the data rate is 2,400 bps, dpsk has an inherently lower error rate than fsk, and the improvement in performance may justify the additional cost for a dpsk system.

Once the type of modulation has been determined, the modems are considered as part of the channel and the coder and decoder are constrained to operate with it. Any attempt to increase redundancy by coding implies an increase in channel bit rate for a fixed user information rate. But, as the bit rate is increased, the basic error rate of the channel usually increases. This means that any improvement in output error rate gained from the additional code redundancy, could be partially or completely negated by the deterioration of the channel error rate.

IV. Media characteristics

Since the choice of modem significantly influences the error statistics of the received signal, it is desirable to compare several signal selection schemes and to evaluate their effectiveness in minimizing channel-error rate for a variety of assumed channel conditions. The selected modem can be further evaluated on the basis of the results of tests reported in the literature.

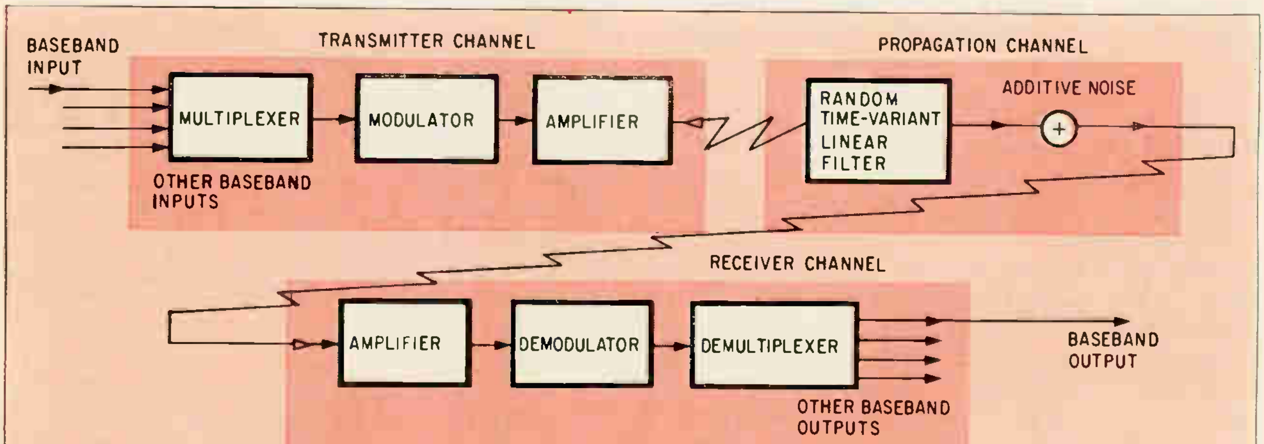
Some of the basic signal transformations in a communication channel are on page 134. The major types of channel disturbances[2] are listed in the table at the right.

The relationship among equipment imperfections, propagation disturbances, and channel error statistics is not generally established for most digital transmission links. Prediction of their performance at present, is best based on error statistics derived from testing other properly designed digital links. The results of these tests can be examined to determine mean error rates, the statistical distribution of the duration of error-free intervals and error-burst lengths. In addition, the statistical distributions can be examined for the possibility of discovering a statistical model of the channel that represents the measured statistics reasonably well. Such a channel model, although not essential to the evaluation of coding procedures for effective error control, can make the task much easier.

Modems and error performance

Many signal selection techniques have been implemented in modems, and each has a unique response to the input signal waveform. Basically, modems use either the phase or the frequency of the transmitted signal as the information-bearing mechanism. They use either binary modulation or multilevel modulation; the latter commonly called M-ary modulation. The subject of M-ary signaling has been discussed in communications literature for a number of years.[3,4,5] With this technique, each transmitted waveform carries more than one bit of information, so that the receiver must decide which bit of information, among the M-alternative waveforms, was transmitted.

Analysis of a modulated waveform in the time domain reveals its efficiency with respect to transmitter power. Analysis in the frequency domain (spectral density), facilitates an examination of its efficiency with respect to bandwidth utilization. The spectral density function, or power spectrum, defines the distribution of average signal power as a function of frequency.



Transmission channel. For error control the digital communications channel is considered as including parts of the transmitter and receiver, and the propagation medium itself. Errors can occur in the transmitter or receiver channel because of the equipment. In the propagation channel, errors can occur because the behavior of the medium isn't constant, or because the signals become affected by the noise in the medium

Important channel anomalies and associated disturbances

Transmitter channel		Propagation channel		Receiver channel	
Anomalies	**Disturbances**	**Anomalies**	**Disturbances**	**Anomalies**	**Disturbances**
Amplifier nonlinearities	Intermodulation noise in linear demodulation schemes	Additive noise	Additive noise	Additive noise	Additive noise
Nonlinear phase and nonflat amplitude versus frequency characteristics	Intermodulation noise in nonlinear demodulation schemes	Multipath effects (frequency selective effects)	Interchannel interference, intersymbol interference and symbol distortion, intermodulation noise in nonlinear demodulation schemes	Nonlinear phase and nonflat amplitude vs frequency characteristics	Intermodulation noise in nonlinear demodulation schemes
Carrier shifts	Interchannel interference produced in receiver channel, reduction in strength of demodulated digital signals	Doppler shift effects (fading or time selective effects)	Interchannel interference and symbol distortion	Carrier shifts	Interchannel interference, reduction in strength of demodulated digital signals
				Imperfect synchronization	Intersymbol interference, reduction in strength of demodulated digital signals

Each of the three channels can affect the transmitted signal. For example, in the propagation channel, the signal is subject to Doppler shift, which can cause distortion in the signal's waveform or interference between signals carried on adjacent frequencies.

For a channel whose response is deterministic and time invariant, an optimum modulation waveform can by synthesized from the spectral density and power spectrum. Such is not the case for a channel that exhibits selective fading and additive noise. In this instance, the channel characteristics must be accurately defined and suitable receiver equipment must be developed.

Three channel models are used to evaluate the effect of a channel on the modulation schemes. One channel model assumes additive, white Gaussian noise as the only perturbing factor. Another model includes the effect of a Rayleigh-distributed fading signal. The third channel model includes the effects of frequency selective fading in addition to the previously mentioned effects.

The table on page 134 gives theoretical expressions for bit error probabilities for matched-filter coherent and incoherent detectors, and it shows that psk is superior for channels that include noise and Rayleigh-distributed fading.

Nonfading and Rayleigh fading channels

For the channel model that assumes additive, white Gaussian noise, the error probability for an ideal receiver (matched filter-coherent detection) is given by

$$P_e = \tfrac{1}{2}\left(1 - \text{erf}\sqrt{\frac{E\,(1-p)}{2N_o}}\right)$$

where E is the average signal energy per bit, N_o the white noise power present in the bandwidth of interest, and p the cross-correlation coefficient of the mark and space waveforms ($-1 \leq p \leq 1$).

In the preceding equation, p is the only parameter that depends on the choice of the modulation system. For a psk signal, $p = -1$, which represents the optimum case. In an fsk system, if the difference between the signaling frequencies is equal to or greater than the digit rate (representing most cases of practical interest), then $p = 0$. By substituting into the equation for P_e, $p = -1$ for the psk case, and $p = 0$ for the fsk case, it follows that E/N_o must have twice the value for fsk as for psk to obtain the same probability of error. Thus, with respect to error probability due to noise, psk has a 3-db advantage over fsk for the postulated channel model.

In addition, psk receivers work on correlation detection principles and their performance is nearly optimum. Fsk receivers are usually envelope detectors, so they suffer an additional 2- to 3-db degradation.

However, differential phase shift systems yield a higher error rate than an ideal psk system, since an incorrectly sensed digit causes an error both for itself and for the subsequent digit with which its phase is compared. For isolated errors in a dpsk system, the error rate is therefore doubled; although for other error distributions, the effect is

Theoretical expressions for bit error probabilities

Signaling method	Receiver characteristic	Nonfading medium	Fading medium (Rayleigh distributed)
Frequency shift keying (fsk)	Matched filter-coherent detection	$1/2\,(1 - \text{erf}\sqrt{E/2N_o})$	$1/2\left[1 - \left(\frac{\bar{E}/N_o}{\bar{E}/N_o + 2}\right)^{1/2}\right]$
Frequency shift keying (fsk)	Matched filter-incoherent (envelope) detection	$1/2\epsilon^{-E/2N_o}$	$\frac{1}{\bar{E}/N_o + 2}$
Phase shift keying (psk) (perfect pilot tone consuming zero power)	Matched filter-coherent detection	$1/2\,(1 - \text{erf}\sqrt{E/N_o})$	$1/2\left[1 - \left(\frac{\bar{E}/N_o}{\bar{E}/N_o + 1}\right)^{1/2}\right]$
Differential phase shift keying (dpsk)	Matched filter-differentially coherent detection	$1/2\epsilon^{-E/N_o}$	$1/2\left(\frac{1}{\bar{E}/N_o + 1}\right)$

Bit-error probability depends on three considerations: whether the propagation medium is a fading or nonfading type; the signal modulation technique used at the transmitter; and the signal detection technique used at the receiver. If these considerations are known, the bit error probability can be calculated from the appropriate theoretical expression in the table, which assumes that white Gaussian noise is present in the medium. In the expressions, E is the signal energy per bit (assumed equal for mark and space signals), $\bar{E}$ is the average received signal energy, N_o is the noise power in a one cycle bandwidth, and the notation erf is the tabulated error function, given below:

$$\text{erf}\,(x) = \frac{2}{\pi}\int_0^x \epsilon^{-t^2}\,dt.$$

less severe, and dpsk systems like psk systems have a lower error rate than fsk systems.

Theoretical expressions for bit error probabilities caused by a nonfading channel for each of the various modulation detection techniques, are given in the third column of the table above.

Each of the modulation detection techniques has a different bit error probability in a channel whose signal is subjected to Rayleigh-distributed fading. Expressions for these bit error probabilities have also been derived and are summarized in the last column of the table. From these expressions it can be demonstrated that when $\bar{E}/N_o$ is very large, the error probability for psk with an ideal receiver is half that for fsk with a similar receiver. This improvement factor decreases slowly with decreasing $\bar{E}/N_o$. The error rate for dpsk also approaches one-half that for fsk, when $\bar{E}/N_o$ is large.

Frequency selective fading channel

The third channel model used to calculate binary error probabilities for fsk and dpsk signals assumes frequency selective fading[6]. In this model, all frequencies within the channel bandwidth do not fade in and out simultaneously as they do in the simple Rayleigh-fading model. Instead, the different frequencies within the channel bandwidth fade more or less independently—more independently if the frequencies are widely separated, less as the frequencies approach one another.

In such a medium, the error probability does not vanish as the additive noise vanishes and the signal-to-noise ratio goes to infinity. For this channel, there is an error probability that can't be reduced. This is to be expected because the waveform distortion caused by the selective fading causes interference between symbols, which will introduce errors, even in the absence of additive noise. Whether fsk or dpsk has a smaller error rate for this channel model depends on the desired bit error probability, the data transmission rate required, and the correlation bandwidth of the medium. Correlation bandwidth indicates the width of that group of frequencies which have strongly correlated fading in the medium.

For a dual-diversity system that has a channel correlation bandwidth B_c, a delivered error probability of 10^{-5}, and a data rate of $0.1B_c$, the fsk system suffers almost no additional degradation due to the frequency selective behavior of the channel. However, for dpsk, the degradation is in excess of 6 db. For very low error probabilities of about 10^{-6}, the fsk mode permits operation at a much higher data rate than the dpsk system, if the signal arriving at the receiver has sufficient power.

Measured error statistics

Measurements of error rates have been taken on a variety of switched telephone networks in the

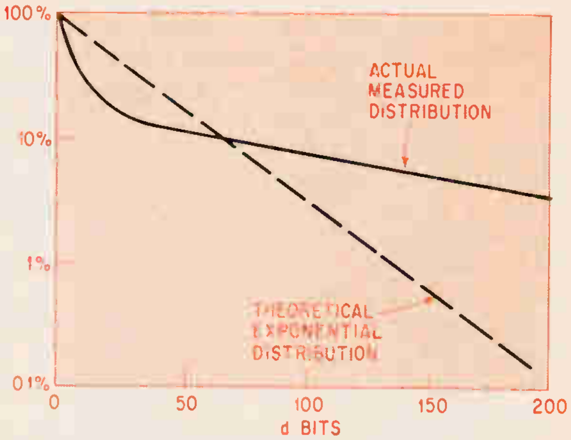
United States[7, 8, 9] and England[10]. In the British tests, the modems accepted messages that were binary coded and operated at data speeds of 100 to 3,000 bps. A pattern generator of 511 bits simulated actual data traffic. The receiving pattern generator was synchronized to the received line signal so that during a noise disturbance no apparent errors were added to the actual errors by the testing equipment. Every information bit was recorded, along with an indication of whether it was received correctly or in error, or whether a circuit interruption occurred. This recorded information was analyzed with the help of data reduction techniques.

Some of the results are presented graphically in the three charts at the right. Perhaps the most important characteristic of the circuit tested is the statistical distribution of the lengths of error-free periods. The chart at the top shows the measured distribution of intervals between errors that exceed the abscissa value, d, in bits. Before discussing this result, it will be informative to examine the statistical distribution obtained if the errors occur independently and the probability of error is constant. In such a case, the probability, P, that the interval between errors will exceed the interval represented by d bits, is obtained from the exponential distribution $P = \epsilon^{-\lambda d}$, where λ is the mean error rate.

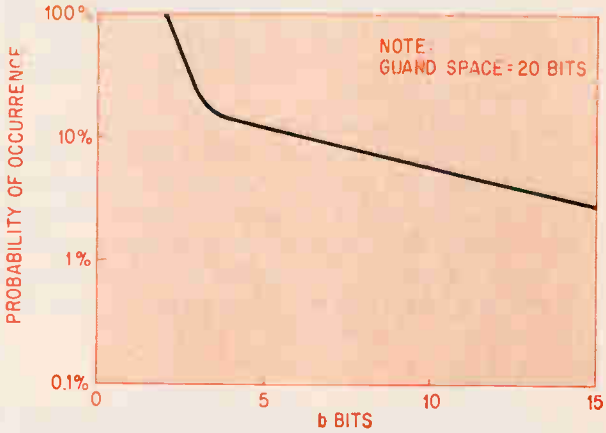
A plot of P versus d on semilogarithmic coordinates yields a straight line whose slope is proportional to λ. This is shown in the graph, where the actual measured distribution and the theoretical exponential distribution have the same mean error rate. The departure of the measured distribution from the exponential distribution indicates a short-term correlation, or bunching, of errors of from 15 to 30 bits. After an error occurs the probability that it will be followed by another error within 15 to 30 bits is higher than that predicted by the exponential distribution.

Another important characteristic of the measured distribution is the burst length of errors. Since useful working definitions of an error burst depend somewhat on the error code there is no standard definition of burst length. However, for illustrative purposes, a guard, or error-free, space of 20 bits has been selected as the minimum number of consecutive error-free bits separating two bursts. The measured distribution of error bursts exceeding a length of b bits is shown in the middle chart. The knee in the curve at b = 3, indicates a tendency toward burst errors, which couldn't be predicted by the exponential distribution curve. The distribution of the distance between bursts is shown in the chart at the bottom of the page.

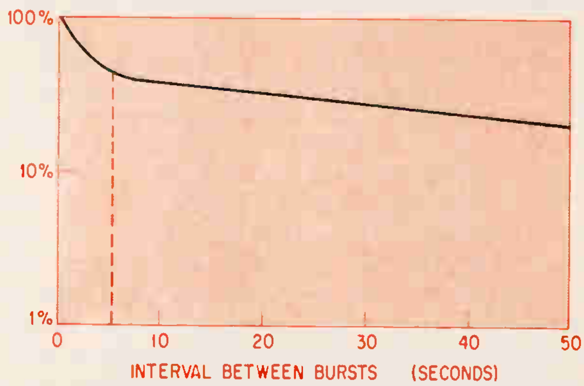
Extensive testing of switched telephone networks at 600 and 1,200 bps was reported by Alexander, Gryb and Nast.[7] The results show the error-free transmission time between successive bursts of various sizes where a burst of length N is defined as a sequence of bits that starts with an error bit and extends for N-1 additional bits, whether or not the additional bits are in error. The curves of



Statistical distribution of intervals between errors. The theoretical curve is based on the assumption that errors occur randomly and that the probability of error is constant. But this isn't the case when data is measured on an actual channel. The curve plotted from the measured data shows that there is a higher probability that another error will occur within 30 bits of the previous error.



Measured statistical distribution of error-burst lengths, plotted as a function of a number of binary bits in the burst. The curve indicates that 90% of the error bursts last less than 7 bits.



Measured statistical distribution of intervals between bursts of errors, plotted as a function of time. The data shows that the probability is rather high that the time between error bursts is less than five seconds.

the measured data in the report form a basis for two suggested channel models. These models, Elliot's modification[11] of Gilbert's burst-noise channel model[12] and the Pareto model[13], are useful for comparing predicted and measured statistical error distributions. The Gilbert model is the more satisfying of the two because it permits an intuitive understanding of the behavior of the channel. The Pareto model is a purely mathematical statement and its major advantage is that it appears to yield a better representation of the channel error statistics for certain media. This model does not, however, throw any light on the mechanism of error generation.

Pareto model

The Pareto model is a heuristic statistical model for describing the occurrence of errors in data transmitted over telephone circuits. An examination of these measured distributions reveals that the probability G(t) of an error-free interval exceeding t (in bit durations) is closely approximated by $G(t) = 1$ for $t < 1$, and $G(t) = t^{\alpha}$ for $t \geqq 1$, where α is a constant that is derived from measured data for a particular channel. Successive error-free intervals are distributed independently according to the same distribution.

On the other hand, certain data appears to indicate that for some circuits the interval between errors approaches an exponential distribution for large intervals, which is not consistent with the Pareto model. Further experimental data for different types of media is required before making a definite determination of which model is most appropriate to each medium.

Gilbert model

A model of channel behavior has been suggested by Gilbert[12] in which the channel is characterized by two states, good and bad. The transition probability from good to bad is assumed to have a value P_1. The transition probability from bad to good is a different value, P_2. If these probabilities are not too high, each of the two states tends to persist. It is further assumed that no errors occur during the good state, but that a rather high error rate, p_e, occurs during the bad state. As a result, the errors predicted by such a model tend to cluster, simulating the observed burst behavior of measured channels. By adjusting the parameters P_1, P_2 and p_e, a reasonable correlation with much of the observed data can be obtained.

This model was improved by allowing an error rate to occur in the good state as well as in the bad state. Of course, the error rate in the good state is chosen to be very low compared with that assumed for the bad state. But the additional flexibility afforded by the extra parameter permits a better correlation to observed data.

Selecting the code

The best code for a communications system depends on the characteristics of the transmission medium, the rate of information transfer, the modulation techniques employed, and the required accuracy in the received data.

Subsequent articles in this series will describe error-control codes and their application, error-control systems such as automatic repeat request (arq) and forward error correction, and the final article will survey available error-control hardware.

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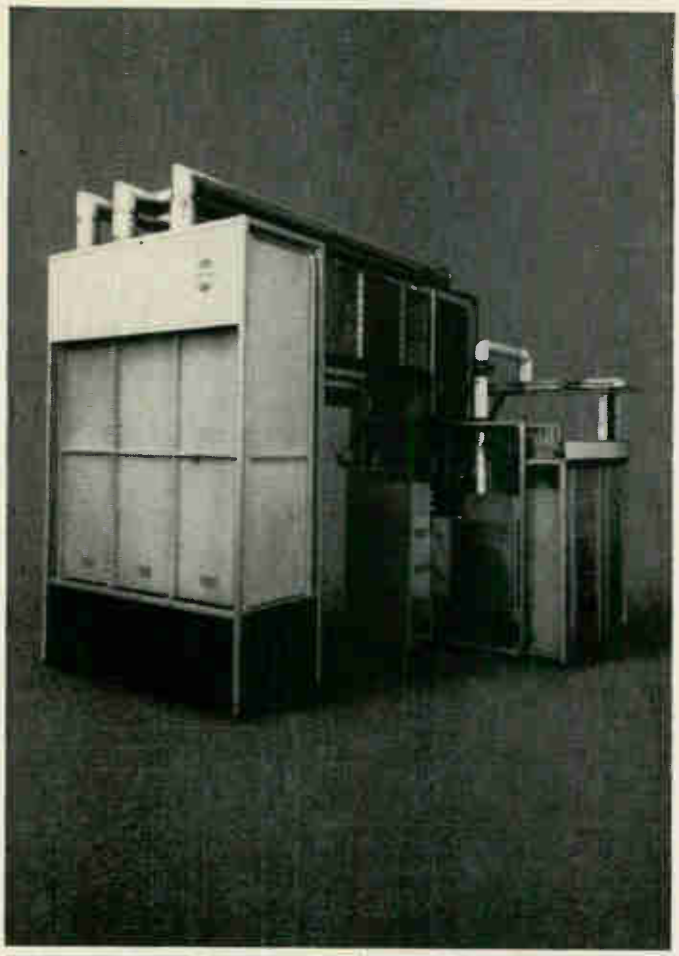

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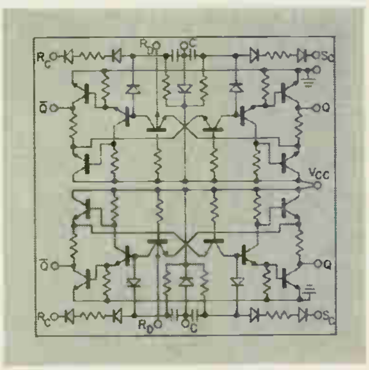
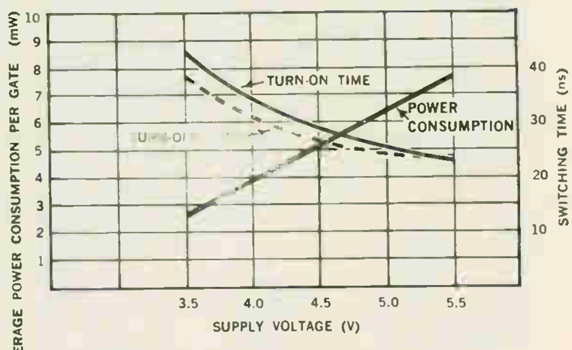
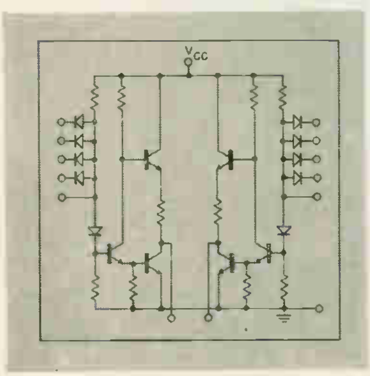


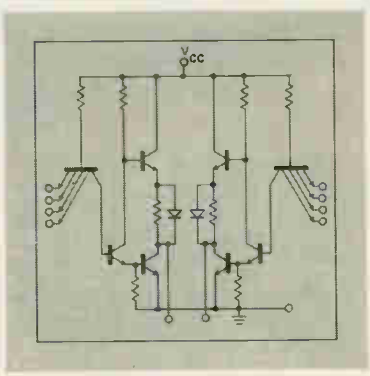
SE424 DUAL BINARY



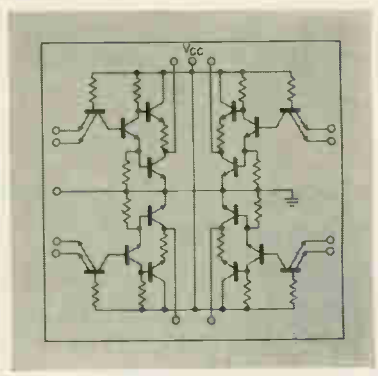
SPEED-POWER CHARACTERISTICS OF SE400 FAMILY



SE416 DUAL NAND GATE



SE455 DUAL DRIVER-BUFFER



SE480 QUAD NAND GATE

SIGNETICS INTEGRATED CIRCUITS

A subsidiary
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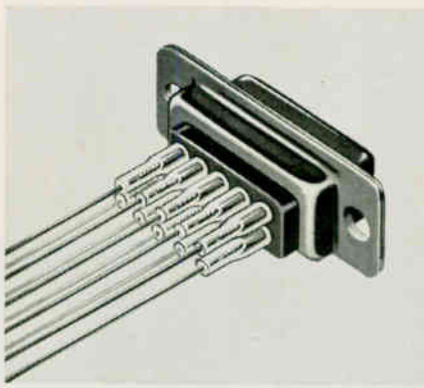
811 East Arques Avenue,
Sunnyvale, California
Tel.: (408) 739-7700
TWX: (910) 737-9965

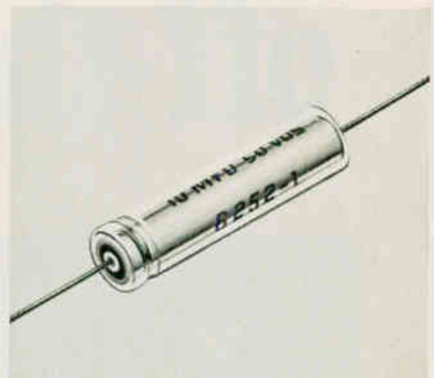
Four reasons for using heat-shrinkable tubing of Kynar*! *(1) It's two to three times tougher than any other shrinkable plastic tubing. (2) It's thermally stable... operates at 150°C, flexible at −65°C. (3) It shrinks 50% at 175°C. (4) It's UL approved for 600 volt rating at 150°C. And how can you use it? Here are just five of the many ways.*

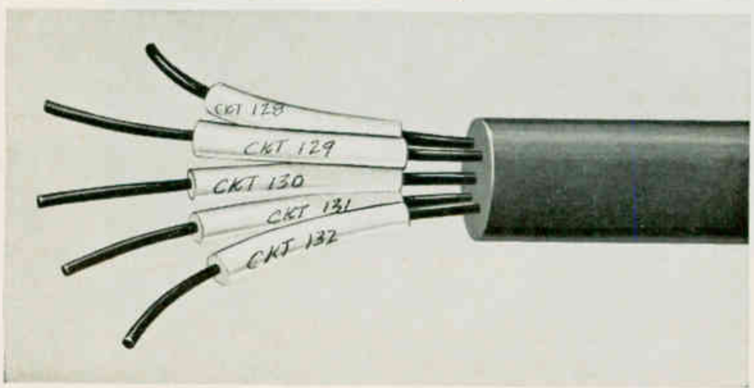
For corrosion protection—Resists chemicals and weathering at battery terminals.

For strain relief—Transfers flex stress away from joint; protects conductors.

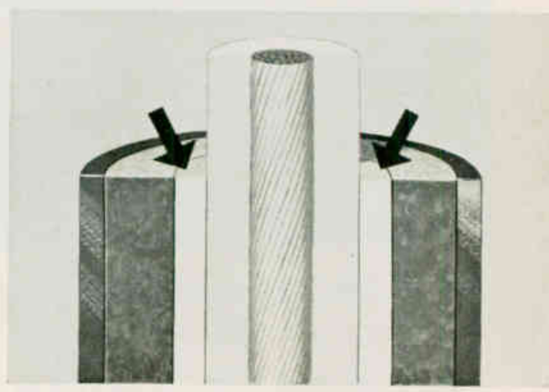


For insulation and mechanical protection—Capacitors, resistors, diodes.





For identification—Eliminates the need for stocking colored or printed wire.



For sealing out moisture—Used over TFE insulation to bond with potting compounds.

*If you are using or considering heat shrinkable tubing, investigate all the advantages of specifying Kynar. It's available in a range of diameters from Raychem Corporation as Thermofit** Kynar. For information, write Plastics Department, Pennsalt Chemicals Corporation, 3 Penn Center, Philadelphia, Pa. 19102.*

Kynar... a fluoroplastic that's tough!

**Kynar is a registered trademark of Pennsalt Chemicals Corporation for its vinylidene fluoride resin*

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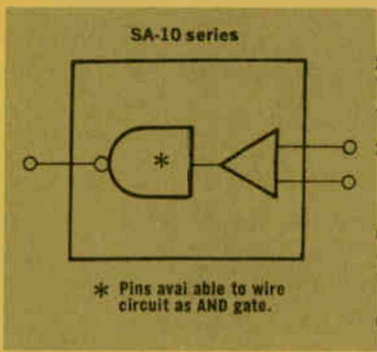
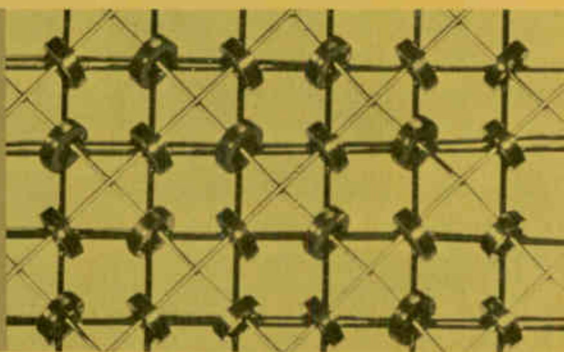
Newest sense amplifier solves wide range of memory subsystem problems





An unusual combination of extreme sensitivity with both minimum offset and high common mode rejection are important characteristics of an outstanding new sense amplifier from Sylvania.

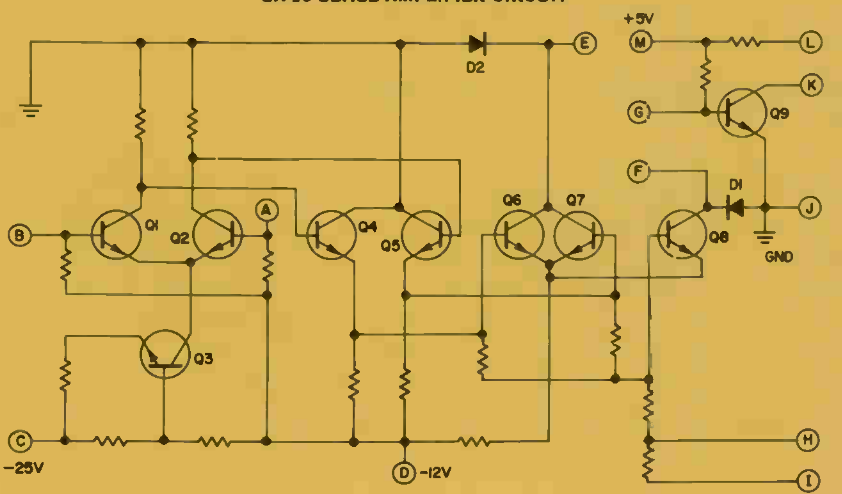
A monolithic silicon epitaxial device, the SA-10 includes a differential amplifier, an externally variable threshold detector, and a positive or negative going digital output gate. This sense amplifier is designed for effective operation throughout the temperature range −55°C to +125°C. It is available in the standard 14-lead flat package.

Especially important to design engineers is the unit's compatibility with the entire SUHL (Sylvania Universal High-level Logic) line. And it can be readily used in conjunction with any other digital logic family. Still other performance characteristics include high speed, fast response time and a wired OR'd capability.

Here, in brief, is how the sense amplifier works. The device's input stage is a differential pair, fed from a current source, with the output connected to a pair of emitter followers. The emitters in turn are grounded through a series of four voltage dividing resistors. An intermediate voltage from the dividing network is the Q8 base voltage. Q8 is normally on and supplies current through its emitter resistor to the −12 volt side. This current sets the reference voltage on the emitters of Q6 and Q7 with the result that the Q6 and Q7 are back-biased.

A positive signal at the base of either Q6 or Q7 overcomes this back-bias, turning either one of them on. This additional current also raises the potential at the emitter of Q8, shutting it off and diverting current flowing through its collector resistor into the base of Q9 This action saturates Q9, producing a negative going output. A negative going output requires

SA-10 SENSE AMPLIFIER CIRCUIT



This issue in capsule

Integrated Circuits—this first single-product issue of IDEAS is totally concerned with ICs, componentry that has had a profound impact on system design. Included are stories on:

Divide-by-Seven—a new simple means to performing this operation.

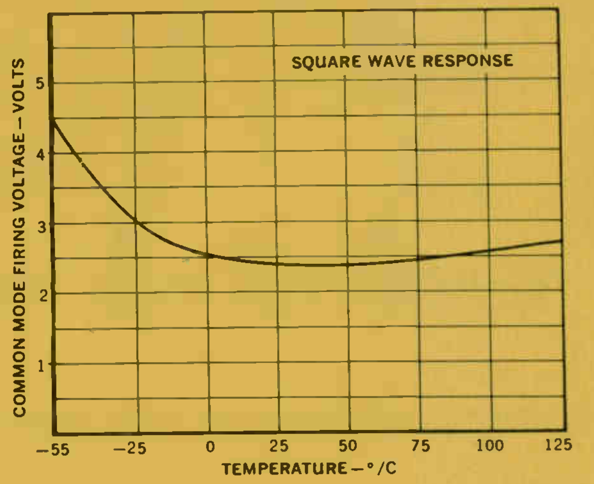
Wired ORs—up to eight gates with a new high-efficiency, low-cost method.

Multivibrators—a new approach to monostable multivibrators with a discrete component timing network.

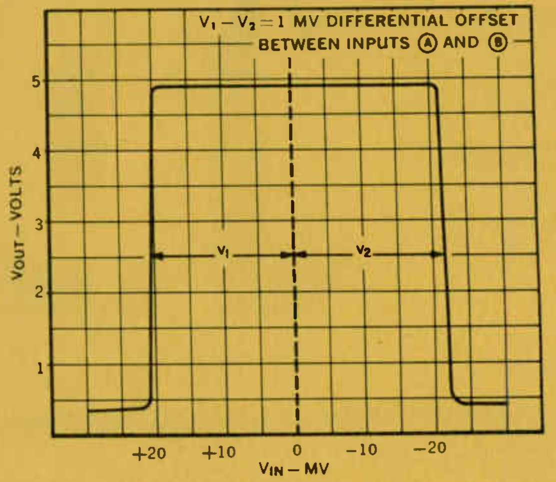
Counter Registers—how to build a 20-mc shift-left shift-right register with only four J-K flip-flops.

Status Report—two complete IC lines with an unusual combination of plus-characteristics, including the fastest saturated logic yet available.

TYPICAL COMMON MODE REJECTION VS TEMPERATURE. GRAPH NO. 5



TYPICAL VOLTAGE TRANSFER CHARACTERISTIC. GRAPH NO. 10



that leads G and F be connected.

If a positive going output is desired, leads G and E must be connected. As a result, lead F remains at −0.7 volts due to diode D-1. In the positive mode, the circuit operates in the same manner as in the negative mode, with Q6 and Q7 back-biased, Q8 on, and Q9 saturated. When an input signal causes either Q6 or Q7 to turn on, the Q9 base current is diverted, resulting in a positive going output.

The sense amplifier threshold level can be altered externally by varying the potential and/or the resistance at leads H and I. Under normal operating conditions leads L and K can be connected or external load resistors can be used.

SENSE AMPLIFIER CHARACTERISTICS

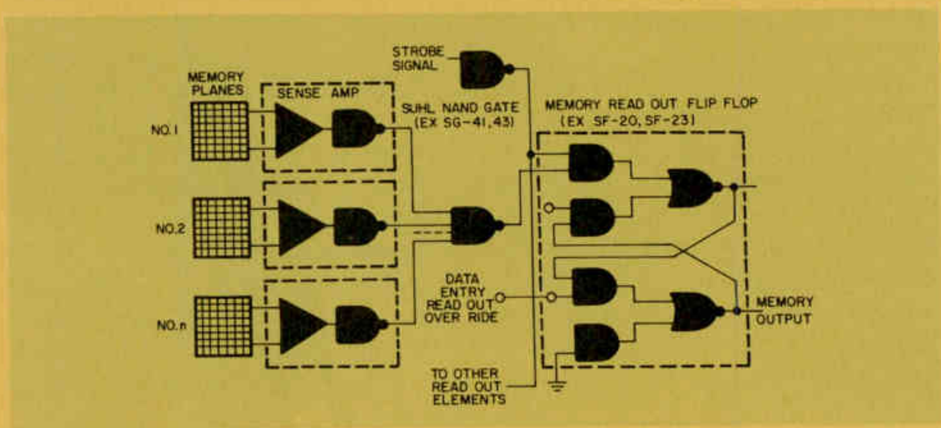
Power Supplies	+5 volts, −12 volts, −25 volts	Common Mode Rejection	±2.5 volts
Power Dissipation	120 milliwatts	Propagation Delay at 20 millivolts	50 nanoseconds
Temperature Range	−55°C to 125°C	Recovery Time at 1000 millivolts	100 nanoseconds
Differential Input Threshold Voltage	20 millivolts	Input Impedance	120 ohms
Differential Input Threshold Voltage Offset	2 millivolts	Output Impedance	Saturated output
Frequency Response	−3 decibels at 5 megacycles	Output Swing (Note: outputs can be OR'd directly)	0 to 5 volts, leads G and E connected; 5 to 0 volts, leads G and F connected

How SA-10 sense amplifier provides sensitive core memory readout

The Sylvania SA-10 sense amplifier can effectively provide readout from a medium-size coincident current memory. The diagram here shows how.

In this instance the sense amplifier output is normally high. Output from any of the sense amplifiers causes a corresponding output to the memory readout flip-flop.

The readout flip-flop, in turn, is AND'd with the strobe pulse which is generated by a gate.



GENERAL MANAGER'S CORNER—Integrated Circuits

ICs compromised or optimized?

The critical and analytic members of the electronics community today recognize that there exist important criteria for a company to be successful in integrated circuits. Using profits and sales leadership as yardsticks for success, we recognize that a new company venturing into this dynamic field of integrated circuits must demonstrate capability in three important areas: namely (1) having a composite of highly competent personnel in both the technical and business areas, (2) a sound management and organizational philosophy, and (3) the necessary large amounts of financial capital to weather the early years. These resources are, without question, the important ingredients that both customers and analysts alike look for in their evaluation of an integrated circuit manufacturer.

Although there is no argument that these resources are extremely important, we often neglect the consideration of how these resources are applied in today's rapidly changing technology. The science and art of integrated circuits is subject to many and varied interpretations by the semiconductor industry, and one will find that a great many manufacturers use their resources in different ways. To a large extent, many make extreme compromises in aspects of the technology for the sake of expediency in their rush to the marketplace. Compromising what resources offer provides a compromised product in terms of value received by the customer.

Sylvania's philosophy with regard to integrated circuits is the very antithesis of compromised technology. With the same three vital resources available to us, we will continue to apply them toward a single end: designing and producing digital ICs along the lines of *optimization*, rather than *compromise*. With this philosophy, Sylvania must optimize five distinct factors—(1) choice of logic circuit, (2) the monolithic process, (3) the photoresist level of resolution, (4) the package, and (5) the degree of production mechanization.

Engineering emphasis has been placed on the choice of high-level TTL digital integrated circuits. This circuit form, unlike any other, offers the best speed-power product for saturated logic and provides the highest level of noise immunity. TTL is truly a systems-oriented circuit design, whether it is destined for military or commercial application.

Of the many monolithic processes available today, Sylvania is working completely with thin single epitaxial layers with buried layer diffusions. These important steps provide integrated circuits with the optimum combination of very high fan-out capability and extremely low parasitic capacitance per unit area. In addition, it provides the most economical form of wafer fabrication, since the processing time and investment, in both epitaxy and isolation diffusion, are greatly reduced.

In the area of photoresist technology, Sylvania integrated circuit masks are designed with registration tolerances of 25-millionths of an inch as well as alignment clearances as small as 0.1 mil. Two years of experience with this ultra-fine line technology enables us to operate with ease at these levels in production. Furthermore, this high degree of resolution provides ICs with extremely small isolation areas and, consequently, extremely high frequency performance.

Flat packages and plug-in packages have been designed using a ceramic-filled glass technique. This provides a combination of hermeticity comparable to TO-5 and TO-18 packages, and extremely low thermal resistance with very definite economic advantages in package fabrication.

Finally, in the area of production tooling, Sylvania's extensive equipment experience provides an integrated circuit production operation unique in the industry. Such important items as the widespread use of laminar flow hoods, high-volume epitaxial systems, automatic aligners and unattended, computer-operated, 14-point probes can be seen in our integrated circuit wafer operations. In the assembly area, mechanized belt transfer of packages through the die bonding, aluminum wire bonding and sealing operations provides an integrated circuit flow at extremely high rates with virtually non-discretionary operations. In final test, all integrated circuits move through completely automatic computer-operated DC and switching tests at *rated temperature* and then are automatically sorted according to customer requirements.

From all of the optimizations in these several areas comes the SUHL line of Sylvania's integrated circuits. The evolution of performance in relation to competitive lines is best illustrated in this table:

Logic Family	Speed	Noise Margin	Power
RCTL	Low	Low	Low
RTL	Medium	Low	Low
DTL	Medium	Medium	Medium
TTL (SUHL I)	High	High	Medium
CTL or ECL	Very High	Low	High
SUHL II	Very High	High	Medium

Obviously, advantages like these in the competitively priced SUHL lines can't result from compromised technology. Inescapably, tomorrow's industry leaders are today's technological leaders.

A. B. PHILLIPS

Now, a one-shot multivibrator IC with discrete components

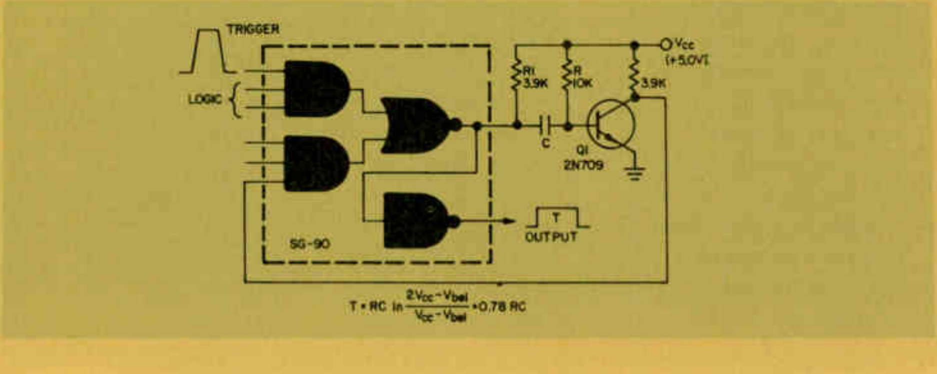
The circuit shown incorporates a single SUHL SG-90 series (Exclusive OR with Complement) integrated circuit with a discrete component timing network. The input arrangement of the SG-90 series is ideal for the combination of input trigger isolation and regenerative "lock up," necessary for a monostable multivibrator.

The trigger is a standard SUHL input with remaining inputs (read and write commands) available to gate the trigger. The output inverter provides isolation of the timing network and circuit drive capability.

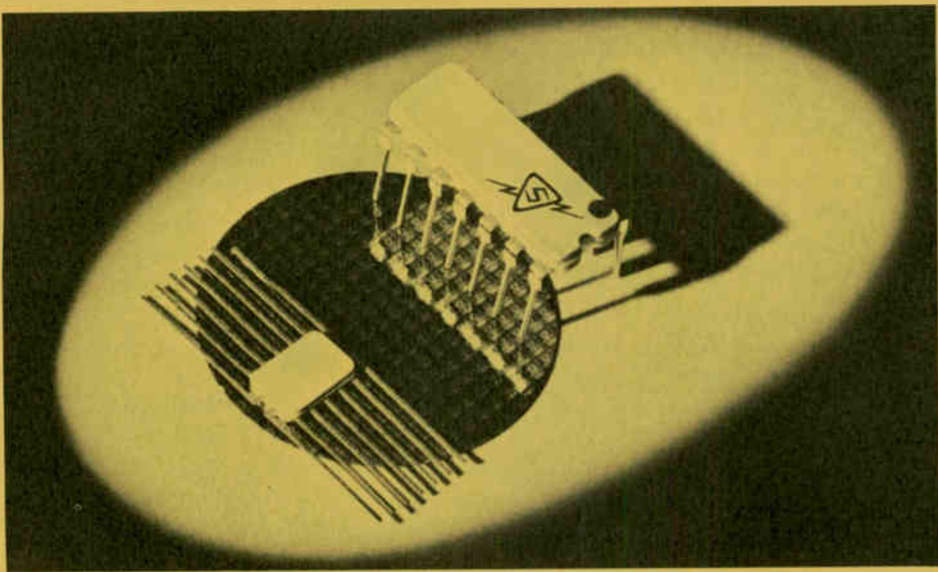
The positive edge of the input pulse turns transistor Q_1 off while forcing the output of the inverter gate high to present the leading edge of the output pulse. The output of Q_1 is fed back to the other side of the Exclusive-OR gate. When collector voltage reaches the gate Logic "1" threshold, Q_1 locks in the output condition established by the trigger pulse.

The high output level of Q_1 will persist until the capacitor has charged up to the E-B threshold of Q_1, turning it back on. The output pulse can never be shorter than the input pulse. Minimum input pulse width equals the T_{off} of Q_1 plus Td_{on} of the Exclusive-OR gate (typically 30-nsec).

An alternate approach, depending on the application, would be use of the SG-110 to perform the Exclusive-OR function and an SG-40 for the inverter stage. While requiring two packages, each element can be utilized to its maximum fan-out capability.



Your status report on two complete IC lines



In the time that Sylvania's two lines of integrated circuits have been available, both SUHL I and, more recently, SUHL II have proven to be the highest quality lines of the industry.

By early 1965, Sylvania had developed several series of ICs using the unusually efficient basic SUHL I circuit shown here. The computer industry found that it was a low-cost, extremely reliable line that reduced can counts without compromising even the severest systems requirements. Today SUHL I circuits are providing designers with the largest selection of compatible digital functions designed especially for tomorrow's computer systems.

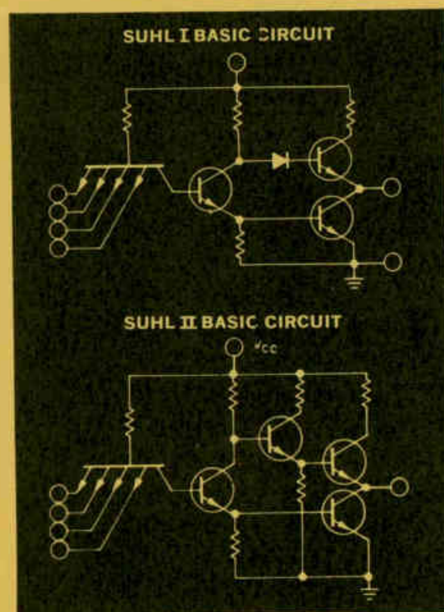
Then in August, Sylvania announced SUHL II, the first integrated circuit line that satisfies extreme high-speed requirements while allowing all other vital characteristics to maintain their full levels of efficiency. Previously several manufacturers had reached comparable speeds, but only at the cost of tradeoffs in noise immunity, logic levels, power drain, temperature stability, fan-out vs. fan-in, or capacitance drive.

Too often speed had been increased by reducing logic function per package. Level restoration, fan-out buffering or bias supply regulators were required, necessitating extra packages. Hence, not only was package speed lost at the system level, but system power, can count, and costs were sharply increased.

Now the new circuits in the SUHL II line provide saturated logic plus propagation delay times in the order of 5 nanoseconds. They come in the flat package and the hermetically sealed plug-in package designed for high-speed, low-cost assembly.

Both SUHL lines are characterized by high noise margin, fast speed, high logic swing, high fan-out, low power and capacitance drive capability. (See characteristics tables.) SUHL is the fastest saturated logic family available today for applications down to 5 nanoseconds.

The logic diagrams and other information on the following pages provide important facts on all Sylvania SUHL circuits.

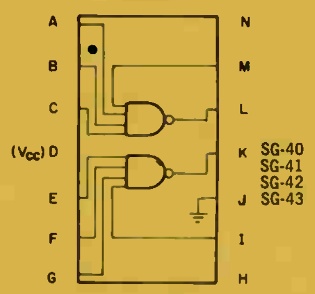


SUHL I TYPICAL CHARACTERISTICS (+25°C, +5.0 volts)

Function	Type Nos.	tpd (nsec)	Avg. Power (mw)	Noise Immunity + (volts)	Noise Immunity – (volts)	Military (–55°C to +125°C) Prime FO	Military Std. FO	Industrial (0°C to +75°C) Prime FO	Industrial Std. FO
Dual 4-Input NAND/NOR GATE	SG-40, SG-41, SG-42, SG-43	10	15	1.1	1.5	15	7	12	6
Expandable Quad 2-Input OR Gate	SG-50, SG-51, SG-52, SG-53	12	30	1.1	1.5	15	7	12	6
Single 8-Input NAND/NOR Gate	SG-60, SG-61, SG-62, SG-63	12	15	1.1	1.5	15	7	12	6
Exclusive-OR with Complement	SG-90, SG-91, SG-92, SG-93	11	35	1.1	1.5	15	7	12	6
Expandable Triple 3-Input OR Gate	SG-100, SG-101, SG-102, SG-103	12	25	1.1	1.5	15	7	12	6
Expandable Dual 4-Input OR Gate	SG-110, SG-111, SG-112, SG-113	12	20	1.1	1.5	15	7	12	6
Expandable Single 8-Input NAND/NOR Gate	SG-120, SG-121, SG-122, SG-123	18	15	1.1	1.5	15	7	12	6
Dual 4-Input Line Driver	SG-130, SG-131, SG-132, SG-133	25	30	1.1	1.5	30	15	24	12
Quad 2-Input NAND/NOR Gate	SG-140, SG-141, SG-142, SG-143	10	15	1.1	1.5	15	7	12	6
Quad 2-Input OR Expander	SG-150, SG-151, SG-152, SG-153	4	20	1.1	1.5				
Triple 2-Input Bus Driver	SG-160, SG-161, SG-162, SG-163	15	15	1.1	1.5	15	7	12	6
Dual 4-Input OR Expander	SG-170, SG-171, SG-172, SG-173	3	5	1.1	1.5				
Dual 4-Input AND Expander	SG-180, SG-181, SG-182, SG-183			1.1	1.5				
Triple 3-Input NAND/NOR Gate	SG-190, SG-191, SG-192, SG-193	10	15	1.1	1.5	15	7	12	6
Set-Reset Flip-Flop	SF-10, SF-11, SF-12, SF-13	20mc	30	1.1	1.5	15	7	12	6
Two-Phase SR Clocked Flip-Flop	SF-20, SF-21, SF-22, SF-23	20mc	30	1.1	1.5	15	7	12	6
Single-Phase SRT Flip-Flop	SF-30, SF-31, SF-32, SF-33	12mc	30	1.1	1.5	15	7	12	6
J-K Flip-Flop (AND Inputs)	SF-50, SF-51, SF-52, SF-53	20mc	50	1.1	1.5	15	7	12	6
J-K Flip-Flop (OR Inputs)	SF-60, SF-61, SF-62, SF-63	20mc	55	1.1	1.5	15	7	12	6

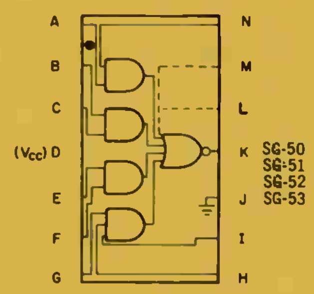
This is SUHL I

Dual 4-Input NAND/NOR Gate



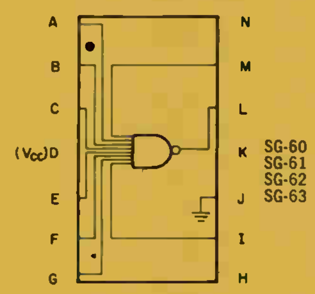
$L=\overline{A\cdot B\cdot C\cdot M}$
$K=\overline{E\cdot F\cdot G\cdot I}$

Expandable Quad 2-Input OR Gate



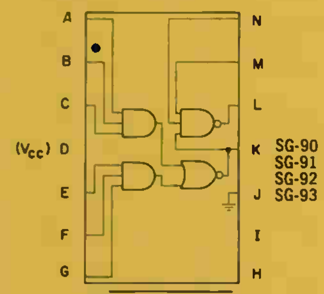
$K=\overline{(A\cdot N)+(C\cdot B)+(E\cdot F)+(G\cdot H\cdot I)+--}$

Single 8-Input NAND/NOR Gate



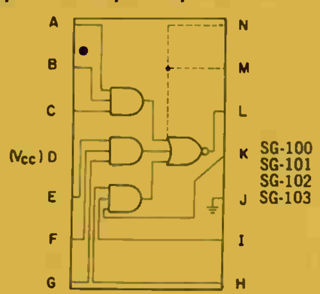
$L=\overline{A\cdot B\cdot C\cdot E\cdot F\cdot G\cdot I\cdot M}$

Exclusive-OR with Complement



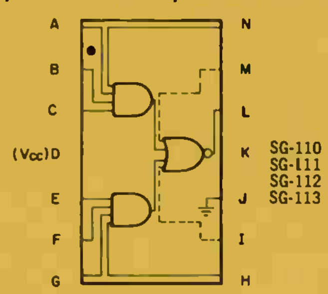
$K=\overline{(A\cdot B\cdot C)}+\overline{(E\cdot F\cdot G)}$
$L=\overline{(K\cdot M\cdot N)}$

Expandable Triple 3-Input OR Gate



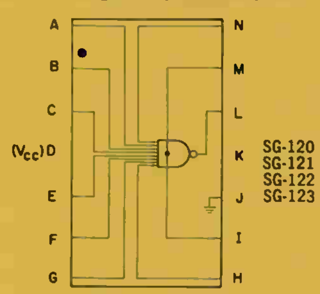
$L=\overline{(A\cdot B\cdot C)+(E\cdot F\cdot G)+(H\cdot J\cdot K)+---}$

Expandable Dual 4-Input OR Gate



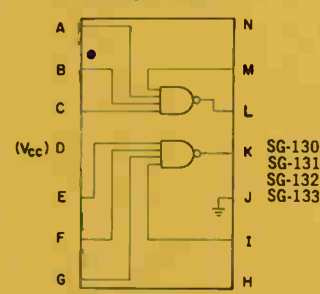
$L=\overline{(A\cdot B\cdot C\cdot N)+(E\cdot F\cdot G\cdot H)+--}$

Expandable Single 8-Input NAND/NOR Gate



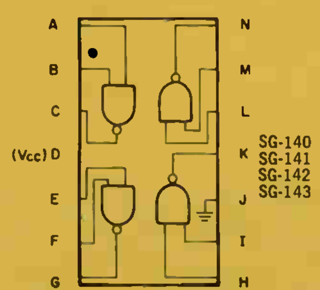
$L=\overline{A\cdot B\cdot C\cdot D\cdot E\cdot F\cdot G\cdot H\ N\cdot ---}$

Dual 4-Input Line Driver



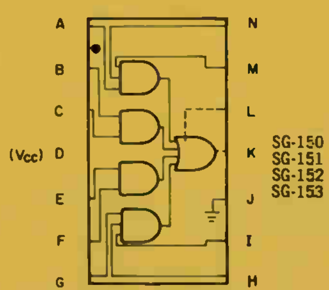
$K=\overline{(E\cdot F\cdot G\cdot I)}$
$L=\overline{(A\cdot B\cdot C\cdot M)}$

Quad 2-Input NAND/NOR Gate



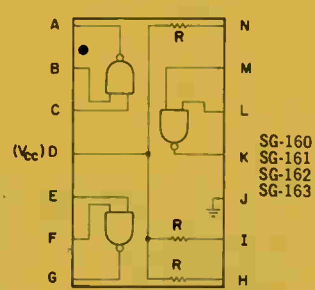
$C=\overline{(A\cdot B)}$ $K=\overline{(H\cdot I)}$
$G=\overline{(E\cdot F)}$ $N=\overline{(L\cdot M)}$

Quad 2-Input OR Expander



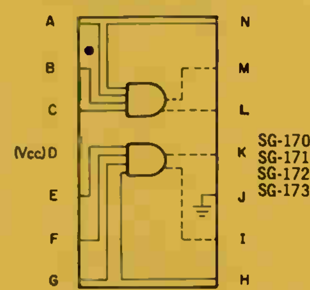
NOTE: USE IN CONJUNCTION WITH EXPANDABLE OR GATES.

Triple 2-Input Bus Driver



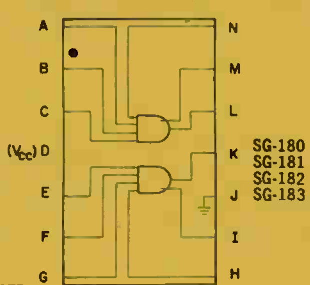
INDIVIDUAL: $A=\overline{(B\cdot C)}$; $G=\overline{(E\cdot F)}$; $K=\overline{(M\cdot L)}$
BUSSED : OUTPUT "1" $=\overline{(B\cdot C)+(E\cdot F)+(M\cdot L)}$

Dual 4-Input OR Expander



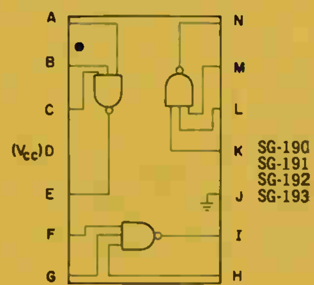
NOTE: USE IN CONJUNCTION WITH EXPANDABLE OR GATES.

Dual 4-Input AND Expander



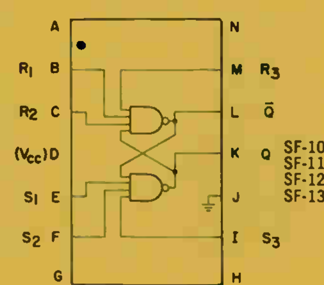
NOTE: USE IN CONJUNCTION WITH EXPANDABLE SINGLE 8-INPUT NAND/NOR GATE.

Triple 3-Input NAND/NOR Gate



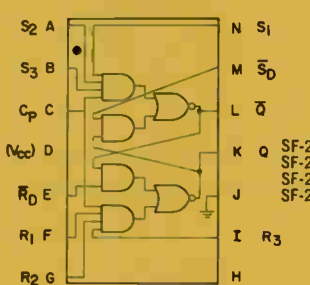
$E=\overline{(A\cdot B\cdot C)}$
$I=\overline{(F\cdot G\cdot H)}$
$N=\overline{(K\cdot L\cdot M)}$

Set-Reset Flip-Flop



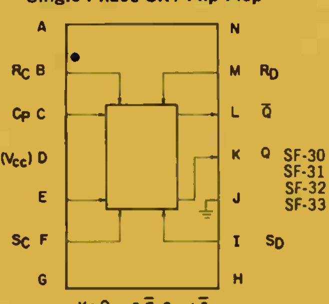
$L=(\overline{B}+\overline{C}+\overline{M}+\overline{K})$
$K=(\overline{E}+\overline{F}+\overline{I}+\overline{L})$

Two-Phase SR Clocked Flip-Flop



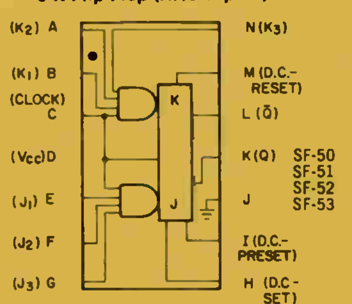
$K=(\overline{F}+\overline{G}+\overline{I}+\overline{C})\cdot(\overline{E}+\overline{L})$
$L=(\overline{A}+\overline{B}+\overline{N}+\overline{C})\cdot(\overline{M}+\overline{K})$

Single-Phase SRT Flip-Flop



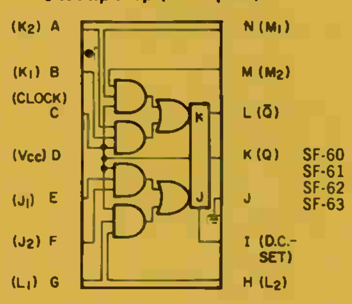
$K=Q_{n+1}=\overline{F}\cdot C_p+\overline{I}$
$L=\overline{Q}_{n+1}=\overline{B}\cdot C_p+\overline{M}$

J-K Flip-Flop (AND Inputs)



$Q_{n+1}=J_1\cdot J_2\cdot J_3\cdot\overline{Q}_n+\overline{K_1\cdot K_2\cdot K_3}\cdot Q_n$

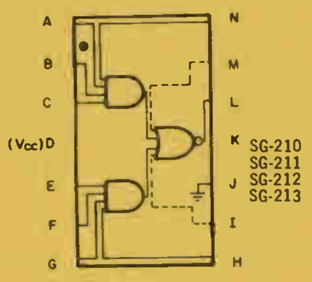
J-K Flip-Flop (OR Inputs)



$Q_{n+1}=(J_1\cdot J_2+L_1\cdot L_2)\cdot\overline{Q}_n+\overline{(K_1\cdot K_2+M_1\cdot M_2)}\cdot Q_n$

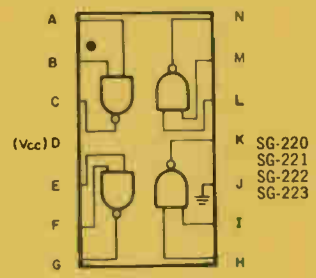
This is SUHL II

Expandable Dual 4-Input OR Gate



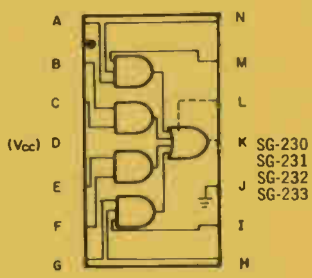
L=(A·B·C·N)+(E·F·G·H)+--

Quad 2-Input NAND/NOR Gate



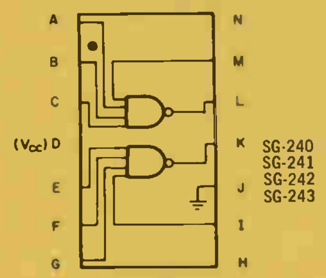
C = $\overline{A \cdot B}$ K = $\overline{H \cdot I}$
G = $\overline{E \cdot F}$ N = $\overline{L \cdot M}$

Quad 2-Input OR Expander



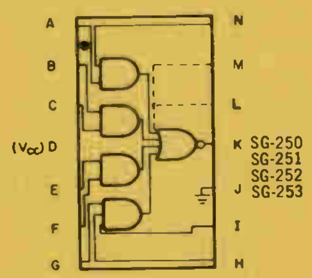
NOTE: USE IN CONJUNCTION WITH EXPANDABLE OR GATES.

Dual 4-Input NAND/NOR Gate



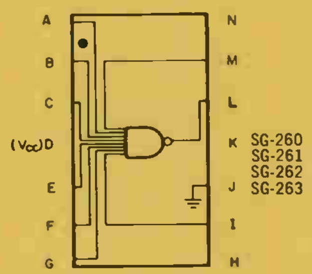
L = $\overline{A \cdot B \cdot C \cdot M}$
K = $\overline{E \cdot F \cdot G \cdot I}$

Expandable Quad 2-Input OR Gate



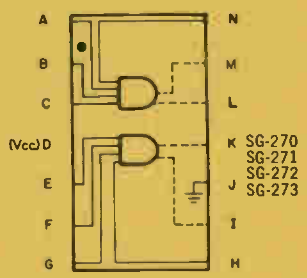
K = $\overline{A \cdot N + C \cdot B + E \cdot F + G \cdot H \cdot I}$

Single 8-Input NAND/NOR Gate



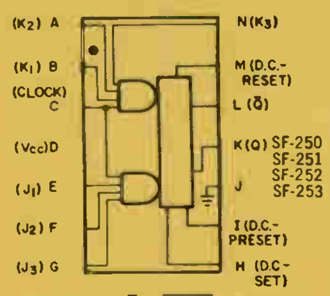
L = $(\overline{A \cdot B \cdot C \cdot E \cdot F \cdot G \cdot I \cdot M})$

Dual 4-Input OR Expander



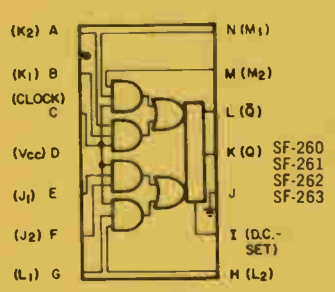
NOTE: USE IN CONJUNCTION WITH EXPANDABLE OR GATES.

J-K Flip-Flop (AND Inputs)

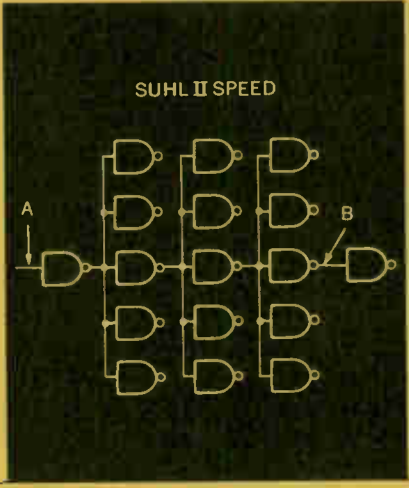


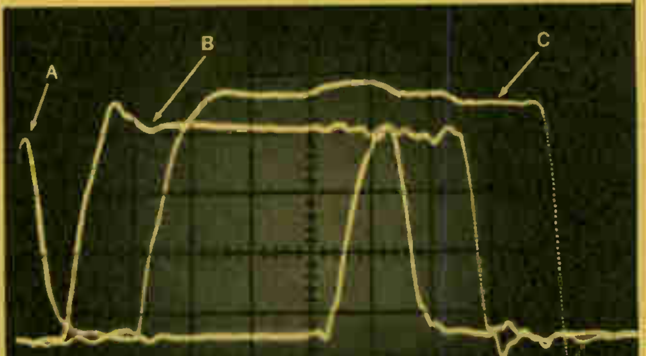
$Q_{n+1} = J_1 \cdot J_2 \cdot J_3 \cdot \bar{Q}_n + \overline{K_1 \cdot K_2 \cdot K_3} \cdot Q_n$

J-K Flip-Flop (OR Inputs)



$Q_{n+1} = (J_1 \cdot J_2 + L_1 \cdot L_2) \cdot \bar{Q}_n + \overline{(K_1 \cdot K_2 + M_1 \cdot M_2)} \cdot Q_n$



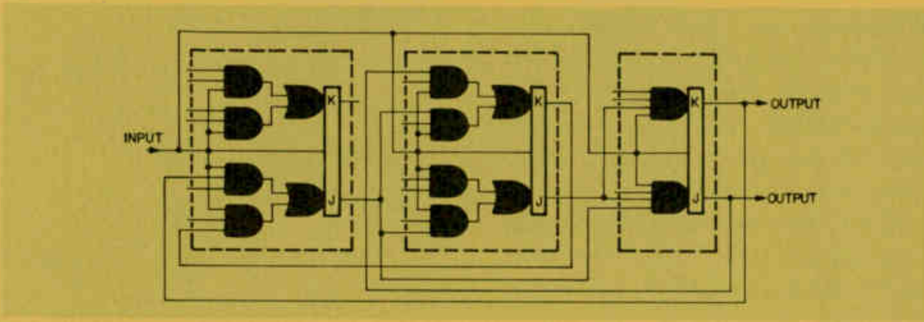


Vertical = 1V/cm
Horizontal = 20 nsec/cm
A = output from SUHL II gate
B = output from SUHL II J-K flip-flop
C = output of last gate

SUHL II TYPICAL CHARACTERISTICS (+25°C, +5.0 volts)

Function	Type Nos.	tpd (nsec)	Avg. Power (mw)	Noise Immunity +(volts)−		Military (−55°C to +125°C) Prime FO	Military Std. FO	Industrial (0°C to +75°C) Prime FO	Industrial Std. FO
Expandable Dual 4-Input OR Gate	SG-210, SG-211, SG-212, SG-213	7	30	1.0	1.5	12	6	10	5
Quad 2-Input NAND/NOR Gate	SG-220, SG-221, SG-222, SG-223	6	22	1.0	1.5	12	6	10	5
Quad 2-Input OR Expander	SG-230, SG-231, SG-232, SG-233	2	28	1.0	1.5				
Dual 4-Input NAND/NOR Gate	SG-240, SG-241, SG-242, SG-243	6	22	1.0	1.5	12	6	10	5
Expandable Quad 2-Input OR Gate	SG-250, SG-251, SG-252, SG-253	7.5	43	1.0	1.5	12	6	10	5
Single 8-Input NAND/NOR Gate	SG-260, SG-261, SG-262, SG-263	8	22	1.0	1.5	12	6	10	5
Dual 4-Input OR Expander	SG-270, SG-271, SG-272, SG-273	2	6.7	1.0	1.5				
J-K Flip-Flop (AND Inputs)	SF-250, SF-251, SF-252, SF-253	30mc	55	1.0	1.5	12	6	10	5
J-K Flip-Flop (OR Inputs)	SF-260, SF-261, SF-262, SF-263	30mc	55	1.0	1.5	12	6	10	5

Build an effective divide-by-seven from 3 modules



A simplified but effective method of performing divide-by-seven operations is described in the logic diagram shown above.

As shown, input conditions would normally call for an OR'ing function for the J-K inputs. But the need for external gating functions is eliminated with the use of a Sylvania SF-60 J-K flip-flop OR input.

The third OR-AND stage of this circuit must also handle three input variables, hence the use of an SF-50 (J-K flip-flop AND input). Note that if the SF-50 had less than three inputs on each side, additional gating functions would be required, thereby raising the can count.

The circuit shown here will operate in the 10-megacycle frequency range. With additional interconnections the circuit can function at frequencies even greater than 20 megacycles over a −55° to +125°C temperature range, without limitations on the low frequency end.

Sylvania J-K flip-flops save packages, power and time

Now available to designers of advanced computer systems are four new series of Sylvania flip-flops, each one a proven, low-cost problem solver.

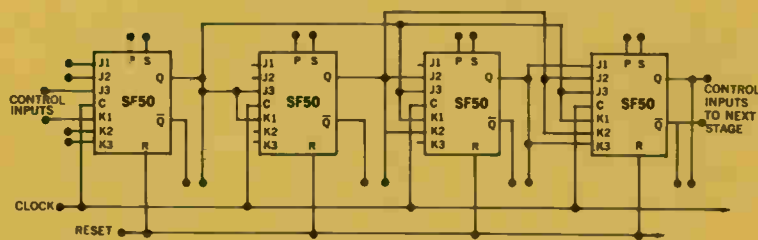
For example, the SF-50 J-K, which ANDs up to three inputs on both the J and K terminals, is an effective module for 20 mc counter designs.

The new SF-60 OR input J-K simplifies and improves shift register design. The 20-megacycle shift-left/shift-right register shown can be built using only four J-K SF-60 flip-flops (OR input). This versatile register can be used as a count-up/count-down counter in the arithmetic portion of a computer.

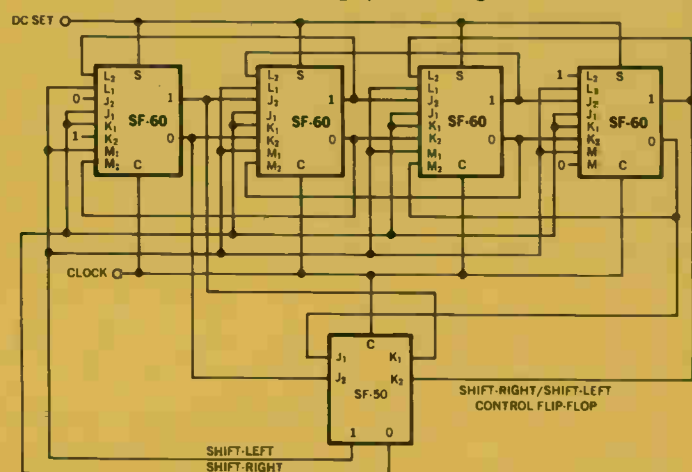
Both designs shown save gate packages, power, interconnections, layout time and money without sacrificing speed, noise immunity, fan-out or capacitance drive.

Typical characteristics on all SUHL J-K flip-flops are shown in the chart elsewhere in this issue.

20 mc synchronous 4-stage binary counter



Automatic shift-right/shift-left register



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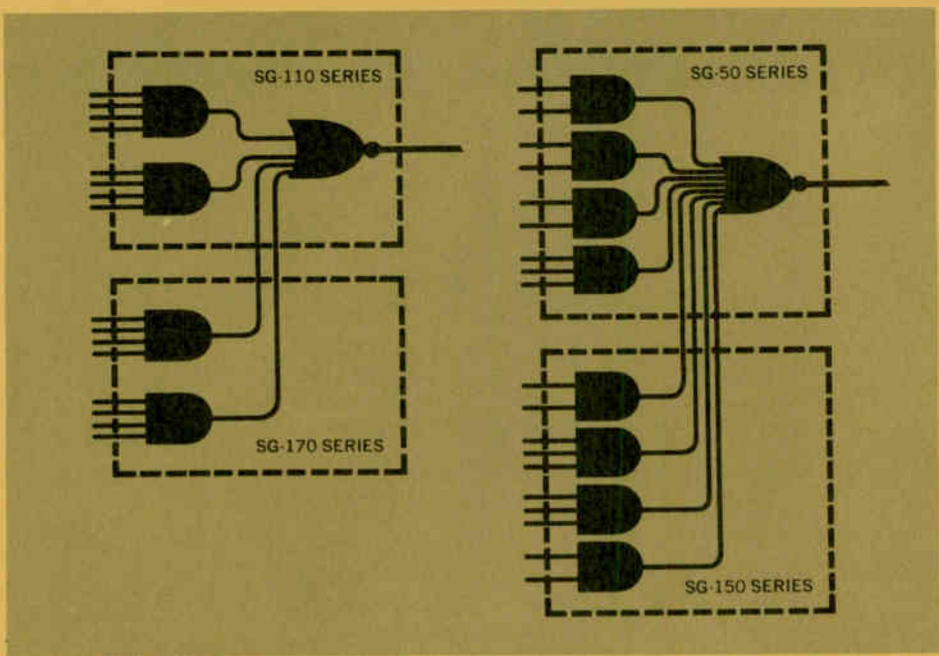
Eight gates wired OR'd together from two low-cost expanders

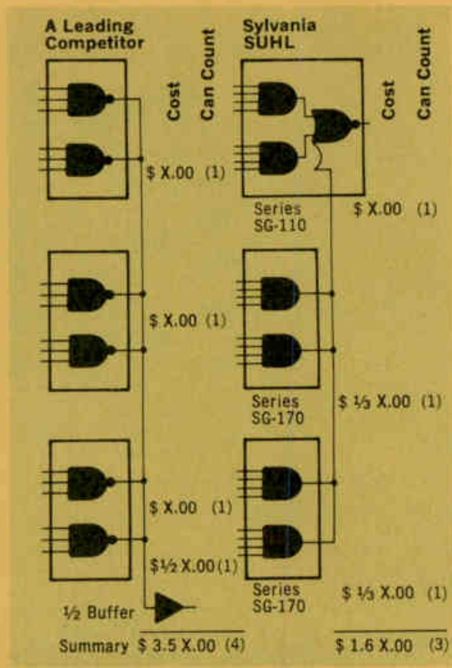
Within the SUHL family there's a complete line of digital functions for producing wired ORs consisting of two to eight gates.

The logic diagrams shown here demonstrate how the low-cost Sylvania SG-170 series OR Expander can accomplish this number of gates wired and OR'd together. Power savings range up to 55% with no accompanying change in fan-out and without a significant sacrifice in speed.

Where the highest wired OR count is required, use either the Sylvania SG-110 or the SG-50 series Quad OR Gate with the SG-150 Quad OR Expander. Either way, the fan-out capability of the gate is retained and a lower can count results.

SUHL circuits include: the SG-100 Expandable Triple 3-Input OR Gate, the SG-110 Expandable Dual 4-Input OR Gate, the SG-50 Expandable Quad 2-Input OR Gate, the SG-150 Quad 2-Input OR Expander, and the SG-170 Dual 4-Input OR Expander.





How to lower cost and can count in wired OR circuitry

A wise philosopher from the Orient said that a picture is worth 10,000 words. He wasn't available as this story went to press to comment on the verbal equivalency of logic diagrams.

We think the schematics and cost figures here speak for themselves. Just let the cost of the basic OR Expander equal *X*. Then choose the logical route to wired OR circuitry.

This information in Sylvania ideas is furnished without assuming any obligations.

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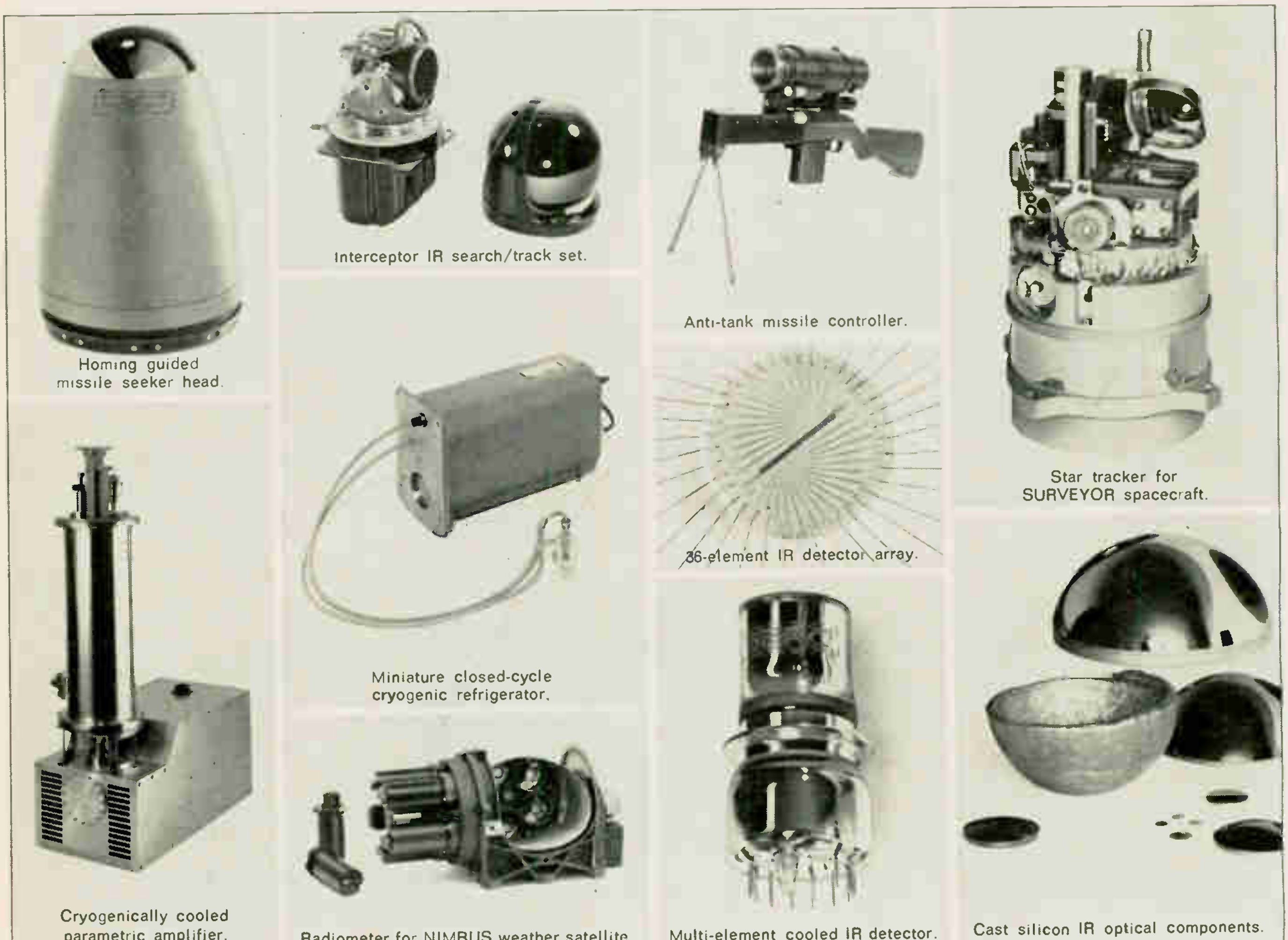

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Multi-element cooled IR detector.

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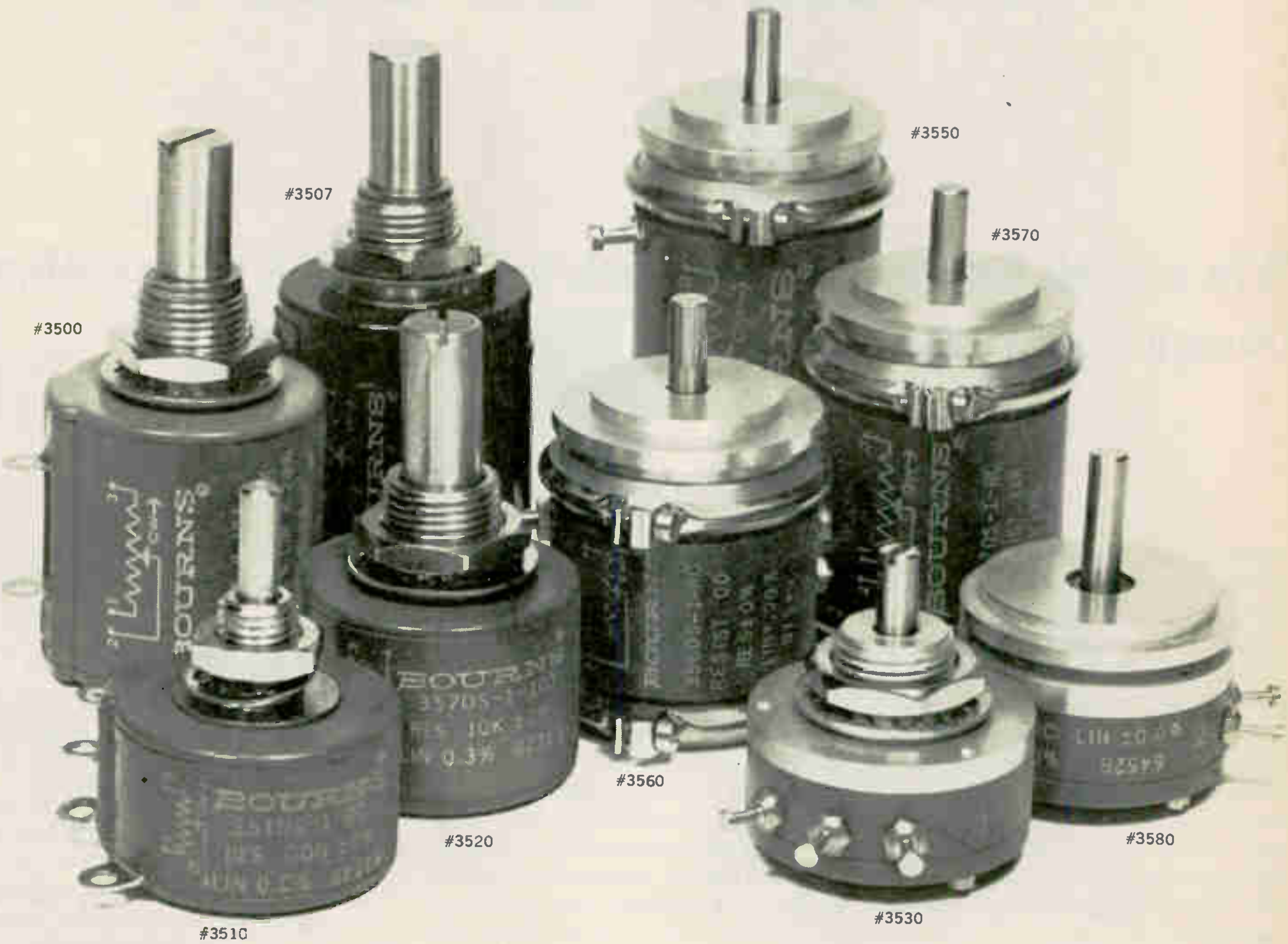

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Fairchild reserves the right to retain and publish, with appropriate credits, any design submitted. No representatives or employees of Fairchild Camera and Instrument Corporation, or their relatives are eligible to enter.

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

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

We will also accept design entries using similar Fairchild Operational Amplifiers, such as the A00-6 and 7. Write for data sheets containing complete details.

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Probing the News

Space electronics

Surveyor program under attack

'One of the least orderly and most poorly executed of NASA projects,' is how a congressional subcommittee describes the program to soft-land a series of 17 tv- and instrument-equipped spacecraft on the moon

By John F. Mason Senior Associate Editor
and
William B. Wallace Los Angeles News Bureau

A congressional subcommittee has accused NASA's Surveyor program, a 17-mission moon study, of mismanagement, delays, high costs, and of using equipment that might cause a spacecraft to crash.

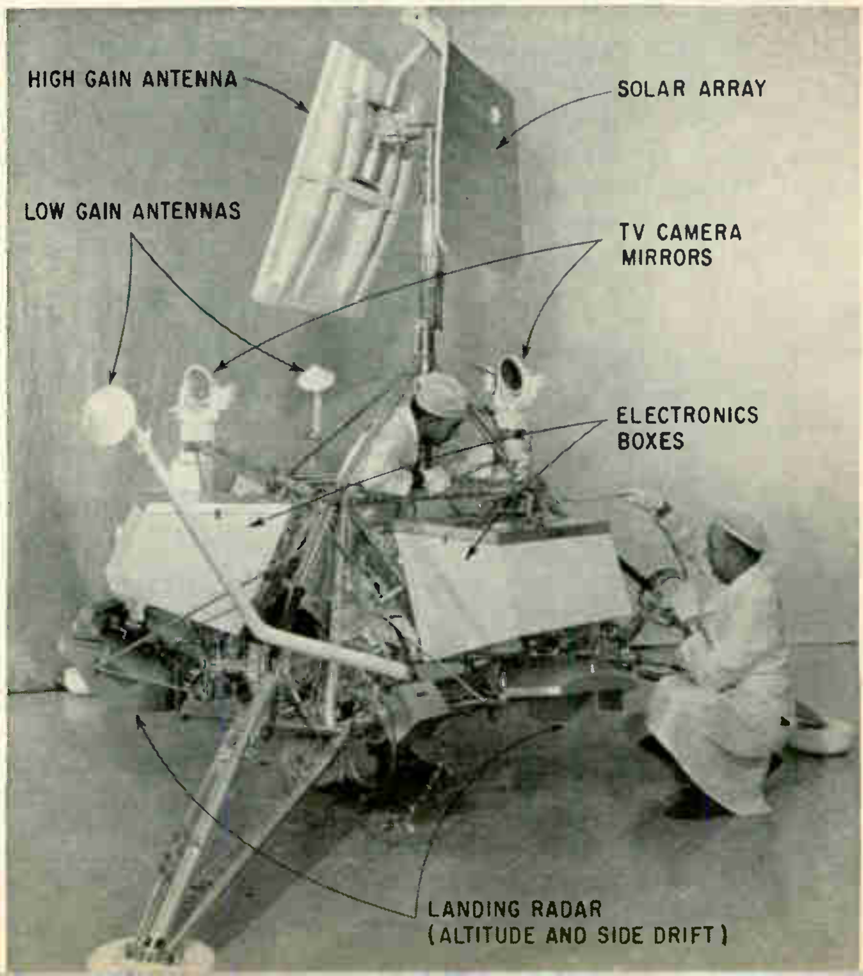
The changes come less than three months before the National Aeronautics and Space Administration attempts the first Surveyor shot—to land on the moon a television camera that can examine objects as small as a grain of sand.

The Subcommittee on NASA Oversight of the House Committee on Science and Astronautics criticizes the Surveyor program in a 35-page report based on its two-day inspection in September of the Jet Propulsion Laboratory (JPL) in Pasadena—NASA's manager of the program—and the Hughes Aircraft Co. in Culver City—prime contractor for JPL.

The subcommittee's report says:

- The spacecraft has a good chance of crashing onto the moon without sending back a single picture. As of September, "certain technical problems" in the radar altimeter and Doppler velocity sensor system—absolutely necessary for landing successfully—still "discourage high confidence in the system."
- Heat losses from the spacecraft during the long lunar night are now expected to be so high that the first four spacecraft won't survive more than a few hours; certain equipment may freeze in minutes.
- The scientific payload on the first four spacecraft, engineering test models, will consist of only 20 pounds—a single-scanning tv camera. The next three flights will carry

First engineering test model is undergoing preshipment tests at the Hughes plant. It will carry a 20-pound payload consisting of one tv camera. Later craft will carry scientific experiments.



six experiments weighing 114 pounds; the payload was planned to weigh 345 pounds. The 10 remaining flights—there will be 17 Surveyor flights in all—have not yet been planned.

- The first launch, now scheduled for February, 1966, had been originally set for August, 1963. "And since the first operational spacecraft [with scientific instruments] will not be flown until 1967, the delay might be viewed as approaching four years."
- Costs have risen unexpectedly. In January, 1961, NASA said the Surveyor program—which then consisted of seven spacecraft—would cost "upward of $50 million." The subcommittee found that by June, 1966, the program will have cost $350 million, exclusive of launch vehicles.

The subcommittee did not stop with only "major" items. Members were unhappy over the government's having to absorb a $2-million loss—plus a delay in the program—when drop tests of two landing packages failed last year. The packages contained the vernier engines, the main retro-rocket and the radar altimeter and Doppler velocity sensor.

Hughes dropped the packages from balloons, 1,500 feet above the desert. An electrostatic discharge caused a failure in the release mechanism during the first test, and the vehicle dropped prematurely and crashed. "The system apparently was not satisfactorily grounded," the report said. In the second drop, five independent components failed and the package became entangled in the balloon's tether.

Hughes has built two new test vehicles and will build four more.

Homer Newell, associate administrator of NASA for space science and applications, bluntly told the subcommittee: "I think the Hughes contractor agrees that these tests weren't prepared for or conducted properly."

Why it happened. The subcommittee ticked off a number of reasons for the discouraging state in which it found Surveyor.

Surveyor was one of NASA's first approved space programs and was undertaken before the agency fully understood "the demanding nature of space research and development projects," the report said. As for Hughes, the firm's vice president and general manager, L. A. Hyland, told the subcommittee: "I think it is fair to say that we pretty much underestimated the magnitude of the job . . . It is a much bigger job than we originally anticipated."

Insufficient planning. Much of the trouble, everyone agreed, has resulted from the lack of work done before the decisions were made to go ahead with the project and to award a contract. Because of this, 46 modifications and 80 change orders in the program have been made since Hughes' contract was awarded March 1, 1961.

The result, the subcommittee said, is "one of the least orderly and most poorly executed of NASA projects."

Also, during the first three years of work on Surveyor at the Hughes plant, the staff at JPL was deeply engaged in two major in-house projects—Ranger and Mariner—both of which would precede Surveyor.

Compounding this obstacle to adequate control of Surveyor, the subcommittee said NASA had not permitted JPL to hire enough personnel. JPL began work on Surveyor with a staff of 20. In three years, this climbed to 100. Now, there are 500 people working on Surveyor at JPL and 2,400 at Hughes.

The subcommittee blames everyone involved for waking up three years too late to find that Surveyor was in serious trouble: NASA for not monitoring JPL and Hughes better, JPL for "virtually turning Surveyor over to Hughes," and Hughes' top management for not giving the program appropriate attention and for being slow to respond to NASA's recommendations to reorganize.

Spokesmen for both JPL and Hughes say they can't argue with a congressional report; and JPL adds that their people "who have read the report consider it technically accurate."

The consensus at JPL is that no one at JPL, Hughes or NASA has a legitimate complaint.

The Surveyor program will continue, since its findings are essential for designing much of the Apollo equipment that will land men on the moon before 1970, and after the subcommittee's report, probably faster and more efficient than before.

Getting there is half the fun; landing is the real problem

Surveyor begins its trip to the moon folded up inside the nose shroud of the newly-developed Atlas-Centaur launch vehicle at Cape Kennedy. Shortly after launch, when the shroud is ejected, the spacecraft extends its legs and antennas; when Centaur later burns out, Surveyor continues its journey alone.

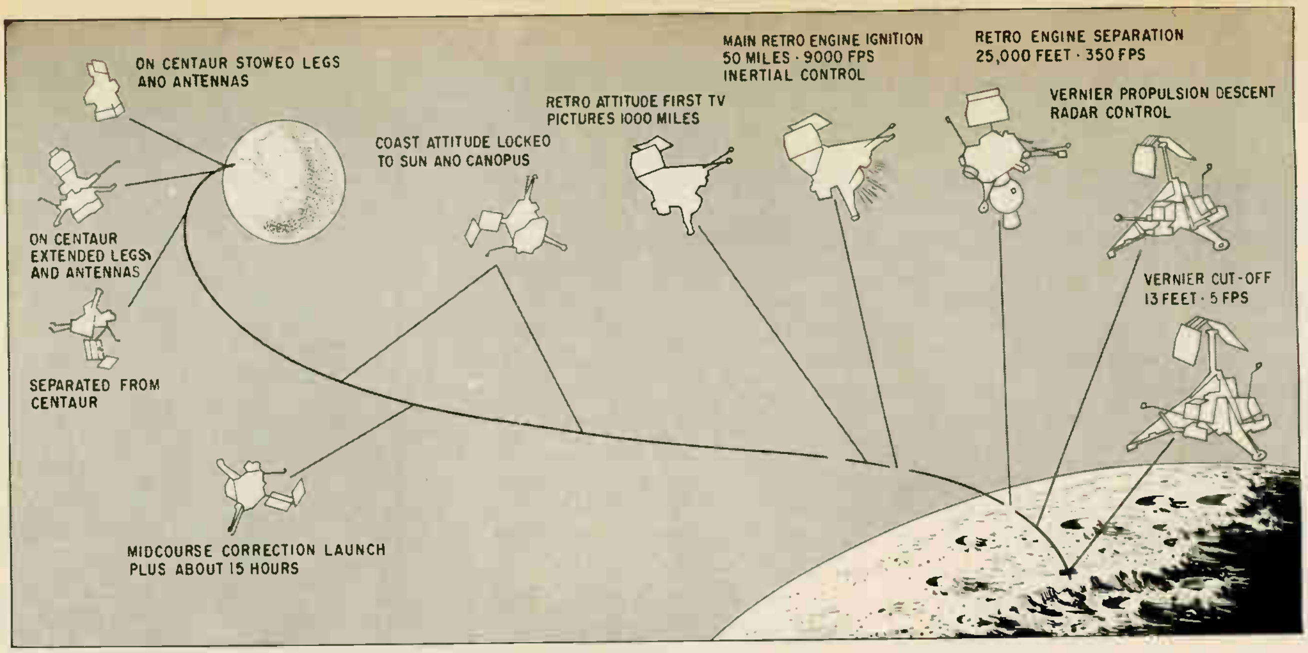
Some 15 hours after launch, the ground tracking station in California gives the craft a mid-course guidance correction plus instructions to turn around. Its landing legs then will be in the correct position, and its solar cells will face the sun. After it locks on the sun, the craft is commanded to roll around its axis and seek the star Canopus. Stabilized by the sun and Canopus, the bus then coasts to the moon. Attitude corrections are made by cold gas jets mounted on the ends of the landing legs.

As the bus approaches the moon, a retro-rocket is fired to slow it from 9,000 feet per second to 350 fps as it descends to about 25,000 feet.

In addition to the main retro-rocket, three controllable-thrust vernier engines—one of which swivels for roll control—there are an altitude-marking radar; yaw, roll and pitch gyros of a three-axis autopilot; an analog computer; three beams of Doppler velocity radar; and a radar altimeter.

This system must perform several critical functions simultaneously, compatibly, and with precision. At an altitude of 13 feet, the vernier system is shut off and the spacecraft free-falls to the surface.

Altitude-marking radar. When the spacecraft is about 120 miles above the moon's surface, a ground station commands the spacecraft's altitude-marking radar (AMR) to begin operating an on-board com-



The surveyor spacecraft, about 15 hours after blast-off, gets a course correction from the California ground station, which also commands Surveyor to turn its legs toward the moon for landing, and instructs it to lock on the sun and the star Canopus for guidance. Sixty-six hours after launch, an elaborate system consisting of a retro-rocket, vernier engines and radars—still not working well, according to the subcommittee's report—is supposed to ease the bus down on the moon.

puter to assume control of the craft during the descent and landing operation. The final moments of flight are too brief to permit commands to be issued from the earth—1¼ seconds away.

Mounted inside its own dish antenna below the nozzle of the main retro-engine, the AMR keeps track of the altitude down to a distance of 50 miles from the touchdown site—whether this distance be straight down or at a slant. At 50 miles the AMR destroys itself by signaling the retro-engine directly above it to fire. The AMR is blown away, and the radar altimeter and Doppler velocity system (RADVS) takes over.

The RADVS, criticized by the subcommittee for "severe technical difficulties," is an adaptation of the Doppler navigational radar built by Ryan Aeronautical Co. for helicopters. To modify it for the spacecraft, its power was increased to about 550 watts, its sensitivity was increased and it was made less vulnerable to spurious noise. These changes were made by upgrading components and circuits and packaging for a space environment.

The technical problem, however, is still noise. The acoustic noise of the vernier engines, JPL says, gives false indications to the radar. The noise may be transmitted to the radar dish via air—which would not exist near the moon, and hence would not be a problem—or it could be transmitted via the framework of the spacebus and would be just as disastrous on the moon as it is on earth.

"Although the problem has not been solved yet," JPL says, "it now appears that the solution is just a matter of a little more time."

Six tests will probe the moon's secrets

The first Surveyor spacecraft is already assembled and is undergoing preshipment tests at the Hughes plant. Hardware for the other three engineering test models is in various stages of readiness. Work is under way for the three operational craft that will each carry six scientific experiments: the television experiment, touchdown dynamics, surface sampler, micrometeorite detector, alpha backscattering experiment and a single-axis seismometer.

Television. Besides the one scanning tv camera carried on the first four engineering test models, the three operational models will have an additional survey tv camera. Both cameras will be fixed to the spacecraft frame but will be trained on movable mirrors that will sweep the horizon in a broad horizontal arc after landing. The mirrors can also be tilted vertically to scan from the landing pads of the spacecraft, or bus, to the moon's horizon.

The two survey cameras have zoom lenses but will be used in two focal-length positions only: 25 mm and 100 mm. Focusing will be linear from closeup to infinity and controlled from the earth. Exposure adjustment will be automatic.

First pictures. Before launch, the survey cameras will be focused on targets mounted on the spacecraft. The cameras will look at these targets immediately after landing to let earth control know if anything was jolted out of adjustment and should be corrected. The first set of terrain pictures will be focused by trial and error. The correct settings will be recorded and used for subsequent pictures.

As lighting conditions around the Surveyor landing site change, subsequent pictures will emphasize different lunar features. The two cameras can be preset to produce stereoscopic pictures.

Color pictures. Although the lunar pictures will be in black and white, green and red filters will be rotated in front of the cameras' lenses in sequence.

Scientists hope that filtering different colors will bring out details otherwise lost. It may also be possible to reconstruct color pictures from the filtered black and white pairs using the Edwin H. Land

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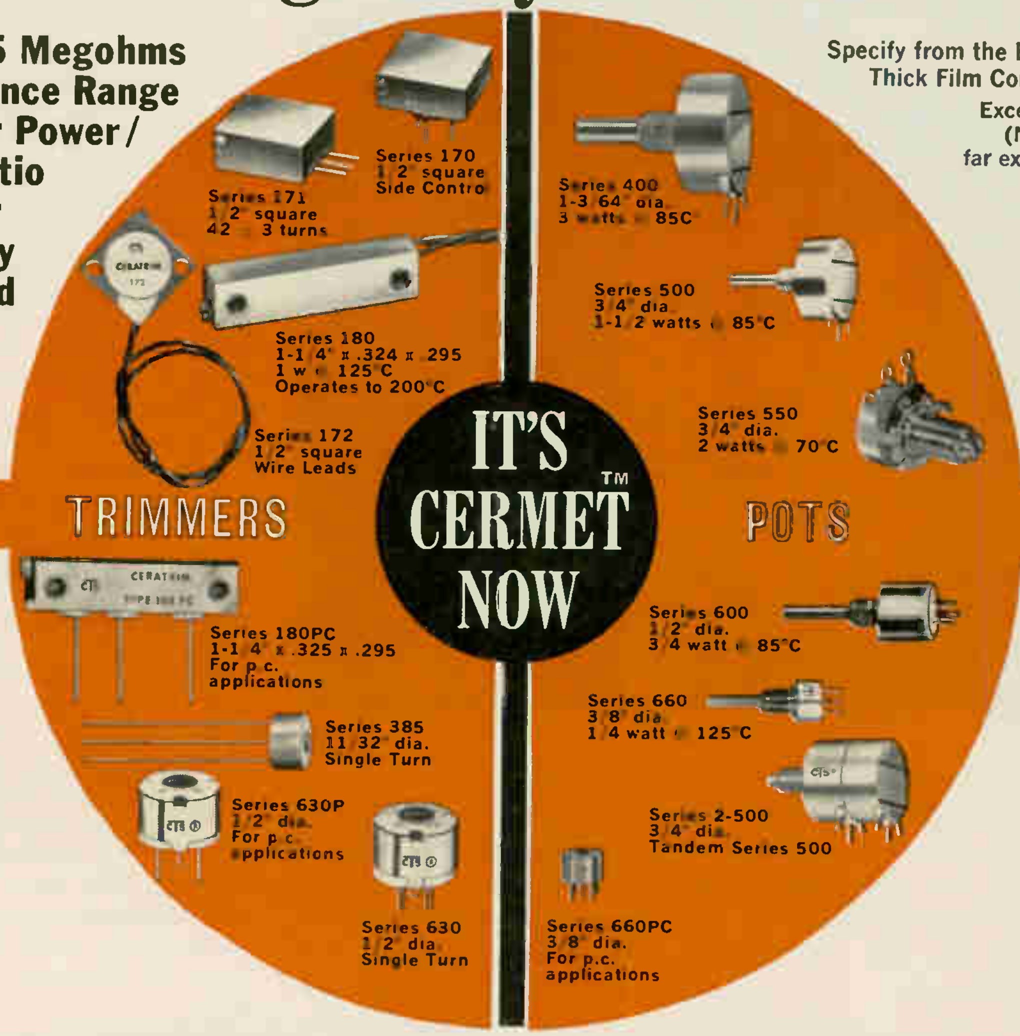

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process [Electronics, July 26, p. 26].

Resolution of the cameras will be 600 lines per frame. Although this is inferior to Ranger's 1152-line resolution in the full-scan cameras, Dennis H. Le Croissette says that this will be good enough to define a near-by grain of sand one-half millimeter in diameter. Le Croissette is manager of instrument development for the Surveyor project at the Jet Propulsion Laboratory in Pasadena.

A third camera. To televise the approaching lunar surface, a third camera may be carried but there is still disagreement over this. Those who oppose this camera argue that so much complex data must be exchanged to land the spacecraft successfully that there would be no room for tv transmission. Also, the pictures would only duplicate those the last three Rangers took and the resolution would not be as good.

The critics also say that while Ranger televised the moon's surface down to an altitude of a few hundred feet, Surveyor's camera would not be able to see the surface after the retro-rocket fires at an altitude of 50 to 60 miles; it would see only the rocket's plume.

Those in favor of the downward-looking camera say it is needed to show where the bus is landing.

All the tv cameras would operate the same way: the complete picture on the vidicon would be scanned in about 1.1 seconds and transmitted in real time. Allowing for vidicon erasure and camera switching, a picture could be transmitted every 3.6 seconds, or 1,000 per hour.

During the 2.5 seconds between picture transmission, the communications carrier would transmit other data.

Engineering and touchdown. Instruments for testing engineering performance of the spacecraft will measure conditions such as temperatures, voltages, pressures in tanks, the inertial guidance system, star locks, earth altitude through Doppler shift techniques, moon altitude and side drift from the bus-mounted radar.

The Surveyor will have landing characteristics similar to the Apollo program's Lunar Excursion Module (LEM). To obtain a preliminary estimate of what the LEM will encounter, engineering instrumentation will provide data on velocities, accelerations, impact and other landing dynamics. Instruments will also measure the condition and attitude of various controllable components or systems: landing legs, antennas, solar panel array and transmitters. In all, engineering data will be received from 200 to 300 sources.

Because of their importance or frequency of change, some instruments will sample more often than others. This will be done mainly through commutation channels before launch, with some sampling possible in flight through earth command selection of commutator banks.

Surface sampler. A scoop-claw with an accordion-like arm will be able to dig a trench under the eyes of the tv cameras to reveal the compaction, uniformity texture, structure, angle of repose and other physical properties of the material down to about two feet.

Strain gauges will provide quantitative data on the bearing and shear strength of the material. The claw also has potentiometers to measure arm position, an accelerometer to measure vertical deceleration as the scoop strikes the surface, and force transducers to measure the vertical force up to three pounds and the retraction force up to 200 pounds.

Micrometeorite detector. Measuring the flux momentum, energy, and mass of particles that could scratch optical surfaces or possibly puncture a space suit is the job of a micrometeorite detector. It consists of a steel plate with detectors bonded on each side and aligned vertically on the spacecraft.

A hit is recorded when a meteorite pierces the capacitor, which results in a temporary short. The size and velocity of the meteorites can be estimated from the pulse height and width of the short, and the sound output through an acoustic transducer bonded to the plate.

Alpha backscattering. To analyze the elemental composition of the lunar material, a curium-242 source of greater than 25 millicuries will be used to bombard a special analyzer box with alpha particles. The alpha-proton reactions to the bombardment will be measured to

determine the chemical elements in the lunar surface.

The alpha scatter analyzer can be moved about by a controllable arm. Either of the tv cameras can be adjusted to look at the analyzer and help guide the claw.

Single-axis seismometer. To determine whether the moon is seismically active, a conventional seismometer with special modifications for the severe lunar environment will be carried. A high temperature spring was developed along with a special thermal shell to reduce temperature changes. During flight and landing, the floating magnet will be held in position by clamps to avoid damage. A double squib arrangement will release the magnet after landing.

The instrument is designed to measure the number, magnitude, spatial distribution and focal depth of moonquakes. It has a frequency response over the range of 0.05 to 10 cycles per second.

In the course of analyzing the seismic records, it is anticipated that other information will be obtained, such as the spectrum of seismic bankground noise correlated with thermal changes and meteorite impact up to 100 miles away. The data should yield some information on elastic properties and structure of the moon along with the internal constitution and damping properties.

Components. Because monolithic circuits were not sufficiently developed at the time Surveyor was designed, only discrete, solid-state components in conventional, high-density, welded, cordwood-type modules are used. Surveyor's electronics are not at the top of the state of the art.

To protect the fragile payload, most of the electronic gear is packaged in two boxes, well-insulated with multiple layers of aluminized Mylar that repel heat from the sun and expel heat generated inside. The tops of the boxes, facing the sun, have a sheet of polished material that reflects solar radiation and yet allows internal heat to pass through. The sides reflect heat from the moon's surface.

When the lunar night begins, batteries maintain heaters inside the boxes. It is hoped that the temperature change inside the boxes will not exceed 125° F or go below 40° in one box and 0° F in the other. The outside temperature changes from +250° F to −200° F. The batteries will not be able to keep the heater going for the full lunar night and eventually the internal temperature of the boxes will drop to the ambient temperature of −200° F, which will put the electronic circuitry out of commission.

Transmission. Tv transmission will be analog and will use 220 kilocycles of the three-megacycle communications bandwidth. The analog signal will modulate the carrier directly instead of a subcarrier; this will permit only one tv camera to transmit at a time and will shut off all telemetry transmission from scientific experiments.

Communication design changes are being considered to permit simultaneous transmission of tv and other science information on later Surveyor shots. This may be done by using sidebands.

While a few of the scientific and engineering experiments will transmit data in analog form, most of it will be transmitted digitally—if the transducer's output is analog it will be converted to digital form before being transmitted—in 10-bit words at an earth-controllable rate between 17.2 and 4,400 bits per second. Sheldon Shallow, chief scientist of the Surveyor program at Hughes' Space Systems division, says that the most common rate will be 550 bits per second.

Transmitter. For redundancy, the bus will carry two transmitters and two antenna systems. To provide spherical coverage, two small, cone-like, omnidirectional antennas will be placed on opposite sides of the bus on extended booms. On the vertical mast, along with the solar cell array, there will be a high-gain planar antenna. Transmission can be switched between the high-gain and omnidirectional antennas by earth command. The high-gain antenna will be used for transmission from the lunar surface. Center frequency of the communication channel is 2.295 gigacycles.

Power for the bus will come from a combination of solar cells and rechargeable silver zinc batteries. The solar-cell array will be adjusted for sun attitude by earth command approximately once every earth day.

Minuteman 2 takeover under way

New radio communications system installed—designed to increase survivability of launch and control network

Two weeks ago, the first Minuteman 2 missiles became operational at Grand Forks Air Force Base in North Dakota. The first of 1,000, the improved missiles will be a powerful force in the United States arsenal.

Not only is the weapon system itself improved, but so is the survivability of the launch and control system because of a radio communications system which is being installed at the Minuteman 2 sites as a backup to the regular underground cable system.

The extensive use of integrated circuits in Minuteman 2 has improved reliability and shrunk the instrumentation so that a payload 30% heavier can be carried. Minuteman 2 weighs about 70,000 pounds to Minuteman 1's 65,000 but the new missile's more powerful second-stage motor has increased the range from 6,300 to 7,000 statute miles. The new missile does everything its predecessor does, but better. Defense Secretary Robert S. McNamara says it is twice as accurate as Minuteman 1.

I. Increased survivability

The Air Force is working to increase survivability for the remotely-controlled intercontinental ballistic missile's command and control network. For example, Wing 6, the first wing of Minuteman 2's, will be spread over 7,500 square miles of eastern North Dakota, comprising 165 underground locations—150 missile silos and 15 launch control facilities.

Like Minuteman 1, the new missiles will be monitored, aimed, and fired by commands transmitted through underground cable, which is pressurized to reveal leaks or detect tampering. But the Minuteman 2 command and control network will have something added—a backup radio communications system which can be used to launch Minuteman 2 if the cable is cut.

Antennas for the radio system will be coaxial cables buried in a criss-cross pattern the size of a football field. Antennas at the launch control facilities (LCF) will transmit to receiving antennas, also buried, at the unmanned missile silos some 30 to 50 miles away.

Radio link. For the past year, the radio link has been tested between two Sylvania Electric Products, Inc. plants, one at Waltham and another at West Roxbury, Mass. Sylvania, the prime contractor for the ground electronics systems, is a subsidiary of the General Telephone and Electronics Corp. Sylvania's system was successfully tested in a Minuteman 2 firing from Vandenberg Air Force Base in California last month, and the first systems are now being installed in North Dakota.

Also, the radio link presumably would be used if the Air Force goes through with a plan, now being considered in the Pentagon, to use a flying command post as a launch backup for the LCF's. The Ballistic Systems Division of the Air Force, which runs the Minuteman program, declines to talk about the flying command post, however.

The new command and control network is highly flexible. A launch control facility can fire its own flight of 10 birds, its own plus a neighbor's, or, if ordered to do so, the entire squadron's five flights of 50 missiles.

Sylvania has contracts totaling $195 million to develop the electronics systems for the 15 launch control centers and 150 Minuteman silos.

A signal data converter, built by Sylvania, is in the missile silo and monitors about 80 individual status indications, multiplexes them and feeds them to the guidance computer. The computer is a part of the ground electronics while the missile is in the silo. The converter, operating with the computer, con-

New communications link for SAC

A low-frequency system now being built will provide communications between SAC and its Minuteman launch control centers, even under nuclear attack.

Evidence of the system will soon be visible across the U.S. landscape. In Nebraska, near SAC headquarters, construction has started on a 1,200-foot tower, first of many which will help provide secret radio teletypewriter communications between the Joint Chiefs of Staff and SAC, and between the SAC commander and his forces.

The backup network is being built by the Westinghouse Electric Corp. under a $27-million contract with the Air Force Electronic Systems Division at Hanscom Field, Mass.

The antenna towers, almost as tall as the Empire State Building, will depend upon dispersion for survivability [Electronics, Nov. 1, 1963, p. 11]. They will radiate low-frequency and very-low-frequency signals, known to be least vulnerable to radio blackout and atmospheric changes caused by nuclear attack.

If conventional SAC communications were knocked out, the low-frequency system—known as 487L—would maintain long-distance communications at a data rate sufficient to order launching of retaliatory Minuteman missiles and other weapons. If one or two of the 487L towers were to be knocked out, the surviving antennas could do the job. Each Minuteman site will have a special antenna to receive signals from the 487L system.

trols basic modes of operation within the launch facility.

II. Guidance and control

The Minuteman was the first major military system to use integrated circuits. (Electronics, Feb. 15, 1963, pp. 26-27). This dramatically illustrated the advantage of IC's and helped launch their use much faster than previously believed likely.

Major use of IC's is in the guidance computer, which has 2,137 of them. The computer has undergone one major design change since its engineering version was built: it has been hardened against electromagnetic pulses and nuclear radiation.

Details are secret but Autonetics division of North American Aviation, Inc., associate prime contractor for the guidance and control system, has built a special electromagnetic laboratory for Minuteman 2, a cube measuring six feet on a side, in which the entire computer and guidance system can be tested.

Autonetics found that IC's reduced the number of electronic parts from 14,672 in the D17 computer it built for Minuteman 1 to 6,434 in Minuteman 2, and helped cut the weight from 61 to 36.5 pounds. The new D37C computer can store a complete ground and airborne operational program—including all target data for up to eight targets—and it can perform many of the ground checkout functions which previously called for special equipment outside the missile. The D17 handles information for only two targets.

The inertial platform is a conventional external gimbal design, with beryllium gimbal and stable element. The unique feature of the guidance package is the control capability. Another small unit, which also makes heavy use of integrated circuits, contains servo electronics for all 12 electro-hydraulic nozzle and injector servos in the control subsystem. Steering and control signals from the computer stabilize the missile in yaw, pitch and roll through nozzle control units in stages 1 and 3. Stage 2, which has a single nozzle instead of the four on Minuteman 1's second stage, has a somewhat different control system: cold, liquid freon is injected into the hot gas stream at the nozzle from four differenc points to create a shock wave that directs the engine thrust and governs the trajectory.

III. New wine in old bottles

There are at present 800 Minuteman 1 missiles at five Air Force bases: Malmstrom at Great Falls, Mont.; Ellsworth at Rapid City, N. D.; Minot at Minot, N. D.; Whiteman at Knob Noster, Mo.; and Warren at Cheyenne, Wyo. Warren has 350 missiles in seven squadrons, 50 to a squadron.

SAC will accept the first two flights, 20 missiles, in December. By the end of 1966, the entire 150-missile Wing 6 should be operational. Fifty more Minuteman 2's will be installed at Malmstrom, and then all Minuteman 1's will be replaced by the early 1970's through a massive modernization program.

Wing 6 is tailored to the Minuteman 2, but the modernization program calls for modifying the ground facilities at the other bases for the new missile. The most obvious need is for deeper silos—the new missile is five feet longer than the old. However, the guidance computer is so versatile that much of the other modernization can be done with tapes, rather than new hardware. It will not be necessary to design new launch readiness testing equipment, for example, since the computer itself can perform most of the tests previously accomplished by equipment outside the missile. Radio Corp. of America has been awarded a $10 million contract to supply the electronic operational and maintenance equipment for the modernization program.

The Boeing Co. is the associate prime contractor for assembly and test of Minuteman 2, which will be the most advanced missile in the arsenal (though it is not as powerful and cannot carry the payload of the liquid-fueled Titan 2, of which 54 are deployed).

The Air Force, however, is looking past the current edition to more sophisticated and more capable weapons. The advanced ballistic reentry systems program (ABRES) is concentrating on penetration aids and more versatile reentry vehicles. It is clear that the division does not consider Minuteman 2 the last word in ICBM's—only the latest.

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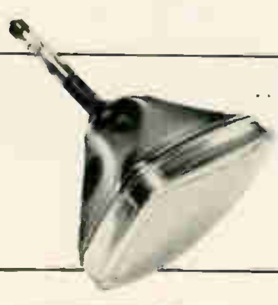

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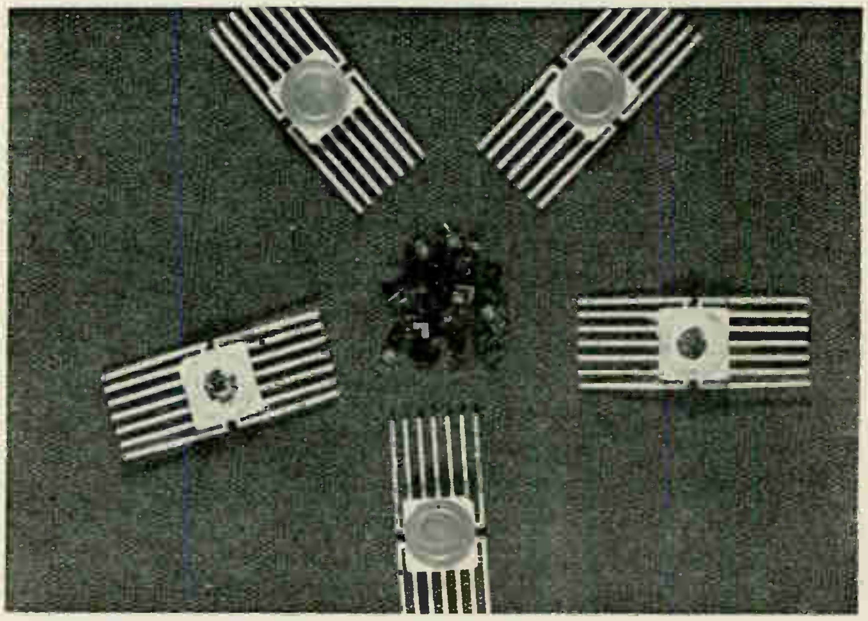
RCA enters integrated circuit market

Broad line of digital and analog monolithic IC's immediately available; more to come next year

From the list of suppliers of commercial, off-the-shelf monolithic integrated circuits, the Radio Corporation of America has been conspicuously missing. This week, the giant corporation served notice that it intended to get its share of the burgeoning IC market. It did so by announcing the availability of a line of 17 silicon monolithic circuits. Initially, eight digital and nine linear types will be offered by the Electronic Components and Devices group; three of the digital types are already being produced for RCA's Spectra 70 computers. During the first quarter of 1966, six more digital and two linear type circuits will augment the line.

The three RCA digital circuits being used in the Spectra 70 computer are the CD2150, CD2151 and CD2152. These circuits are emitter-coupled current-steered logic types (ECL) intended for nonsaturated switching. They have average propagation delay times of only 3.6 nanoseconds with a fanout of 1, and a 10-picofarad load. The CD2150 and the CD2151 are both dual 4-input OR/NOR gates. The CD2152 is a single 8-input OR/NOR gate. Also included in the digital line are an ECL NOR gate and an ECL OR/NOR gate with 5.6-nanosecond delay times, a DTL (diode-transistor logic) dual 4-input gate, a DTL quad 2-input and a DTL J-K flip-flop. Typical logic levels for the ECL devices are −1.6 volts for zero and −0.8 volt for one; for the DTL units they are +0.1 volt for zero and +3.4 volts for one. The DTL gates have average propagation delays of 100 nanoseconds; the delay time for the flip-flop is 175 nanoseconds. The gate circuits have very low power dissipation, typically 2.3 milliwatts per gate. The flip-flop dissipation is about 8 milliwatts. The circuits can be operated from one power



Specifications

Digital circuits:

Type	Description	Noise immunity (typ., mv)	Delay time (nanosec.)	Load fan-out	Power supply range (volts)
CD2100	ECL dual 4-input positive OR/NOR	±320	5.6	1	−5.2±10%
CD2101	ECL quad 2-input positive NOR	±320	5.6	1	−5.2±10%
CD2150	ECL dual 4-input positive OR/NOR	±350	3.6	1	−5±10%
CD2151	ECL dual 4-input positive OR/NOR with Phantom OR output capability	±350	3.6	1	−5±10%
CD2152	ECL single 8-input positive OR/NOR with Phantom OR output capability	±350	3.6	1	−5±10%
CD2200	DTL dual 4-input positive NAND	±1200	100	6	3.8–6.3
CD2201	DTL quad 2-input positive NAND	±1200	100	6	3.8–6.3
CD2203	DTL J-K flip-flop	±1200	175	5	4±5%

Linear amplifiers:

Type	Use	Dissipation (ma)	Input current (μa)	Common-mode rejection (db)	3-db down freq. (Mc)
CA3008, 10	Operational	3.0	5.3	94	0.3
CA3004, 5, 6	R-f	2.6	19–21	98–101	100
CA3001	Video	60	10	70	16
CA3000	Dc	30	23	97	0.65
CA3002	If	55	20	...	11
CA3007	Audio	30	10.5	77	0.02

supply at voltages from 3.8 to 6.3 volts.

The six digital circuits to be added to the line next year, all DTL types, are another J-K flip-flop, three gate circuits with phantom OR output capability, a NAND buffer gate and an input expander circuit.

The linear-integrated circuit line consists of a d-c amplifier, a video amplifier, an intermediate-frequency amplifier, an audio-frequency amplifier, three radio-frequency amplifiers and two operational amplifiers. Additional linear circuits, to be available early next year, are an intermediate-frequency amplifier and an audio-frequency amplifier.

The operational amplifier circuits exhibit typical power gains of 60 db at bandwidths of 300 kc and have typical common-mode rejection ratios of 94 db. They include controlled constant-current sources and feature a low input offset voltage of 1 millivolt. Input voltage ranges from 1.0 to 3.5 volts. The amplifier circuits are intended for use as feedback amplifiers, band-pass amplifiers and servo drivers, and in d-c and video applications.

The radio-frequency amplifiers can provide power gains from 12 to 16 db at a bandwidth of 100 Mc. Gains for the other circuits are 37 db at a bandwidth of 650 kc for the d-c amplifier, 19 db at 16-Mc bandwidth for the video amplifier, 23 db at 11-Mc bandwidth for the intermediate-frequency amplifier, and 22 db at 20 kc bandwidth for the audio-frequency amplifier.

The CD2150, CD2151 and CD-2152 are rated for operation from +10°C to +50°C. The other digital circuits and all of the linear circuits can be operated from −55°C to +125°C.

The digital integrated circuits are mounted in 14-lead ceramic-metal flatpacks. Prices for the digital circuits start at $1.60 per gate in evaluation quantities of 1 to 24 units. All of the linear integrated circuits are available in TO-5 style packages. The operational amplifiers, however, are also available in modified flatpacks. Prices for linear circuits start at $4.40 in evaluation quantities.

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The Special Products Division of Transitron has added a complete line of temperature-compensated, time delay relays for application in electronic and electrical equipment.

Formerly products of Electronic Fittings Corporation, a recent Transitron acquisition, the line includes both thermal/magnetic relay types and solid-state models with no moving parts or contacts.

Typical units are the "J" Series low-cost, glass-envelope type and the "S" Series snap-action type shown below. Also available are high-vibration and shock resistant models, voltage and temperature compensated units with instantaneous reset, etc.

All models are now being manufactured in Transitron's Wakefield, Mass. plant, and are available to customers through Transitron Sales Offices in all parts of the country.

"J" Series Time Delay Relay

"S" Series Time Delay Relay

Typical time delay relay types

"J" Series Time Delay Relay
• Low cost • Glass enclosed • Hermetically sealed • Miniature

"S" Series Time Delay Relay
• Snap-action contacts • Vibration and shock resistant • Hermetically sealed • Temperature compensated

Recent acquisition adds broad line of connectors, components

Wakefield, Mass. — An extensive line of precision electronic connectors is now being manufactured and sold through a newly-established division of Transitron Electronic Corporation.

The connector line, which represents a new segment of the electronic components field for the company, was obtained through Transitron's recent acquisition of Electronic Fittings Corporation, formerly located in Danbury, Connecticut, and well-known as a manufacturer of high-quality components. All elements of the line are now being produced by Transitron's new Precision Connector Division, located in the firm's East Boston plant.

To be sold through distributors

According to a Transitron spokesman, connectors constitute a logical complement to the semiconductor and special products which currently represent a major portion of the firm's business. He indicated that they would be sold through Transitron's nationwide network of sales offices (see below).

Initially the line, which includes both MIL-type and commercial connectors, will correspond essentially to that previously offered by EFC.

Series 7030 Micro-Miniature Connector

Printed circuit — Miniature types

Foremost among the standard connector series currently available are sub- and micro-miniature types, and printed circuit connectors such as the typical units shown at left.

The line also includes cable connectors, high-density packaging connectors, solderless terminal blocks, relay receptacles, and a number of other special-purpose units.

In addition to standard, catalog types, Transitron has the capability for designing and producing, to exacting specifications, an unlimited range of custom connectors to meet special applications and requirements.

Edge-Type Printed Circuit Connector

Typical connector types

PRINTED CIRCUIT CONNECTORS	No. of contacts (single or dual row)
Series 062	for 1/16" board 6, 10, 15, 18, 28, 30, 43
Series 093	for 3/32" board 10, 15, 18, 22, 25

Edge-Type Printed Circuit Connectors are also available (Series 062WP for 1/16" boards; Series 093WP for 3/32" boards).

MICRO-MINIATURE CONNECTORS	Number of contacts
Series 7030	5, 7, 9, 11, 14, 20, 26, 29, 34, 44

Send today for new, free catalog data on Transitron Precision Connectors and/or Time Delay Relays . . . available from Transitron Electronic Corporation, Wakefield, Mass., or from your local Transitron Sales Office.

PCD **Precision Connector Division**

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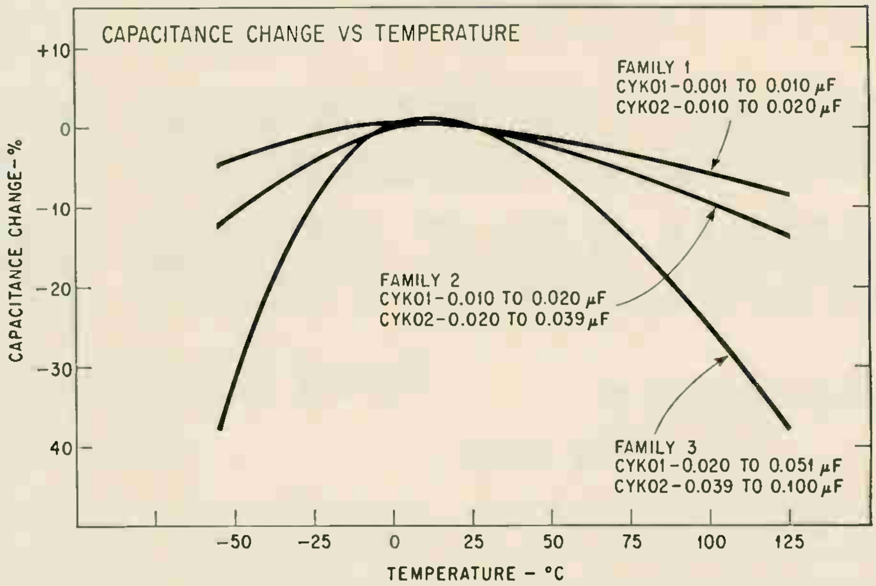
Circle 171 on reader service card

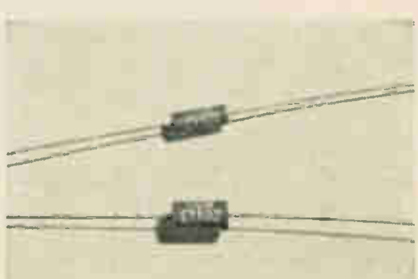
New Components and Hardware

Glass capacitors offer reliability



Miniature glass capacitors that offer the size advantages of ceramic capacitors and the consistent performance associated with glass dielectrics have been developed by the Electronic Products division of the Corning Glass Works. The physical size and values of capacitance meet the requirements of both military and commercial applications. The larger capacitance values are suitable for point-of-use filtering in computers and for bypassing and coupling elements in miniaturized circuitry, while the smaller capacitance values are suitable for more critical circuit functions.

The capacitors are 0.25 inch long and are made in diameters of both 0.10 and 0.14 inch. The smaller-diameter capacitor is designated as series CYK01, and includes capacitances ranging from 0.001 to 0.051 microfarad. The larger-diameter capacitor, the CYK-02, includes capacitances from 0.01 to 0.1 microfarad. Both series are



rated at 50 volts d-c and are supplied in tolerances of 10% and 20%.

Because of the glass dielectric, the percentage variation in capacitance with temperature and voltage is both predictable and repeatable. The graph above shows typical curves of percentage change of capacitance versus temperature (TC) for the three families in the CYK01 and CYK02 series. In any one family, every capacitor will exhibit a similar TC curve within a small percentage range. With repeated recycling over the same temperature range, a particular capacitor will always exhibit the same characteristics. Applying rated voltage over the temperature range (TVC) does not increase the change in capacitance for families one and two, but does produce a slight increase in family three.

The small size and the electrical performance of the capacitors is the result of a new Corning technique for producing high-dielectric-constant glass with uniform characteristics. Ribbons of glass of optical purity are covered with electrode material and are sandwiched together to form the plates of the capacitor. The ends of the capacitor are plated, and Dumet leads, which can be soldered or welded, are attached. High temperature is then applied to produce the microcrystals dispersed throughout the glass

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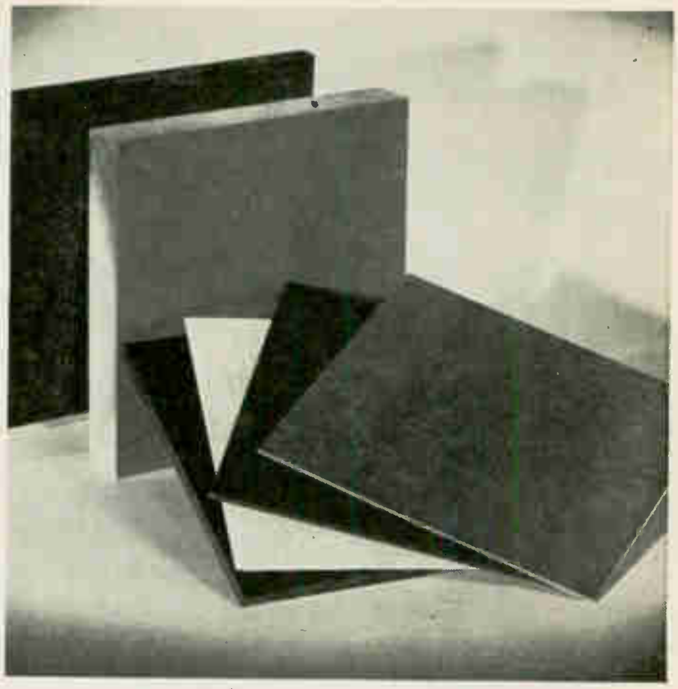
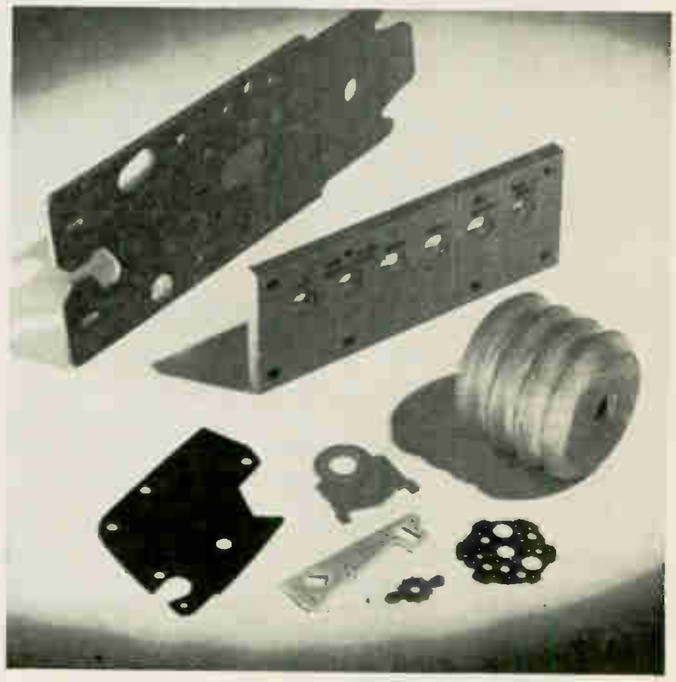


many grades, many thicknesses

instant stock



fabricated

So varied are the needs for thermosetting laminated plastics that we now make Synthane sheets in 81 grades, each with its own combination of physical, mechanical, electrical and chemical properties—all machinable. We produce Synthane sheets in a variety of thicknesses—from 0.005″ up to 8″, depending upon the grade, in standard colors and finishes, and in copper-clad.

Our sheet sizes are normally 36″ x 36″ and 72″ x 36″ but certain grades are also available in sheets 96″ x 24″. Over 75% of orders for Synthane sheets can be filled immediately from our Instant Stock, a convenience that also enables us to start fabrication of parts made from our sheet materials promptly. Write for information about Synthane sheets and parts fabricated from Synthane sheets today. Synthane Corporation, 36 River Road, Oaks, Pennsylvania.

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Synthane-Pacific, 518 Garfield Avenue, Glendale, Calif. 91204

Circle 173 on reader service card

that give the glass its high dielectric constant. The baking process also produces a rugged glass chip in which the leads are firmly imbedded. The chip is then potted in a Dow-Corning silicone case, which is relatively impermeable to moisture and is not flammable.

Sometime in the future, the capacitor chips—without any leads or silicon jacket—will be available for monolithic or integrated circuitry that requires larger values of capacitance than can be obtained by thin-film or diffusion techniques.

The capacitors are designed to exceed the specifications of MIL C-1105.

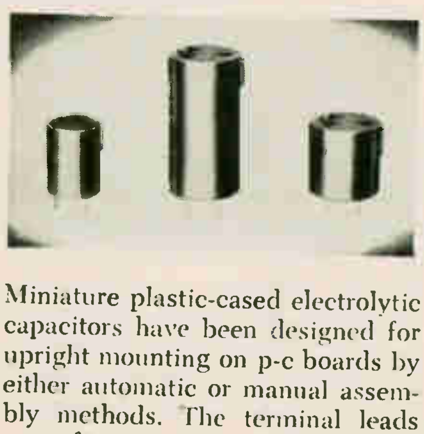
Specifications

Length-in.	0.25		
Diameter-in.			
CYKO1	0.1		
CYKO2	0.14		
	Fam. 1	Fam. 2	Fam. 3
Max. cap. —uf			
CYKO1	0.01	0.02	0.051
CYKO2	0.02	0.039	0.1
Max. power factors*	1.5%	1.5%	3%
Min. resistance-ohms	10^{11}	10^{11}	10^{10}
TC (—55° to 125° C)	+2,—10%	+2,—15%	+4,—40%
TVC (—55° to 125° C)	+2,—10%	+2,—15%	+4,—50%
Δ C after life test*	2%	5%	10%
Δ C after moisture resistance test*	2%	2%	10%

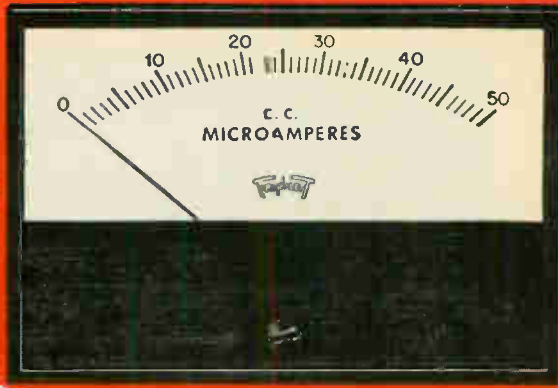
* Values are for CYKO2. Tighter control exercised for CYKO1.

Corning Glass Works, 3900 Electronics Drive, Raleigh, N. C. [351]

Plug-in electrolytics encased in plastic



Miniature plastic-cased electrolytic capacitors have been designed for upright mounting on p-c boards by either automatic or manual assembly methods. The terminal leads are of steel to ensure sufficient



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2 sizes: 3-1/2", 4-1/2"

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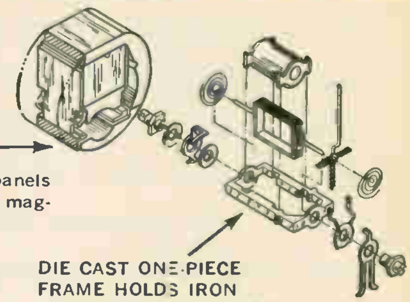

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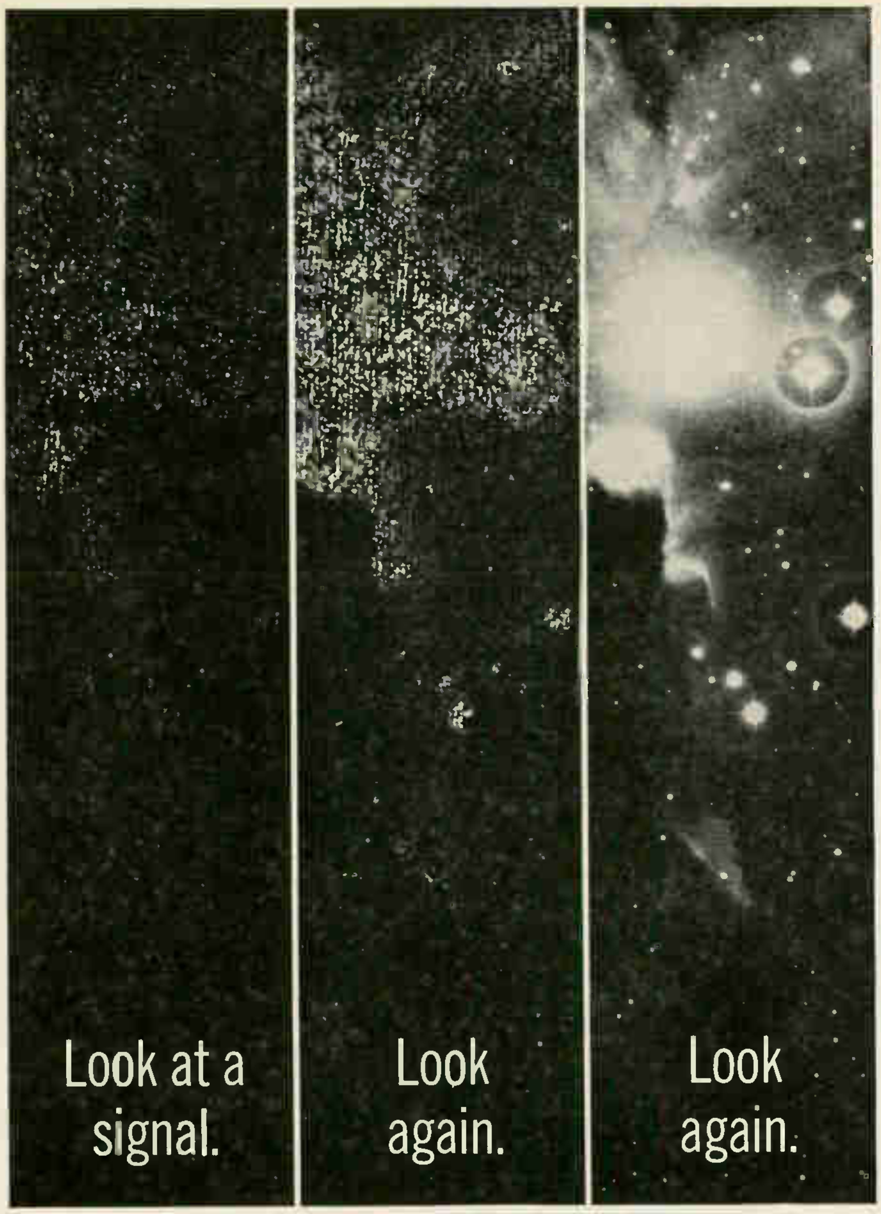
TRIPLETT ELECTRICAL INSTRUMENT COMPANY, BLUFFTON, OHIO

Circle 175 on reader service card



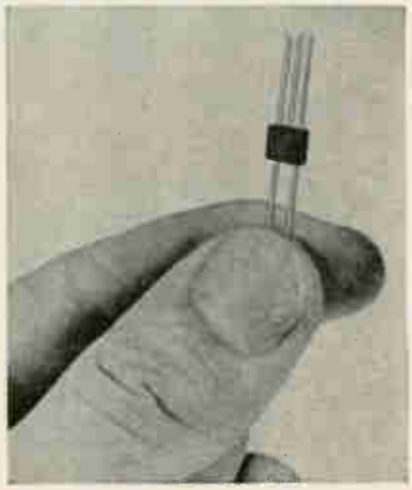
rigidity for mechanical insertion; they are welded to the internal foil and are copper-plated and tinned for ready solderability.

Capacitance, voltage and a + symbol are molded into the top of the plastic case, which is completely sealed and is color-coded for immediate indication of working voltage. The positive terminal can also be identified tactually by means of a rib on the case alongside it. These features simplify equipment inspection as well as assembly.

Twenty values are now available, from 500 μf at 3 v to 50 μf at 50 v. Temperature range is —20° to +70°C. Quantity prices start at less than 10 cents.

British Radio Electronics, Ltd., 1742 Wisconsin Ave., N.W., Washington, D.C., 20007. **[352]**

Microminiature transistor chopper



A solid-state silicon microminiature chopper is said to be the smallest ever devised. Model 6 Microchopper will connect and disconnect a load from a signal source, and may also be used as a synchronous demodulator to convert an a-c signal to d-c. Linear switching or chopping of voltages can be accomplished over a wide dynamic range from ±20 μv to ±5 v. Model 6 is an inertialess device that can be driven from d-c to 100 kc.

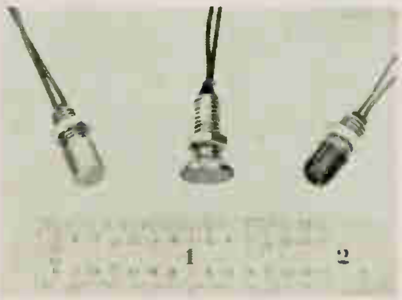
The device is immune to the effects of shock and vibration, making it ideally suited for military, missile, and portable applications, or where power conservation, miniaturization and elimination of maintenance are a necessity. The transistor chopper has an inherently long life and is not subject to contact bounce, wear, pitting or burning.

Dimensions of the model 6 are 0.06 x 0.20 x 0.20 in. Weight is 0.5 gram nominal.

Applications include low-level voltage measurements, d-c amplifier stabilization, high-speed servomechanisms, thermocouple instrumentation, and low-level switching.

Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. [353]

Tiny indicator lamps feature rfi shielding



New subminiature indicator lights use internal grounding and bonding to suppress rfi conduction and radiation. All components meet requirements for use in radiation-free airborne electronic panels conforming to MIL-I-26600.

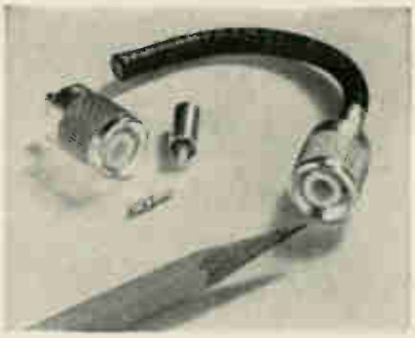
In these lights, rfi is absorbed by a mesh shield within the plastic indicator lens. A special conductive seal connects this shield to the indicator case, which in turn provides a low-impedance r-f path to ground. The combination effectively eliminates rfi radiation in the important 0.15-to-1,000-Mc range.

The lights measure $\frac{9}{16}$ in. over-all and weigh less than 0.032 oz. Three basic types are available: (1) type L10020 and L10420 with $\frac{7}{32}$-in.-diameter, dome-shaped lens projecting $\frac{9}{32}$ in. in front of panel for all-round visibility; (2) type L10220 & L10620 with flat $\frac{3}{8}$-in.-diameter circular lens in beveled ring, for mounting flush with panel face; and (3) type L10120 & L10520

with flat 0.220-in.-diameter, circular lens in ¼-in.-long cylindrical stainless steel sleeve. All types can be furnished with 5 to 28 v d-c lamps, and with white, red, green, blue, yellow, amber or clear lenses. In all models, lamp and lens are integrally molded into the stainless steel case, forming a sealed, moisture-proof unit.

Controls Co. of America, Control Switch division, 1420 Delmar Drive, Folcroft, Pa. [354]

Fast-crimping-type TNC co-ax connectors



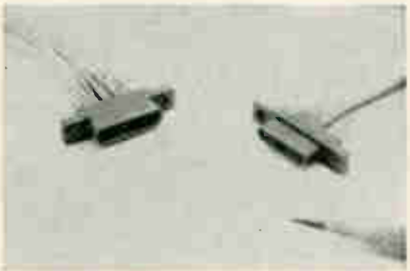
A complete line of Quick Crimp TNC coaxial connectors has been developed to meet revised military specification MIL-C-23329A. Known as MIL-Crimp TNC's, the connectors can be assembled in about 30 seconds as compared with 5 to 15 minutes for a standard solder and clamp type connector, and are far superior electrically to their older counterparts.

The TNC threaded coupling mechanism, designed for use in high vibration applications, eliminates the possibility of noise generated within BNC bayonet-coupled connectors. Other than coupling, TNC connectors are dimensionally and electrically similar to BNC units.

The new connectors provide lower swr than the 1.25 called out in MIL-C-23329A and have cable pull-off strength above the 70 lb specified. Vswr is held to just 1.2 at 10 Gc. Cable pull-off exceeds the braid strength, typically 90 lb, compared to 35 lb for most connectors with a cable clamping device.

MIL-Crimp TNC's have gold-plated captivated contacts and are classed as weather-proof. Optional heat shrink tubing is recommended for applications in extremely severe environments.
Amphenol RF Division, 33 E. Franklin St., Danbury, Conn. [355]

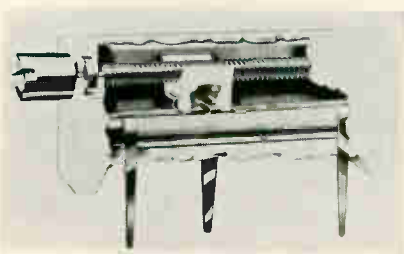
Coaxial connector with 7-contact layout



The Micro-D, a microminiature connector with coaxial contacts, is available with a seven-contact layout—five standard Micropin and two coaxial contacts. It is designed to accommodate cables RG196/U and RG178, and 50-ohm coaxitube with an outside diameter of 0.070 in. RG 188/U cable will be added in the near future.

Crimp techniques are used to terminate inner conductors to contacts. Outer conductors are also crimped, except the outer conductor of the coaxitube, which is soldered.
ITT Cannon Electric, 3208 Humboldt St., Los Angeles, Calif. 90031. [356]

Tiny trimming pots have high resolution



A series of microminiature trimming potentiometers now available use a new production process called Weld-Fast to fasten the tiny trimmer lids permanently to the cases.

The 2600 line of trimmers measure ¾ in. long, $\frac{5}{16}$ in. high and $\frac{5}{32}$ in. wide. Yet resolution is said to be 53% better than most comparable units, because the mandrel runs the full length of the trimmer. Unnecessary mounting holes have been eliminated.

Weighing only 0.04 oz—less than half the weight of comparable units—the 2600 trimmers exceed MIL-STD-202A, steady state, for humidity, while the humidity-proof 2610 versions exceed MIL-STD-202B. Both series utilize an improved low-mass wiper design for positive setting stability. This design prevents wiper shift under shock or vibration, assuring contact up to 50 g's. The new wiper carrier is made of a high-temperature plastic for improved continuity.

The 2600 trimmer is available at $1.46 per unit for 25- to 49-piece orders. The humidity-proof 2610 version is available for less than $2 per unit.

Amphenol Controls Division, 120 S. Main St., Janesville, Wis. [357]

Rfi-shielded push-button switch

A dpdt push-push design switch features the use of internal bonding and grounding to eliminate mechanical discontinuities that could serve as points of rfi emission. All switches meet radiation requirements for use in airborne electronic equipment designed to MIL-I-26600 specifications.

A low-impedance ground path for spurious rfi is provided by connecting all moving metal parts within the switch to the switch case

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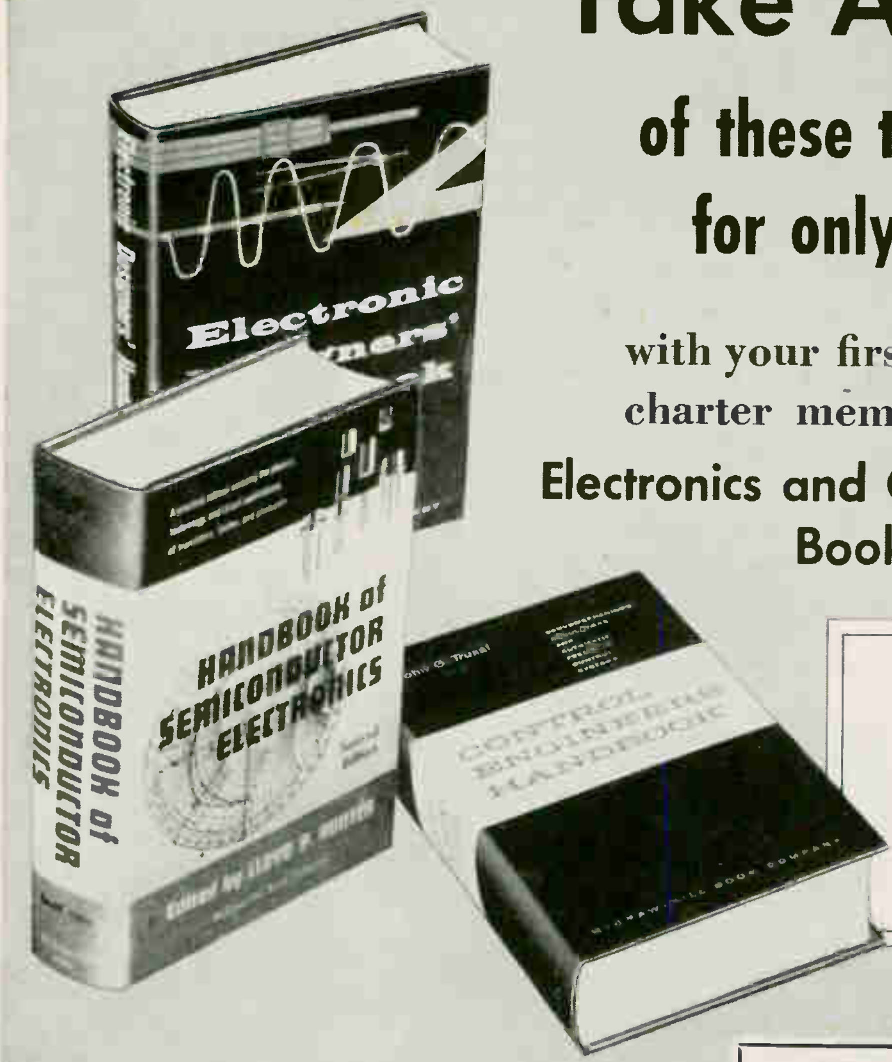

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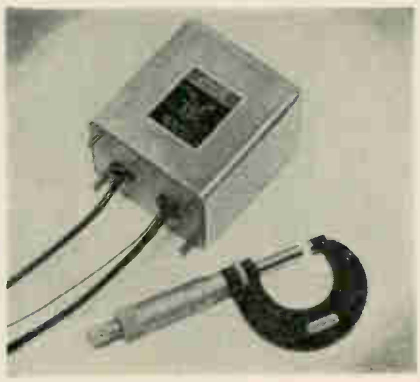
through multipoint-contact spring wipers. The cadmium-plated brass case insures a high-conductivity connection to the mounting panel. The result is effective suppression of rfi radiation in the critical 0.15- to 1,000-Mc range.

The new push-push switch, designated type J334P6, is rated for 1 amp resistive at 28 v d-c or 120 v a-c. Minimum life expectancy at this load is 25,000 cycles. Small and lightweight, the unit measures just 1⅝ in. over-all and fits a ⅝-in. mounting hole.

Controls Co. of America, 1420 Delmar Drive, Folcroft, Pa. [358]

Power transformers are highly shielded



Low-noise, highly shielded power transformers are now available. Eight models (8851 through 8858) in the Electro-Guard series are rate at 25 watts resistive with output voltages ranging from 6.3 to 150 v. Primary input for all models is 117 v, 60 cps. They are designed for use in strain gage power supplies, d-c amplifiers, bridge power supplies, signal conditioners, and other high-isolation applications.

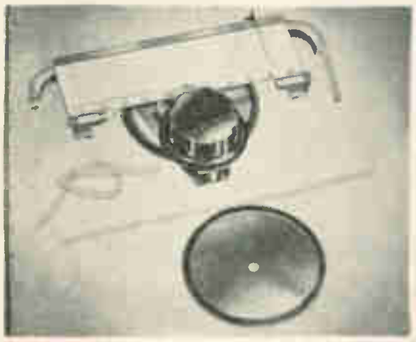
The units have complete primary and secondary box shielding to assure low winding-to-winding capacity. Shield effectiveness per winding is 55 db minimum. Maximum interwinding capacitance is 5×10^{-5} picofarads. When operating at full load, temperature rise is held to 30°C maximum. All models are available with secondary center tap.

Power efficiency between primary and secondary windings when operated at 25 w is 85% typical. The insulation between windings will withstand 1,000 v a-c at 60 cps.

The 25-watt transformers measure 2¾ in. long x 2⅜ in. wide x 3 in. high, not including the four threaded mounting studs. Each weighs 30½ oz. The units terminate in two shielded cables, grommeted at the header. Price range is from $25 to $37 each.

James Electronics, Inc., 4050 N. Rockwell St., Chicago, Ill. [359]

Illuminated dial has no indicator stutter



Model 10037 is a sturdy dial assembly that completely eliminates the annoyance of string-driven pointers, eliminates all indicator stutter or wobble and provides positive pointer travel and resetability. The pointer is driven positively by a flexible but nonelastic molded gear-driven rack which cannot slip, break or fall off a pulley. The geared flexible rack rides in a multi-slot extruded aluminum channel.

The drive mechanism is a smooth friction drive with 180° rotation of the output shaft. Teflon bearings, which never need oil, assure a lifetime of smooth operation. The ¼-in. output shaft is supplied with an antibacklash flexible coupling to facilitate installation. The 5½ turns of the knob result in 6½ in. of pointer travel. The dial face has one scale printed 0-100 plus blank scales. The dial has a convenient adjustable zero-set and an anti-parallax pointer.

The dial is supplied with a scale bezel for the front of the panel. Outside dimensions of the scale bezel are 8 in. wide x 2⅝ in. high. The behind-the-panel space required is 8½ in. wide x 6 in. high x 1 5/16 in. deep over-all.

James Millen Mfg. Co., 150 Exchange St., Malden, Mass., 02148. [360]

New Semiconductors

Silicon rectifiers rated at 12 amps

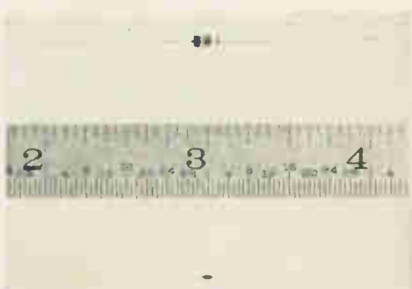
A 12-ampere stud-mounted silicon rectifier is applications-rated to give designers more power-handling capability at substantially less cost than virtually any other DO-4 device in the low-to-medium-current area.

The MR1120-30 series, ranging from 50-1,000 volts, carries its full rated 12-ampere load at an elevated case temperature of 150°C. Prices start at 65 cents (100-up) for a 50-volt unit, lower than for standard 200-ma stud rectifiers.

Additional advantages of the new series are 300-ampere current surge protection, 0.55 average forward voltage and availability of reverse polarities.

Motorola Semiconductor Products, Inc., Box 955, Phoenix, Ariz., 85001. [371]

Silicon diodes are magnetically pure

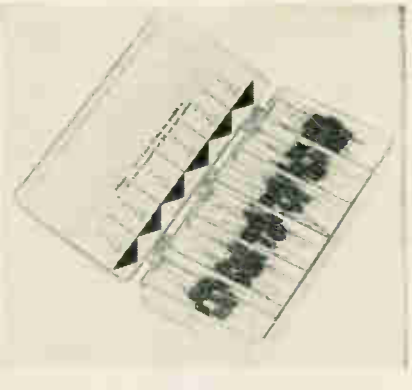


Magnetically pure silicon diodes are designed for space environments requiring low-density residual magnetism leads for magnetometer experiments add/or space mapping of magnetic fields. The magnetically pure leads (less than 1 gamma at a 3-inch distance) will eliminate the need for magnetic shielding or parts placement for field cancellation.

These highly reliable processed devices encompass electrical characteristics of fast switching computer devices, less than 2 μsec recovery, low leakage signal silicon devices and high-voltage microdiodes in excess of 1,000 volts. Dissipation is 300 milliwatts and higher. Lead material is gold plated silver 0.003 x 0.018 in. flat ribbon. Body size is 0.050 X 0.100 in.

MicroSemiconductor Corp., 11250 Playa Court, Culver City, Calif. [372]

Lab-kit determines zener tolerance



A "Zener Lab" has been introduced for use in accurately determining the zener tolerance of a circuit. It consists of a kit of 80 one-half-watt zener diodes, supplied in increments of 0.1 v throughout the range of 2.0 to 10.0 v. Each zener is graded to ±0.05 v. tolerance at each voltage, which is stamped on the zener body.

With this kit the circuit designer can find the optimum zener for a particular circuit, and then by substituting zeners with higher and lower voltages, find the tolerance spread. He thus avoids specifying a high-priced, close-tolerance diode when one of wider tolerance would fulfill the requirements. The kit is priced at $49.50.

Schauer Mfg. Corp., 4300 Alpine Ave., Cincinnati, Ohio, 45242. [373]

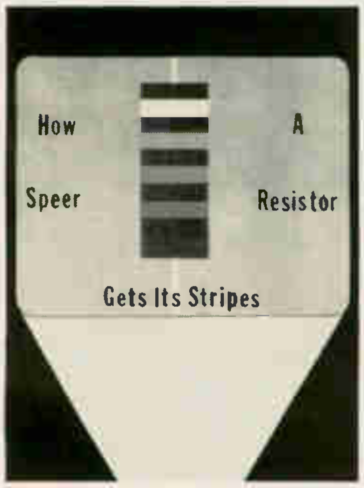
COMPONENT COMMENTS *From Speer*

Has our traveling resistor show visited you yet?

We're referring to our new slide film presentation called "How a Speer Resistor Gets Its Stripes."

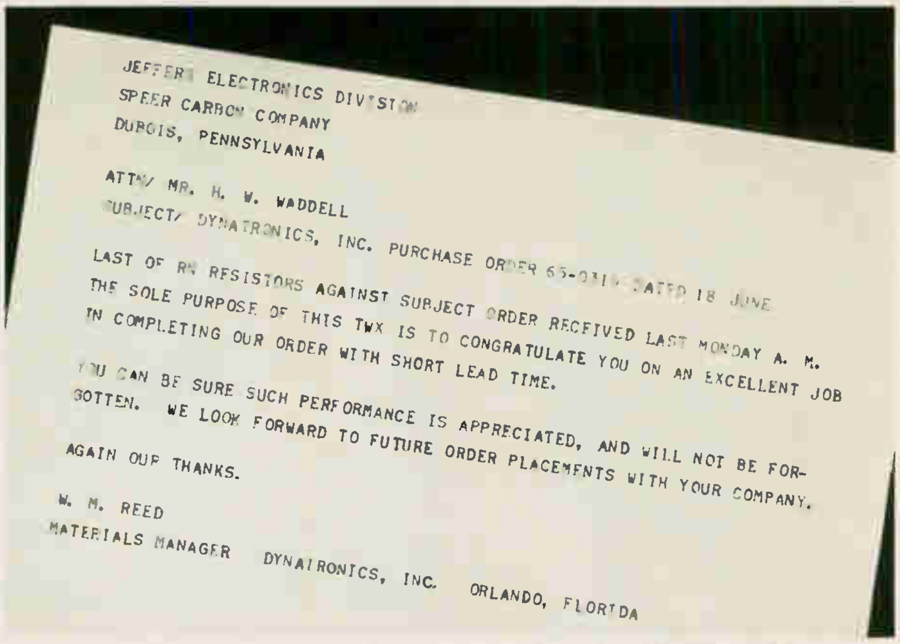
This lively 20-minute sound and color film follows a typical group of Speer composition resistors as they try to "shape up" to today's tougher MIL-R-39008 specs.

Starting with the first manufacturing steps, you'll see the



various tests that the raw materials have to pass. You'll see the exhaustive checks that accompany every step of resistor production. You'll see the latest electronic quality control and reliability equipment in action. And you'll see the proud moment when the resistors receive their insignia of uniformity and high quality—five colorful stripes.

If you're concerned with meeting military specifications, you'll want to arrange a free screening of this slide film. To do so, simply contact your nearest Speer representative. If you don't have his name, mail the coupon and we'll let you know where to reach him.



JEFFERS ELECTRONICS DIVISION
SPEER CARBON COMPANY
DUBOIS, PENNSYLVANIA

ATTN/ MR. H. W. WADDELL
SUBJECT/ DYNATRONICS, INC. PURCHASE ORDER 65-031 DATED 18 JUNE

LAST OF RN RESISTORS AGAINST SUBJECT ORDER RECEIVED LAST MONDAY A. M.
THE SOLE PURPOSE OF THIS TWX IS TO CONGRATULATE YOU ON AN EXCELLENT JOB
IN COMPLETING OUR ORDER WITH SHORT LEAD TIME.

YOU CAN BE SURE SUCH PERFORMANCE IS APPRECIATED, AND WILL NOT BE FOR-
GOTTEN. WE LOOK FORWARD TO FUTURE ORDER PLACEMENTS WITH YOUR COMPANY.

AGAIN OUR THANKS.

W. M. REED
MATERIALS MANAGER DYNATRONICS, INC. ORLANDO, FLORIDA

Fan letter. *It seems that Dynatronics needed large quantities of .1% tolerance metal film resistors in a week. And only Jeffers Electronics would promise to meet their deadline. As you can see, we also kept that promise. Do we always deliver this fast? No. But even our normal delivery of standard JXP resistors is three times faster than the service you may be getting elsewhere.*

If you're looking for the best temperature stability and least cost in a precision resistor, forget about its TC

We're as respectful of traditions as anyone. And we're well aware that the traditional determination of resistance-temperature stability is based upon resistance measured at two specified temperatures. (Otherwise known as "TC".)

We believe, however, that there is a more advantageous way to express resistor temperature stability—one that will prove less costly to you in situations where a high degree of stability is required.

We recommend instead a "design tolerance" or "total resistance deviation limit" expression of the stability of a precision resistor. For example, a resistor with an allowable total resistance deviation limit of 1,000 ppm over a given temperature range will satisfy the same circuit requirement as a resistor that is specified by a ± 5 ppm TC. Yet specifying a 1,000 ppm limit delivers a resistor that would cost only one third as much (and delivers it a lot faster, too).

We might mention our ultra-precise JXP metal film resistor at this point. It is available in tolerances that can meet your *toughest* stability requirements.

A detailed discussion of our new stability determination method can be found in our article entitled "Specifying Resistance Temperature Stability." If you'd like a copy, simply mail the coupon.

JEFFERS ELECTRONICS DIVISION,
Speer Carbon Company
DuBois, Pennsylvania

Speer Carbon Co. is a Division of Air Reduction Company, Inc.

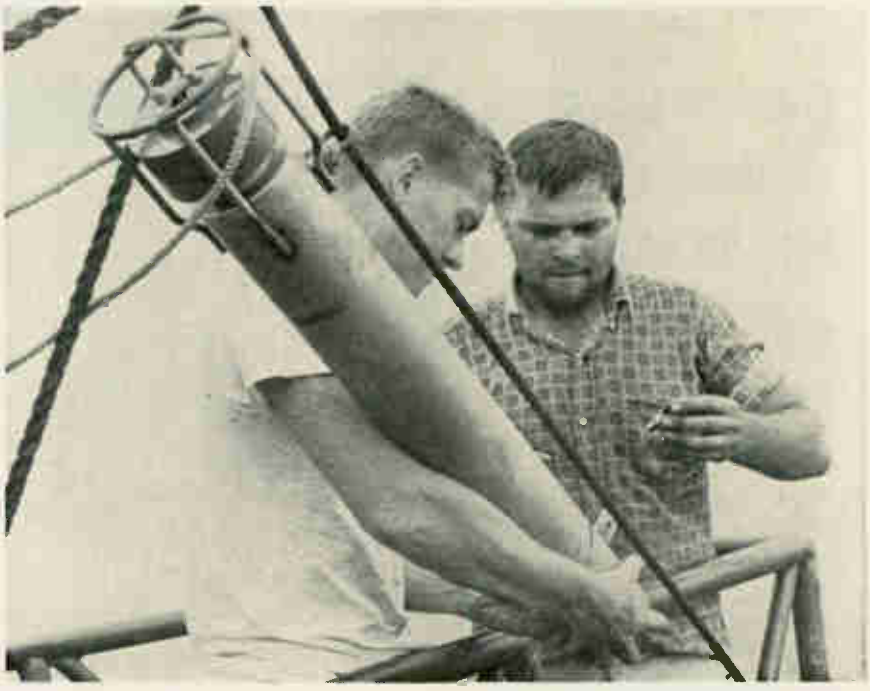
☐ Rush "Specifying Resistance Temperature Stability."

☐ Rush the name of my nearest Speer representative.

Name__________
Title__________
Company__________
Street__________
City__________
State__________ Zip__________

Circle 185 on reader service card

Telemeter transmits undersea data



Depth telemetering transducer is being shackled to the warp of the towing wire just ahead of a fish-sampling net by Richard Haedrich, left, and Charles Karnella of Woods Hole Oceanographic Institution.

Among the many mysteries of the ocean is a deep layer that scatters acoustic signals as layers of the ionosphere scatter radio signals. The layer, consisting of floating plants and animals collectively called plankton, varies in depth with temperature, currents and the upwelling of enriched waters. Sonar engineers as well as oceanographers and antisubmarine-warfare strategists would like to know more about this anomaly and how it can be predicted, identified, used or avoided.

In most investigations, a plankton net is towed to sample concentrations of fish and organisms. Crux of the investigation is depth, and how it varies with time. A conventional time-depth recorder, using a pressure-actuated tube, provides a record for later study, but this is not sufficient for many projects. A combination of wire length let out and wire angle at the surface will give only a rough estimate.

It was to satisfy the researchers' need for a real-time, accurate and continuous record that the Benthos Co., of Falmouth, Mass., developed its depth telemeter. "But a second market appears to be opening," says Benthos president Samuel O. Raymond. "In commercial fishing, it is important to monitor the depth of trawls for systematic sampling of fish."

The wireless acoustic link consists of a cylindrical stainless-steel housing with a transmitting transducer mounted on one end. The assembly is fastened to the wire just in front of the net. Pings of sound emitted by the unit travel through the water to the ship, where they are received by a standard echo sounder at the bottom of the vessel. The pings are displayed on the chart of the echo sounder, or they can be displayed on a battery-powered oscilloscope.

The pings come in pairs. The A ping occurs exactly once a second, and can be recorded on a sounder which has a sweep of one second or less. Each B ping occurs a variable time after each A ping. As depth increases, circuitry inside the telemeter causes the time interval between A and B to increase. By reading the time interval on a scale

We can deliver power as you like it...

and we've recently proved it again!

Shipment of the prototype power converter for IMP, NASA/Goddard's Interplanetary Monitoring Platform, is the latest in a long line of satellite power system achievements by Space Craft, Inc.

Since IMP's mission includes the measurement of fields, the system requires a power supply which generates no significant magnetic field. In response to this requirement, Space Craft designed and built a non-magnetic power converter. It converts DC to RF through a 1 Mc oscillator and demodulates back to DC at four output voltages. Voltage regulation is better than ±0.05%.

Thus IMP takes its place among more than a score of power conversion contracts successfully completed or under way at Space Craft, Inc. These systems have combined conversion efficiencies as high as 86% with minimum weight, minimum volume and maximum reliability.

When you have specialized power problems, go where the experience is . . .

SPACE CRAFT, INC.

8620 SO. MEMORIAL PKWY. / HUNTSVILLE, ALA. 35802

Circle 303 on reader service card

GLOBE

For prototype motors/blowers not on anyone's shelf, call Globe 513 222-3741

When you need prototypes you need them fast—and you may want one or several units.

We know this. That's why the Globe Small Order Department has its own manufacturing facility separate from our extensive production operations. Standard components are assembled for quick delivery of your custom designs.

You name your requirements — d.c. or a.c., speed and torque, available voltage, cfm, back pressure, size, environment, any special performance characteristics. We'll design with you or for you—build it off the back of an envelope if necessary—see that you get what you ordered and stay with you through the modification stages until your project is honed to everyone's satisfaction.

Globe Industries, Inc., 2275 Stanley Avenue, Dayton, Ohio 45404, U.S.A., Tel: 513 222-3741.

Circle 187 on reader service card

New Instruments

calibrated in depth, it can be determined how deep the towed device is.

The depth telemetering pinger operates by a pulsed spacing technique. The master oscillator puts out a pair of gated 12-kilocycle pulses. These go through a transistor amplifier, and are matched through an output transformer to the ceramic transducer mounted on the end of the pinger housing. As the instrument descends, increasing water pressure actuates an internal pressure-potentiometer, which causes the oscillator generating the pings to modulate the spacing between the first and second pings. At the ocean surface, the spacing is 20 milliseconds. This increases with depth to a maximum of 400 milliseconds.

The technique is not restricted to monitoring of depth. Telemeters can be designed to transmit, for instance, angle of inclination, temperature, light level, and magnetic- or gyrocompass orientation. Any sensed variable that can be converted to a varying resistance or voltage can control the electronics.

A manual stainless steel switch allows the depth telemeter to be turned on just before submersion and stopped soon after recovery, without opening the housing.

The unit can be calibrated by applying pressure through a tapped hole at a port on the end of the housing. Full-scale depths are available from 65 to 3,400 meters, at prices ranging from $1,750 to $1,875.

A calibration curve plotting depth against time delay is supplied with each instrument.

Specifications

Operating frequency	12,000 cycles per second
Beam pattern	Basically omnidirectional
Electrical input to transducer during pulse	48 watts
Pulse length	2 milliseconds
Slant range	More than 2,000 meters
Type of battery	Manganese-alkaline, 16 cells
Battery life	More than 100 hours to 0.5 output power
Housing material	Stainless steel (glass housing optional)
Transducer	Cylindrical ceramic type, potted in silicone rubber

Benthos Co., Falmouth, Mass. [381]

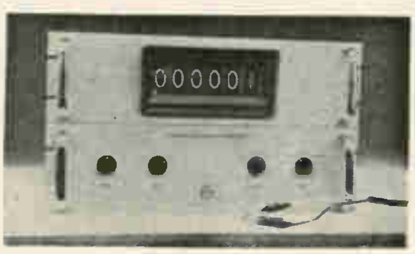
Dual-range centrifuge tests components

A precision dual-range centrifuge, model 444, has many design features that suit it for testing highly precise components under simulated g-forces. Range 1 is infinitely variable from 5 to 100 g's, with over-all accuracy of 0.005%. Range 2 is 10 to 600 g's, infinitely variable, and an over-all accuracy of 0.25%. Either mode will accommodate a 12-in.-cube test package, up to 50 lb dead weight, at each end of the boom. Maximum g-rating of either mode is 10,000 g-pounds.

Other features of the model 444 include a servo-controlled magnetic drive for smooth, precise speed control; a 6,000-pulse generator for digital speed indication; a dynamic radius monitor; air bearings, which result in less than 0.01-g vibration at any speed; a temperature chamber for combined environment testing from $-100°$ to $+350°F$; a speed deviation meter, which provides continuous analog presentation of wow and drift; and a dynamic force and moment balance-sensing system.

Gyrex Corp., 3003 Pennsylvania Ave., Santa Monica, Calif. [382]

Digital ohmmeter features wide range



A digital ohmmeter now in production is said to be the widest-range high-accuracy instrument for au-

Circle 189 on reader service card

tomatic digital measurment of electrical resistance. There are many uses for the model 2050 in a wide range of scientific, industrial and military applications, including: conductor and semiconductor materials research, quality control and production of electronic/electrical devices and materials where resistance is important, and check-out of complete electronic and electrical systems. The meter has already seen use in measuring integrated circuit parameters, transformer coil resistances, and resistivity of semiconductor materials.

Model 2050 has six automatically selected ranges, measures over the extremely wide range from 1 milliohm to 10 megohms, displays its measurement as a 5-digit number accurate to $\pm$(0.01% of reading +0.001% of full scale) over most of its range, and will operate recording, computing and control devices.

Non-Linear Systems, Inc., P.O. Box 728, Del Mar, Calif. [383]

Magnetic-flux-balance current sensors

A line of solid-state, highly accurate current sensors utilize magnetic-flux-sensitive resistors in a magnetic-flux-balance circuit. The sensors measure d-c current in ranges from 0 to 1 ma to 0 to 100 amps and develop 0 to 5 v output.

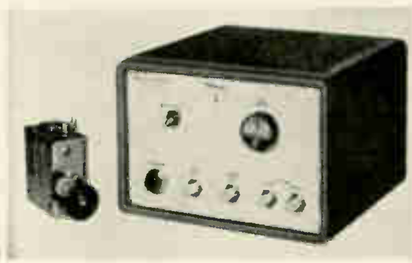
Type 3009A is designed for measuring and controlling current in aerospace, military and industrial applications. The sensor is accurate to better than 1% and can be excited from a 28 v unregulated d-c source such as a battery. The component operates over a —55° to +85°C temperature range.

The current sensor is particularly applicable where complete electrical isolation between input current and output voltage is desired, and in telemetering systems where high voltage and low power consumption are important parameters.

Size is 1⅝ x 1⅝ x 2⅜ in., and weight is 7 oz. The entire power drain is less than 20 ma. No filters are required on the output, and response time is less than 10 msec. In the high current ranges, the conductor cable passes through a tube in the sensor, allowing the current to be measured without breaking the integrity of the vital cables.

American Aerospace Controls, Inc., 129 Verdi St., Farmingdale, N.Y. [384]

Sweep generator tests uhf-tv tuners



A uhf, solid-state sweep generator, model CS-77, has been introduced for testing and aligning uhf-tv tuners. It permits the user to sweep the entire uhf band in a single sweep, with pulse markers appearing at each end of the band. The unit provides a system for rapid check of tuner gain over the entire uhf band, and detailed bandpass checks at each end, without making adjustments to the sweep generator.

The CS-77 divides the wide sweep into three segments. The first third of the scope trace is set to cover channel 14; and the last segment, channel 83. This allows the center portion to cover the remainder of the uhf band. Complete solid-state design also results in a small, lightweight unit and eliminates downtime due to tube failure.

The instrument sweeps from 460 to 920 Mc. It has a fixed sweep width of 460 Mc and a flatness of ± 0.5 db. Sweep rate is 50 to 60 cycles with an output of 0.5 v rms. The unit operates on either 110 or 220 v.

Physical size of the CS-77 is 8½ in. wide x 5¾ in. high x 8 in. deep. Weight is 8 lb. Price for quantities of 1 to 5 is $445 each; 6 to 25, $425 each; quantities above 26, $395 each. Delivery is 60 days.
Texscan Corp., 51 Koweba Lane, Indianapolis, Ind., 46207. [385]

Monitor scope is fully transistorized

A large-screen monitor oscilloscope for general-purpose use, model KM-105, is entirely transistorized except for the magnetically deflected cathode-ray tube, has a 21-in. screen and offers a resolution of 25 lines per cm with a full-scale linearity of 1%.

Drift is very low (less than 5 mm in 8 hours), and x- and y-axis sensitivities are 0.5 v per cm with a full-scale step-function response of 12 μsec, stabilizing to within 0.25%. Maximum spot velocity is 2.5 cm per μsec. Provision for intensity modulation is offered with a bandwidth of 10 Mc.
ITT Industrial Products Division, 15191 Bledsoe St., San Fernando, Calif. [386]

Heat-transfer meter cuts testing time

Model 5900 heat-transfer meter—designed to reduce the test time required to measure the amount of heat or energy dissipated by a heat sink—is ideal for companies developing or working with new plastics or ceramics. A company might have as many as 10 plastics or ceramic mixtures which need thermal-resistance testing and it would take weeks to get the results by other methods compared to a day with the heat-transfer meter.

The method used consists of heating a rod at one end and measuring time and temperature differences. Energy dissipated is measured by calculating how long heat takes in getting from one point to another on the rod. The model 5900 indicates temperature at the sample surface, and also includes a watt meter which measures dissipated energy.

The heat-transfer meter can also be used by receiving inspection to test thermal resistances of purchased products or materials. Price is $495.

International Electronic Research Corp., 135 W. Magnolia Blvd., Burbank, Calif., 91502. [387]

Nanosecond-type h-v pulse generator

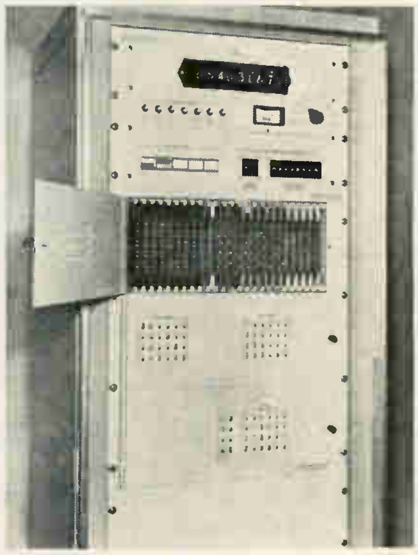
Model 961D provides high-voltage nanosecond pulses into a 50-ohm load for research and development, engineering, and calibration applications. Output pulses are selectable in width from 2 to 20 nsec and rise and fall times are ½ nsec. Output amplitude is adjustable from 0 to 2,000 v. Pulse repetition rate is line frequency or push-button single pulse. Modifications available on special orders are 3,000 v maximum pulse amplitude and 1 cps pulse repetition rate. A trigger pulse sync signal is available from a front panel jack.

Primary application for the model 961D is simulation of scintillations from nuclear events by driving nanosecond light sources such as up to 64 PEK-118 gas lamps. Others include photosynthesis timing, impedance measurements, multiplier phototube testing, nanosecond response testing of photosensitive devices, and magnetic materials research.

Single quantity price is $900; availability is immediate.

Huggins Laboratories, 999 E. Arques Ave., Sunnyvale, Calif. [388]

Clock marks time for computers



Time-shared computers need an accurate, versatile clock to schedule programs, subroutines or problems, and to synchronize the computers with a desired time base. Large computer systems usually have their own built-in clock; but smaller units used in a time-sharing mode must be modified by the addition of an external clock.

A clock and time interval generator just introduced by Datametrics Corp. is said to allow effective time-sharing of digital computers.

Capable of microsecond resolution, model 300 is crystal controlled with a basic clock frequency of 1 megacycle. There are seven time bases available, from 1 microsecond to 1 second, selectable manually or by program. The time base stability is 1 part in 10^8 per 24 hours.

Model 300 has a highly flexible command structure. Seven rate functions and one command mode are combined with control mode commands fed into the device from the computer. These make possible 53 different commands related to timing functions. The eight control modes permit the device to synchronize a computer to any one of seven selectable time bases, update digital-to-analog converters at precise intervals, provide time-variable output signals as a function of computer calculation or program, control analog-to-digital conversion data sampling, and determine and store elapsed time intervals.

The input to the Datametric device is a 30-bit binary word. Six bits represent commands; the remaining 24 bits represent the desired time interval. The output data structure is in the form of a 24-bit word representing time accrued.

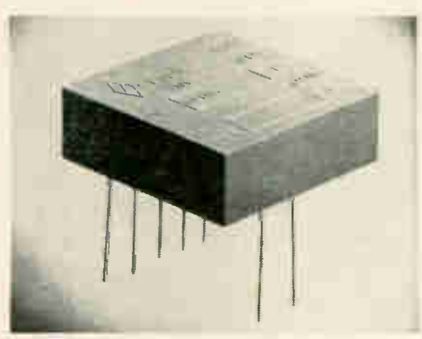
Although specifically designed to interface with the Univac 490 and Univac CP 462B computers, model 300 is adaptable to most other computer systems.

Specifications

Selectable time bases	1, 10 and 100 microseconds, and 1 second
Visual display	Eight digit readout of time data
Input data structure	30-bit command-and-data word; 3 bits for time and selection, 3 bits for mode control selection, and 24 bits of either time-interval generation or time-marker signal indication
Output data structure	24-bit data word plus input data request, interrupt, input acknowledge, and time-marker signals
Command structure	53 commands consisting of combination of 7 selectable time bases plus hold and 8 control modes
Input power	115 volts, 60 cps, 300 watts

Datametrics Corp., North Hollywood, Calif. [401]

Operational amplifier is only 0.4 in. high



The 116 series of miniature-module differential operational amplifiers features a height of only 0.4 in., permitting high-density stacking of the modules on ½-in. centers.

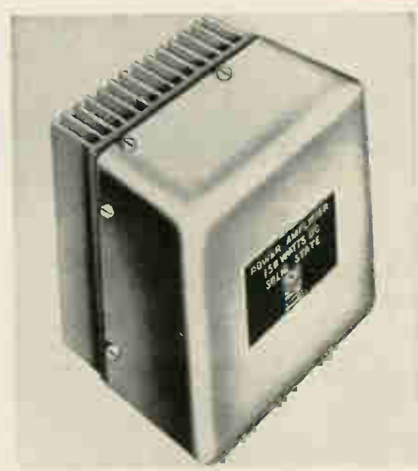
Electrical highlights are a fast

slew rate of 10 v/μsec for the model 116 and 0.6 v/μsec for the model 116B; d-c voltage gain of 50,000 for the 116 and 20,000 for the 116B; a 200,000-ohm differential input impedance and 20-megohm common-mode impedance. Output voltage swing is ±10 v at 4 ma, with short circuit protection. Offset current is less than 0.5 μa without internal trims.

Price in quantities of 1 to 9 is $47 for the model 116 and $32 for the model 116B. Availability is 2 weeks.

Zeltex, Inc., 2350 Willow Pass Road, Concord, Calif. [402]

D-c servo amplifiers are transistorized



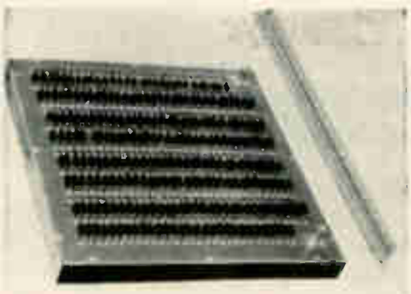
A line of modular d-c servo amplifiers is available in 50-, 150-, and 350-watt sizes. All are completely transistorized. Essentially, these operational power amplifiers, along with d-c direct-drive torque motors, provide a complete servo system. Gain is adjustable from a value of less than unity to 5 x 10^5 v/v, which eliminates the need for a preamplifier.

Protection circuitry is incorporated in all models. The 50-watt model is short-circuit-protected by disabling the low-level circuitry. The 150- and 350-watt models feature short-circuit protection by means of an adjustable current-limited output and are capable of driving load impedance down to zero ohms.

Provision is made for the incorporation of servo compensation networks on a removable card. All models feature multiple inputs, which can be operated single-ended or differential. When they are operated single-ended, one side of the input terminals can be grounded. The input impedance for the noninverting input is greater than 1.0 megohm. The inverting summing input will operate from source impedances greater than 200,000 ohms. The d-c voltage drift is less than 10 μv per °C referred to any input.

All models feature operation from a single d-c supply voltage of 28 v ±15% and an operating temperature range of −25° to 50°C. Inland Controls, Inc., 342 Western Ave., Boston, Mass., 02135. [403]

Delay network provides 250 taps



Model 30A61 delay line has a maximum delay time of 4.0 ± 0.01 μsec, and provides 250 equally spaced taps along its length. Impedance of the line is 150 ohms, attenuation is 3 db, and rise time is 0.05 μsec. Connection to this 10 x 10 x 1-in. delay network is made by two BNC connectors. Specially designed variations can be supplied to individual needs. ESC Electronics Corp., 534 Bergen Blvd., Palisades Park, N.J. [404]

Diode injection laser uses simple pulser

The DLP-4 diode injection laser consists of lasing diode and pulser, and is priced at $365. The GaAs lasing diode has an output wave length of 8450 angstroms, a peak power of 10 watts, and a threshold of 4 x 10^3 amps/cm^2. Junction area is 0.020 x 0.010 in.; beam diver-

For protection of all types of electronic and electric devices

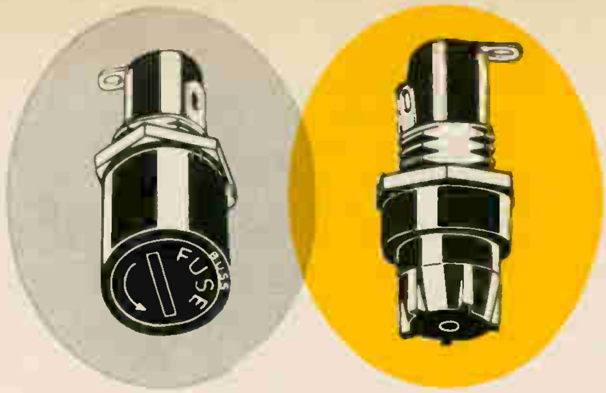
The complete line of BUSS and "TRON Family" fuses includes quick-acting, slow-blowing, signal or visual indicating fuses in sizes from 1/500 amperes up.

All standard items are easily obtained through your BUSS distributor, but if you don't find what you want get in touch with us.

Insist On BUSS QUALITY Fuses

Write for BUSS Bulletin SFB

BUSSMANN MFG. DIVISION, *McGraw-Edison Co.,* **St. Louis, Mo. 63107**



Screw type slotted knob that is recessed in holder body and requires use of screwdriver to remove or insert it.

Screw type knob designed for easy gripping, even with gloves. Has a "break-away" test prod hole in knob.

BUSS Space Saver
Panel Mounted Fuseholders

Fuseholder only 1⅝ inches long, extends just 29/32 inch behind front of panel Takes ¼ x 1¼ inch fuses. Holder rated at 15 ampere for any voltage up to 250.

Military type available to meet all requirements of MIL-F-19207A.

Insist On BUSS QUALITY Fuseholders

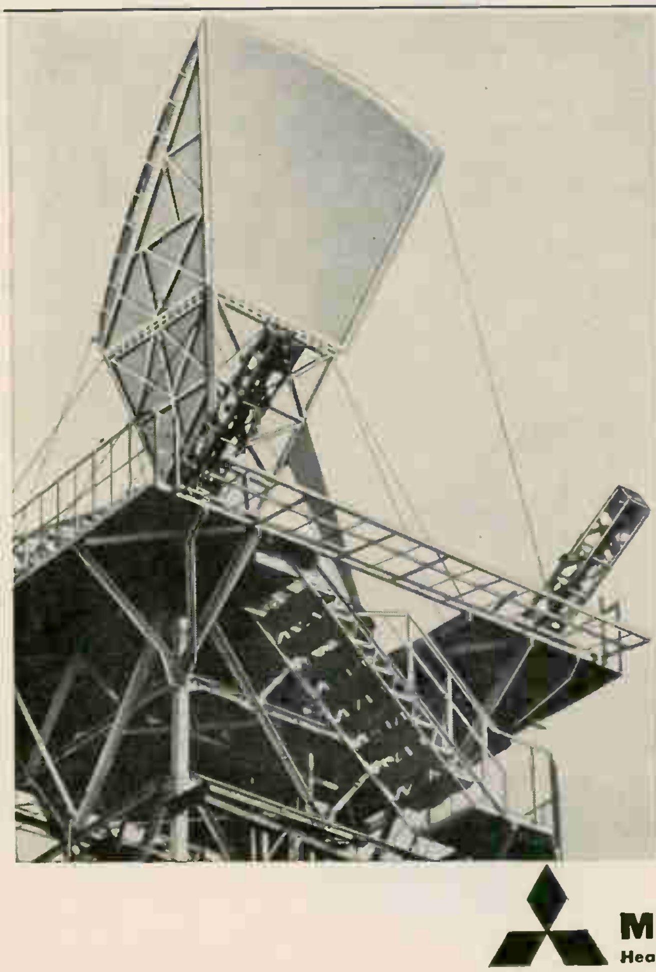
Write for BUSS Bulletin SFH-10

BUSSMANN MFG. DIVISION, *McGraw-Edison Co.,* **St. Louis, Mo. 63107**

BUSS: The Complete Line of Fuses and . . .

Circle 199 on reader service card

Circle 199 on reader service card



MITSUBISHI MICROWAVE ANTENNAS FOR TELECOMMUNICATIONS

Japan today has the second largest microwave network in the world. Mitsubishi Electric, with the longest microwave antenna experience in Japan, has supplied 90% of the antennas used in the trunk lines of this extensive network. Mitsubishi antenna systems include parabolic, scatter, horn reflector and radar types, as well as a complete line of wave guide components and accessories. Frequencies from 900 Mc. to 24 KMc. are covered. The horn reflector antenna MA 6040HR, shown left and specified below, is typical of the outstanding performance of Mitsubishi microwave antennas. Full technical information on any of these types is available at your request.

Horn Reflector Antenna MA 6040HR

Frequency Range	3,600 - 4,200Mc and 5,925 - 6,425Mc
Polarization	Vertical and Horizontal Plane
Gain over Isotropic Radiator	41.2dB (H) 3,900Mc 41 5dB (V) 〃 45.0dB (H) 6,100Mc 44.9dB (V) 〃
Cross Polarization Discrimination	65dB minimum
Front to Back Ratio (over 90 degrees)	65dB minimum
Guaranteed Wind Speed	215Kmph (134 mph)
Net Weight	2,000kg. (approx.)
VSWR	V 1.02 H 1.01 at 4,000Mc band V 1.02 H 1.02 at 6,000Mc band
Waveguide and Fittings	69mm I.D. Circular Waveguide

MITSUBISHI ELECTRIC CORPORATION

Head Office: Mitsubishi Denki Bldg., Marunouchi, Tokyo. Cable Address: MELCO TOKYO

New Subassemblies

gence is 8° to 10°; dynamic resistance is 0.2 to 1.0 ohm.

The simple, manually operated pulser requires a dewar and a small d-c power supply capable of delivering 7.5 v for each output amp, and it will provide a nominal 1-μsec pulse to the diode. Other pulse widths will cost extra.
Maser Optics, Inc., 89 Brighton Ave., Boston, Mass., 02134 [405]

Data amplifier covers wide band

A compact, low-level data amplifier, model 8875A, is a differential, wideband d-c amplifier designed for use with modern data-acquisition systems employing such devices as analog-to-digital converters, digital printers, magnetic data recorders, oscillographs, digital voltmeters, and similar instrumentation. It has an output of ±10 v, 100 ma and features d-c to 75-kc bandwidth, 100 × amplification, ±0.1% gain accuracy and stability, and 120-db common-mode rejection.

The 8875A includes an integral power supply, measures just 4¾ in. high by 1$\frac{9}{16}$ in. wide by 15 in. deep, and is priced at $495. For multichannel use, ten units can be mounted in a 5 x 19-in. modular cabinet that contains input and output connections, power cable, on-off switch, cooling, fuse, and mating connectors for ten amplifiers. The modules can be stacked, or equipped with tilt stands for bench-top use. When used individually, the completely enclosed amplifier requires no cooling. Built-in cooling in the 10-unit module makes for long life in densely-packed multichannel installations.
Sanborn Division of Hewlett-Packard, Waltham, Mass., 02154. [406]

Directional coupler spans 50 to 500 Mc

A new 7-db directional coupler offers a frequency range of 50 Mc to 500 Mc. A completely new circuitry concept gives the model CD-101 coupler a coupling flatness of ±0.5 db over its one-decade frequency range.

Directivity of the unit is greater than 20 db. Vswr is less than 1.5/1 main line, and loss is less than 2 db.

Dimensions are 3¼ x 1⅜ x 1⅛ in; weight is 3.5 oz. Price is $160

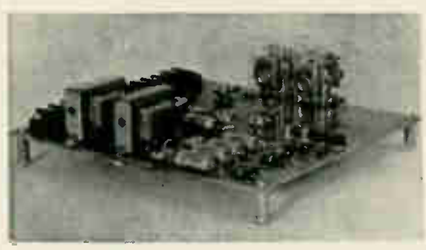
for units using BNC, TNC or N type connectors. OSM-fitted units cost $168. Delivery is from stock to three weeks.
Anzac Electronics, Inc., Moody's Lane, Norwalk, Conn. [407]

Transistor amplifiers feature low noise

Transistor amplifiers now available feature extremely low noise figures in the uhf and vhf ranges. Typical of the new line is the model TQN-2251-2 dual-transistor amplifier assembly. It operates over a range of 225 to 235 Mc with a gain of 25 db and a maximum noise figure of 2 db.

Incorporating two matched amplifiers and a bandpass filter, the new assembly provides more than 60 db of rejection at 210 and 250 Mc. It employs a solid-state power source for operation from 115-v, 60-cps lines, and is packaged in a weatherproof sealed container.
Micro State Electronics Corp., a subsidiary of Raytheon Co., 152 Floral Ave., Murray Hill, N.J. [408]

Servo amplifier for industrial use



Cloosed-loop control from low-level d-c signal input is provided by this transistorized servo amplifier. One of two output relays is energized in response to an error signal between a feedback potentiometer and a d-c current or voltage command.

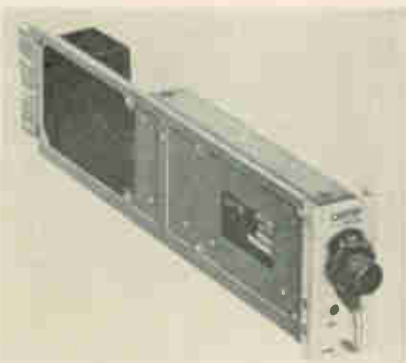
Model AA-8230 may be used with reversing motor starters, solenoid-operated directional control valves, two-phase three-wire reversing actuators and similar applications. A third braking relay for use in dynamic braking at null is an optional feature.

The standard feedback signal source provided is 2 v d-c regulated reference voltage. The input signal can be 1 to 5, 4 to 20, 10 to 50 ma or 0 to 2 v d-c.

The amplifier, which was designed for rugged industrial applications, has a sensitivity adjustable from ±1 to ±5%.

Jordan Controls, Inc., 5607 West Douglas Ave., Milwaukee, Wis., 53128 **[409]**

Direct-coupled wideband amplifier



Model 3400 is a wideband amplifier for driving medium-power recorders, passive filters and display devices. One of the company's direct-coupled differential amplifiers in the 3000 series, it has a full-scale load current of 10 ma. The full-scale output voltage is ±10 v, and the small-signal bandwidth is a minimum of 50 kc. The unit offers a totally isolated power supply, also modular dimensions that allow 10 model 3400's to fit into one model 3010 rack enclosure.

The 3000 series offers a line of direct-coupled differential amplifiers for laboratory and systems applications with gains from 0.2 to 2,500. The series combines high accuracy and low noise.

Dana Laboratories, Inc., Irvine, Calif. **[410]**

Mixer noise cut to 5 decibels

The performance of a mixer circuit depends mainly on the inherent noise in the mixer diode itself. American Electronic Laboratories, Inc., has developed a mixer diode, model AEL C-51, which the company says reduces the over-all noise figure of a mixer circuit to 5 decibels; this is about 0.5 db lower than could be attained with any other diode, according to the company. This noise figure was measured with a mixer circuit using the new diode with an intermediate-frequency amplifier having a 1.5-db noise figure.

The reduction was achieved by using for the diode's whisker element a new material that the company declines to describe. Other diodes use tungsten as the whisker. The semiconductor material in the AEL diode is silicon, as in other diodes.

The noise figure was measured with a 2-gigacycle, 0.5-milliwatt input signal to the C-51 diode, which in turn fed a 30-megacycle i-f amplifier having a noise figure of 1.5 db. The amplifier's impedance to the diode was 100 ohms d-c. The voltage standing-wave ratio was 1.2. Increasing the input power level to 5 milliwatts increased the over-all noise figure by about 0.5 db.

Although designed for L band, the mixer diode can be used at S band, the next higher frequency range, with less than 0.5 db degradation in noise figure at 4 gigacycles, the company says.

Specifications

Model	AEL C-51
Frequency	L or S band
Power	500 milliwatts c-w, maximum
Impedance	100 to 300 ohms at i-f
Price and Oelivery	Upon request

American Electronic Laboratories, P.O. Box 552, Lansdale, Pa. [421]

Digital phase shifter spans 8.5 to 9.6 Gc

Precise, incremental phase-shift values can be switched into or out of a signal path at high speed by the model D14H1 digital phase shifter. Four phase shift increments of 180°, 90°, 45°, and 22.5° can be switched either singly or in any combination at average switching rates up to 5 kc.

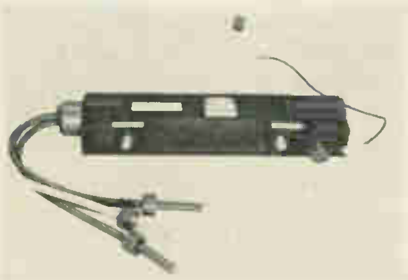
Covering the 8.5- to 9.6-Gc range in WR-112 waveguide, the D14H1 has a switching time of 1.5 μsec maximum from the time a d-c command signal is applied to a bit terminal. Total energy to switch all four bits can be made low as 600 microjoules.

Phase length accuracy as well as unit-to-unit phase matching, either per bit or any bit combination, do not deviate more than ±5° from the nominal value over the entire frequency range. Power capability is 25 kw peak, 100 w average; the maximum phase deviation as a function of average power is less than 5%.

The D14H1 is particularly applicable in digital phase shift arrays as well as in instrumentation and test facilities. Other bit combinations and/or frequency ranges are also available.

Sperry Microwave Electronics Co., P.O. Box 1828, Clearwater, Fla., [422]

Traveling-wave tube covers C and X bands



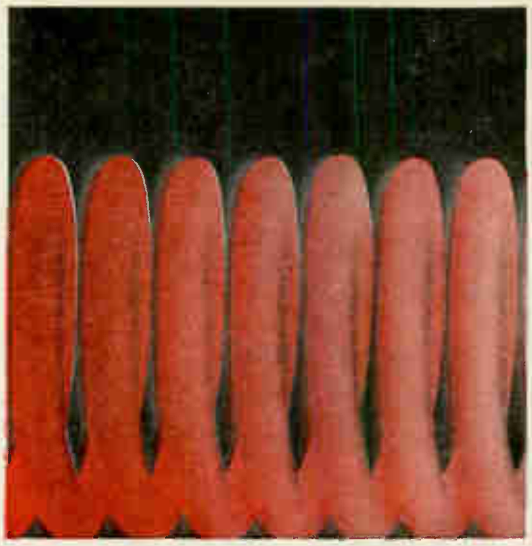
A broadband traveling-wave tube has been announced that delivers peak pulse power of more than 1 kv at a 2% duty cycle. The QKW-1366 covers both C and X bands in a single tube with a frequency range of 5 to 12 Gc. Gain is 34 to 40 db.

Periodic permanent magnets make the 11¼-in., 4¼-lb. tube the smallest and lightest available for this service, according to the manufacturer. This also eliminates the need for external mounts and reduce substantially problems of magnetic field interference. The conduction-cooled twt is constructed of ceramic and metal for high reliability within the MIL-E-5400 specifications.

Raytheon Co., Microwave and Power Tube Division, Waltham, Mass. [423]

High-power t-w tube designed for S band

A compact high-power traveling-wave tube for S-band use is designed for applications that include



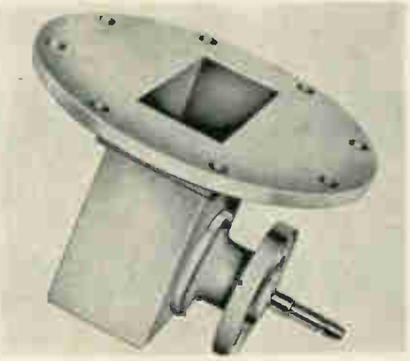
Circle 203 on reader service card

New Microwave

telemetry and electronic countermeasure systems.

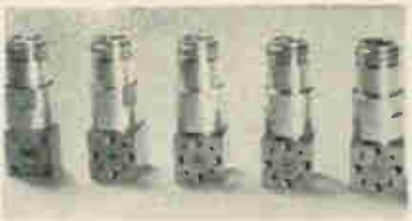
The MA-3012 features metal-ceramic construction and uses a hollow electron beam and solenoid focusing for reliable performance under extreme missile environments. The tube provides 300 w continuous wave from 2 to 4 Gc with a 27-db gain. The 10 x 2⅜-in. package weighs 8 lb. Delivery: 75 to 90 days after receipt of order. Microwave Associates, Inc., Burlington, Mass. [424]

Waveguide-to-coaxial transition section



A high-power S-band transition section for a WR-284 waveguide flange to ⅞ in. coaxial handles 600 watts average with a peak of 25 kw. Frequency range is from 3.1 to 3.5 Gc; vswr is less than 1.2 to 1. Specialty Automatic Waveguide Corp., 12 Wilmington Road, Burlington, Mass. [425]

Millimeter-wave mixer diodes



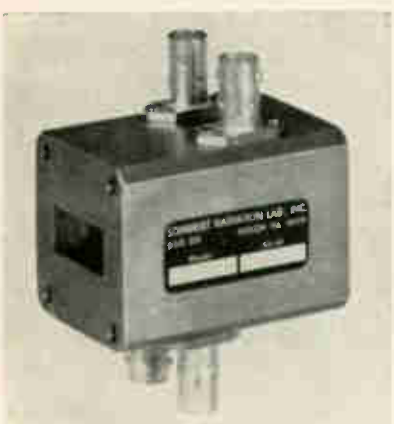
Millimeter-wave mixer diodes are available covering a frequency range from 26.5 to 170 Gc with a corresponding maximum conversion loss from 8.0 to 13.0 db. (Typical conversion losses average 6.5 to 11.5 db.) The diodes are hermetically sealed and are available in fixed or tunable units.

A nominal 50-ohm i-f output impedance is provided when used at microwave intermediate frequencies, which are recommended for single ended mixing so that the local oscillator noise contribution remains a negligible fraction of the crystal noise ratio.

These units are designed to provide a very large instantaneous i-f bandwidth and hence are suitable for such applications as high-sensitivity radiometers and receivers for wide-band or extremely short pulse systems.

Advanced Technology Corp., 1830 York Road, Timonium, Md., 21093. [426]

Digital phase shifter features low vswr



Model X710 crystal-diode, X-band digital phase shifter features a vswr of 1.04:1, a switching time of 100 nsec maximum, low insertion loss of 0.6 db, and a peak power capability of 1,000 w. In addition to being ideal for phased-antenna arrays, the unit is suitable for general laboratory, microwave-system, and classroom service as a phase shifter and phase modulator.

Nominal frequency range is 8.2 to 12.4 Gc. The model X710 operates on the principle of discretely varying two pairs of symmetrical inductive posts electronically to obtain phase shifts. The separation between the diode pairs is one-quarter wavelength at 9.3 gigacycles.

Price of the digital phase shifter

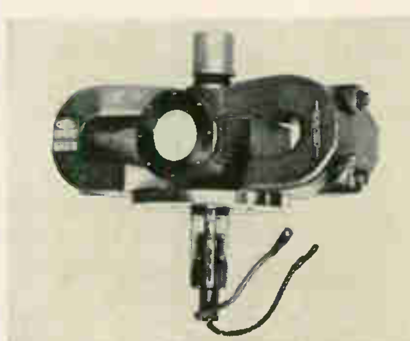
is $160 each; availability, 20 days after receipt of order.
Somerset Radiation Laboratory, Inc., P.O. Box 201, Edison, Pa., [427]

Temperature-stable X-band amplifier

A light-weight, X-band tunnel-diode amplifier now on the market requires no temperature-controlling heaters. Model D65X3 typically has 20 ± 2 db gain from 8.3 to 9.7 Gc over a temperature range of −10° to +60°C. The noise figure under these conditions is 6.0 db maximum. Bias power requirements are 10 mw maximum at 1.25 volts from external source. An internal battery can be provided if desired. Other frequency ranges are available.

The unit dimensions, including connectors and mounting flange, are $4\frac{7}{16}$ x $3\frac{7}{8}$ x $1\frac{5}{32}$ in.; package weight is 16 oz. Delivery: 90 days.
Sperry Microwave Electronics Co., P.O. Box 1828, Clearwater, Fla., [428]

Air-cooled magnetron for C-band radars



An air-cooled magnetron has been introduced that delivers pulses of a million watts for C-band radar systems. The QKH1214 is tunable

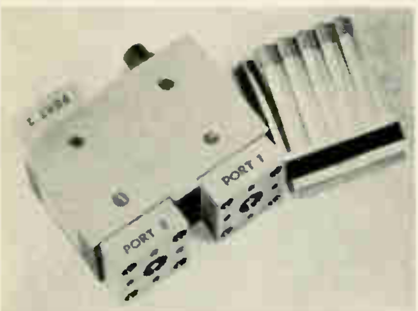
←Circle 206 on reader service card

from 5.665 to 5.715 Gc, thus offering more latitude in tracking radar system than the fixed frequency QK539 for which the new tube can be a direct replacement.

Pulse width is 1 μsec. The 1-Mw peak power output is delivered with an 0.001 duty cycle. Anode voltage is 35 kv. Peak anode current is 65 amperes. The magnetron weighs 50 pounds and has a waveguide output.

Raytheon Co., Microwave and Power Tube division, Waltham, Mass. **[429]**

Circulators operate from 3.7 to 4.2 Gc



A line of circulators designed to operate at liquid-nitrogen or liquid-helium temperatures is offered for use with ultra-low-noise parametric amplifiers. By cooling the circulator, the noise contribution of its input losses is significantly reduced, and degrading long-line effects caused by diode-circulator separation are eliminated.

A typical 4-port circulator, model CHC-1474, covers the 3.7-to-4.2-Gc frequency range with 0.25-db single-junction insertion loss and 20-db single-junction isolation at 77° Kelvin.

Western Microwave Labs., Inc., 1045 DeGiulio Ave., Santa Clara, Calif. **[430]**

Equalizer provides constant gain

An equalizer has been announced which provides a constant gain over a one-octave instantaneous bandwidth compensating for the gain-frequency curve of traveling-wave tubes.

The unit is available in the 2- to 4-Gc region, with maximum vswr of 1.5. Maximum attenuation is 0.5 db at 2 Gc; 2.3 db (±0.2 db for any given unit) at 3 Gc; and 0.5 db at 4 Gc.

Power is 0.25 w c-w, with 100 w peak. Environmental temperature can be −65° to 95°C; over-all size is 3⅛ x 1⅛ x ½ in.
Microlab/FXR, Livingston, N.J. [431]

Waveguide isolators span 2.6 to 14 Gc

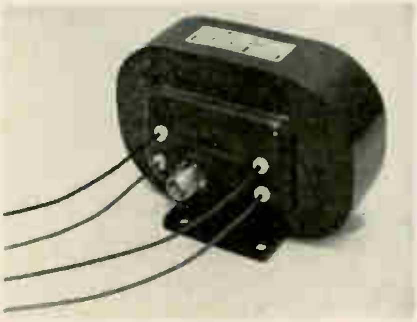
The series 200 line of waveguide isolators offer up to 30 db isolation and cover frequencies from 2.6 to 14.0 Gc in bands up to ½ octave. Vswr's are 1.15 typical, 1.20 maximum. The loss in broadband models is 0.8 db typical, 0.9 maximum. In medium- and narrow-band units the loss is typically 0.3 db to 0.8 db. Delivery is 3 to 4 weeks after receipt of order.
Microwave Technology, a division of Alpha Industries, Inc., 381 Elliot St., Newton Upper Falls, Mass., 02164. [432]

Seven terminations cover 3.95 to 40 Gc

A series of seven high-power terminations cover the frequency range from 3.95 to 40 Gc. A newly developed dissipative material eliminates such common problems as deterioration at high temperature, moisture absorption, and damage due to shock and vibration. All units have external cooling fins, and are equipped with standard waveguide flanges. These dummy loads provide excellent high-power absorption combined with minimum vswr characteristics in a small physical configuration, and no auxiliary external cooling is required.

Maximum average power ranges from 75 w to 2,000 w. Maximum vswr is 1.10. Over-all length ranges from $4\frac{3}{16}$ in. to 9¾ in., and price from $80 to $175.
Waveline Inc., Caldwell, N.J. [433]

High-power magnetron is voltage-tunable



A high-efficiency, high-power, voltage-tunable magnetron can be electronically tuned over the 3- to 3.5-Gc frequency range at 100 watts minimum power with an electronic efficiency of 70%.

The complete package weighs 3½ lbs and measures 4½ x 3 x 2½ in. exclusive of the r-f connector which is TNC. Units are available in three weeks.
Mictron, Inc., 265 Osborne Road, Albany, N.Y., 12211. [434]

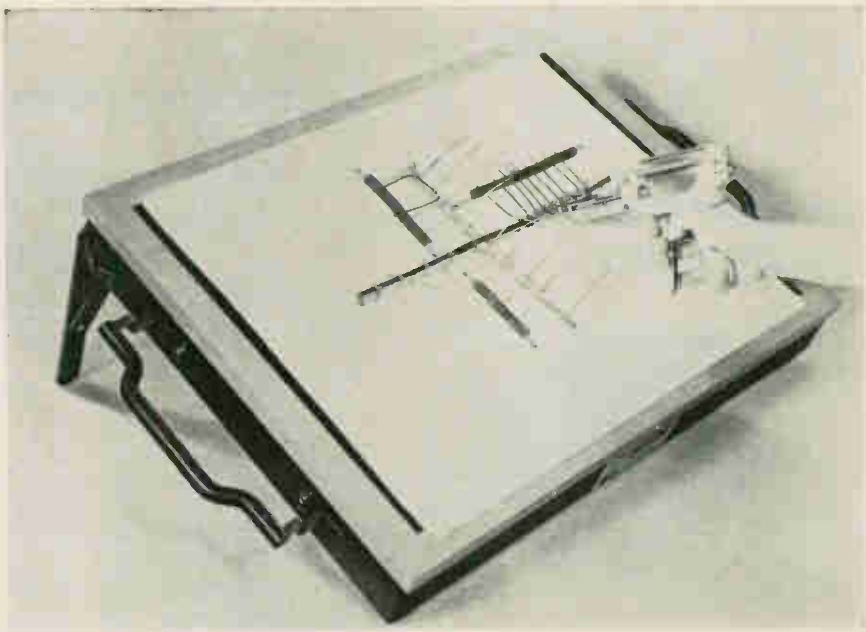
Power amplifier operates at S-band

Model P-51 power amplifier delivers 100 w of c-w output in the frequency range of 2.2 to 2.3 Gc. It utilizes a new type of plate tuning and a unique heat-sink arrangement for its metal-ceramic planar triode. With a plate efficiency exceeding 30%, the rugged module is useful in S-band telemetry applications, as well as in other electronic systems where 13-db gain and 20-Mc bandwidth are desirable.

Maximum dimensions including adjustments are 2 x 3 x 4 in.; weight is 19 oz.
Resdel Engineering Corp., 990 S. Fair Oaks Ave., Pasadena, Calif., [435]

New Production Equipment

Two-panel harness board



Wire-harnessing boards with reusable, retractable wire-routing pins are two ways better than the homemade harness boards that have been used for decades to prefabricate wiring assemblies, says the Thomas & Betts Co. The problems of board storage are avoided, and the pins don't interfere with harness tying and removal from the board.

The new type of board has two panels mounted in a frame. The top panel is aluminum, perforated with holes that are 9/64 inch apart. The bottom panel, made of plywood, can be moved up and down by handles on the sides of the frame.

To set up the board, a wiring diagram is taped to the aluminum panel. Guide pins are pushed through the paper and the holes in the aluminum until the pins touch the plywood. The pins are driven into the plywood with a hand drill. Harnessing aids, such as coil springs, to hold wire ends, are fastened to the top panel with self-tapping screws.

The harness wires are then put in place; a few ties are made to hold the wire bundles together and the pins are retracted by lowering the plywood panel. The amount of retraction is adjustable.

When a different harness is to be made, the pins are removed and the board is set up again.

Thomas & Betts has also introduced a new hand tool, shown in the photo, to tighten and trim the plastic harness and cable ties sold under the trade name Ty-Rap.

The Thomas & Betts Co., Elizabeth 1, N.J. [451]

High-conductance fast-pump evaporator

A fast-pump vacuum system now available produces pressures of below 10^{-6} torr in less than five minutes, with ultimate vacuum of

10^{-7} torr or better. Model DV-503-FP pumps at approximately twice the speed of conventional systems. Higher pumping speed of over 400 liters per second at the base plate is obtained by means of high-conductance components, including a stainless steel valve, a multicoolant cold trap, and high-speed 4-inch diffusion pump. Higher pumping speed at the base plate results in faster evacuation of the bell jar and is particularly valuable in maintaining good working pressures during actual evaporation and under adverse conditions.

Some typical applications include evaporation and deposition of thin films for optics, semiconductors, microelectronics and printed-circuit production, carbon evaporation and electron microscope shadow casting, environmental testing, and other research and production applications requiring the fast, efficient attainment of high vacuum. With the proper electrodes and auxiliary equipment, the system can also be employed in conventional or triode low-pressure sputtering.

The system measures 44 x 30 x 98 in. over-all. Base plate is 20-in.-diameter solid stainless steel; vacuum chamber is 18-in.-diameter x 30-in-high stainless steel or Pyrex bell jar.

Denton Vacuum, Inc., 801 Fellowship Road, Cherry Hill, N.J., 08034. [452]

Accessory improves wafer-test machines

Testing integrated circuits and transistors in wafer form is accomplished by needle-like probes. These probes must contact the wafer's pads simultaneously; that is, they must be coplanar. Also, they have to contact at just the right angle, at the proper pressure, and have to scrape off the oxide

Production Equipment

film that forms due to exposure of the metal to air.

Setting up a machine to test wafers is a time-consuming job. Siliconix, Inc., however, has devised an accessory for its wafer-test machine that enables an operator to make the probes coplanar in about five minutes to an accuracy of 0.0005 in. In other words, all the probes will contact the wafer pads nearly simultaneously. The device, called a planerizer, comes in either 12- or 18-point models.

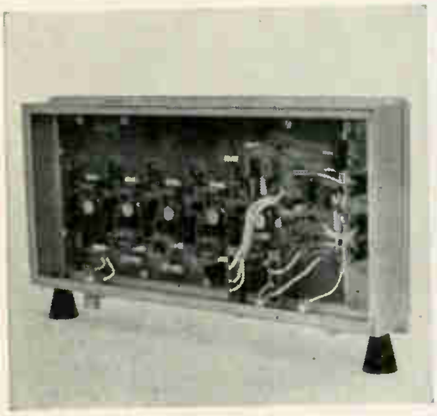
Indicator lights on a panel tell the operator when the points contact the plane. The trick is to get the indicator lights to come on at the same time when the head is raised and then lowered to the work piece. The needle probes are adjusted by set-screw-type controls.

A simple electrical circuit through the needle probes and the indicator lights isn't suitable. The probe tips are so small that the arc generated by the 14-ma current needed to light the indicator lamp could ruin the point. Therefore, the manufacturer designed a circuit in which a field effect transistor is used to carry the lamp current. The FET gate current, in the picoamp range, passes through the probe tips. This low value of current cannot damage the tips. Voltage is also low—in the 5- to 6-volt range.

In setting up the wafer-probe machine, the probe points are first leveled using the planerizer. Then the tips are brought down on a lapping plate, and a flat is lapped on the tip using an orbital motion of the lapping plate. The probes are then rechecked with the planerizer and the machine is ready to use. Point force is adjusted with a dial micrometer.

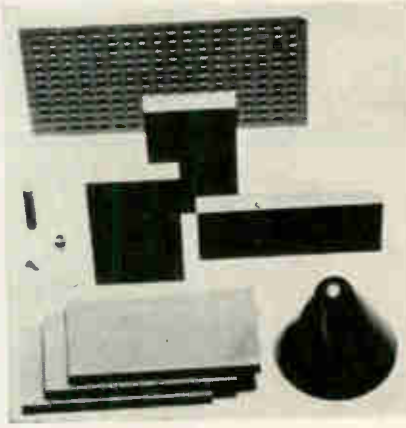
The probe-point planerizer may be connected directly to the manufacturer's wafer-probe machine, or may be used with a separate power supply and adapted to work with any test machine of this type. The 12-point model sells for $150, or $180 with power supply. The 18-point model sells for $199, or $230 with power supply. All are available on two weeks' delivery.

Siliconix, Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif. [453]



New Materials

High-purity graphite is dense, uniform



A dense, isotropic, high-purity graphite of unusual structural uniformity, called RG-504, combines excellent thermal shock resistance with high mechanical properties. The dense, uniform structure of the material is said to offer higher oxidation resistance than other commercial graphite products. RG-504's close-grained structure permits easy machining to extremely close tolerances and fine detail. Impurities range as low as 200 ppm. Flexural strength is 10,000 psi.

The new material is offered for use in R&D applications requiring high-purity graphite combined with reproducibility from lot to lot. Applications include: thin-film masks, semiconductor alloying boats, glassing molds for header manufacture, integrated-circuit sealing molds, epitaxial heaters, brazing and soldering fixtures, and high-purity plating electrodes.

The research-grade graphite is available from stock in various standard rods ranging from ¼-in. diameter to 4-in. diameter, and in plates from ¼ x 4 x 6 in. to 1½ x 7 x 7 in. Prices are from $1.05 to $175 per piece. The manufacturer also offers custom-made parts.

Aremco Products, Inc., P.O. Box 145, Briarcliff Manor, N.Y., 10510. **[441]**

Conductive coatings for bonding purposes

Five new conductive metal coatings are announced for bonding to ceramic (such as alumina or steatite), glass and epoxy base components. These materials were developed for work on printed circuitry, ceramic-metal bonding, resistor terminations, conductors and hybrid microelectronic circuitry. All formulations can be applied by the silk screen process as well as by brush.

New developments include three fired-on conductive silver compositions with a range of 90% to 96% silver, an ohmic resistance of less than 0.003 ohm per sq per mil coating thickness; and firing ranges from 925° to 1250°F, 1250° to 1650°F, and 1400° to 1900°F respectively.

These materials give excellent adhesion to ceramic components, have high conductivity and can be soldered and plated with ease.

Also available is a platinum-gold coating for depositing high-reliability conductive films onto ceramics. This material is particularly valuable for applications where silver migration must be avoided. It is fired at temperatures in the vicinity of 1700°F and provides a film with resistivity in the order of 0.04 ohm per sq per mil coating thickness. The platinum-gold coating is directly solderable with standard lead-tin solders and can be electroplated with ease.

The company also has available a two-part epoxy coating containing silver for use in the repair of p-c boards and for cementing leads where solder cannot be used. This silver-epoxy paste may be cured in less than 45 minutes at 140°F. It provides a coating with a volume resistivity of about 0.003 ohm-cm and is directly plateable with a variety of metals.

Electro Materials Corp. of America, 605 Center Ave., Mamaroneck, N.Y. **[442]**

ADVANCED ELECTRONICS

opportunities exist in the following areas at Douglas Missiles & Space Systems Division

ELECTRO-OPTICS

A requirement exists for a scientist/engineer to lead the work of an Electro-Optical Group engaged in research and development, both analytical and experimental, in support of advanced missile and space programs. Activities include tracking and communication in the visible and I.R. spectral regions, research into optical propagation in the atmosphere and other laser applications. The successful applicant will have appropriate advanced degree with evidence of experience and personal contributions in the field of geometrical and physical optics including lasers and I.R.

INERTIAL GUIDANCE SYSTEMS

Ph.D. or M.S. with 5 years experience to be Electronics Dept. Staff Technical advisor on inertial guidance systems. Should have extensive experience in the detail design of stabilized platforms, as well as a complete knowledge of inertial instruments. Initial assignment will be the analysis of a sub-contractor effort to design and produce an attitude reference unit for tactical missile system. Additional duties will require analysis and design of advanced guidance systems to be used on future Douglas missile and space vehicles.

ELECTRONIC PACKAGING DESIGN

Immediate opening for Senior Engineer with BS in EE, ME, or Physics and four years experience in electronic packaging design of missile airborne equipment. Experience should include design of large electronic assemblies containing complex electronic circuitry such as used for missile control systems and employing the latest in multi-layer printed circuit board technology.

Responsibilities will include coordination with other groups and the customer for design requirements and technical direction of other design personnel for packaging. Initial assignment will be on design of a high performance tactical missile.

If you are interested in any of the above positions, send your resume in confidence to A. X. MacDonald, Douglas Missile and Space Systems Division, 2700 Ocean Park Blvd., Santa Monica, California.

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- ★ Package volume 200,000 per cubic foot.
- ★ Unique coupling—less than 3% with two units side by side.
- ★ Operating temperature —55°C to 125°C.
- ★ Very low direct current resistance.

90537 SERIES Molded-Shielded Inductor **manufactured per MS-90537.** Stocked in 73 values. Inductance range 0.10 uh to 100,000 uh with 10% Tolerance. Molded envelope 0.395" length by 0.157" diameter. Units color coded.

SUPER WEE-DUCTOR Molded-Shielded Inductor designed to meet MIL-C-15305C. Stocked in 73 standard values. Inductance range 0.10 uh to 100,000 uh with ±10% tolerance. Molded envelope 0.395" in length by 0.157" diameter. Units color coded.

WEE-DUCTOR Designed to meet MIL-C-15305C. Exceptional inductance range 0.10 uh to 180,000 uh in 76 stock values. Encapsulated, non-flammable envelope only 0.375" long by 0.157" diameter. Pertinent data printed. Tolerances: 5%, 10% and 20%.

WEE WEE-DUCTOR Designed to meet MIL-C-15305C. Smallest shielded inductor available—in 49 stock values. Encapsulated, non-flammable envelope only 0.335" long by 0.125" diameter. Inductance range of 0.10 uh to 1,000 uh with 10% and 20% tolerances. Color coded markings.

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New Books

Versatile relays

Fundamentals of Relay Circuit Design,
Alan R. Knoop,
Reinhold Publishing Corp.,
312 pp., $15

Relays have been treated sparingly in print; S.L. Prakken's "Subject Guide to Books in Print" lists only 11 other books on the subject and very few of these cover relay applications similar to those examined in this book. Much of the material Knoop presents was available, but only in manufacturers' literature and in magazine articles.

The book covers the fundamentals of magnetism; the operating characteristics of relays, both a-c and d-c-actuated; relay descriptions —including magnetic latching, polarized, motor contactors, railway and telephone—and tables of pictorial and alphabetical symbols needed to follow the author's explanation of relay circuits. About 60 pages are devoted to basic circuit concepts—repeating, sticking, delaying, oscillating, sequencing, counting, time, pulsing and controlling.

The author provides a lengthy treatment of state-of-the-art relay applications in industry, public service and railroads. In preliminary chapters, he reviews relay design considerations for the coil, contacts, core, air gap and armature.

The book is not intended for the relay-design engineer. According to the author, "The system and control circuits used in these sections are not theatrical but are the actual control circuits used by designers in their respective fields. . . . This book will prove exceptionally useful to design and maintenance personnel in the industrial process fields, in military systems work, in public utilities and in transportation."

The book is partly useful for military systems work because time-proven circuits are shown. However, no assistance is given in interpreting government documents on systems, components, and tests. The relays discussed are used in ground-based rather than airborne and shipborne applications.

But many relay applications are not discussed, such as high-voltage protective applications. Newer relay types, such as the dry and wet (mercury) reed relay and solid state devices, are omitted. The military designer will find the scope of the book limited, because redundancy, voting and nonrepairable (space) applications are omitted. However, designing reliability and fail-safe provisions into systems is adequately covered, especially in the field of railroad switching and signaling.

The book is best when discussing applications. The explanations of operation are thorough and nonmathematical; the sketches, photographs, and diagrams (a total of 270 figures) are more than adequate. Relay part numbers are often included. Graphic tools, rather than mathematical equations, are used to explain some difficult topics, such as polarized relays and their applications. The book is weakest in its discussion of the theory of magnetism and relay operations.

Cross-referencing of various relay symbols permits circuits to be easily interpreted; however, the reference tables, figures 25 and 26, contain several typographical errors.

Elliot H. Diamond
Arinc Research Corp.
Annapolis, Md.

Recently published

RCA Silicon Controlled-Rectifier Experimenter's Manual, Electronic Components & Devices Division, Radio Corp. of America, 80 pp., $.95

Fields and Waves in Communication Electronics, S. Ramo, J.R. Whinnery, T. Van Duzer, John Wiley & Sons, Inc., 754 pp., $13.50

Electronic Components, Tubes and Transistors, G.W.A. Dummer, Pergamon Press, 166 pp., $3.95

Plasma Turbulence, B.B. Kadomtsev, Academic Press Inc., 149 pp., $6.50

Principles of Radiation Protection Engineering, Translation of Jaeger's Principles of Radiation Protection, L. Dresner, McGraw-Hill Book Co., 451 pp., $15

Recent Advances in Selenium Physics, edited by European Selenium-Tellurium Committee, Pergamon Press, 160 pp., $15

Preparing for the Professional Engineer's Examination: A Review with Questions and Answers, I.J. Levinson, Prentice-Hall, Inc., 349 pp., $12.50

Solid Status Report 11/65

Look what our new InAs Infrared detectors can do better than good old PbS detectors:

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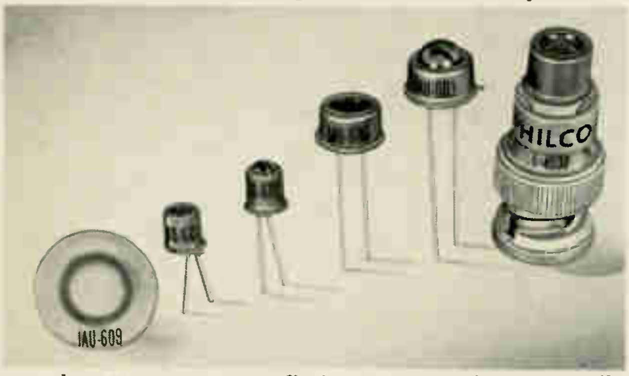

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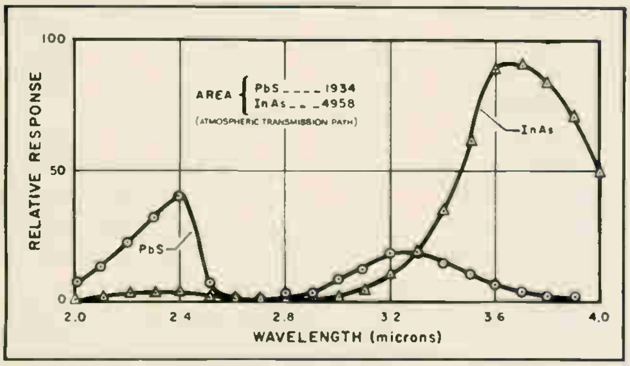

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Technical Abstracts

Nonintercepting grid

An advanced type of nonintercepting grid for convergent-beam electron guns
Ronald A. Forbess,
Microwave Tube Division,
Hughes Aircraft Co., Los Angeles

The Microwave Tube division of the Hughes Aircraft Co. has developed a type of nonintercepting grid for use with convergent-flow electron guns in traveling-wave tubes. A major achievement of this effort was the development of a grid configuration which intercepts less than ½ of 1% of the cathode current with a minimum effect on the electron-beam parameters. This is a significant performance improvement, since a conventional type of grid typically intercepts between 10% to 15% of the cathode current. As a result of the reduced interception, it is now feasible to grid control an electron beam having over 100 kilowatts of average power. With the conventional grid, about 8 kw of average beam power is the upper limit.

Conventional intercepting grids are used in convergent-beam electron guns to pulse the beam on and off using a relatively low voltage pulse compared to the cathode voltage, thus reducing modulator size and power requirements. Such grids are fundamentally limited to low average-power tubes to prevent thermionic grid emission or melting of the center portion of the grid. This paper discusses a type of nonintercepting grid designed for use on convergent-beam electron guns where excessive grid temperature would prohibit use of an intercepting type grid.

The nonintercepting nature of the grid is achieved by means of a double aligned pair of grids with a shadowing grid closest to and electrically connected to the cathode. Using this type of grid, guns for high-power traveling-wave tubes have been built and tested with excellent results. In a specific case, a gun which typically intercepts 10% to 15% of the cathode current using a conventional grid had only 0.11% interception with the double grid. This gun, which is used on a C-band tube, has been successfully operated at 2.5% duty cycle at 37 kilovolts. Nonintercepting gridded guns are being incorporated into S-band and X-band tubes.

Presented at the International Electron Devices Meeting, Washington, D.C., Oct. 20-22.

Light-sensitive glass

Photochromic glass—a new tool for the display system designer
Benjamin Justice and F. B. Leibold Jr.
Corning Glass Works, Corning, N. Y.

Transparent silicate glass containing silver halide particles darkens when exposed to visible light, and is restored to its original transparency when the light source is removed. These glasses have been suggested for self-erasing memory displays, readout displays for air traffic controls, and optical transmission systems.

The wavelengths that cause the glass to darken occur near the ultraviolet through the visible spectrum to about 5,000 angstroms, depending upon the chemical composition of the glass. Most of the glasses so far investigated darken to a grey or reddish grey when activated by light. The photochromic reaction is completely reversible with no degradation of photochromic properties after 60,000 light-dark cycles. Only a slight degradation of contrast is observed after three months of storage.

The speed of the light reaction depends upon the optical density of the glass and the intensity of the light source. In some cases, the glass reacts to light in a few milliseconds, and in less than 100 microseconds with a high energy light source. The original transparency can be restored in 5 to 10 seconds, by changing the temperature.

Typical compositions of several silver halide glasses are given, with their sensitive wave lengths, range of darkening transmittance, time relationships, temperature dependence, and resolution.

Various types of glasses can be made—for example, with gradients in photochromic density under uniform illumination.

Presented at the Sixth National Symposium, Society for Information Display, New York, Sept. 29.

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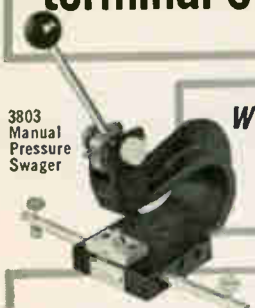

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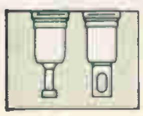

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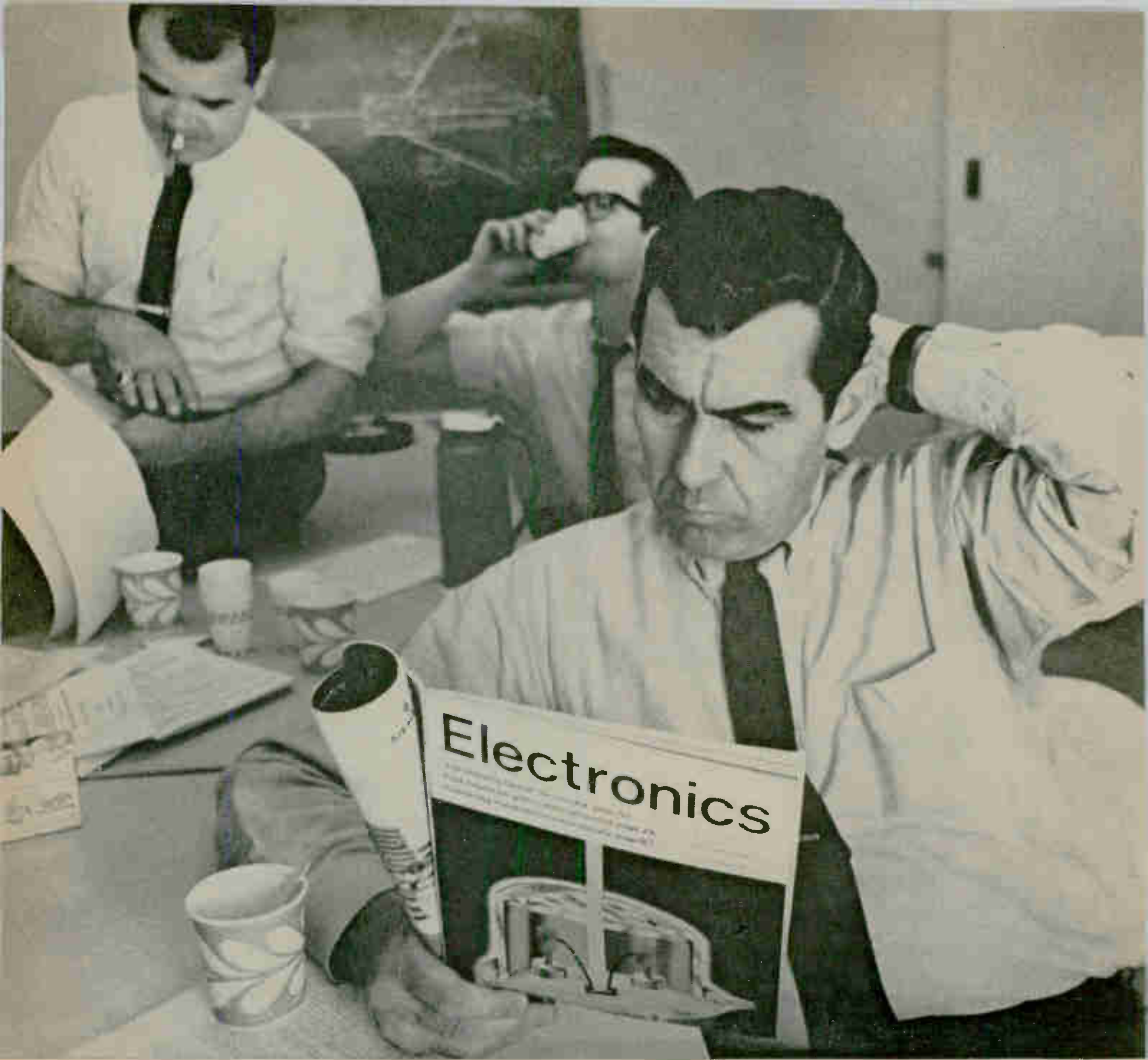
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* These advertisements appeared in the Nov. 1 issue.

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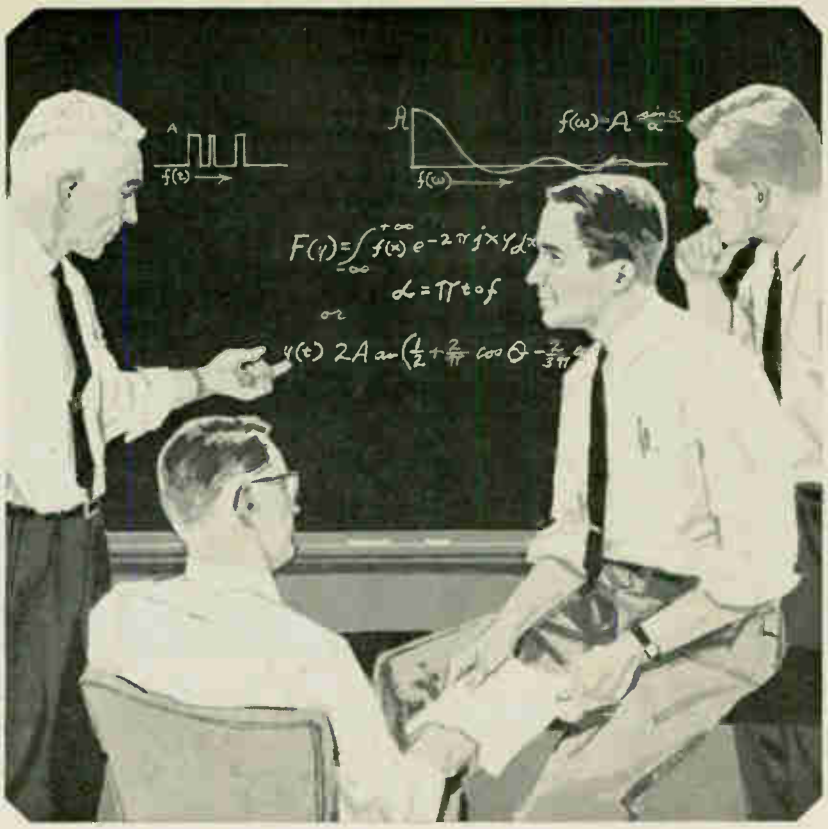

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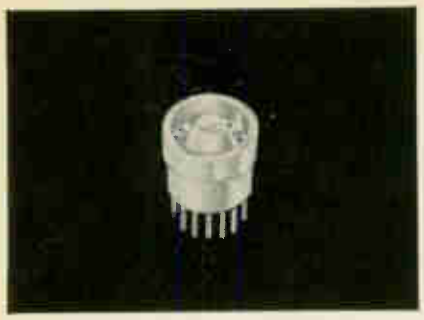

New Literature

Screen-printed microcircuits. E.I. du Pont de Nemours & Co., Wilmington 98, Del. A 12-page booklet provides an explanation of how to convert the manufacturer's resistor and conductor compositions into reliable low-cost microcircuits using the screen printing process. Circle 461 on reader service card

Vacuum relays. Jennings Radio Mfg. Corp., P.O. Box 1278, San Jose, Calif., 95108. A 16-page catalog describes the characteristics, construction and applications of vacuum relays. [462]

D-c/d-c signal isolator. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif., 91343, has released a bulletin on model DCI-175, a solid-state silicon d-c/d-c signal isolator. [463]

Refractometer size reduction. Clairex Corp., 8 W. 30th St., New York, N.Y., 10001. The second issue of Photocell Forum deals with the way photocells have allowed redesign of the refractometer to produce a smaller packaging than was previously possible. [464]

Connector contacts. Cinch Mfg. Co., 1026 S. Homan Ave., Chicago, Ill., 60624. Bulletin PBM-60 describes versatile Bow-Pin contacts for ultraminiature strip, circular and rack and panel connectors with 0.075-in. and 0.100-in. centers. [465]

Nickel-cadmium cells. Gulton Industries, Inc., 212 Durham Ave., Metuchen, N.J. Hermetically sealed, nickel-cadmium cells in cylindrical configuration are described in bulletin VO119a. [466]

Instrumentation amplifier. Epsco, Inc., Data System Products division, 411 Providence Highway, Westwood, Mass., 02090. Three variations of the model ADS-95 d-c instrumentation amplifier are discussed in technical bulletin 096502. [467]

Dry reed switches. Automatic Electric Co., Northlake, Ill., 60164. An 8-page Product News is devoted exclusively to the new printed-circuit dry reed switches known as Correeds. [468]

Power supplies. Kepco, Inc., 131-38 Sanford Ave., Flushing, N.Y., 11352. Catalog B-657 (48 pages) describes and illustrates a wide line of power supplies. [469]

Tape transport. Potter Instrument Co., 151 Sunnyside Blvd., Plainview, N.Y., 11803, offers a brochure on a high-performance, tape transport designed for military environments. [470]

Industrial control instruments. API Instruments Co., Chesterland, Ohio, has issued bulletin 48 describing controlling instruments for use with any variable putting out a voltage signal. [471]

Industrial timing motor. A.W. Haydon Co., 232 N. Elm St., Waterbury, Conn., 06720. Bulletin CM804 contains essential data on the industrial series S4000 timing motor. [472]

Nickel-alloy magnetic cores. Infinetics Inc., 1601 Jessup St., Wilmington 2, Del. Tech-Data 53-1 points out the technological and price advantages of nickel-alloy magnetic cores for mag-amp and transformer designers. [473]

Microwave water loads. General Electric Co., Schenectady, N.Y., has prepared brochure MD-038 on a broad line of standard model water loads for high power uhf, microwave radar and troposcatter transmitters. [474]

Power transmission components. Fourdee, Inc., P.O. Box 6006, Orlando, Fla., has available a 40-page catalog on miniature flexible couplings, universal joints, and other allied precision components such as shaft collars, gear clamps, and coupling kits. [475]

Impulse counters. Landis & Gyr, Inc., 45 W. 45th St., New York, N.Y., 10036. Bulletin 212 covers a line of small, shallow, electromagnetic impulse counters. [476]

Integrated circuits. Westinghouse Molecular Electronics Division, Box 7377, Elkridge, Md., 21227. An eight-page quick-reference guide (91-000) presents diagrams design features, and complete model designations of 64 digital and linear integrated circuits. [477]

Filter selection. American Electronic Laboratories, Inc., P.O. Box 552, Lansdale, Pa. offers an 80-page technical brochure to help the engineer or purchasing agent select, specify and order filters from d-c to 12 Gc. Copies may be obtained by writing on company letterhead.

Indicator lights. Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y., 11237, has published a catalog on subminiature indicator lights (conforming to MS-25010-Revision D) for translucent-panel edge lighting. [478]

Analog-to-digital converter. Electronic Engineering Co. of California, 1601 E. Chestnut Ave., Santa Ana, Calif., 92702. Increased resolution to four decimal digits plus sign and nine different types of output signals are described in a new data sheet on the 760A analog-to-digital converter. [479]

Connectors. ITT Cannon Electric, 3208 Humboldt St., Los Angeles, Calif., 90031, announces catalog RX-2 describing the CA-RX series of connectors that will mate with existing connectors designed to specification MIL-C-5015. [480]

Microwave switches. Guide Industries Inc., 11855 Wicks St., Sun Valley, Calif., has available a four-page catalog to help engineers order custom-made microwave switches. [481]

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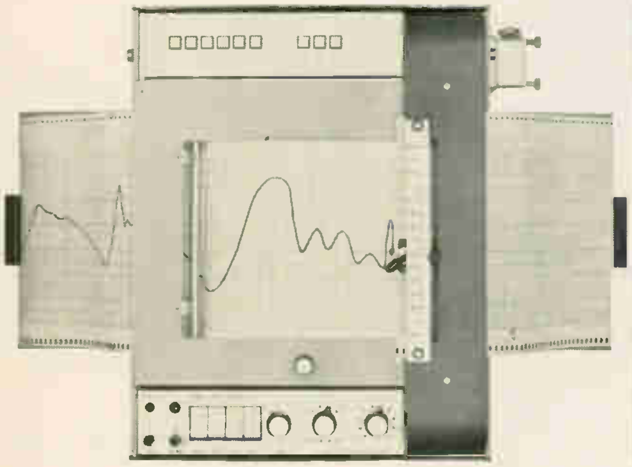

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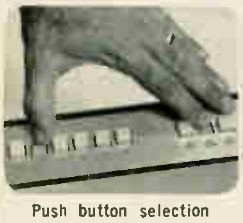

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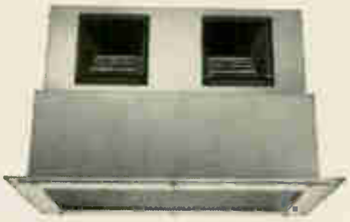

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November 15, 1965

Electronics Abroad

Volume 38
Number 23

Switzerland

Busy signal for pcm

Long before Alexander Graham Bell displayed his analog telephone system in 1876, inventors were toying with the idea of digital techniques for sending sound. As early as 1837, Charles G. Page in the United States, Charles Bourseul in France and J. P. Reis in Germany were trying to "telegraph" speech and music.

And 28 years before Mariner 4 sent television pictures of Mars 134 million miles to the United States, the digital system it used—pulse-code modulation (pcm)—was invented by Alec Harley Reeves in Britain [Electronics, Nov. 1, p. 8].

Where's the hardware? These men were far ahead of their time. Their ideas were sound, but the hardware necessary to make them practical was still to be developed.

Now the components exist; pcm is in commercial operation on both sides of the Atlantic, and integrated circuits are expected to spur enormous expansion in its use during the next decade. That prospect was dramatized at the International Telecommunications Union's 100th-anniversary meeting, which closed this month in Montreux, Switzerland.

ITT-Europe, an affiliate of the International Telephone and Telegraph Corp., conducted a day-long lecture series on pcm. Plessey Industries, Ltd., of Britain, exhibited a pcm system that is being field-tested between Reading and Marlow in England. The General Electric Co. of Britain also showed pcm equipment.

The future. Trunk lines for pcm are already in commercial service in the United States and Italy, and experimental systems are being tested in Japan and Britain. The appeal to telephone companies is pcm's ability to step up traffic capacity on two pairs of wires from two conversations to 24 conversations; cable installations constitute about 60% of the cost of a telephone system. Another advantage is pcm's immunity to noise.

With integrated circuits shaving costs for complex digital circuits, specialists at Montreux were predicting that pcm systems would soon become less expensive than cable-laying for distances of 3.5 miles or more.

Terminal rack. This unit is part of a pcm system being tested by British Post Office, which administers country's telephone system. Rack was built by Standard Telephones and Cables, Ltd., an ITT affiliate.

International standards. Europe's telephone networks, which are largely government-run, have not yet agreed on standards for pcm systems, but the equipment on display at Montreux gave some clues as to what can be expected.

Twenty-four voice channels on a pair of wires will probably be the norm, with a 25th channel allotted for synchronization signals. Sampling frequency almost certainly will be eight kilocycles, giving a channel period of five microseconds. During each channel period, the system would transmit seven speech-information binary digits; an additional binary digit in each channel would handle signaling.

These, incidentally, are the major specifications for an integrated pcm system now under development by the Laboratoire Central de Télécommunications, a French member of the ITT group. The French system is designed to handle both switching and speech digitally. The company proposes to cut down the cable pairs for telephone systems by concentrators, which would hook up 24-channel pcm units to groups of phones. The number of subscribers in each group would vary according to its traffic.

The pcm "highways" from the concentrators would be time-multiplexed at the exchange in groups of eight. For every three groups, logic units of a control circuit would handle the signals needed for signaling and switching. The control circuits would contain memories to store information about the subscriber lines and the programs for the logic units. Next year, the company plans to deliver to the French military a scaled-down version of the system; company officials hope this will be the forerunner of full-blown commercial telephone-exchange equipment.

Enter IC's. A hint of the impact integrated circuits may have on the price of complex encoding-decoding circuits was given by the Bell Telephone Manufacturing Co. of Belgium, which unveiled at Montreux military pcm equipment using μL, a micrologic system developed by the Fairchild Camera & Instrument Corp. μL contains 906 monolithic circuits, each consisting of eight transistors and eight resistors; the system also contains discrete components. All the circuitry, Bell says, was designed for eventual switch-over to IC's. The mix of integrated circuits and discrete components was determined by cost considerations, the company explains. The gear is now being field-tested for the Belgian Army.

The Bell unit, designated TU-12 and designed for modulation of a microwave link of 235 kilocycles per second, has a basic capacity of 12 channels. Unlike most commercial systems, it uses only six bits per channel sample, although the sampling rate is eight kilocycles. This arrangement sacrifices some audio quality, but simplifies the encoding-decoding circuitry somewhat. The equipment is compatible both with the United States AN/TC-44 operation, where synchronization is obtained using one bit per channel period, and with the French Laboratoire Central de Télécommunication's, where synchronization information is bunched in an entire channel period.

All the channel encoding-decoding circuitry is grouped in one rack, and the common circuits—timing, video input and output, and power supply—in a second rack. If a second channel-circuit rack is added, a 24-channel system becomes possible.

Japan

Now there are five

Another Japanese company has achieved continuous-wave operation of a Gunn-effect diode. The Tokyo Shibaura Electric Co. (Toshiba) announced its success last month, a few weeks after the Nippon Electric Co. had become the first in Japan—and only the fourth company in the world—known to have developed a c-w gallium-arsenide oscillator.

The only other companies in the race are the International Business Machines Corp. and Bell Telephone Laboratories in the United States, and Standard Telecommunications Laboratories, Ltd., a British affiliate of the International Telephone and Telegraph Corp.

The Gunn effect is the generation of coherent microwave oscillations by a bulk semiconductor when an electrical field exceeding a specific threshold is applied.

Nearly 10 milliwatts. The Toshiba oscillator, developed by Junichi Okada, Isamu Kuru and Haruhiro Matino, is said to deliver almost 10 milliwatts at 2 gigacycles per second. Nippon Electric said its device delivered "several milliwatts" at a center frequency of about 3 gigacycles. IBM has predicted that 10 milliwatts of continuous power at 9 gigacycles would be achieved soon.

The Toshiba device can be tuned from 1 to 6 gigacycles, with a bandwidth of less than 50 kilocycles—the resolution of the spectrum analyzer with which measurements are made. Nippon Electric claims to have attained pulses at frequencies of more than 10 gigacycles.

For its oscillator, Toshiba buys single crystals of gallium arsenide from the Monsanto Co. in the United States. The Monsanto crystal's resistivity, although high—10 to 100 ohm-centimeters—is still lower than in the best material in use at Bell. Okada says the resistivity of the gallium-arsenide sample with which his group achieved c-w oscillation was about 30 ohm-cm.

Since announcing its oscillator last month, Nippon Electric has achieved c-w oscillation with material grown by the company. Hiromi Murakami, head of the research group at NEC, says detailed measurements of the material have not yet been made. The Monsanto gallium arsenide with which his group achieved c-w oscillation had a resistivity of about 3.5 ohm-cm.

Cooling. A key to Toshiba's success, as with Nippon Electric's [Electronics, Nov. 1, p. 157], is the efficient removal of heat from the semiconductor. The Gunn-effect diode is cooled by forced air blown into the frequency-determining cavity, in which the diode is operated. Toshiba plans to add fins to the cavity and to improve heat conduction from the diode package to the cavity, so the unit can be cooled by convection. Two watts can be dissipated with the Toshiba system compared with five watts for NEC's.

The crystal pellet is 200 microns in length and width, and 70 microns thick. The diode is mounted in a microwave varactor package 1 centimeter high and 5 millimeters in diameter. The cavity in which the diode operates is separate from the diode package.

The Toshiba oscillator operates at 50 volts with a current of about 30 milliamperes, for an input of 1.5 watts.

The future. Like STC in Britain, Toshiba is interested in epitaxial single-crystal material for Gunn-effect oscillations. The principal reason is that more economical use of the expensive gallium arsenide is possible.

In addition to oscillators, Toshiba spokesmen say the research will work on solid state amplifiers and mixers.

France

After the election

The French electronics industry, which has thrived during the administration of Charles de Gaulle, has every reason to expect the President to be reelected on Dec. 5. With the opposition badly split, the 75-year-old general seems a sure bet to win.

Spurred by the President's well-known ambitions in space, arms and industrial technology, the government has provided substantial financial support for electronics, which it regards as a "frontier industry." Last month, for example, Paris gave about $7 million toward the development of the Secam color-television system. The money came from a $200-million bond issue aimed at helping such "frontier industries" to expand.

Military plans. In another recent action, the Defense Ministry disclosed more details about its second-stage strategic strike force. Plans call for the installation of at least 30 ground-to-ground missiles in underground silos in the southern Alpine region. Little information about the missiles has been given out, but the first units are expected to be operational by 1968.

France's first-stage strategic force, now nearly fully operational, is built around 62 mach-2 Mirage-4 bombers equipped with nuclear weapons. By 1973 a third-stage force is expected to be ready, based on three nuclear submarines, each carrying 16 Polaris-type missiles.

Such grand military plans obviously mean big contracts for the electronics industry. So does the world's third-largest space program, including the development of a booster known as the Diamant. So far, the government has earmarked about $100 million for the booster's development.

The 1966 military budget calls for $290 million for electronics; a long-range schedule anticipates $320 million in 1967 and $330 million in 1968.

Companies expect some of these programs to be reduced if de Gaulle should be defeated next month. But a political upset of that magnitude would amaze even the general's opponents.

Great Britain

Zippier code

By mid-1966, letters arriving at the post office in Norwich, England, are scheduled to be sorted into postmen's mailbags without any human handling. Machines will do the work at Britain's first automatic post office, which is to be tested in the small city (population 120,000) 100 miles northeast of London.

Most of Britain is expected to have postal automation by 1970. Much of the necessary equipment is available and the rest is under development.

Pinpointing the destination. The big advance in Britain's system is the precision of the area code. Unlike zip codes in the United States and West Germany, which specify only a general postal area, the British code pinpoints the neighborhood served by each postman.

For example, one code is NOR 55T. The first part stands for Norwich, the second for a specific delivery area within the city. At the post office where the letter is mailed, the envelope is carried by a conveyor belt past an operator—the only human link in the system—who copies the code from the envelope onto the keyboard of a coding unit; the coder produces two rows of phosphorescent dots on the envelope, in a binary code that can be "read" by an electronic scanner. One row, representing the NOR part, is scanned at the sending station at 7,000 an hour, for routing. The 55T part is scanned at the same speed at the receiving station, for sorting into delivery areas.

Mail handler consists of feed-in section at left, scanning shelves in center and stamp-canceling and letter-stacking unit at right. Conveyor belt carries letters from one section to another.

While it reads, the scanner sends signals to a translator unit, where they are converted into binary signals that open slots farther along the route of the belt on which the letters are conveyed. Sorting consists of getting each letter to slip through the proper slot. The translator can serve 30 coding desks, 4 high-speed sorters, and 10 low-speed sorters on a time-shared basis.

Faster sorter. The sorter is manufactured by the Thrissell Engineering Co. A faster unit—20,000 items per hour to only 20 locations—is being built by Elliott Automation, Ltd. The translator was developed by the Post Office Research Station. Both Thrissell and Elliott make coding desks.

Another machine detects the stamp's position on the envelope and turns the letter right side up. This facing machine, another Elliott product, cancels stamps and puts dates on envelopes at 400 a minute. For detection, the stamps must be treated with a phosphorescent substance.

An electronic character-recognition machine, for converting typewritten or hand-written area codes into a binary form that can be understood by the scanner, is being studied at the Post Office Research Station in London. Ability to cope with handwritten addresses is particularly important in Britain, where 80% of all mail is addressed by hand, compared with 50% in the United States.

The cost. Britain's 10-year program to modernize the postal system is expected to cost $112 million. But with 30 million letters mailed daily, each one requiring handling by four or five people, the saving in labor could be enormous.

Plans call for installation of automatic mail-handling equipment at the 75 main post offices that process three-quarters of the country's mail.

India

Market for Red tv

Indian officials are shopping in Eastern Europe for television sets and tv broadcast equipment. Already, 9,000 receivers have been ordered—6,000 from the Soviet Union, 2,000 from Hungary and 1,000 from Yugoslavia. The prices have not been announced, but trade circles in New Delhi say they average $120 to $130 per set.

That amount of business is far from startling—at first glance. But in light of the fact that there are only 666 tv sets in India, a country with 450 million inhabitants, the purchases take on new significance. India has begun a 20-year plan to provide tv service throughout the country, at a cost of $120 million [Electronics, Mar. 8, p. 222]; only $12 million has been appropriated so far.

More broadcast facilities. One immediate goal is to expand India's only tv station, in New Delhi, to double its broadcasting to two hours a day; other objectives are to establish stations in Bombay, Madras, Calcutta and Kanpur within three or four years.

The West German government has supplied $420,000 worth of equipment, as a gift, for expanding the New Delhi station; Bonn also has offered to train Indian technicians in handling the equipment.

But Bonn will not take kindly to reports that India is considering offers from the Communist governments of East Germany and Poland to help India build plants for manufacturing tv receivers and equipment. Negotiations also are under way with Czechoslovakia, another Communist country, to supply tv sets.

Reason is economics. Why is India taking actions that assuredly will antagonize the two giants in tv manufacturing—West Germany and the United States? The reason seems to be a shortage of foreign exchange. Every transaction with an Eastern European country specifies payment in nonconvertible Indian rupees over a five-year period.

India also is seeking radio equipment in Eastern Europe. The Soviet Union and Yugoslavia already have agreed to supply a 1,000-kilowatt transmitter apiece, also to be paid for in rupees over a five-year period. The Russian transmitter, scheduled for delivery in mid-1967, costs $1.7 million. The price includes antennas and technical installation and operation.

Hong Kong

Chinese puzzle

How advanced is China's electronics industry? In Hong Kong there are two ways to try to find out: listen to questionable reports emanating from Communist Chinese radio broadcasts and imaginative local businessmen, or window-shop at the China People's Products stores in Victoria and Kowloon, the two major cities in the British Crown Colony. Unfortunately, you sometimes get conflicting answers.

Radio assemblers repeatedly hear reports that China is producing transistorized radios. But so far, the China People's Products stores have shown only vacuum-tube sets —large, expensive, and looking like leftovers from a 1938 clearance sale at Macy's.

Similarly, rumors indicate extensive semiconductor production in China, but few people have ever seen a Chinese transistor in Hong Kong.

New products. Whether or not Westerners have seen Chinese transistors, New China Press Agency says the Shanghai transistor factory has teamed up with a musical-instrument plant to produce a transistorized organ. The instrument has two keyboards, each with 3½ octaves and a pedal system that produces 13 bass tones. The Chinese say they have equipped it to imitate Western woodwinds and strings, as well as Chinese instruments.

Here are some more Chinese claims:

- A vacuum-tube factory in Shanghai is said to have developed an indicating tube for use in digital instruments, computers and automatic control devices. It sounds similar to the Nixie tube produced by the Burroughs Corp. in the United States.
- A steel-wire plant in Peking is reported to be making iron-chrome-aluminum resistors so small they are almost invisible. The material is used in meters, instruments and medical equipment that requires high specific resistivity and sensitivity.
- A factory in Swatow, a coastal city near the Formosa Strait, is said to be producing an ultrasonic detector that operates on a frequency of 2.5 megahertz. The instrument detects flaws in railroad tracks, reportedly as small as 0.3 millimeters in diameter at a depth of 200 millimeters.

Around the world

West Germany. Short, powerful pulses of 100 megawatts from a ruby laser have been predicted by researchers at Siemens & Halske AG. Siemens already has obtained one-kilowatt pulses from a continuously pumped laser by inserting a passive Q switch, made with simple methylene blue, between the laser and the external mirror. Dieter Roess, who developed the technique, predicts applications in radar and communications.

Britain. Plessey Industries, Ltd., has signed a million-dollar contract to help Communist China build a potentiometer plant. The Chinese plan to make "several million" potentiometers a year in about 15 varieties, starting early in 1968, Plessey says. Plessey engineers will work in China and Chinese engineers will be trained at Plessey's plant in Swindon, 70 miles west of London.

Soviet Union. Soviet researchers claim to have solved the problems of laser communication, but don't explain how. The Russians say a three-mile-long laser beam will soon carry telephone messages on a commercial basis. Laser communication has always been plagued with attenuation and absorption in the air and by background light; to overcome these problems, the Russians say sensors feed atmospheric data to a receiving point, which filters out interference and changes the output of the gas laser.

Japan. The Sony Corp. has entered the high-fidelity field with a series of high-quality, high-priced transistorized amplifiers and other hi-fi components. The amplifiers are said to contain "stable epitaxial passivated" transistors; response is within a one-decibel band for all frequencies between 10 and 100,000 cycles per second.

Israel. Construction of a $1.7-million plant for the manufacture of electro-optical instruments has begun in Tel Aviv. The new company, Israel Electro-Optical Industry, is owned 40% by the Israeli government and 60% by Oude Delft, Ltd., of the Netherlands. Production is scheduled to begin late in 1966.

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