VOL. 14, NO.

Electronic Design 23

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

OCTOBER 11, 1966

Computer-aided design—exciting challenge to electronic engineers. From an amplifier to a feedback system, here is how this new technology has been applied to solve typical design problems. Also included is a table of available computer programs that will help you to put this powerful design technique to work (turn to p. 54).

HI-FI

Transistor output; matches any PP transistor to 4, 8, 16 Ω speaker. Primary 48, 36, 12 Ω C.T.; 20 ∼ to 20 KC; 40 watts.

MINIATURE MIL TYPE

Metal case hermetically sealed to MIL-T-27B. Gold Dumet leads spaced on 0.1 radius, for printed circuit application.

CHOPPER

Magnetic shielded plus electrostatic shield for voltage isolation of 2x10^6. Primary 200K C.T. to within 0.1%. Secondary 50K.

HIGH POWERED AUDIO

Low distortion 2.5 KW output transformer, PP 450 TH's 18,500 ohms C.T. to 24/6 ohms, 20 KV hipot. 520 lbs.

CATHODE FOLLOWER OUTPUT

Provides equal voltages to 5 loads. Primary inductance maintained to 5% with 20% change in DC unbalance and 30% change in AC voltages.

HI-FREQUENCY CARRIER TO MIL-T-27B

Electrostatically shielded, humbucking, +30 dbm level. Within .5 db 250 cycles to 110 KC. 600/135: 600 centertapped to .1% tolerance.

HYBRID TRANSFORMER

Two transformers each 600 Ω primary. 40K Ω C.T. secondary 250 cycles to 5 KC within 1/4 db. 40 db isolation over band.

MICROMODULE

Life tested per micromodule specs.: no failures. 10K Ω C.T. to 10K Ω, 100 mw from 400 ∼ to 20KC.

SUBMINIATURE MOLDED TRANSFORMER

Grade 3 with printed circuit leads for transistor application. 150 Ω to 150 Ω at 10 dbm level. Size 1/2 x 1/2 x 1/2"; weight 5 grams.

BOLOMETER TRANSFORMER

Primary 10 ohms, secondary 530K ohms, 230:1 ratio, response from 1/2 cycle to 25 cycles. 120 db magnetic shielding, plus full electrostatic shielding.

ULTRA-MINIATURE

Electrostatically & magnetically shielded output transformer 5/16 D. x 1/4" H. Pri. 15K CT, Sec. 8K CT; max. level 50 mw; audio range response. To MIL-T-27B, grade 4.

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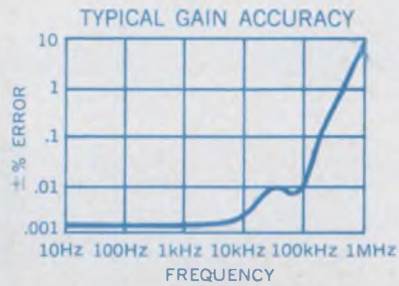
ON READER-SERVICE CARD CIRCLE 208

Check your application against each performance feature of the new 463A Precision Amplifier

☐ **1.** **0.01% gain accuracy and stability—80 db dynamic range**

☐ **2.** **Wideband application—dc-1 MHz**

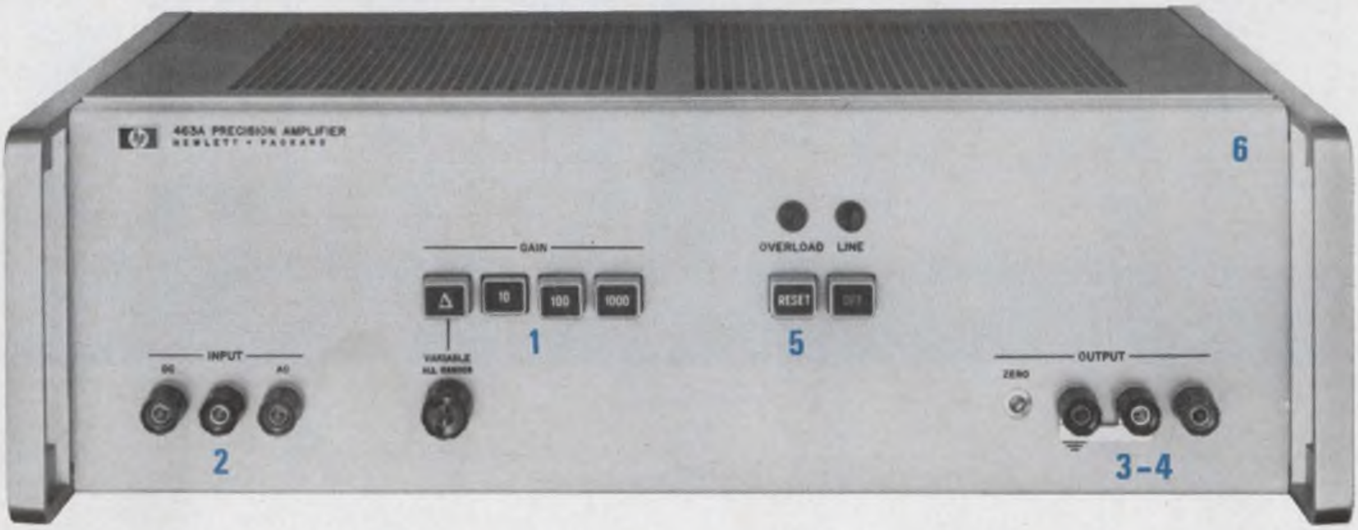


☐ **3.** **0.01% ultra-low distortion**

☐ **4.** **100 v rms out, 5 watt continuous power**

☐ **5.** **Front-panel overload indicator, reset button**

☐ **6.** **All solid-state**



The Hewlett-Packard 463A Amplifier has totally unique benefits for almost every application—calibration system work without introducing error, ac and dc measurements with thermocouples or differential voltmeters, amplification of stable solid-state oscillators, driving magnetic memory cores, data acquisition amplification, bridge measurements, very low frequency amplification for biomedical, servo, geophysical applications, in-system amplification (BNC rear-panel terminals).

Adjustable gain is also provided with a range of 0 to 100% of selected gain. The 463A meets the most critical demands of wide-range, low-distortion amplification. Ideal as a preamp for the hp 741A AC/DC Differential Voltmeter, DC Standard and 3440A/3445A DVM and Range-Unit Plug-in, for making low-level measurements. Hewlett-Packard 463A, $590.

Call your Hewlett-Packard field engineer for complete specifications, related to your particular amplifier need. Or write Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

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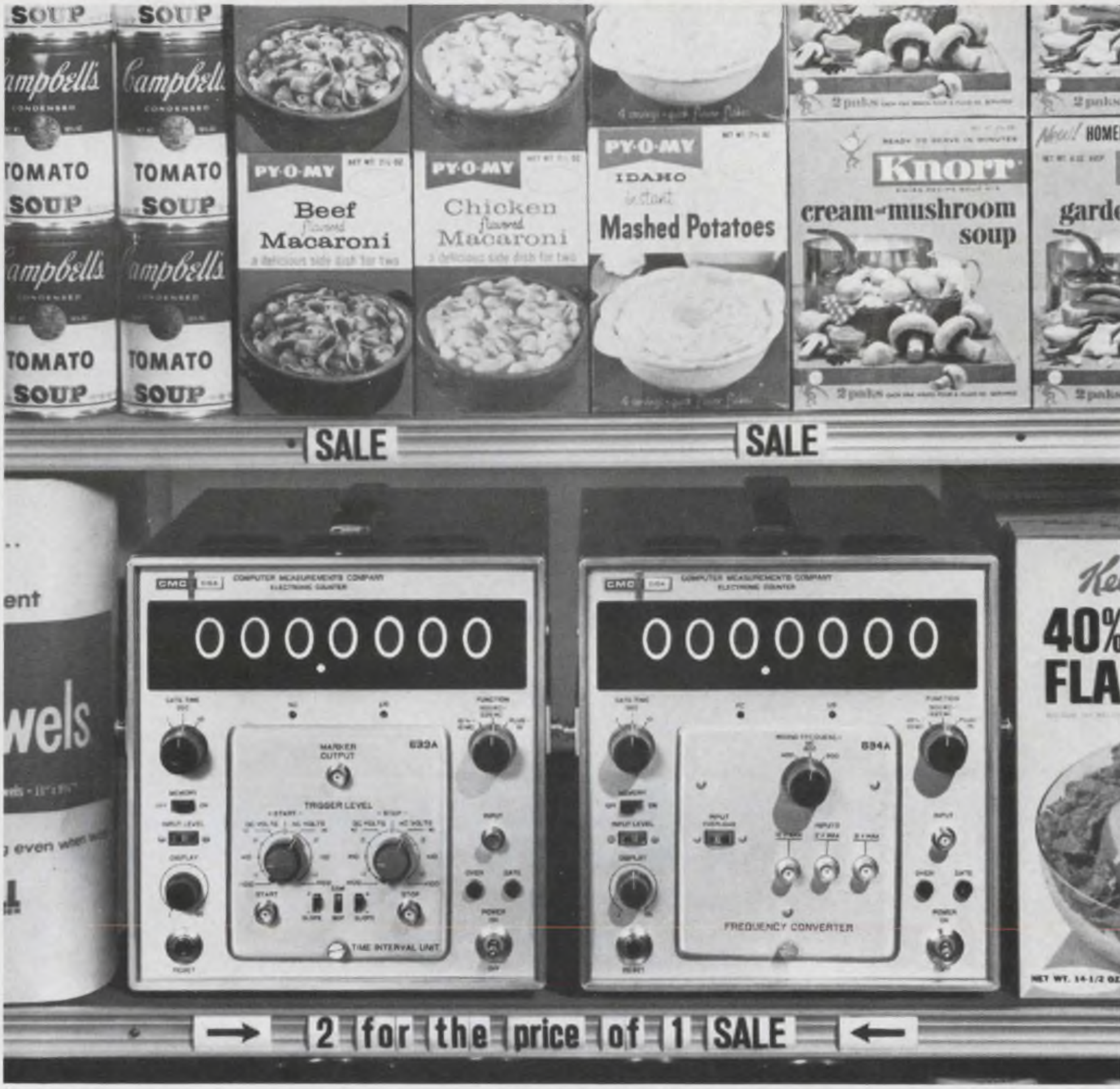
1647

ON READER-SERVICE CARD CIRCLE 2



No, it's not the start of a price war. We're simply demonstrating that our new solid-state Model 616A frequency meter costs about half the price of any other comparably performing instrument now available. But, since the 616A is so versatile, who needs two of them anyway? This clever little instrument, with all silicon semiconductor insides, gives you direct frequency measurement through the entire 225 Mc telemetry band, and as high as 12 gigacycles with one plug-in. That's because we cunningly built in the prescaler.

But Hewlett-Packard and Beckman didn't. Theirs is a plug-in to a counter, and the total cost is twice that of our 616A. Then they sell you a second plug-in to measure above 400 Mc. Speaking of plug-ins . . . the 616A comes well equipped! Slip in a frequency converter or other special CMC frequency extender plug-ins, and your frequency measurements can soar to 1,000 Mc, 3,000 Mc, and even a phenomenal 12 gigacycles! Or, with our time interval plug-ins, measure time from .1 μsec. to 1 sec., or 1 μsec. to 10 sec.

Not only is the Model 616A half the price, but notice, it's half-rack size too! One reason is because, like others in the 600-Series, it features an advanced "mother board" technique. Lost are excess size, weight, and components; gained are new shape, reliability, and ease-of-maintenance. Button it up with its front cover and this rugged 28-pound wizard goes right out in the field.

All this for just $2,185. Interested? Then send now for the complete specs. And, if you're new at comparing our specs to high-powered H-P and big, bad B, you can earn a glorious Crusading Engineers' medal which reveals to everyone that you had the guts to look at somebody else for a change. It's also a great conversation opener for sweet young things you want to dazzle at your next T. G. I. F. party!

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ON READER-SERVICE CARD CIRCLE 3

VOL. 14, NO.

Electronic Design 23

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

OCTOBER 11, 1966

NEWS

TECHNOLOGY

PRODUCTS

Departments

ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N.Y. 10022. James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled-circulation postage paid at Chicago, Ill., and New York, N.Y. 59,721 copies this issue.

BOURNS® BUSHING MOUNT POTENTIOMETERS

Diameter (In.)	Model No.	Turns	Resistance④ Ω	Tolerance (%)	Linearity (%)	Power (Watts)	Maximum Operating Temp. Range (°C)	Humidity (MIL-R-12934)	Shock (G)	Vibration (G)	Case Length (In.)
1/2	3700	10	100-100K	± 5	±0.25	1.0 at 70°C	−65 to +125	Yes	100	20	1
	3707	10	100-100K	± 5	±1.0	1.0 at 40°C	−55 to +105	③	50	10	1
7/8	3500	10	100-250K	± 3	±0.20	2.0 at 70°C	−65 to +125	Yes②	100	20	1
	3501	10	1K-500K	± 5	±0.50	2.0 at 70°C	−55 to +125	Yes②	100	20	1
	3507	10	100 to 100K	± 5	±0.50	2.0 at 25°C	−55 to +105	③	50	10	1 1/8
	3510	3	50-100K	± 3	±0.30	1.0 at 70°C	−65 to +125	Yes②	100	20	5/16
	3520	5	50-100K	± 3	±0.30	1.5 at 70°C	−65 to +125	Yes②	100	20	11/16
	3530	1	25-50K	± 3	±0.50	1.0 at 70°C	−65 to +125	Yes	50	15	1/2
1 1/16	3430	1	50-100K	± 3	±0.50	1.5 at 70°C	−65 to +125	Yes	50	15	5/8
	3438	1	100-50K	±20	±1.0	1.0 at 40°C	−15 to +80	③	15	10	3/4
1 13/16	3400	10	100-500K	± 3	±0.15	5.0 at 40°C	−65 to +105	Yes	50	10	1 3/4
2	3410	1	50-100K	± 3	±0.30	4.0 at 70°C	−65 to +125	Yes	50	15	5/8
3	3440	1	100-150K	± 3	±0.25	6.0 at 70°C	−65 to +125	Yes	50	15	5/8

BOURNS KNOBPOT® POTENTIOMETERS

Diameter (In.)	Model No.	Turns	Resistance④ Ω	Tolerance (%)	Linearity (%)	Power (Watts)	Maximum Operating Temp. Range (°C)	Humidity (MIL-R-12934)	Shock (G)	Vibration (G)	Case Length (In.)
3/4	3600	10	100-100K	± 5	Accuracy① % ±0.50	1.5 at 25°C	−65 to +85	③	50	10	1
1 1/4	3640	10	100-100K	± 3	±0.10	2.5 at 25°C	−65 to +85	③	50	10	1 1/2
1 1/4	3650 DIGITAL READOUT	10	100-100K	± 3	±0.10	2.5 at 25°C	−65 to +85	③	50	10	1 1/2
1 1/4	3660 LABPOT™	10	100-100K	± 1	±0.10	2.5 at 25°C	−65 to +85	③	N/A	N/A	N/A

① Accuracy of Readout vs Output (Including Linearity)
② Moisture Resistance per Method 106, MIL-STD-202 Available.

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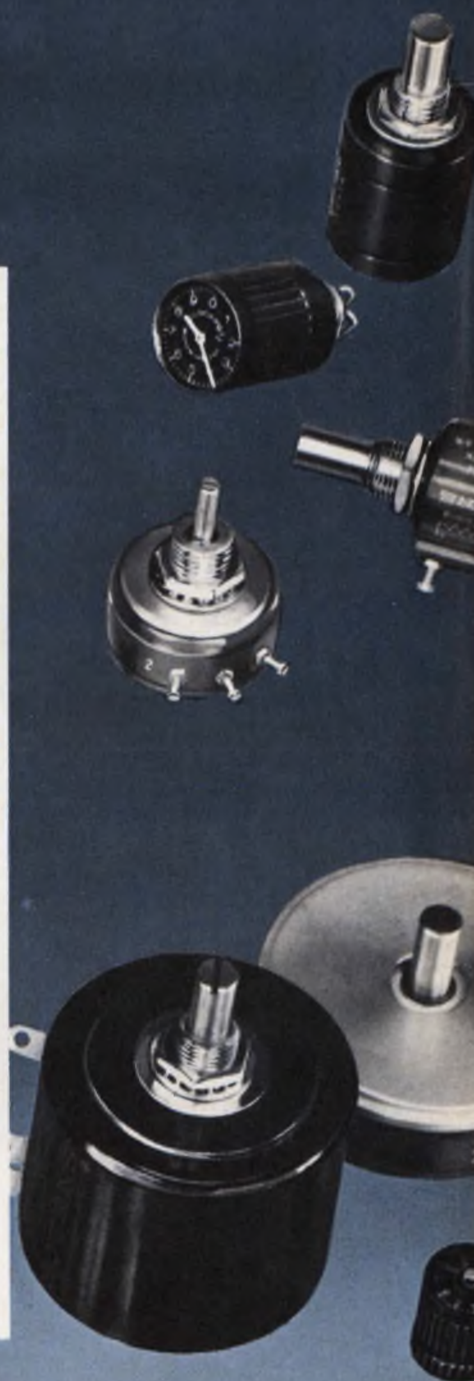
"A complete in-stock, in-depth line of proven standards and capability to adapt any model for special requirements."



BOURNS® SERVO-MOUNT POTENTIOMETERS

Diameter (In.)	Model No.	Turns	Resistance④ Ω	Tolerance (%)	Linearity (%)	Power (Watts))	Maximum Operating Temperature Range (°C)	Humidity (MIL-R-12934C)	Shock (G)	Vibration (G)	Case Length (In.)
1/2	3750	10	100-100K	±5	±0.25	1.0 at 70°	−65 to +125	Yes	100	20	1 3/16
7/8	3550	10	100-250K	±3	±0.20	2.5 at 70°C	−65 to +125	Yes	100	20	1 9/16
	3551	10	1K-500K	±5	±0.50	2.0 at 70°C	−55 to +125	Yes	100	20	1 9/16
	3560	3	50-100K	±3	±0.25	1.5 at 70°C	−65 to +125	Yes	100	20	1 3/64
	3570	5	50-100K	±3	±0.25	2.0 at 70°C	−65 to +125	Yes	100	20	1 3/16
	3580	1	25-50K	±3	±0.50	1.0 at 70°C	−65 to +125	Yes	50	15	5/8
1 1/16	3480	1	50-100K	±3	±0.50	1.5 at 70°C	−65 to +125	Yes	50	15	9/16
2	3450	10	100-500K	±3	±0.15	5.0 at 70°C	−65 to +125	Yes	50	10	2 1/4
	3460	1	50-100K	±3	±0.30	4.0 at 70°C	−65 to +125	Yes	50	15	5/8
3	3490	1	100-150K	±3	±0.25	6.0 at 70°C	−65 to +125	Yes	50	15	5/8

1" *TURNS-COUNTING DIALS*

Model No.	Shaft Diameters (In.)	Brake	Body Finish
H-491	3/32, 1/8, 1/4	No	Clear
H-492	3/32, 1/8, 1/4	Yes	Clear
H-493	3/32, 1/8, 1/4	No	Black
H-494	3/32, 1/8, 1/4	Yes	Black

1/2" *TURNS-COUNTING DIALS*

Part No.	Description
H-351	10-Turn, clock-dial readout. Accepts 1/8" or 3/32" Dia. shafts.
H-353	Adapter for shaft extensions
H-354	Turns Counting Dial with brake
H-355	Snap-on Color rings*

*Per FED. STD. 595

③ Steady State Humidity per Method 103, MIL-STD-202
④ Lower and High Resistance Values than those shown are available in most models.

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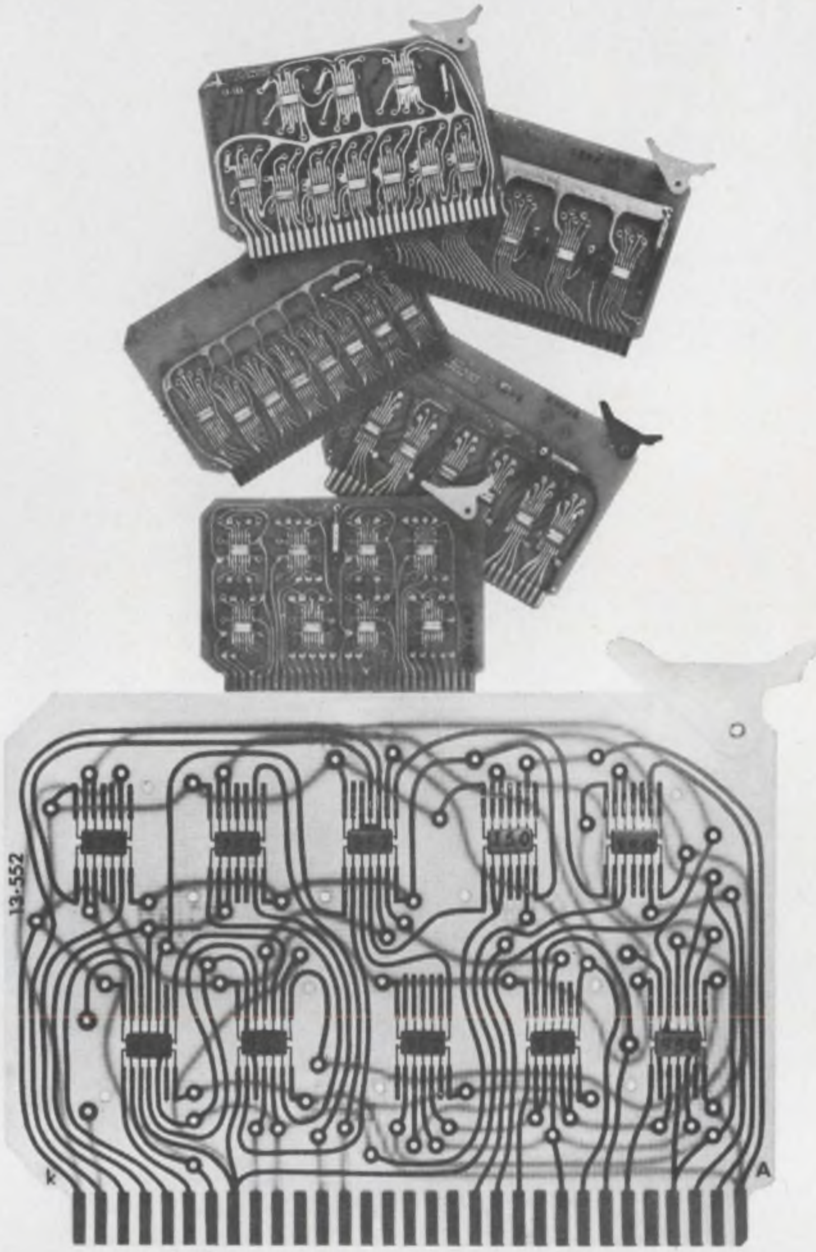
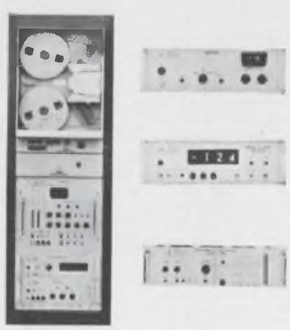
MICROCIRCUIT MODULES



HIGHEST DENSITY

...and simplified Gating Rules Reduce Costs



The ADC 13-Series features unique function grouping, simplified gating rules and a 62 pin connector which permits the highest density per board. This means more functions per board — fewer boards required — less wiring — less noise problems — less cost. The 13-Series offers the most economical logic implementation as well as field proven performance ■ The ADC 13-Series further expands (more than 30 new modules) the most complete line of logic modules available. ■ The 100 kc - 10 Series, with germanium semi-conductors, is simple, economical and reliable. The 1 mc 11-Series using silicon semiconductors, is ideal for high performance applications and the 11G-Series meets all applicable MIL/NASA specifications.

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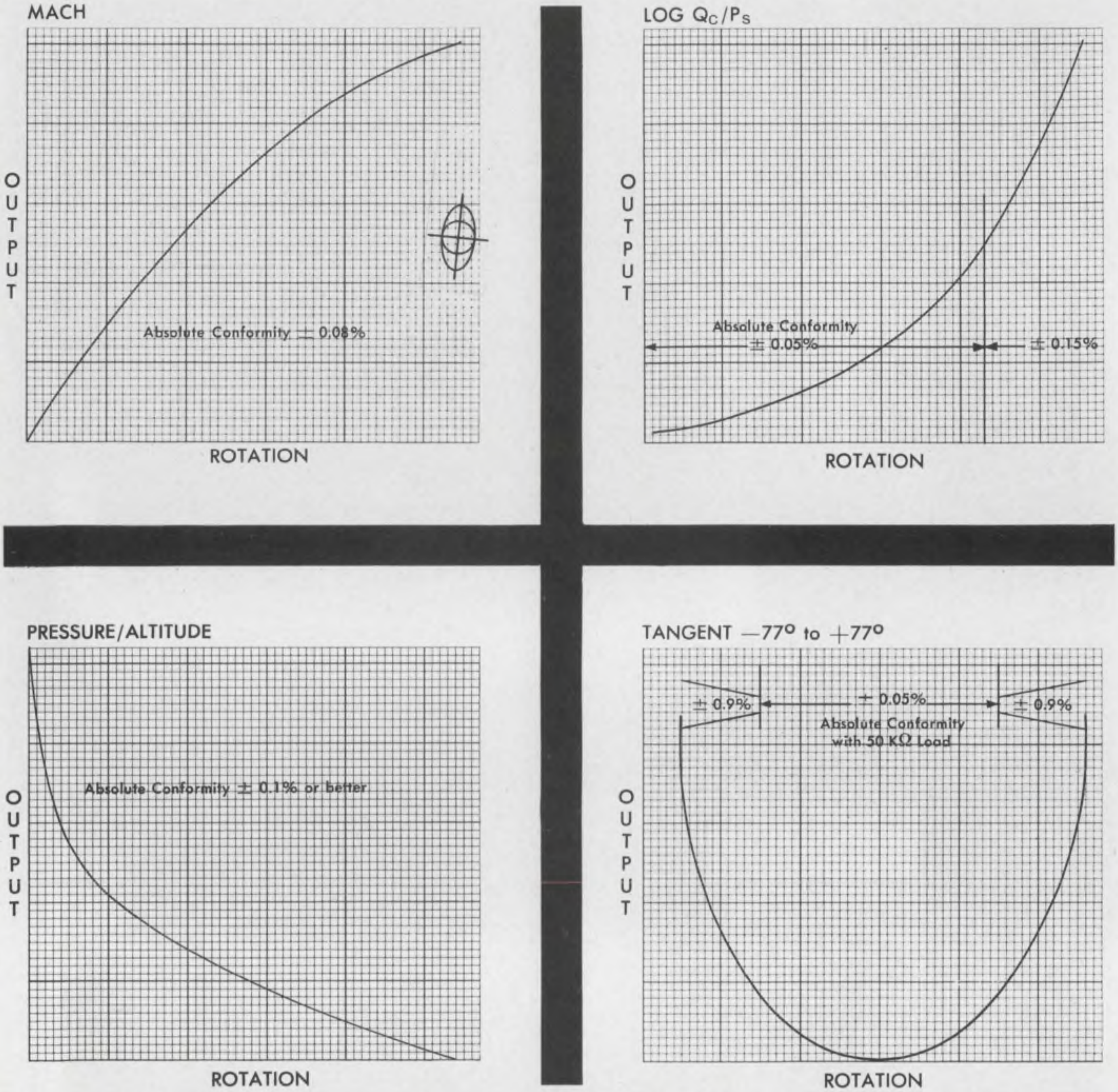
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OUTPUT
ROTATION
Absolute Conformity ± 0.08%
LOG Q_C/P_S
OUTPUT
ROTATION
Absolute Conformity
± 0.05%
± 0.15%
PRESSURE/ALTITUDE
OUTPUT
ROTATION
Absolute Conformity ± 0.1% or better
TANGENT −77° to +77°
OUTPUT
ROTATION
± 0.9%
± 0.05%
± 0.9%
Absolute Conformity
with 50 KΩ Load


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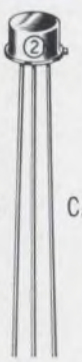
NOW AVAILABLE IN PNP TYPES!

NPN TRANSISTORS		
Type No.	**Application**	**Features**
TN53-TN54	high voltage switch	$BV_{CEO} = 45V$ (min.), $BV_{CBO} = 75$ V (min.), $f_T = 100$ (min.)
2N4383-2N4386 (TN55-TN58)	low level switch	wide-band noise figure = 2 db (typ.), $h_{FE} = 100$ at 10 mA
TN59-TN64	high speed switch	f_T up to 100 mc, h_{FE} up to 100 at 150 mA
TN79-TN80	chopper	$V_O < 500$ mV at $I_B = 5$ mA, $R_S < 20\ \Omega$ at $I_B = 5$ mA
TN81	power amplifier	600 mW P_{OUT} at 50 mA, typical gain of 9 db

PNP COMPLEMENTS
2N4412-2N4413 (TQ55-TQ56) Low Level, Low Noise (complement of TN55, TN56)
TQ59–TQ60 General Purpose, High Gain (complement of TN59, TN60)
TQ61–TQ62 High Speed Switch (complement of TN61, TN62)



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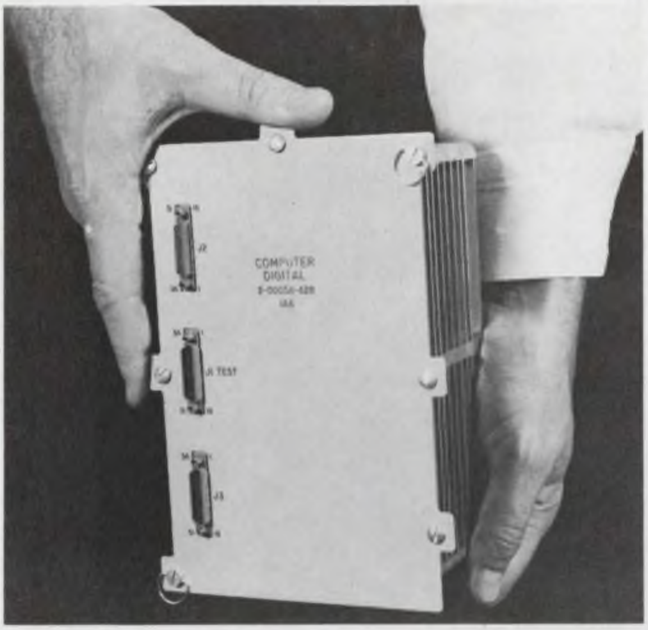
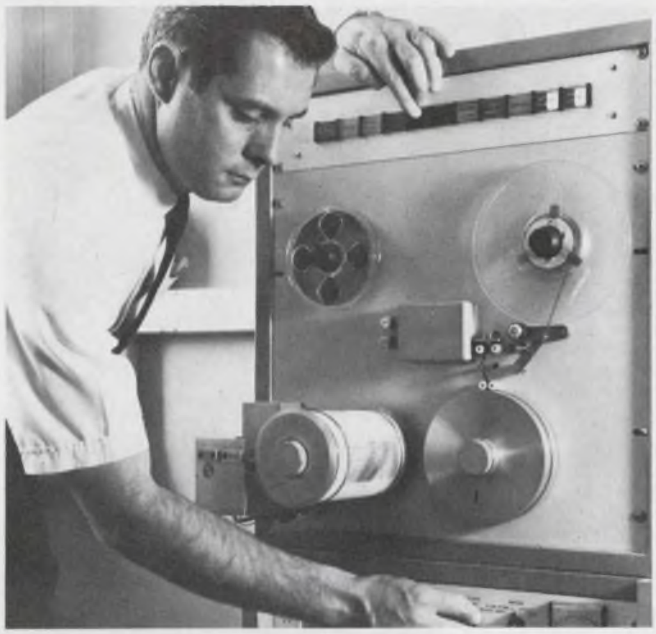
ON READER-SERVICE CARD CIRCLE 9

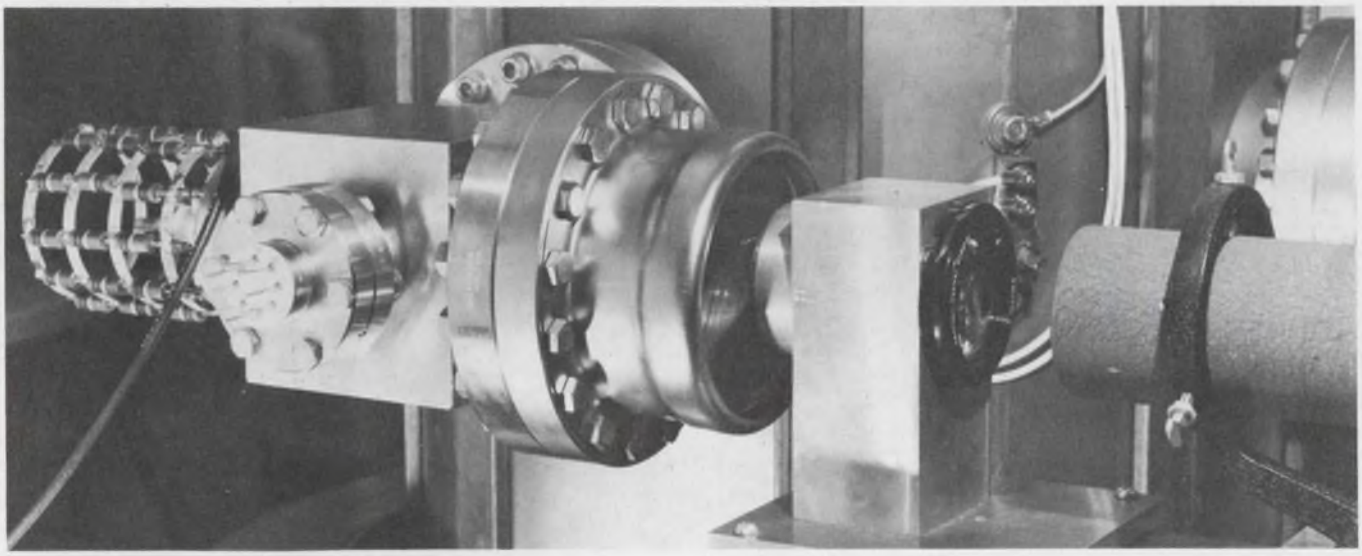
News



Portable inertial guidance system rapidly aligns aircraft navigation platform. Page 21



Solid-state spectrograph prints taped sound pictures in a matter of seconds. Page 20



A laser beam may be used to trigger a high microwave power switch. The gaseous plasma created by an ionization process in the beam is used as a transmission path. Page 33

Also in this section:

New X-ray unit shows 3-D internal views

A new development in X-ray technology affords the physician a three-dimensional view of the inside of his patient. Stereofluoroscopy gives a live view of the heart, liver and other internal organs such that their contour and depth may be seen at a glance.

This technique allows the physician to make more accurate and speedier investigations and simultaneously cuts the time that the patient is exposed to the possibly destructive radiation.

The new system, called Stereo Fluoricon by its maker, General Electric's X-ray Dept., Milwaukee, is an improvement of existing methods of enhanced two-dimensional fluoroscopy. It can be used in normal artificial light and is based on the use of a dual-beam X-ray tube that irradiates the patient from two slightly different angles. An optical polarizing arrangement superimposes left and right images on a mirror so that they appear as a single three-dimensional image to the human eye.

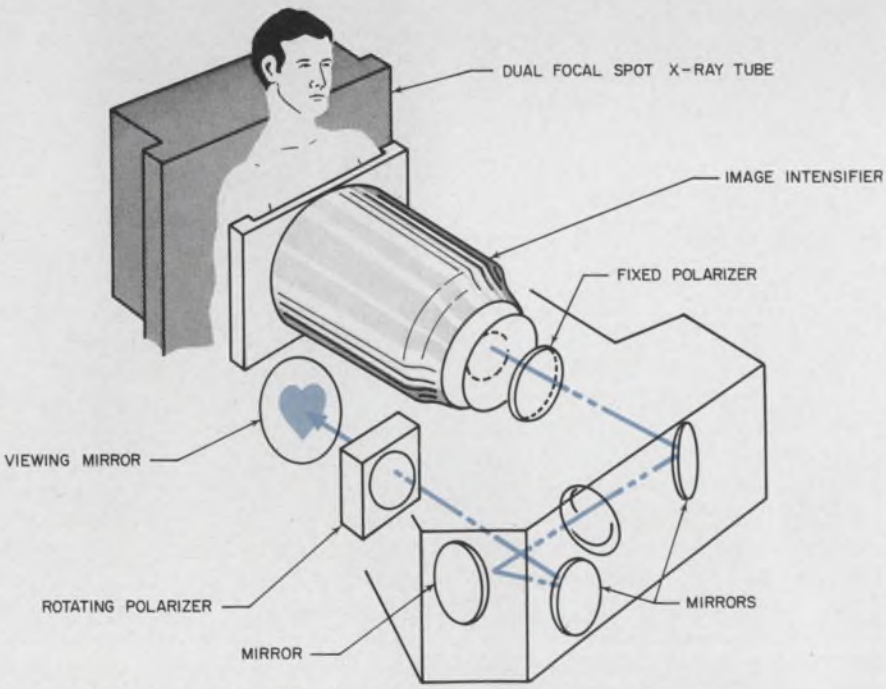
The system is particularly valuable for locating foreign objects within the body and placing catheters within the heart. A heart catheter is a long, fine, highly flexible tube that is inserted in an artery at the wrist and snaked all the way to the heart. The procedure is used to inject X-ray-opaque dye into the heart for analysis of heart function. It is also employed to examine the composition of cardiac blood for aeromedical studies of pilots' reactions under conditions of acceleration and stress.

Fluoroscopy is based on the ability of X-ray radiation to illuminate a fluorescent screen. The patient is placed between the X-ray tube and the viewing screen and bursts of radiation project negative images of internal structures onto the screen. These can be viewed directly or filmed for later study.

This process was vastly improved about 15 years ago with the introduction of the image intensifier tube which enhanced the image through application of electron microscope optics. Image brightness was increased as much as 6000 times. The patient could be viewed in a normally lit room. The technique was also safer because the X-ray energy level could be lowered and radiation dosage decreased.

The GE unit now introduces the third dimension into fluoroscopy. The two X-ray beams that it uses are two inches apart and are triggered alternately at 60 hertz. Because of their separation, each beam produces a slightly different image. After enhancement by an intensifier, the images are passed through the polarizing system and flashed successively onto the viewing mirror. The flashing rate is fast enough for the composite to appear as a continuous stereoscopic image.

Optional extra equipment makes it possible to vary depth perception. Altering the firing rate of the dual X-ray tube increases or decreases the angle of convergence so that the perception of depth can be increased or decreased.



X-ray looks inside the body in 3-D

NASA funds may be cut by one billion dollars

One billion dollars will definitely be cut from NASA's budget this fiscal year, it is reliably reported. Leslie Carpenter, a highly respected and well-informed special writer for the *Washington Star*, contends that President Johnson has before him right now a proposal that will certainly reduce NASA's funds by that amount some time during the remaining ten months of Fiscal 1967.

The proposal, he reports, was submitted to the President by his economic advisers, who believe that NASA can better stand such a cutback than any other government agency. Carpenter claims that both the President and his aides feel that the reduction in funds will delay a lunar landing by only a year or so.

Sodium-sulfur battery to power electric car

A new type of battery said to be lightweight, cheap and powerful enough to propel a "subcompact" car has been unveiled by Ford Mo-

News Scope CONTINUED

tor Co. researchers (see ED 13, May 24, 1966, pp. 17-22).

The battery contains liquid sodium and liquid sulfur separated by a crystalline ceramic sleeve. The production model will be a sealed unit that can be recharged with ordinary household current, a Ford spokesman said.

A major feature of the battery is the ceramic sleeve, which is made from aluminum oxide and beta-alumina. The selective qualities of this composition allows only the sodium ions to pass through, and interact with the liquid sulfur.

Because the battery is sealed and the action between the chemicals is a relatively simple process, the new battery is said not to suffer from the deterioration that occurs in conventional batteries.

Within 10 years, Ford said, they will be able to produce a 5- to 10-kW battery weighing 50 to 100 lb capable of powering a small car 150 to 200 miles at 40 miles per hour.

Zenith demonstrates laser TV system

Zenith Radio Corp. has announced development of an experimental laser TV system that is said to produce large pictures with a sharpness and detail approaching that of conventional TV pictures.

An unusual feature of the display system is that horizontal scanning of the laser beam is accomplished by an ultrasonic deflection cell. The cell directs acoustic waves of varying frequency to intercept the laser beam and deflect it across the screen 15,750 times per second.

The system consists of a 50-mW, helium-neon laser source (producing a black and red picture on the screen). A first ultrasonic diffraction cell for intensity modulation. A second diffraction cell that acts as a horizontal deflector, and a vertical deflector. These perform essentially the same function as a conventional TV receiver.

Checking the weather

16-lb weather station operates on batteries

A 16-pound portable weather station that operates on four conventional flashlight batteries has been delivered to the Army for use in the field.

The all solid-state unit, manufactured by Cambridge Systems, Inc., of Newton, Mass., can be put into operation by one man within the space of five minutes.

Also to be made available commercially, the station measures basic weather variables, including wind speed, direction, barometric pressure, temperature, dew point and precipitation levels.

Designated the AN/TMQ-22, the device will aid Army meteorologists in providing tactical weather.

It may be hard to pass the buck

The Pennsylvania State University, University Park, Pa., has begun tagging some of the wild animals in the woods of central Pennsylvania with tiny radio transmitters.

Deer—bucks, does and fawns—are first shot with tranquilizer-tipped needles and then outfitted with bright plastic collars that contain the minute devices. The entire collar, containing transmitter, circular antenna and battery, weighs less than a pound.

The electronic tagging is a university project called Radio Deer. Its aim is to learn more about the movement of the wildlife.

When the tagging is completed, graduate students will track the deer. Each student will carry a shoulder-strap receiver as he trudges through the chilly autumnal woodland. A handheld loop antenna will zero in on the animal and the student will pinpoint its whereabouts on a map for future study. The students will keep in touch with one another with walkie-talkies.

Atom power urged for ocean living

A nuclear generator that would be placed 1200 feet below the ocean surface and supplying up to a million watts of power for a small underwater community has been suggested by B. D. Pritchard, vice president of R&D for T.M.C. Systems, Springfield, Va. The company has been studying the feasibility of such a project.

The reactor would provide electricity for protein farming and would operate equipment for mining the large reserves of mineral d-posits known to exist under the seas. Sheltered inhabitants of the underwater community, Pritchard says, would receive enough generated power to live for extended periods without coming to the suface.

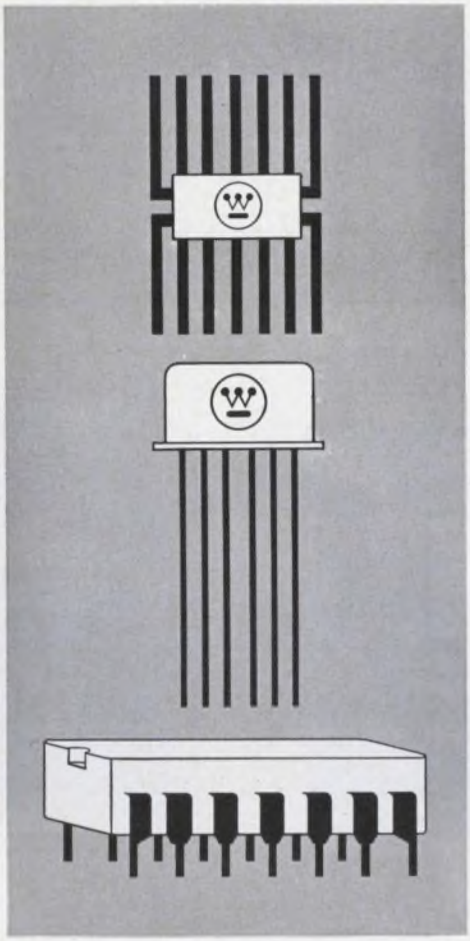
The reactor and generator would be contained in its own module and connected by cable to fully equipped community modules, providing living and recreational facilities. A floating platform would provide communication with the outside.

Airline installs portable radios

A hand-held vhf radio that permits an airline pilot to talk directly to a control tower or rescue plane without relying on the aircraft power system has been developed. The two-channel unit is being placed aboard all United Airlines planes.

The wet-cell battery that powers the unit will last up to 20 years without recharging, says the radio manufacturer, Granger Associates of Palo Alto, Calif.

Development of the radio is said to be significant in that previously an aircraft with electrical failure lost all communications.



Workhorse DTL

Four reasons why Westinghouse WC 200 IC's are a clear first choice for trouble-free computer and control systems.

The Westinghouse DTL line has been designed into so many successful computer and control equipments that it has won the supreme endorsement: It is being second-sourced by four major integrated circuit producers.

Reasons? First — reliability. WC 200 series designs have been proved by 5 million hours of life testing since their introduction in 1962 and have been continually improved since then. Major users report a 20 to 1 improvement in system reliability over previous discrete-component circuits. Just try to find any other digital line backed by such massive proof of reliability!

Second reason — speed. WC 200's six volt design with or without built in collector resistors increases speed and flexibility, keeps power dissipation down. And the use of the single-stage JK flip-flops rather than a master-slave arrangement makes WC 200 inherently fast.

Third reason — the greatest versatility in commercial DTL. Circuits are available in all 3 industry accepted packages. The line includes 15 gate circuits with 1 to 6 gates per package in a variety of input arrangements, 2 RS flip-flops, 2 JK flip-flops, 1 pulse binary counter, plus diode expanders and a large variety of interface circuits.

Fourth reason — immediate local availability at competitive prices. Behind the Westinghouse WC 200 line are both the most advanced IC plant in the industry and the longest production experience in integrated DTL. Result: high yields, and the greater production, increased reliability, and lower costs that you would expect to go with them.

These should be all the reasons you need to investigate WC 200 series DTL now. For immediate delivery, call your Westinghouse electronic distributor. For technical data, write Westinghouse Molecular Electronics Division, P.O. Box 7377, Elkridge, Maryland 21227.

You can be sure if it's Westinghouse

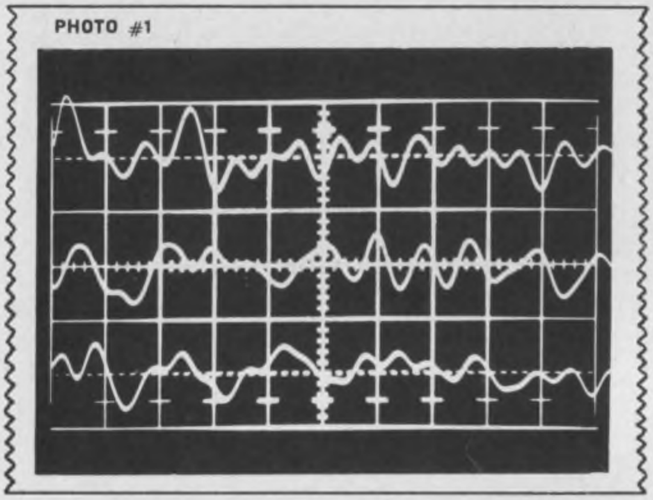
J-09134

ON READER-SERVICE CARD CIRCLE 11

Solve Your Noise Problems...

fish out those elusive weak signals from gooey backgrounds of noise

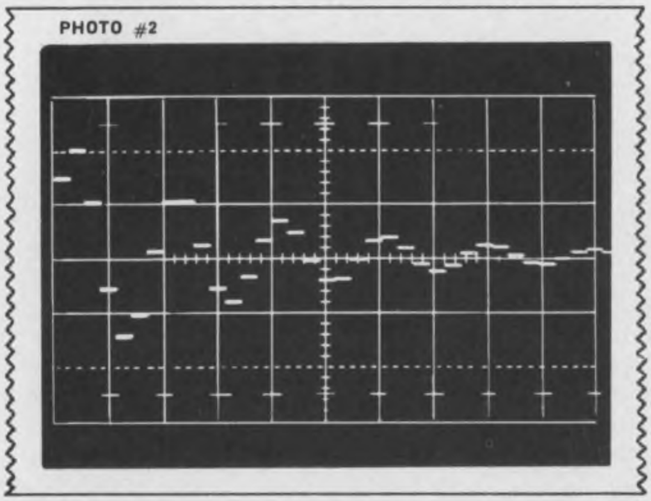
. . . Since our first "solve-your-noise-problems" advertisements ran, we've sold a lot of PAR Lock-In Amplifiers and helped to solve a lot of noise problems. **But** — we couldn't help everybody . . .



Three traces of a repetitive 50kHz signal buried in noise. Time: 10 μsec/cm

certain applications require "fishing out" a faithful reproduction of the waveform of the desired signal and the lock-ins just didn't quite do this.

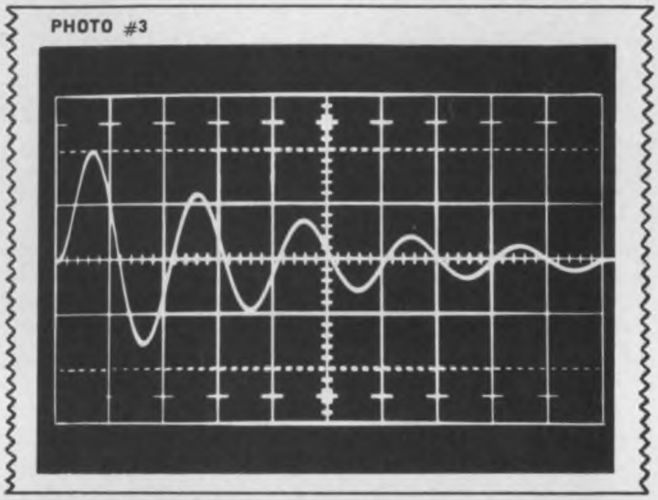
Heretofore — if the frequency was low, and the customer had lots of money, some sort of reproduction could be obtained with Brand X and similar types of complicated and expensive types of signal averaging machines.



Output of Brand X at max. sweep with similar shaped waveform as signal input. As Brand X did not work with the 50 kHz signal, the input frequency had to be reduced to 5 kHz. Time: 100 μsec/cm

See us at ISA Booth 1437

NOW — good news for searchers for small signals — the PAR team has again broken the noise barrier.



Output of PAR TDH-9 Waveform Eductor with the noisy 50 kHz signal shown in Photo #1 as input. Time: 10 μsec/cm

Using an entirely new principle (an old PAR dodge), the PAR TDH-9 Waveform Eductor offers much faster speeds, much higher frequency response, all at a much lower cost! In the Waveform Eductor, special active filters combine the latest in field-effect and high-speed-switching techniques to get information into and out of information storage channels in nanoseconds. Thus, you can put 100 separate channels across one cycle of a 10 kHz signal or, on slower signals, these narrow channels can be used to study portions of the waveform in great detail for unexcelled resolution.

You can purchase a PAR Waveform Eductor for only $4,200 and, of course get, for free, application help from the world's foremost noisy signal processing specialists.

TDH-9 Specification Summary:
Averaging Time—1 to 100 sec
Averages up to—10^5 separate scans
Sweep Duration—100 μsec to 11 sec
Operates from —0.1 Hz to 100 kHz
Outputs—Fixed and variable for oscilloscopes and/or recorders.

PAR Model TDH-9 Waveform Eductor

Write for Bulletin #126 to:

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ON READER-SERVICE CARD CIRCLE 12

NASA spurs unity in computer-aided design

Compiles library of its programs as a first step toward ending overlap among programs in field.

Peer Fossen
West Coast Editor

For a newcomer to the fertile field of electronics, computer-aided design has been growing more like a weed than a healthy seedling. With an estimated 2000 programs in use, wasteful and costly duplication of effort have abounded. The trouble: the lack of a clearinghouse for designers to locate and evaluate programs.

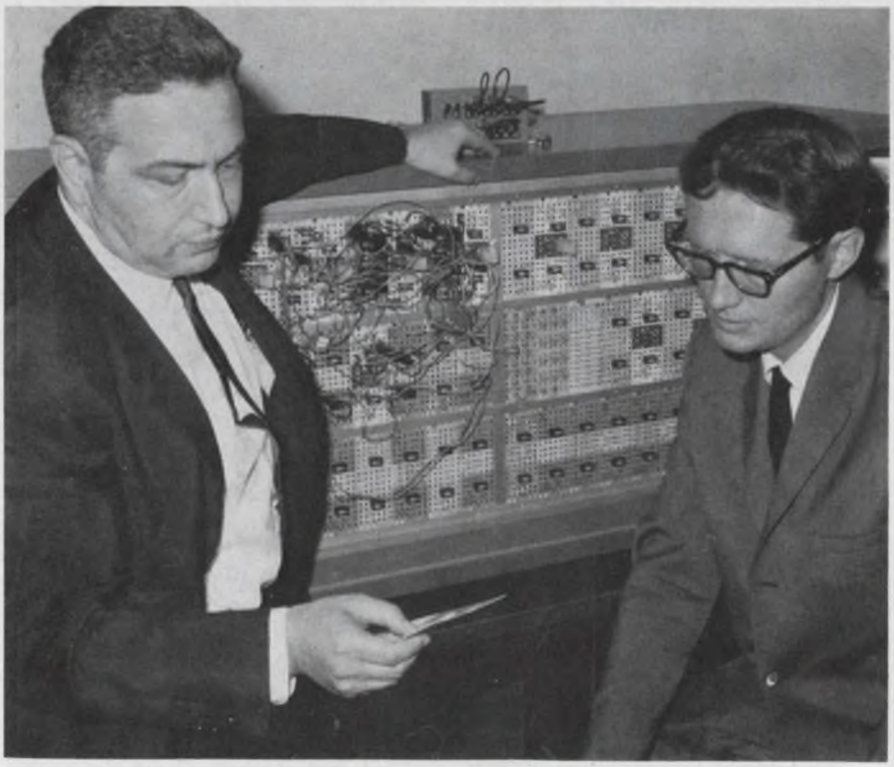
This picture emerged from the Institute on Modern Solid-State Circuit Design, held Sept. 15-16 at the University of Santa Clara, Calif. But for participants at the institute there was also good news: the first steps are being taken to correct the trouble. The most significant of these is a NASA survey of computer programs for circuit analysis and design. NASA is compiling a library of its programs and is making the contents available to industry for a nominal fee.

The present information gap, speakers at the institute emphasized, exists not only between competing electronic companies but also between Government agencies and even different divisions of the same company.*

A preliminary report on the NASA survey, being conducted by the agency's Electronics Research Center (ERC) at Cambridge, Mass., was presented by Dr. John Staudhammer of Arizona State University and Dr. William W. Happ, chief of the Design Criteria Branch at the NASA center. They stressed the value of setting up "standardization and qualification procedures to assure the usefulness and reliability of a program."

Their report noted that several hundred programs had so far been provisionally encoded and that specific information on individual programs would be made available through NASA's COSMIC project.

*See ED 4, June 7, 1966, p. 31 and ED 20, Aug. 3, 1966, pp. 34-36.



Dr. Dorf (right) explains a circuit, simulation program, set up on the University of Santa Clara's Systron-Donner 80 analog computer, to Dr. Happ.

Under COSMIC, the Computer Center at the University of Georgia, Athens, is compiling the library of verified NASA programs. Apart from NASA's Cambridge center, the main sources of information for COSMIC are NASA's Marshall Space Flight Center, Huntsville, Ala., and the Manned Space Flight Center in Houston.

Macroprogram distributed

NASA/ERC offered institute participants its "macroprogram," Network Analysis for Systems Application, confusingly abbreviated to NASA. Richard Carpenter of NASA/ERC said that the program was based on the "dichotomy" implied in the flowgraph associated with any active network. This dichotomy, Dr. Happ explained, was what distinguished flowgraph, cutset and similar approaches to solid-state circuit design from node- or loop-analysis and like algebraic approaches. It stemmed from the fact that "to describe a passive element a decision . . . *must be made*: Is the element *either* a voltage-controlled current source *or* a current-controlled voltage source."

Carpenter described the NASA program based on this as particularly useful to circuit designers and reliability analysts with access to a medium-size or desk computer or to a time-sharing outlet. The final form of NASA was expected to become available more widely later through the COSMIC project.

Balanced program was presented

The participants' consensus was that the formal portions of the institute afforded a good balance between academic and design-oriented lectures.

The two basic trends of the institute became apparent from the outset. The first day's formal program consisted of two main sessions on models of active elements and methods of circuit analysis. Five papers

(computer design, ***continued*****)**

were presented. On the second and last day several practically oriented papers were heard.

Perhaps the most compelling paper given was "Inductorless Filters" by H. J. Orchard, of Lenkurt Electric Co., San Carlos, Calif. Orchard stated that the production of inductorless filters with RC active networks led to circuits that were very much more sensitive to component tolerances than conventional LC filters. An alternative and apparently optimum solution, according to Orchard, is merely to replace each inductor in a conventional doubly loaded LC filter with a gyrator-capacitor combination.

Iterative method disapproved

Both the next two speakers spoke against the usefulness of computer-aided design by iterative methods.

Dr. G. Temes, of Ampex Corp., Culver City, Calif., flatly warned against such methods in a paper, "Iterative Optimization Techniques." He said: "It is like brain surgery and should be used only after everything else has been tried. The iterative methods should only see use if no 'classical' synthesis technique is available to solve the design problem." One reason that he adduced was that the iterative methods take from 10 to 100 times longer than direct circuit synthesis.

Dr. E. A. Huber, of Sylvania Electric Co., took a less vigorous stand against iterative methods by suggesting that perhaps an approach involving both science and art should be considered for computer-aided circuit design.

Dr. Richard Dorf of the host university's Electrical Engineering Dept. also came out strongly for the direct synthesis approach. Speaking on the topic, "Sensitivity," he said: "Going into computer-aided design is going to mean quite a bit of effort in some direction on the part of any company or individual. It is therefore necessary to think out, before starting, whether to go the route of building a large block of analysis programs or to try to develop design programs in themselves."

No obvious choice exists

To judge from the informal portions of the institute, there is no clear-cut answer to which route to choose. The trend seemed to be for companies not concerned with the cost of computer time to become more involved in analysis programs while engineers designing with an eye to the profit and loss statement favor direct synthesis.

It was Dr. Temes who best summed up the divergence of views when he said at an informal evening session: "This institute has brought together two groups interested in computer-aided circuit design: those who know how to design and go ahead and do it; and those who don't know how to design and go the guess-and-analyze route. They are both very competent groups, but they need to get together!"

Other issues remain undecided

The informal sessions also brought out a number of other questions for which there are as yet no ready answers. These included:

- Why isn't more done to simplify computer languages?
- How do you persuade a design engineer who is "afraid" of the computer to use this important tool?
- Why is there not greater implementation of those programs and ideas that are available?

The legal problems of computer-aided design also exercised participants in the institute, particularly industry's idea of copyrighting computer programs. It has been customary for computer programers to exchange information on an informal basis. They now see the possibility of copyrighting as a threat to this practice.

A spokesman for one firm deeply involved in computer-aided design gave his views in this fashion: "Anyone with a specific problem can just call his buddy at the company next door, and his buddy can in most cases help him out, either by steering him in the right direction, or by offering a program he already has on hand. Usually a deal of this sort ends up in a 'horse-trade' situation without anyone losing on the deal, least of all the general industry and the public.

"Now, if the legal and patent people become involved through copyrighting—and they see the litigation that is possible as a result—this lower-level horse-trading will be closed up tighter than a drum. The net result will be a tremendous duplication of effort all round, increased manpower demands and higher cost." ■ ■

Latest in typesetting: Magnetic-tape "print shop"

A new automatic typesetting system being offered by International Business Machines is, in effect, a one-man print shop on magnetic tape.

The system consists of four units—a recorder for storing copy on magnetic tape, a tape reader, a console control station, and a composer that produces the justified copy—but only one operator is needed to perform the complete direct-printing process.

The four units can store and print about 4000 words—equivalent to a solid page of newspaper copy. The magnetic tape makes it possible to produce the printed copy automatically in any composition format desired.

The copy is first typed on a modified IBM typewriter. The typing action records all printing-machine functions, such as type selection, capital shift, paragraphing, spacing and tabulating in code on the tape. A 100-foot-long tape can store the 4000 words. The operator can erase any errors by automatically backspacing and typing over them.

After removal from the recorder, the tape is placed in the reading unit. Type style and the system instructions are selected on its control panel.

The composer then composes camera-ready copy, according to the format instructions, at speeds up to 14 characters a second. ■ ■

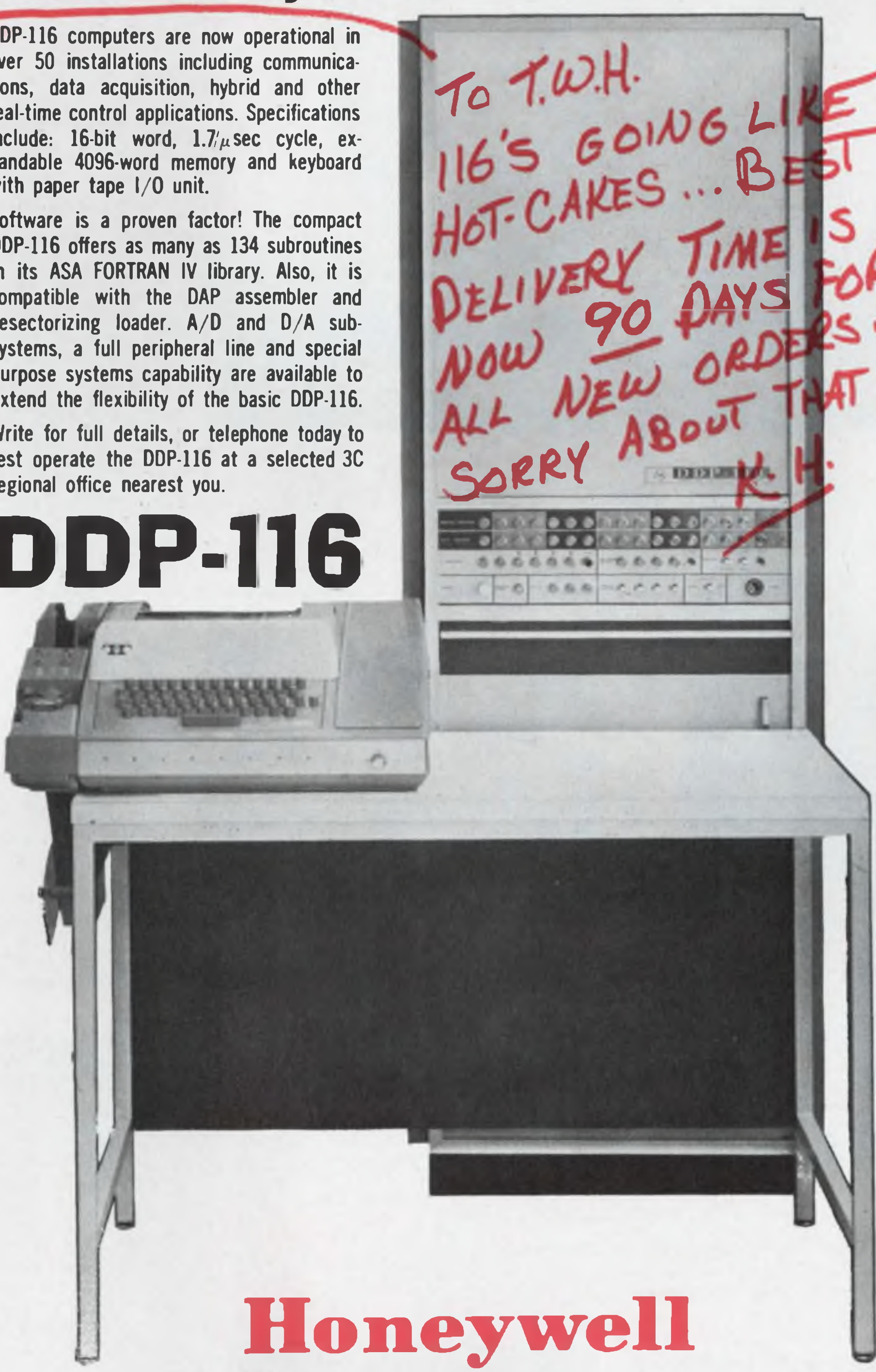
ONLY 3C OFFERS 30 DAY DELIVERY ON THE HOTTEST COMPUTER IN THE $28,500 PRICE RANGE

DDP-116 computers are now operational in over 50 installations including communications, data acquisition, hybrid and other real-time control applications. Specifications include: 16-bit word, 1.7/μsec cycle, expandable 4096-word memory and keyboard with paper tape I/O unit.

Software is a proven factor! The compact DDP-116 offers as many as 134 subroutines in its ASA FORTRAN IV library. Also, it is compatible with the DAP assembler and desectorizing loader. A/D and D/A subsystems, a full peripheral line and special purpose systems capability are available to extend the flexibility of the basic DDP-116.

Write for full details, or telephone today to test operate the DDP-116 at a selected 3C regional office nearest you.

DDP-116



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ON READER-SERVICE CARD CIRCLE 13

New spectrograph cuts process time

"Pictures" of sounds are printed directly from standard magnetic recording tape in 80 seconds with a solid-state spectrograph developed by Bell Telephone Laboratories.

Sound spectrographs have long been used in research. They can analyze speech, diagnose heart disease or malfunctioning jet engines, or check communications equipment.

Earlier spectrographs took five minutes to produce a spectrogram, and an intermediate step was required: the taped data had to be transferred to plated drums or metal loops. With direct printing from mylar tape, the new model has better fidelity and lower background noise, according to Bell.

In operation, the spectrograph scans the tape in narrow bands of successively higher frequencies. Information from each scan is transferred to electrically sensitive paper, resulting in a graph of frequency and amplitude. For an analysis of frequencies up to 7000 cps, the tape is scanned 400 times. Lower frequencies are printed at the bottom of the spectrogram paper and higher frequencies at the top. Sound intensity is indicated by light and dark shading, and time is read from left to right. Each spectrogram represents 2.4 seconds of sound.

The designer of the machine is Anthony J. Presti, an engineer member of Bell's Acoustics Research Dept. at Murray Hill, N. J. ■ ■

High-speed spectrograph, developed at Bell Telephone Laboratories, works directly from standard magnetic tape.

And now . . . inertial guidance in a suitcase

Portable system aligns navigation platform in carrier aircraft in seconds, instead of 30 minutes or more.

Neil Sclater
East Coast Editor

Inertial-guidance platforms, wonderful for navigating, are lazy about getting started. They must be warmed slowly and coaxed into working position. This poses a problem on the pitching, rolling deck of an aircraft carrier, with only minutes available for take-off preparations under combat conditions.

Engineers at the Arma Div., American Bosch Arma Corp., Garden City, N. Y., say this is a good place to use their Master Reference System, an inertial navigator in a suitcase. By feeding essential carrier position and speed data into the portable system and transferring it, as needed, to the aircraft, sailors can set up airborne platforms for flight in about 60 seconds.

At present, alignment of the platform usually takes about 30 minutes, and, under adverse conditions, it can stretch as long as 80 minutes. A cable running between the plane and the ship's inertial navigation system is ordinarily used to feed such reference signals as latitude, longitude, velocity and the ship's heading into the aircraft navigation system.

Arma's portable system, not intended for flight, includes a complete sensing platform, a digital computer and an electronic control —all mounted in a case weighing less than 100 pounds. The system is being completed under a contract from the Grumman Aircraft Engineering Corp. of Bethpage, N. Y.

Arma engineers say that miniaturization was possible because of the use of two-degree-of-freedom fluidless gyros and a compact digial computer, constructed largely of monolithic integrated-circuit modules.

The portable system consists of two major sections: the reference unit/transfer fixture and the electronics unit.

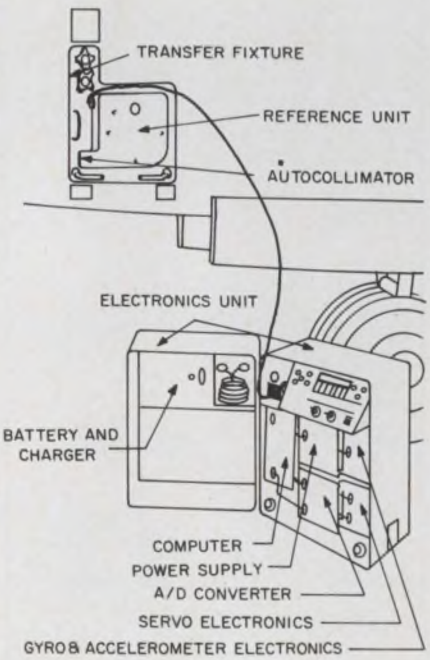
The reference unit and transfer fixture, containing the stabilized platform, is attached directly to the outside of the aircraft through access holes. This action connects the aircraft's inertial unit to the portable transfer cable. When the transfer fixture is properly mounted, the autocollimator, mounted on the reference unit, lines up with a mirror on the aircraft's unit. The operator observes the autocollimator output on a null meter and manually reduces any misalignment in azimuth between the two units to less than 1.0 minutes of arc.

The electronics unit is placed on the deck near the operator and is connected by cable with the reference unit and transfer fixture. It has a self-contained power supply.

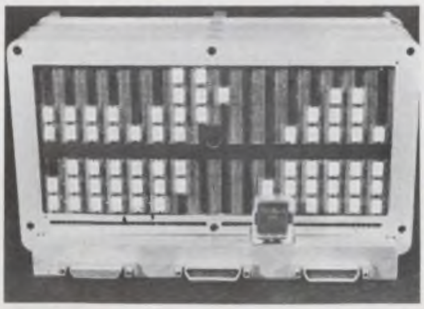
The reference unit-transfer fixture weighs only 25 pounds, light enough to be carried by one man. More than 40% of the total 100-pound weight of the system is in the carrying case and combination battery and battery charger.

The reference unit contains the three-axis stabilized platform, which carries two 2-axis gyros and two inertial quality accelerometers whose sensitive axes are leveled and aligned to north and east. The transfer fixture is used to orient the azimuth axes of the portable platform and that of the aircraft navigato in order to permit rapid transfer of azimuth synchro signals.

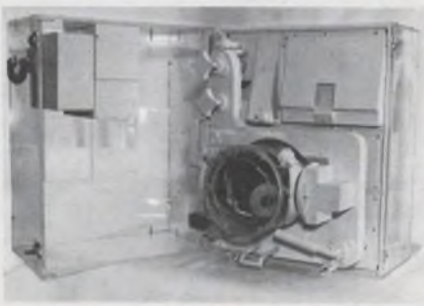
The electronics of the system include a digital computer, analog-to-digital converter, power supplies, battery and other circuitry for navigation computation, gyro drift auto-compensations, mode control and data display.



Master reference system shown in working position. Arma system, used on aircraft carriers, will transfer position and speed from ships' inertial navigator to aircraft.



Digital computer weighs less than 5 lbs and requires 25-W power. It is made up of eight plug-in card assemblies; 3 logic, 1 input/output, 4 memory electronics plus a plug-in memory stack. Outside dimensions are approximately 7 in. by 4 in. by 3 in.



Master Reference System mock-up showing components in storage position. The L-shaped unit (right foreground) is reference unit/transfer fixture that is lifted out and attached to the aircraft. The platform is contained within the 8-in. sphere.

(suitcase guidance, ***continued*****)**

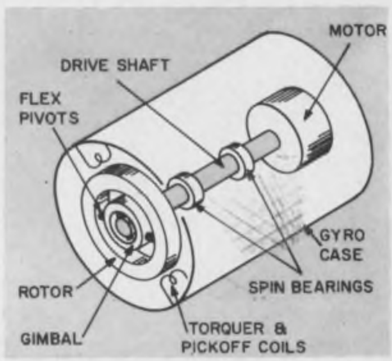
Gyros: One or two degrees of freedom. Which is best?

In an inertial navigation system, motion must be controlled about three axes. The designer generally has two options: three single-degree-of-freedom-gyros (SDF) or two two-degree-of-freedom gyros (TDF). The advantages and disadvantages of both approaches have been debated by many people. So far the debate is a stand-off.

In terms of attainable performance in systems, both appear equivalent. In simple terms, it is largely a matter of two relatively costly TDFs as against three SDFs whose individual cost is slightly less.

Most gyro manufacturers tend to fall into one or the other of these camps. Single-degree-of-freedom proponents include the Instrumentation Laboratory at Massachusetts Institute of Technology, Honeywell, A.C. Spark Plug Division of General Motors and Nortronics. Arma Corp is in the two-degree-of-freedom camp along with Litton Industries and the Autonetics Division of North American Aviation. Some, like General Precision, Inc. and Sperry Gyroscope Co. cover both sides.

Dr. Bernard Litman, program manager at Arma, says that the use of two gyros and only two accelerometers along with advanced IC circuitry permitted the company to obtain the desired characteristics in a suitcase-sized package.



The two-degree-of-freedom gyro used in the Arma Master Reference System is shown in this simplified drawing.

The calibration alignment and navigation computations are performed by the digital computer.

Alignment of the portable system is accomplished by use of the ship's inertial navigation system for leveling and self-gyrocompassing for azimuth. The local vertical reference is obtained by comparing the ship's velocity outputs, modified by relative velocity computations, with the integrated outputs of the reference-unit accelerometers. Differences in the match of velocity signals yields an error signal to torque, or force, the platform to a matched position. Modified gyrocompassing is used to accomplish north alignment. Platform misalignment in azimuth is corrected by compensating for tilt, as determined by the difference between the north accelerometer and the ship's north signal.

Transfer alignment is made after the transfer fixture is attached to the aircraft and electrical interconnections are made. Azimuth transfer is done with synchro signals.

The computer is a simple, general-purpose microcircuit unit that has a wired-in program memory. It is organized for whole-number, single-address serial operation with an 18-bit word length. With a computation speed of 225 bits per second, the computer includes 1792 words of random-access magnetic core memory for operational programs and constants, plus 256 words of scratch-pad memory. With the exception of parts of the memory and clock pulse generator, the electronics of the entire unit is made up of transistor-transistor logic IC modules.

The A/D converter is used to convert reference-data analog velocity and synchro signals to a usable form for the digital computer. It also uses monolithic ICs similar to those in the digital computer.

Dr. Bernard Litman, the system's program manager, said that while the concept was being developed primarily for carrier-based aircraft, it could be adapted for use with land-based planes or missiles, where the alignment time for the inertial navigator was critical. ■ ■

Audio/video system checks into hospitals

Systems engineering results in simple yet flexible system for TV, intercom and patient monitoring.

Hospital patients in many parts of the country are now using television for both audio and visual communication with their nurses as well as for private entertainment. The system has been developed specifically for hospital use by Bell Hospital Systems of Bridgeport, Conn.

Actually, the system is two systems in one. SteriVision, as one is called, provides the patient with his own television receiver. The other, SteriCall, allows the patient to use his TV set for remote communication with his nurses. Both systems operate from a single coaxial line at the patient's bedside.

Systems engineering used

SteriVision was designed to eliminate as nearly as possible all the objectional aspects of conventional hospital TV. This required not only that the patient be borne in mind, but also the doctors, nurses and hospital administrators.

The end result is a system that includes the following:

- Master antenna system
- Amplifier system
- Mixing system
- Broadcast system
- Power and stand-by power system
- Receiver
- Receiver positioning system
- Power and signal cabling

The master antenna system is an array that has a separate tuned element for each TV station broadcasting in the area. The antenna signals are fed to the amplifier system, which contains a separate transistorized amplifier for each station received. Each amplifier is tuned to pass the signal of only one TV station. During installation the gain of the amplifiers is adjusted so that all deliver the same output signal level. The outputs of the amplifiers are combined into a single composite signal in the mixing system. This signal is distributed throughout the hospital by a coaxial cable.

The broadcast system consists of one or more FM tuners, tuned to local radio stations. Their outputs are sent over the same coaxial wire as the television signals, and are heard on unused channels on the patients' TV sets.

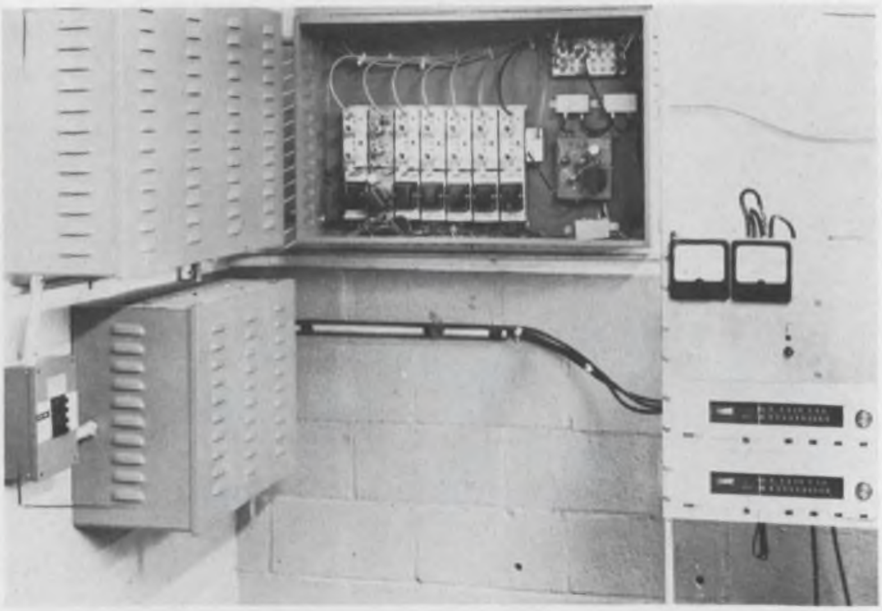
The coaxial wire also carries 12-volt dc power to power the TV receivers. A special network built into the room outlets separates the dc power from the RF signal and allows inclusion of a power circuit breaker in the outlet. The dc power comes from a 12-volt supply that operates from commercial power. A stand-by battery source is automatically switched into operation should the commercial power fail.

The receivers used for the SteriVision system are commercially available units with 5-inch screens. Modifications to the sets include removal of the power supply, which is not needed, and removal of the speaker. The patients listen in using disposable headsets.

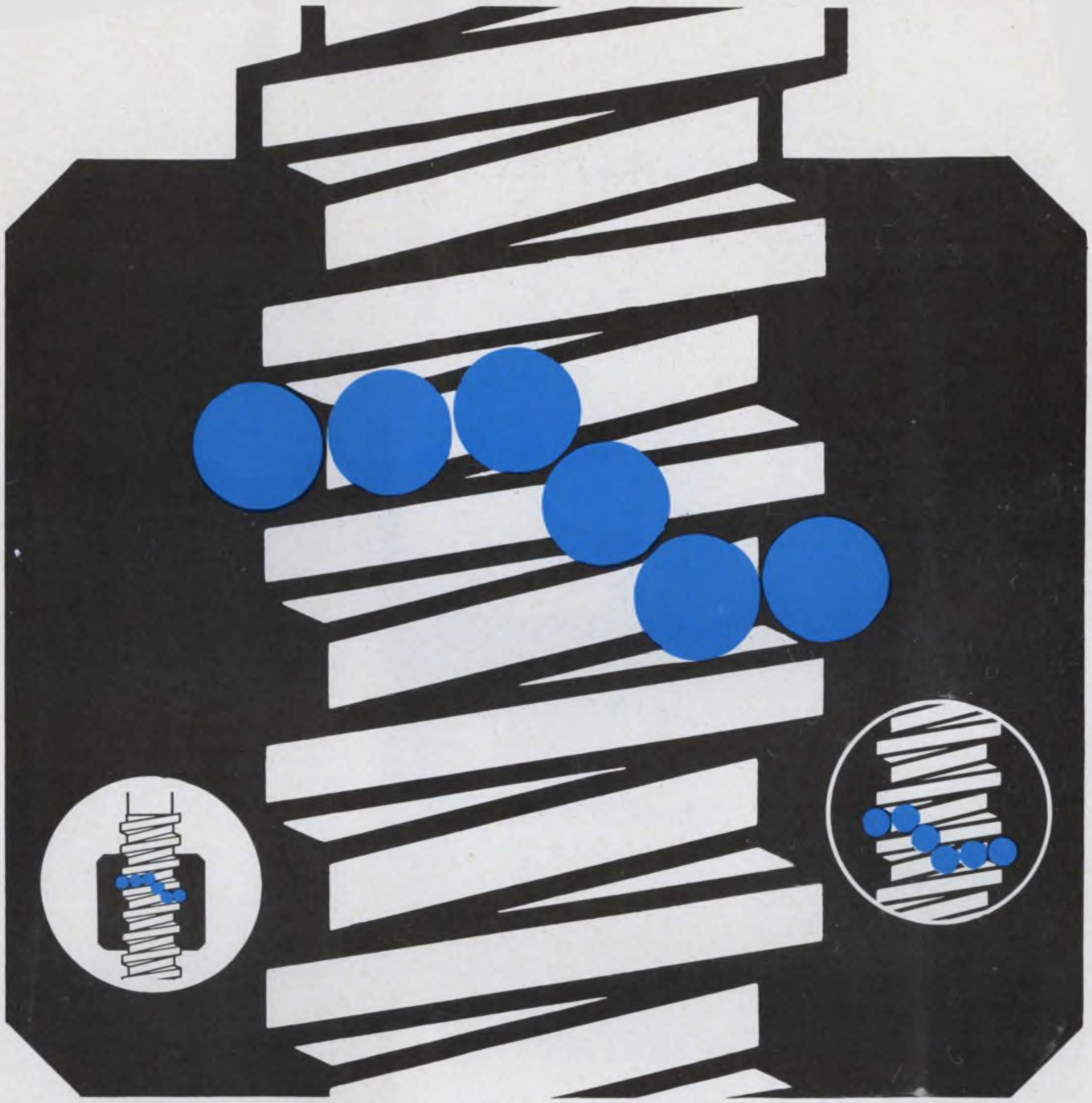
The specially designed receiver positioning system allows the receiver to be positioned within four feet of any bed post. The receiver "floats" at the end of a positioning arm; it can be tilted in any direction and swiveled through 360 degrees.

SteriCall complements SteriVision

The SteriCall system uses the TV receiver and circuits of the SteriVision system, plus additional intercom and signaling equipment. A master station at the nurses' desk and a station at the patient's bed allow the patient both to signal and talk to the nurse. A kinescope at the master station permits the nurse to be seen on the patient's TV screen as they talk. If desired, the patient's TV receiver and the nurses' kinescope can be interchanged, so that the nurse can monitor a patient constantly without leaving her desk. ■ ■



Head end of SteriVision system includes master antenna console (left) atop stand-by power console, and open console (center) containing signal amplifiers for each TV channel. At lower right are the broadcast system FM tuners.



Kidde Ballscrews

SIZE AND WEIGHT PROBLEM SOLVERS

Kidde Ballscrews do more than solve friction problems of prime movers and drives. They can solve size and weight problems, too—and meet the demands for high efficiency transfer of motion and power. Here's why:

Their compact design results in smaller envelope dimensions. Weight is reduced because external tubes and fittings are eliminated. Kidde designs allow optimum usable power, due to extremely high efficiencies.

To solve these major problems, Kidde has designed a wide range of Ballscrew sizes—from units less than 1" long to 32 foot custom assemblies. From 6" diameters down to 1/8"; sizes 3/16" to 1-1/2" (with various lead) are stocked.

Learn how Kidde Ballscrews can become your problem solver. Write for your free copy of "Standard and Precision Ballscrews." Walter Kidde & Company Inc., 675 Main Street, Belleville, New Jersey 07109.

Kidde

ON READER-SERVICE CARD CIRCLE 17

Laser gyroscope measures Navy's roll, pitch and yaw

A three-axis laser gyroscope has been delivered to the Navy's Ordnance Test Station, China Lake, Calif. The Navy is conducting a series of tests to determine the gyroscope's ability to sense a ship's roll, pitch and yaw precisely. The unit was designed and built by Honeywell's Military Products Div., Minneapolis.

Several companies have been active in the development of laser gyros—Sperry Gyroscope and Autonetics, to name two. The big problem to be combated is a phenomenon known as "lock-in," a tendency of the gas in a laser tube to lase in phase. This prevents the laser from measuring extremely slow rotation rates.

The laser gyroscope works by measuring the beat rates between two waves that propagate in opposite directions within the same rectangular or triangular tube. When the laser is not rotating, there is no beating and the waves traveling in each direction in the tube are indistinguishable. When the tube starts to rotate, the effective path length of one wave lengthens by the distance that the laser moves during the time it takes the wave to travel around the tube. Similarly, the effective path length of the wave that propagates in the opposite direction shortens by the same amount. At low angular velocities, however, the two path lengths differ very slightly and the two waves tend to lock on to each other.

Three-axis laser gyroscope uses mechanical biasing to keep beams from locking in phase at very low rates of rotation.

Honeywell overcomes this problem by mechanically biasing the lasers. They vibrate the lasers to keep them moving and prevent the waves from locking in phase. Sperry Gyroscope of Great Neck, N. Y., has been working on a method of optical biasing. It uses Faraday biasing cells that provide a false signal to give the effect of moving the ring. Its working unit is due to be ready within a few months.

The Honeywell unit has measured as small a rate of angular rotation as 0.1 degrees/hour, according to the company. It reports that it has maintained this fineness of measurement during runs of more than an hour. Sperry anticipates similar results. ■ ■

Electronically controlled pellet gun shoots back at Army marksmen

The marksman stalks his quarry.

Riflemen just don't behave the same when their targets fire back at them, according to human engineers at the Army's Aberdeen, Md., Proving Ground.

Wearing headgear that contains a fan for ventilation and electrodes to measure heartbeat, the riflemen fire at targets that appear at random and return their fire. The targets are electronically controlled to pop up and down, and an electronically controlled BB gun shoots at the marksmen. The BB gun has a sawed-off barrel and rests behind sandbags. It is powered by CO_2 cartridges.

Recorders register the times of target appearances, the number of shots fired by the riflemen, the number of shots fired by the sawed-off BB gun, and the number of hits scored by the riflemen. No record is kept of the number of hits.

The vital organs of the human marksmen are protected by pads but the BBs sting when they hit unprotected areas. Even when they miss, the BBs strike a plywood backstop, making a loud clack. The BB gun fires at the shooters every half second.

The threat of return fire places the soldier under much greater stress than he encounters when he fires at passive targets, according to the human engineers. In fact, they say, the stress persists even when the gun doesn't fire back. ■ ■

Silicon increases diode light output

Silicon dopant in the active regions of gallium-arsenide electroluminescent diodes has tripled their light-producing abilities. They have typical efficiencies of about 6 per cent, as compared with 1 to 2 per cent in earlier zinc-doped versions.

Scientists at the International Business Machines Corp., developers of the new technique, report that the key to the diode's performance is the use of silicon as both an n-and p-region dopant.

According to the IBM scientists, light emitted by the new devices has lower frequency than that from zinc-doped diodes. They also say that another characteristic—lower internal light absorption—is the probable reason why light output is improved in silicon-doped diodes.

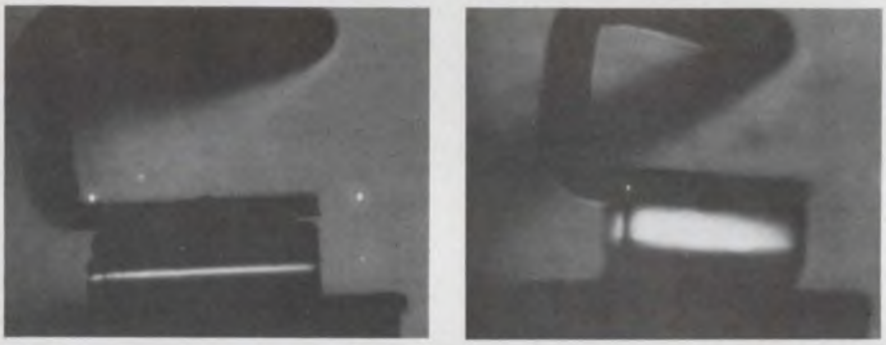
The solution regrowth technique used to fabricate the diodes calls for close temperature range and cooling cycle control. Silicon is incorporated on the gallium sites of a 40-micron thick layer. Silicon is then incorporated on arsenide sites, where it acts as an acceptor.

After the structure has been formed, the p side is reduced to a thickness of 50 to 60 microns, and external zinc diffusion forms an ohmic contact.

Light emission occurs across the entire 50-micron thickness of the p layer, rather than over the typical 2 to 3 microns in zinc-doped diodes. The width of the recombination regions is believed to be another reason for the high efficiency of the diodes. But it also causes the relatively long turn-on time of about 200 ns.

The energy peak of the light from the diodes at room temperature is at 9300 Å. This emission is virtually independent of current through the diode.

The research was supported in part by the Army Electronics Command, Ft. Monmouth, N. J. ■ ■



Light from a gallium-arsenide electroluminescent diode doped with zinc offers about 1 to 2 per cent efficiency (left). Light-producing ability is tripled when silicon is used as the active dopant (right).

Fluidic integrated DDA the size of a cube of sugar

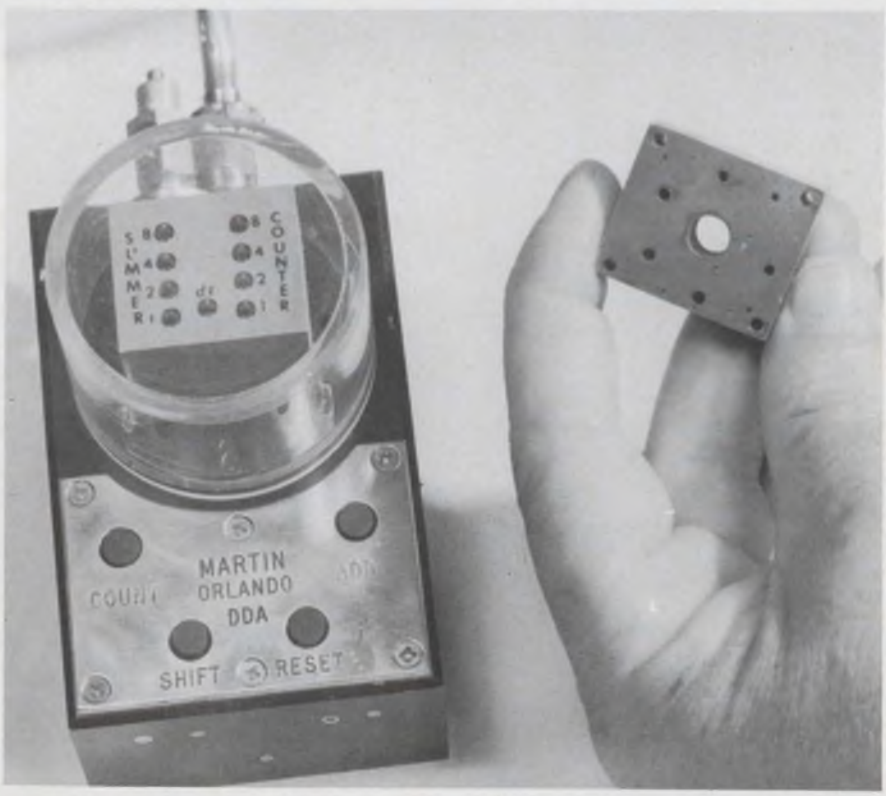
An integrated fluidic differential digital analyzer one inch square by 6/10 inch can solve relatively simple differential equations.

Little balls move up and down in cylindrical holes so that the operator can follow counting and adding operations visually.

The unit is fabricated from many thin sheets of beryllium copper that have etched channels for the flow of fluid (in this case air). The unit contains 132 individual devices that are interconnected by passageways that run through and across the layers.

The main advantage of the miniaturization of fluidic devices is the resulting improvement of response speed. The operating rate of fluidic devices is seriously limited by the total pathlength. The fluid must travel considerably less than the speed of sound.

This device was developed by Martin-Orlando for the Harry Diamond Research Labs, Washington, D. C. ■ ■



Digital differential analyzer can calculate areas under simple curves.

Aerospace firms look to Europe

Washington Report

S. DAVID PURSGLOVE,
WASHINGTON EDITOR

ESRO may become U.S. market

U.S. aerospace manufacturers may find a market for their products in the European Space Research Organization (ESRO). ESRO requires that contracts be spread evenly among participating nations—of which the U.S. is not one. But the working-level ESRO scientists are impatient to buy U.S. hardware and look forward to the organization's easing its restrictions. They believe that their modest budget—$280 million over eight years—would go further in the U.S. than in Europe. They say that in the U.S. they would be able to buy what they want off the shelf, whereas in Europe they will not only have to wait longer for the goods but also pay for their development.

European scientists, shopping around Washington recently for free ideas, claimed that ESRO's budget was enough to give European industry no more than a nibble at an exciting technology. State Dept. officials remain close-mouthed about the situation, referring only to NASA's programs of international cooperation. Commerce Dept. spokesmen, however, are more sanguine about what may become a much enlarged market for U.S. aerospace firms. Privately they concede that the ESRO governments may more readily relax their rules if the State Dept. stays out of it. Meanwhile, Commerce Dept. officials are not reluctant to show the Europeans what U.S. companies have to offer at low prices.

Some "Made in U.S.A." hardware will soon be on view at the newly inaugurated launching site near Kiruna, Sweden, 100 miles above the Arctic Circle. It will be brought there, however, by individual teams of participating nations, who will be using the facilities on a tenant basis. A West German team, for instance, will conduct a program with U.S. Nike-Apaches, considered far more effective for the money that the Germans paid for them than their European counterparts—Britain's Skylark and France's Centaur. It is these nonetheless that ESRO would have to buy to conduct a program of its own.

Big opening for oceanics in Europe

The Commerce Dept. is promoting Europe's mushrooming underwater programs as an important market for U.S. manufacturers of oceanic equipment. At the same time, The Bureau of International Commerce (BIC) is spreading word in Europe of the terrific products that U.S. firms have for sale. As a further boost, BIC is sponsoring an exhibition of U.S.-made ocean equipment and instrumentation at the U.S. Trade Center in Frankfurt, West Germany, Nov. 2 through 9. The Commerce Dept. is urging U.S. companies—mostly electronics-oriented—to send products and representatives. BIC has tagged the week-long show "a rare opportunity to establish liaison with policy-making and purchasing agents of marine exploration groups" in Europe. It has prepared a comprehensive study of the European oceanics market available to interested manufacturers.

BIC's study calls Europe a "prime market for marine equipment and services" and implies that it has outstripped the U.S. as a sales field. For its part, the Commerce Dept. says: "In Europe private and government groups are heavily involved in well-budgeted oceanographic studies; many of these organizations have gone beyond the basic research stage on to commercial enterprises." It adds: "The results of marine research are being applied to many areas, including fishing, marine meteorology, oil/gas exploration, ocean mineral development, salvage operation and corrosion metallurgy."

BIC's study describes the West German

market in detail as an example of the potential in Europe. It also spotlights the market in the U.K. and touches on eight other countries.

Auto safety agency in first gear

A new National Traffic Safety Agency has begun to function, but its operation is still on a very limited scale and is likely to remain so for some time to come. Its administrator, Dr. William J. Haddon, a physician formerly involved with New York safety programs, has not yet been confirmed by the Senate, although no hitch is anticipated. Nor have any funds been made available so far for the agency, which is expected to be transferred into the domain of a proposed new Transportation Dept.

Meanwhile Dr. Haddon and his assistant, Dr. Robert Brenner, have set up shop in a temporary, partitioned-off section of the Commerce Dept. Building on Federal Triangle, Washington, D. C. Their staff at present is miniature, but they are expected to borrow additional personnel from existing agencies whose functions they will take over. Some Bureau of Public Roads people, who have been engaged on the National Driver Register and on safety in highway design, may be assigned to the agency on loan, for instance.

The agency, set up under legislation that came out of this summer's hearings on automobile safety, is within the purview at the Commerce Dept. of Alan Boyd, Under Secretary for Transportation and former Federal Aviation Agency Administrator. Boyd and his staff have made no secret of their commitment to electronics in highway safety, driver education and testing, and other areas where the new agency will have competence. Should a new Transportation Dept. be set up, Boyd is looked upon as its most likely first chief.

EIA to hear aerospace role in cities

The National Institute of Public Affairs has chosen the fall conference of the Electronic Industries' Association as the forum at which it will make public its report on the "California aerospace experiments." Those were contracts awarded last year, under which five major aerospace companies applied their military-space-systems approach to the solution of urban and social problems. The report, sponsored by the Ford Foundation, is expected to praise the experiments. The White House is expected to use it to back up an order to government agencies that the advanced technology and systems management must be applied, wherever possible, in fulfilling Federal contracts in urban development, transportation, pollution control, housing, education and other nonspace, nonmilitary fields.

Officials of both the Aerospace Industries' Association and the National Security Industrial Association admit privately that it is a feather in the electronic industry's cap that the EIA meeting in San Francisco, Oct. 17-20, was chosen for formal presentation of the report. They view the choice as an indication that the report will come out in favor of electronic firm's recent moves into such rapidly growing nontechnical areas as highway safety, crime control, high-speed ground transportation and pollution abatement.

EIA ready to play new parts

The pat on the back that the electronic industry anticipates at San Francisco will not catch the EIA unprepared. The association has made a number of studies analyzing various areas of Federal activity and their potential for the industry.

In August, John Sodolski, staff manager of the EIA Requirements Committee, put out a 6,000-word analysis of one such area—medical electronics. It took particular notice of new hospital systems and the role of all levels of government in them, as well as of such predictable items as remote biosensors and cardiac pacers. Sodolski told EIA members: "The Federal Government has increasingly been funding programs directed at what it considers to be major national problems of an economic and social nature." He added: "The Federal Government is in the process of spending, or planning to spend, billions of dollars in areas such as transportation, education, crime prevention, water and air pollution and medical facilities, among others."

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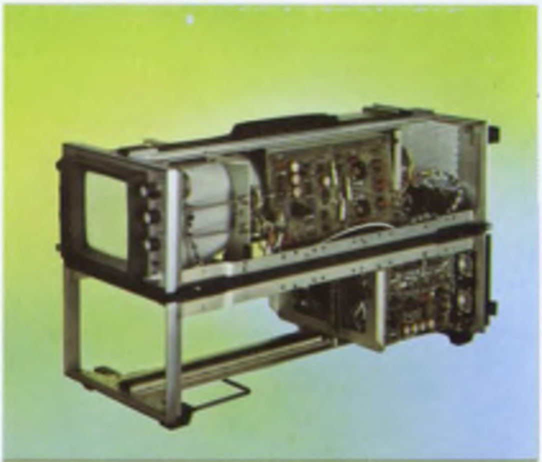
- Operates on 115 or 230 volts, 50-1000 Hz, only 95 watts—convection cooled.
- New hp CRT design permits 3 v/cm drive; therefore, vertical amplifier is smaller, lower power. Amplifier drives CRT vertical deflection plate directly. These features provide extended bandwidth capability.
- DC coupled Z axis input.
- New etched circuit delay line for clean pulse response—minimum weight and size.



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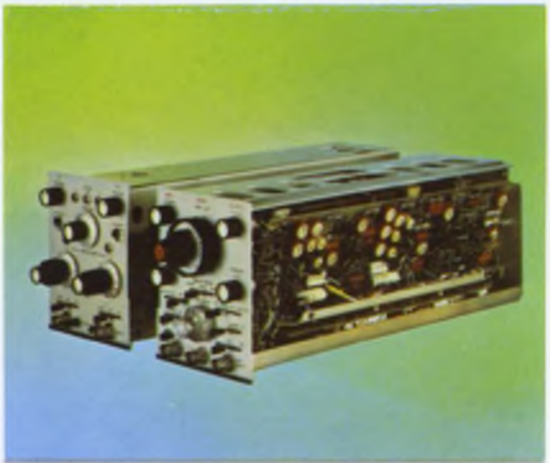
- Deflection plates require only 3 v/cm drive—allows extended bandwidth capabilities.
- 12 kv accelerating potential produces bright, easy-to-see traces, even at 5 nsec/cm sweeps.
- Snap-off bezel for easy installation of new hp contrast filters or special graticules.
- Beam finder for rapid location of trace.
- Internal graticule calibrated in centimeters eliminates parallax error; flood guns allow variable background illumination for optimum contrast of graticule and trace.



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  - —triggering to 90 MHz.
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  - —easy-to-use delayed sweep.
  - —mixed sweep for slow/fast sweep display.
  - —bright line automatic triggering.
- *Now* 1820A time base
  - —triggering to 90 MHz.
  - —sweeps from 2 sec/cm to 5 nsec/cm.
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- More plug-ins to come—for extended capabilities.

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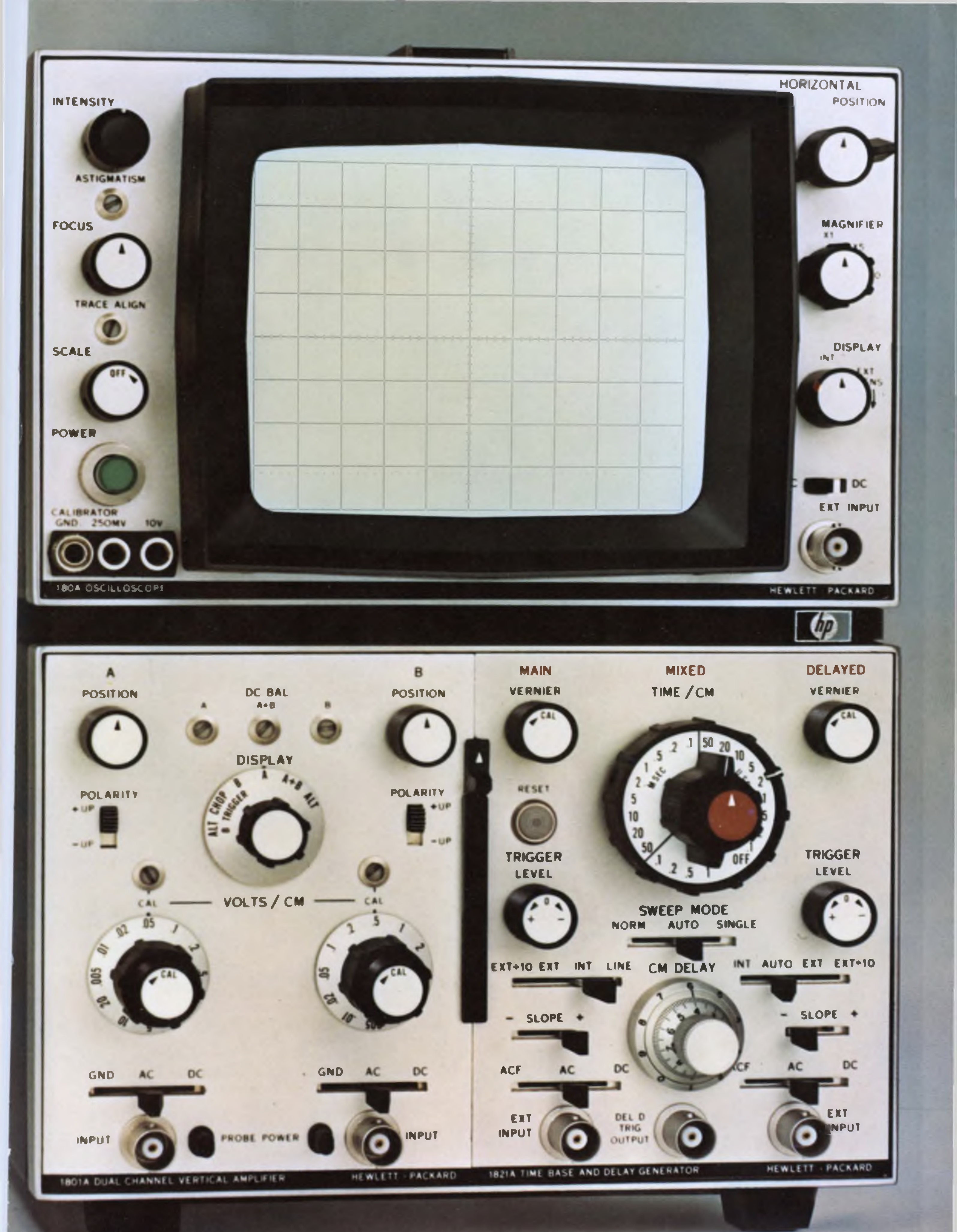
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POLARITY
+UP
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LEVEL
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EXT÷10 EXT INT LINE
CM DELAY
INT AUTO EXT EXT÷10
- SLOPE +
- SLOPE +
ACF AC DC
AC DC
EXT INPUT
DEL D TRIG OUTPUT
EXT INPUT
1821A TIME BASE AND DELAY GENERATOR
HEWLETT · PACKARD

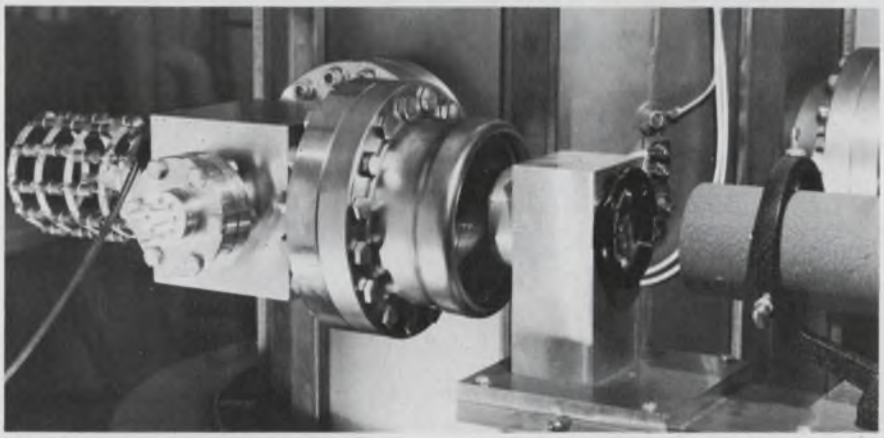
ACTUAL SIZE

Laser may switch high RF power

The laser is being considered for triggering a high-microwave-power switch. Metal within a vacuum would be used to ionize metal at precise intervals, and the plasma formed would be used as a transmission path.

The investigation is being conducted at the Cornell Aeronautical Laboratory, Buffalo, N. Y. under the sponsorship of the Rome Air Development Center, Griffiss AFB, N. Y. Preliminary research by Dr. A. S. Gilmour of the Cornell laboratory has shown that a precisely controlled laser beam creates a gaseous plasma when it is focused on one of the electrodes of a switch within a vacuum chamber. High current through the switch is conducted on the plasma, and conduction is maintained in the resulting arc until the power source is discharged. Dr. Gilmour said that with the use of a ruby laser approximately 10 megawatt pulses 1 to 10 microseconds in duration had been produced. He believes the concept can be applied to power switching in ultra-high-power radar modulators where precise pulses are required from a single power source and power levels are too high for existing pulse-forming network switching tubes.

Cornell laboratory engineers point out that the experimental switch is one of the first applications of the laser as a component of electronic circuitry. ■ ■



Experimental laser-actuated switch has possible application in high-power radar transmitters. Ruby laser beam at right is focused on electrodes in the vacuum chamber. The resulting plasma switches the power.

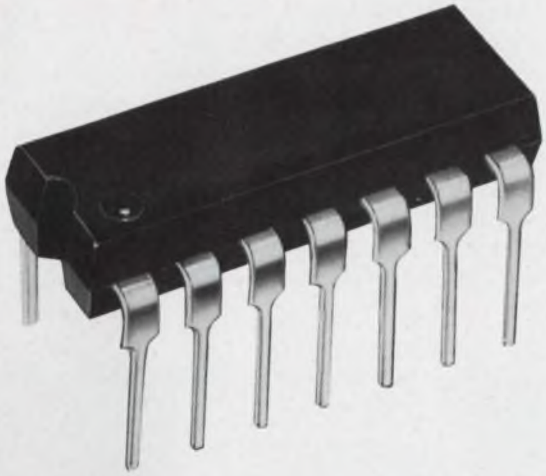
Robot chemist performs laboratory tests

An electronic robot is now able to perform many ordinary chemical laboratory tests that formerly had to be done by technicians.

Solid-state sequential logic circuitry controls various solenoid-triggered air valves, liquid pumps and indexing mechanisms for sliding racks and a rotating tray that hold test tubes. As the robot operates, probing pipettes dip into test tubes and suck up preset amounts of the sample; plastic tubes carry drops of reagent to be mixed with the sample. Test tubes and pipettes are then promptly washed, dried and rewashed to ensure that residual droplets of reagents or samples do not contaminate later tests. The machine evaluates the chemical by comparing its light transmission with that of a control sample. The output is digital, and it is printed on a paper tape.

The Robot Chemist was designed by Warner-Lambert Pharmaceutical Co., Richmond, Calif., to dupli-

(continued on p. 36)



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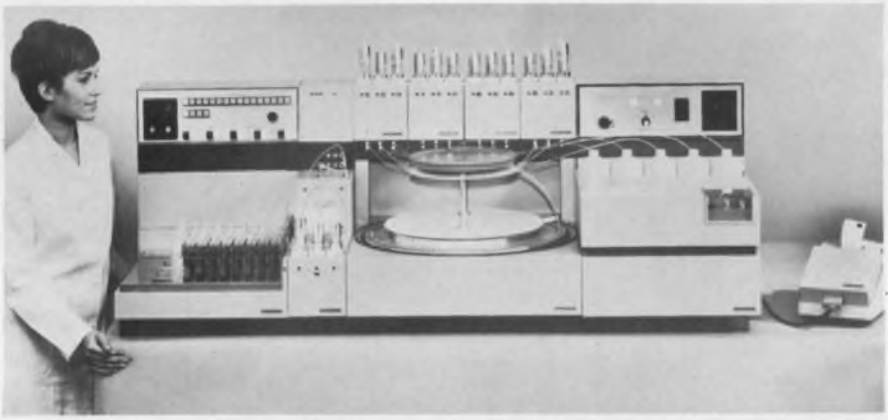
(**Robot,** *continued*)
cate precisely the step-by-step procedures of a working technician. By changing reagents, cycle times, and the order of procedure, the user should be able to adapt the robot to any future tests.

Though this is the first such machine that physically imitates the motions of a human technician, it is not the first automatic testing device for laboratory use. A company called Technicon has produced for some time a machine called the Autoanalyser. It can run up to 12 tests simultaneously, with a minimum of mechanical moving parts. Its heart is a set of plastic tubes that carries samples one after another through each tube. The samples are separated in the tubes by air bubbles. ■ ■



Electronic robot chemist duplicates the work of a laboratory technician.

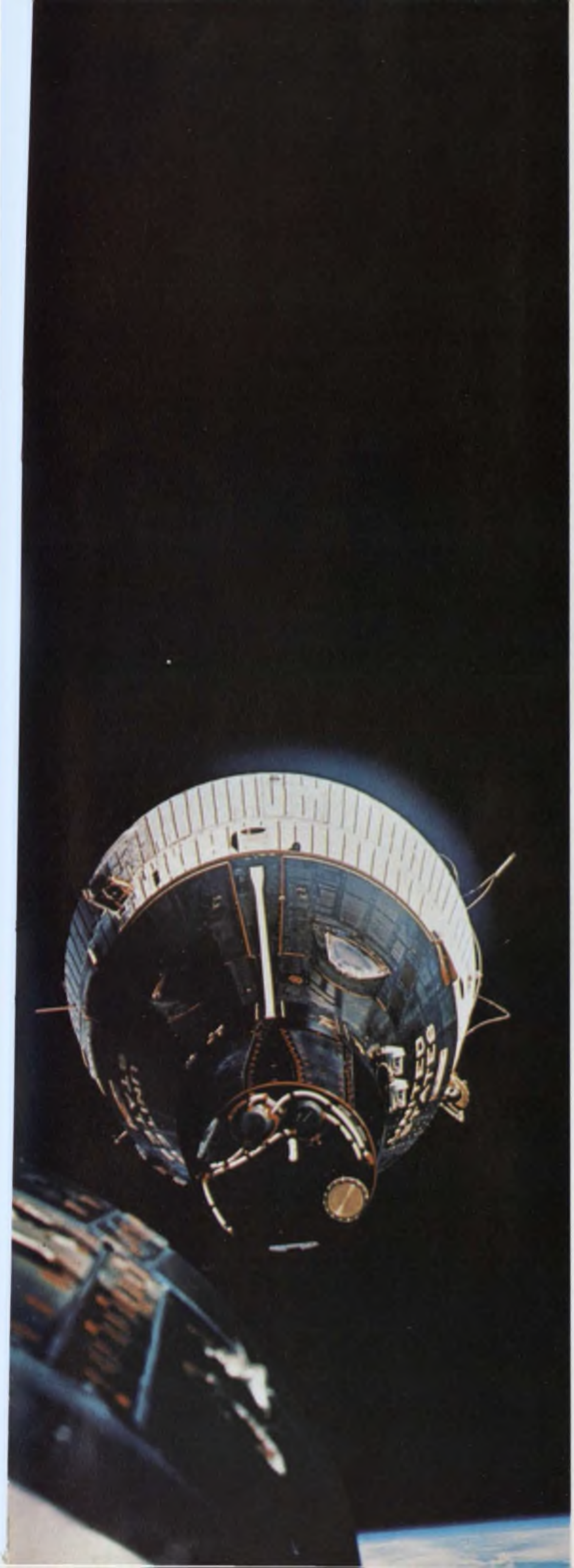
For metal rips in space, an electron welder

What does an astronaut do after the hull of his spacecraft has been torn by a jagged meteorite somewhere out in space?

Well, he might find a nine-pound electron-beam welder just the thing for an emergency repair. One has recently been developed by the Hamilton Standard Div. of United Aircraft Corp. for NASA, and successfully tested under conditions like those 73 miles up.

The welder, with a 1.5-kW beam power, can join titanium, aluminum and other metals up to one-quarter-inch thick. It is designed to operate off an on-board power supply. Only 10 inches long and 3.5 in diameter, the gun fires tightly packed electrons at a velocity of 50,000 miles a second. The operator holds it flat on the metal, where it rides along the weld seam on metal rollers. A shield around the welder muzzle protects the operator from the splatter of molten metal and radiation; he checks the welding through windows in the shield. ■ ■

Astronaut uses electron-beam gun to weld stainless steel in chamber that simulates conditions 380,000 feet up.



Two sets of our switches meet quietly in space.

When Gemini 6 caught up with Gemini 7 late in 1965, the programmed approach to space exploration was proved. Our skilled Astronauts, the NASA team, McDonnell, and America's aerospace industries had passed a major milestone on our way to the moon.

Cutler-Hammer people are especially proud of this achievement. Many of our positive-action switches are employed on each Gemini vehicle.

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Our leadership is built on reliability. Through painstaking design and manufacture. Proved by exhaustive in-process inspection and 100% final testing.

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There are Cutler-Hammer positive-action switches, miniature and standard size, for almost everything that flies.

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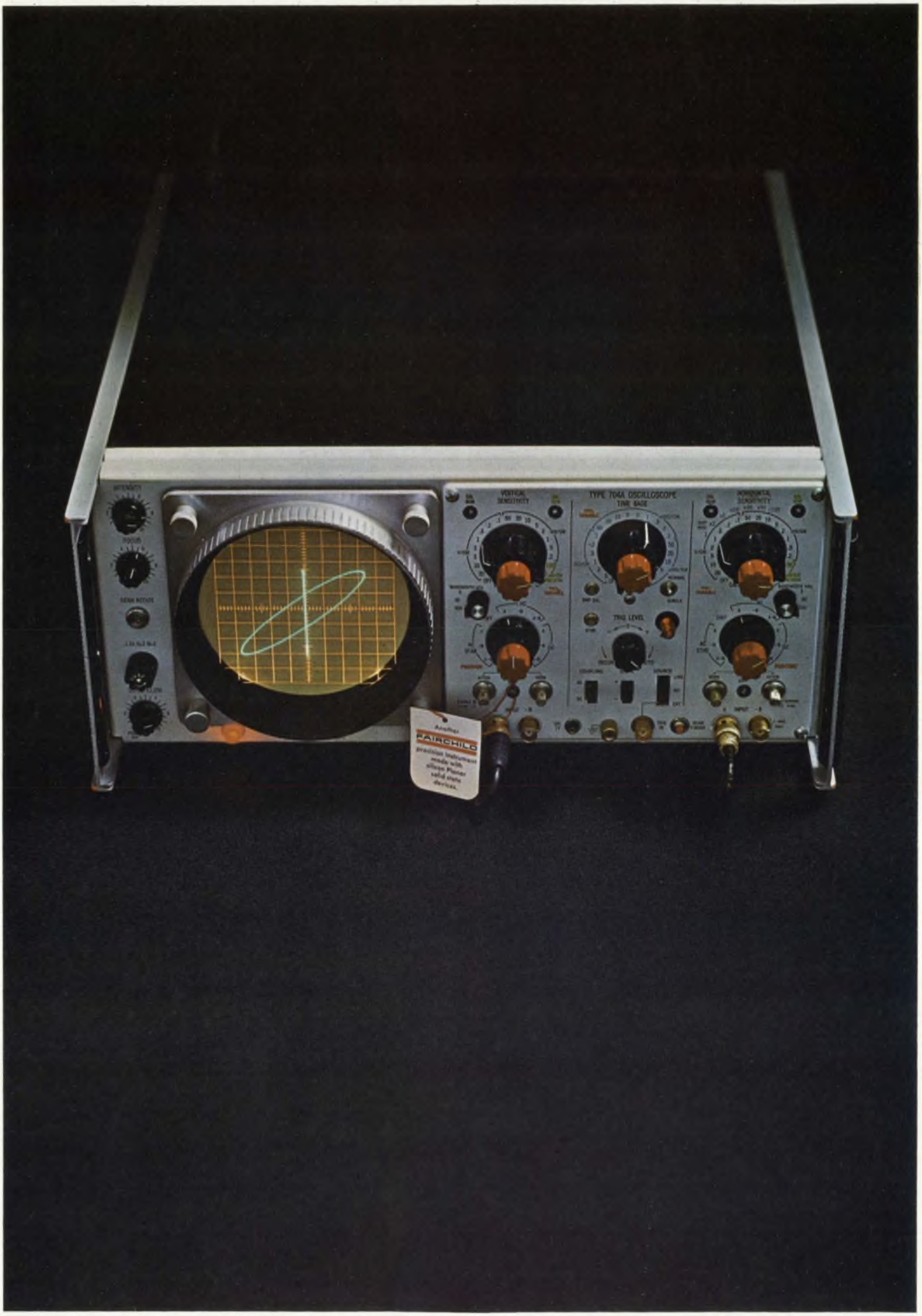
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Letters

Editorgrams are our guidelines

The editorial staff of ELECTRONIC DESIGN is grateful to you readers for the steady flow of Editorgrams into our offices. Suggestions, criticism, praise—these brief comments help us to put together a magazine that corresponds as closely as possible to your interests. Of course, we cannot act on every suggestion, but whenever an obviously useful or telling point is made and whenever a number of requests for a specific type of article are received, we do our best to follow through. So keep them coming. They cost you only a few minutes of time; to us they are invaluable.

Here, for instance, is a couple of suggestions that we have taken up:

"If you put the issue number at the bottom of the page with the date, it would be easier to find an article listed in your semiannual index of articles, which catalogs by issue number only."

(Note: The number is being included at the foot of each page of every issue from ED 22, Sept. 27, 1966, onwards.)

* * *

"How about printing 'Index Issue' on the binding so that those of us who file ED can find the index more easily?"

(Note: 'Index Issue' will appear on the cover spine of the year-end issue and all subsequent numbers that contain a semiannual index of articles.)

Topics for articles proposed

Many readers come forward with suggestions for articles that they would like to see. Here are some recent ones:

* * *

From Montreal, Canada: "I'd like to see articles on broadband phase detectors, phase-lock receivers and phase-locked loop FM detectors."

* * *

From Flensburg, West Germany: "Tunnel diode applications in microwave circuits."

* * *

From Mountain View, Calif.: "I'd like to see something on nanoamp, high-impedance, 75-megohm voltage sensors using unipolar transistors and FETs."

* * *

From La Spezia, Italy: "More about low-noise amplifiers, filters (active and passive) and linear circuits in general."

* * *

Such Editorgrams are grist to our mill, for they are the key to the contents of future issues. If you feel that you are able and willing to write articles for us to publish on such subjects as those suggested above, or on any other timely topic of immediate interest to design engineers, we shall be very happy to send you our author's guide. This outlines our editorial requirements, sketches the best way to put your article together and tells you how to go about submitting an article idea to us. For your copy of "How to Write Articles for ELECTRONIC DESIGN," check the box at the bottom of the Editorgram at the back of this issue.

Past articles draw praise

Along with the suggestions, comments and occasional brickbats come plaudits:

"I especially like "Rid mixers of spurious signals" (ED 19, Aug. 16, 1966, pp. 210-216) because of its new approach and the expanded data that ED made available."

* * *

"The article on mixer spurs was very timely because I am involved in the design of local oscillators and mixers at present."

* * *

"Your Wescon information was very useful and helped me to plan my visit."

* * *

"Your editorial, "The quest is on for the perfect micronym" (ED 17, July 19, 1966, p. 43), was first-class

(continued on p. 44)


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(continued from p. 40)

because humor is essential to a *readable* technical magazine."

* * *

One last Editorgram gave us pause to reflect for a moment. An "Atoms Scientist" in upstate New York told us: "Change your magazine's name to 'Electrons Design' " Well . . . it's an idea!

Polyurethane protects devices against moisture

Sir:

I enjoyed your article, "Electronics needed for guerrilla warfare" [ED 17, Aug. 2, 1966, pp. 36-47]. One of the areas that stood out as a problem is the protection of electronic components and circuitry from moisture.

Here at Kennedy Space Center and Cape Kennedy we have a similar problem. We do not have quite the same degree of humidity as Viet Nam, but, in addition, we have the salt and sand problem.

We have developed a family of thin-film polyurethane conformal coatings which can be easily and economically applied to printed-circuit boards and terminal boards. The coating does not appreciably change electrical properties, but almost entirely seals the units from the detrimental environmental conditions which render many printed circuits useless. The coatings are covered by the Kennedy Space Center specification KSC-C-183, and KSC-QPL-183-1.

The Department of Defense, as well as NASA, has been doing work for several years on both epoxy and polyurethane coatings. Both materials in very thin coatings (2 mils or less) seem to have very little effect on the *Q*-factor and other electrical properties. Both protect the equipment from moisture and fungal attack and add terrifically to its handling characteristics. For example, six commercially built boards were vibrated to more than 50 G from 0 to 2000 Hz while plugged in and operating. They should easily withstand parachute drops and rough handling without damage.

Polyurethane was chosen because it is more elastic and is very wear-resistant. Epoxy, by comparison, is rigid, and in thicker coatings (above 2 mils) tends to crack solder joints and components under varying heat loads. Some of the thick polyurethane coatings have also caused like problems.

The thin coatings are so thin that they have very little heat insulative effects and should reduce the cooling required of other sealed modules. Since the coatings are thin, replacement of components is no problem. Repair or touch-up of the coating is simple.

The biggest advantage of these coatings to the manufacturer is reduction in labor, material, and facilities costs. Masking is almost eliminated, and by using the "Ferris-wheel technique" one person can coat a large number of boards in a short time without expensive spray guns, vacuum chambers, or banks of ovens.

Using this new family of coatings, off-the-shelf commercial equipment can be easily, quickly, and economically protected to withstand the stringent environmental conditions of Vietnam.

J. M. Fisher
NASA Office of Quality Assurance
John F. Kennedy Space Center
Cape Kennedy, Fla.

Devices stave off power surges

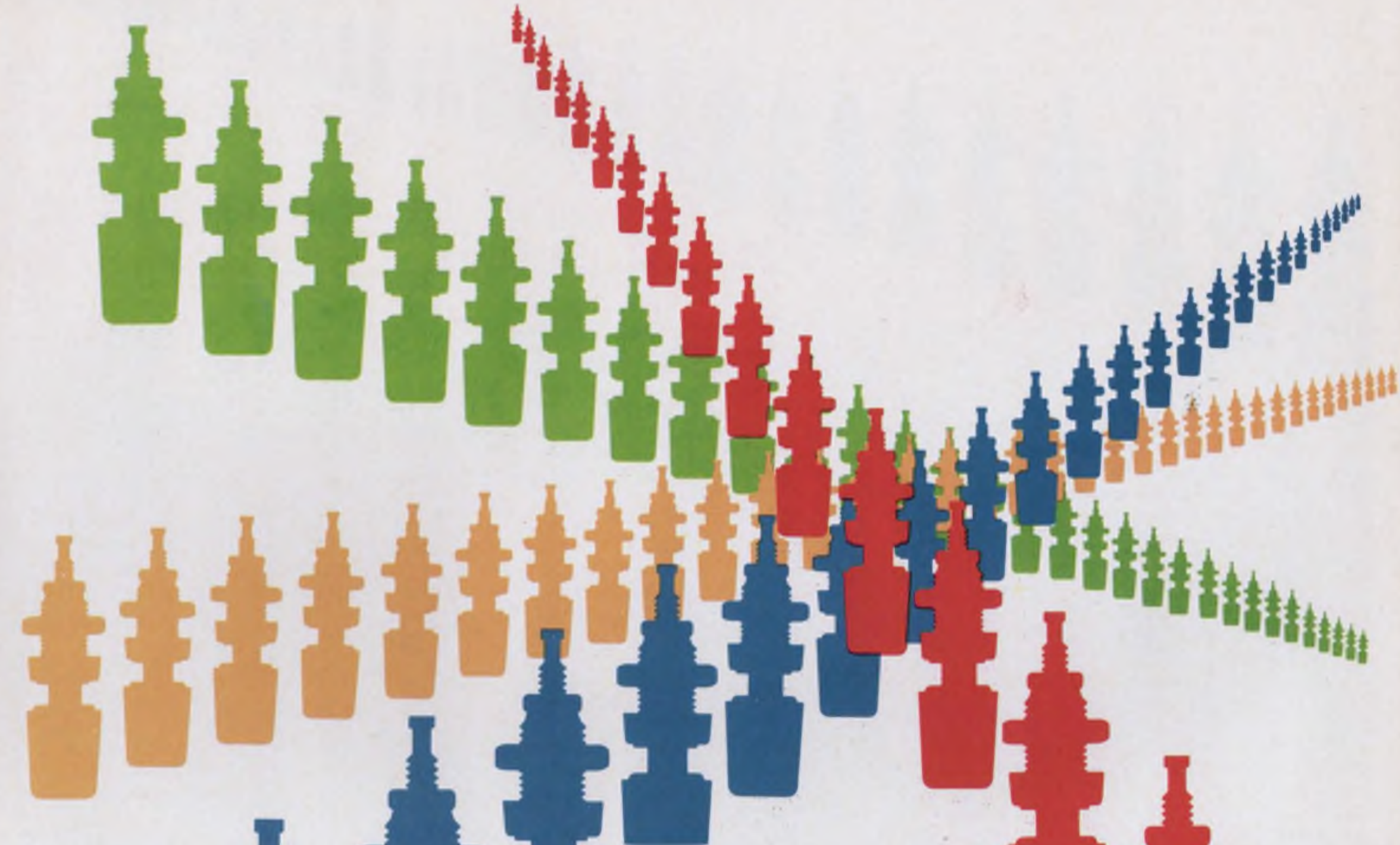
Sir:

I read with extreme interest your interview, "Electronics needed for guerrilla warfare," in which Chief Warrant Officer Carl Sellers referred to the problems of power surges and generators.

ATI Industries has been marketing for over two years a solid-state device that protects electronic equipment from overvoltage surges and transients. The device, known as the Solid-state Circuit Protector (SCP), has a triggering response time of 500 ns or less, and is available with automatic reset, therefore eliminating the need for any fuse or circuit breakers.

SCPs have also been developed for undervoltage protection as well; for instance, should the line or generator voltage drop below a preset voltage, the SCP switches to emergency battery operation. The SCP

(continued on p. 47)



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E. F. JOHNSON COMPANY

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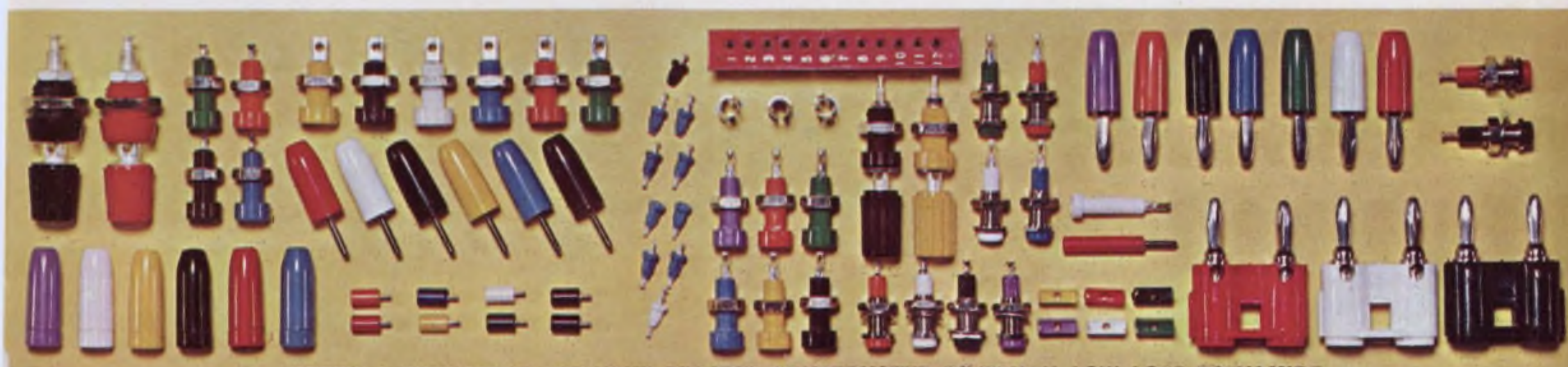

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Look to Johnson for all your component needs

CONNECTORS

SUB-MINIATURE INSULATED TYPES – Designed for printed circuit applications. Operating voltages to 1500 volts RMS . . . 5 amperes current carrying capacity . . . contact resistance less than 2 milliohms. Capacitance between two adjacent jacks less than one pf at 1 Mc. 10 colors available. Test-Point Strip/Handle – rapid-mounting polyamide body contains 12 test points each rated at 5 amps., maximum current capacity. Operating voltage 1500 volts RMS at sea level, 350 volts RMS at 50,000 feet. Contact resistance less than 2 milliohms.

STANDARD INSULATED CONNECTORS – A complete line of connectors molded of tough, low-loss, shock-proof polyamide in 10 colors meeting Fed. Std. 595. Tip, Banana and Dual Banana Plugs; Tip and Banana Jacks; Metal-Clad Tip Jack, Military; Jack and Sleeve; Binding Posts.

RIB-LOC TERMINALS – A new line of miniature, one-piece, insulated terminals with a unique serrated conical design, which resists loosening and turning. Provides an inexpensive approach to convenient press-in type terminals. Six colors conforming to Federal Color Standard No. 595. Terminal styles include single and double turret feed-thrus and stand-offs, .040" dia. tip plug and mating jack for .040 plug.

CAPACITORS

MACHINED PLATE TRIMMER AND TUNER TYPES – U, UA, UB, U-LC, V, AND W – Available in both printed circuit and chassis mounting types. U types available in differential and butterfly printed circuit mounting types in addition to single section types. V and W capacitors available in single section type only. Maximum capacities of up to 54 pf. Tuners consist of a machined plate trimmer and high Q air wound silver plated inductor, in resonant frequencies of 100 to 750 Mc.

SOLDER PLATE TYPES – Type M: Capacity values to 30 pf. Voltage ratings to 1250 volts peak. Available in single section, differential and butterfly types.

Type S: Capacity values to 100 pf. Voltage ratings to 3000 volts peak. Available in single section, differential and butterfly types.

Type K: Capacity values to 150 pf. Voltage ratings to 3800 volts peak. Available only in single section types. May be furnished in production quantities in full compliance to MIL-C-92A.

Type R: Capacity values to 340 pf. Voltage ratings to 4400 volts peak. Available only in single section type.

Type L: Capacity values to 200 pf. Voltage ratings to 3500 volts peak. Available in single section differential, butterfly and dual section types.

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Type F: Capacity values to 400 pf. Voltage ratings to 3000 volts peak. Available in single section and dual section types.

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KEL-F SERIES – Molded of low dielectric loss-factor Kel-F plastic – designed for use with a wide selection of high power transmitting tubes.

STEATITE WAFER TYPES – Available in 4, 5, 6, 7, and 8-pin standard socket types, as well as Super Jumbo 4-pin types. Also giant 5 pin, and 7 pin Septar and VHF Septar Sockets.

SPECIAL PURPOSE TYPES – Includes sockets for special purpose tubes.

Note: For detailed specifications, request Socket Standardization Booklet 536 on your company letterhead.

INSULATORS – Low loss, high-voltage breakdown in either steatite or porcelain. Complete line includes Thru-panel Bushings and Insulators, Antenna Strain and Feeder Types, Cone and Stand-off Insulators, Lead-in Bushings and Feed-Thru Bowl Assemblies.

PILOT LIGHTS – Over 47 separate assemblies. Continuous indication neon types, models for high and low voltage incandescent bulbs, standard or wide angle glass, and lucite jewels. Specials, including types meeting military specifications, also available in production quantities.

PANEL BEARINGS – For use on ¼" shafts and panels up to ⅜" thick. CRYSTAL SOCKETS – For low capacity, high voltage and high temperature operation. Glazed steatite, Grade L-423 or better. DC-200 impregnated. RF CHOKES – High quality construction. For 1.7 to 30 Mc range.

Johnson also offers a complete line of heavy-duty RF components for broadcast transmitting, RF heating, antenna phasing and other commercial applications.

Equipment in this line includes fixed and variable inductors, antenna phase sampling loops, isolation filter inductors, feed-thru bowl insulators, static drain chokes, RF contactors, and heavy duty make-before-break switches.

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(continued from p. 44)

would eliminate line surges from ever entering areas where electronic equipment is used.

ATI has available on request its standard SCP Catalog that shows available ranges of its devices.

John S. White, Sr.
Dir. of Communications Products
ATI Industries
Los Angeles

Guerrilla detectors are in production

Sir:

After the pleasure of reading "Electronics needed for guerrilla warfare," I felt compelled to write regarding the statement, "Sensitive metal detectors planted around the perimeter of the camp might have alerted the Americans and saved the village" [p. 36].

Texas Instruments, Inc., does in fact manufacture a device now in use in Vietnam for this and other tactical action programs. It is called the Model SID-X-150A Seismic Intrusion Detector, and it signals an alarm when activated by persons, animals or machines moving within the detection range of either a single hidden seismometer or an array.

The unit, in its present configuration, is compact, light in weight and can be installed as much as a mile from a control point. This makes it ideal for use for perimeter protection of areas such as those described in the article. Seismometers can be installed in the ground or attached directly to fences, buildings or bridges, or even placed in water.

The SID-X-150A sensors operate in the subaudio frequency range from about 15 to 30 Hz and the electronic circuit converts the elastic wave motion of a man, animal or moving vehicle into a distinctive audible sound. Furthermore, the operator, after a short training period, can easily identify the source of these characteristic sounds. Six size-D dry-cell flashlight batteries power the unit; under normal use the average life of the batteries is four months. This power supply, although quite inexpensive compared with some complex systems now in use, provides reliable service in jungle warfare.

Frank Lord
Manager of Merchandising
Science Services Div.
Texas Instruments, Inc.
Dallas, Tex.

Note: A copy of a brochure describing this equipment was forwarded to the Green Berets. Ed.

Full-wave rectifier tubes are in push-pull

Sir:

In your interesting article relating to electronics in Vietnam, I should like to call your attention to some inaccurate comments on page 44 about a high-voltage power supply.

The comment begins: "This is full-wave rectification, the two tubes are in parallel." This is incorrect, for in a common full-wave rectifier (not bridge) the tubes are in fact in push-pull.

It adds: "So when one goes, it throws the full load on the other tube." This also is false. In a full-wave rectifier circuit, the duty cycle on each tube is 50%. Only one tube is conducting at any one time. With one tube removed from the circuit, the duty cycle is still 50% on the remaining tube. It does not throw the full load to the other tube.

Arnold J. Carmody
Engineer
Electronic Design Co.
Fairport, N. Y.

Professionalism is a state of mind

Sir:

Anent Miss Dekany's editorial of July 5 ["An ill wind blows for the baccalaureate," ED 16, p. 35], there are three points that I would like to state briefly. One is that "professionalism" is more a state of mind, or attitude, than a matter of formal education. Usually, increasing the formal education does not change a student's basic attitudes.

Second, much good engineering work can be done and is being done by men who stopped at the bachelor's degree. It would be unfair to exclude them from professional status, particularly when so many men with graduate degrees are not really using them. It would be more to the point to revise the undergraduate curriculum, eliminating the superfluous and outdated material, and making it into a course that was truly professional.

Last but not least, I think that professional status should include a certain amount of practical experience. A recent graduate, whether bachelor or master, is far from being a true professional. My idea of a professional engineer is a man with at least a bachelor's degree and five years of applicable experience. Incidentally, I have a master's, so my feelings on the subject are not sour grapes.

Alex Richardson
Sr. Member Tech. Staff
ITT Federal Labs.
Nutley, N. J.

Accuracy is our policy

In "Stabilize gain in a dc amplifier," ED 19, Aug. 16, 1966, p. 180, Fig. 1 ("Open-loop gain . . .") a solder dot was omitted at the junction of $R2$, R_L, E_0 and the emitter of $T2$.

In "Cure switching system noise," ED 19, Aug. 16, 1966, pp. 186-189, the following corrections should be made.

Equation 1, p. 186, should be amended to read:

$$Z = [(R + j\omega L)/(G + j\omega C)]^{1/2},$$

inserting the square root.

In the Table, p. 187, the remarks applying to single wire near a ground plane, the entire second sentence ("Can be fabricated with multilayer printed wiring") should be deleted.

The captions for Figs. 2 and 3, p. 188, should be switched, so that that under Fig. 2 applies to Fig. 3 and that under Fig. 3 to Fig. 2.

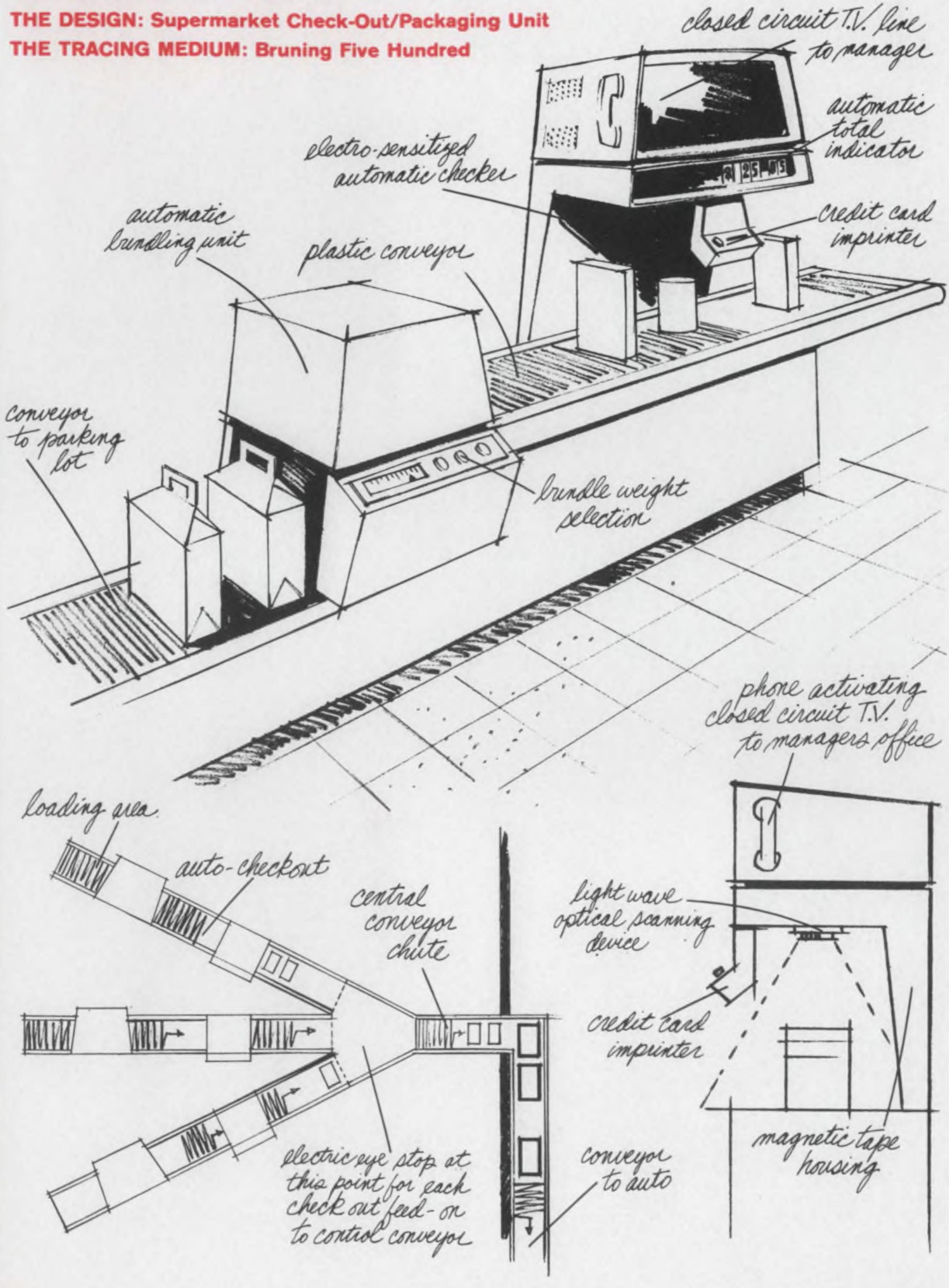
The entire paragraph, beginning "Decoupling capacitors can be located . . ." at the foot of column 1, p. 188, and ending ". . . to supply transient currents" at the top of column 2, should be deleted.

DESIGNERS 1985

THE DESIGNER: Lester Beall Inc.

THE DESIGN: Supermarket Check-Out/Packaging Unit

THE TRACING MEDIUM: Bruning Five Hundred



DESIGNERS 1985
THE DESIGNER: Lester Beall Inc.
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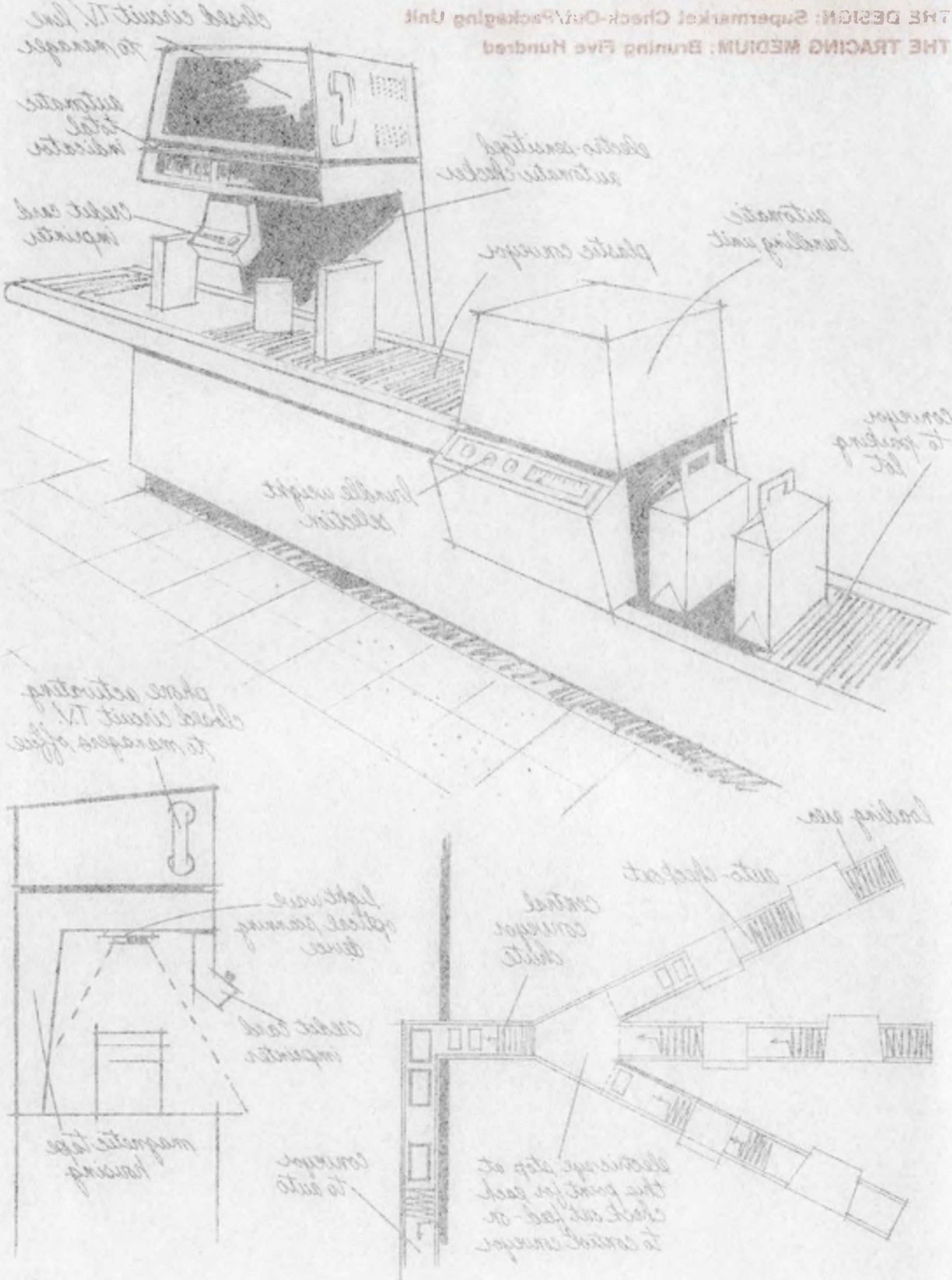

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ON READER-SERVICE CARD CIRCLE 33

EDITORIAL

Engineer's black box complements MD's black bag

Electronic designers can be proud of their accomplishments in just about every phase of modern society from home entertainment to mass education. But nowhere is this pride more justifiable than in the area of medical electronics. If Hippocrates was the father of medicine, electronic technology is proving a most worthy stepfather.

The reasons for the growing accommodation between electronics and medicine are many. To some extent, it is a case of the "art" of medicine having a need and the "science" of electronics having the means. This is proven by the fact that many techniques now widely used for measuring various bodily processes of the sick would be impossible by other than electronic means. Another reason is that the doctor-to-population ratio in the United States has been steadily declining, while the public demand for medical services has been steadily increasing. As a result, both doctors and hospitals have had to increase their efficiency drastically to serve their increasing patient loads. Electronic instrumentation and data-processing equipment have allowed them to do this, in many cases with resounding success.

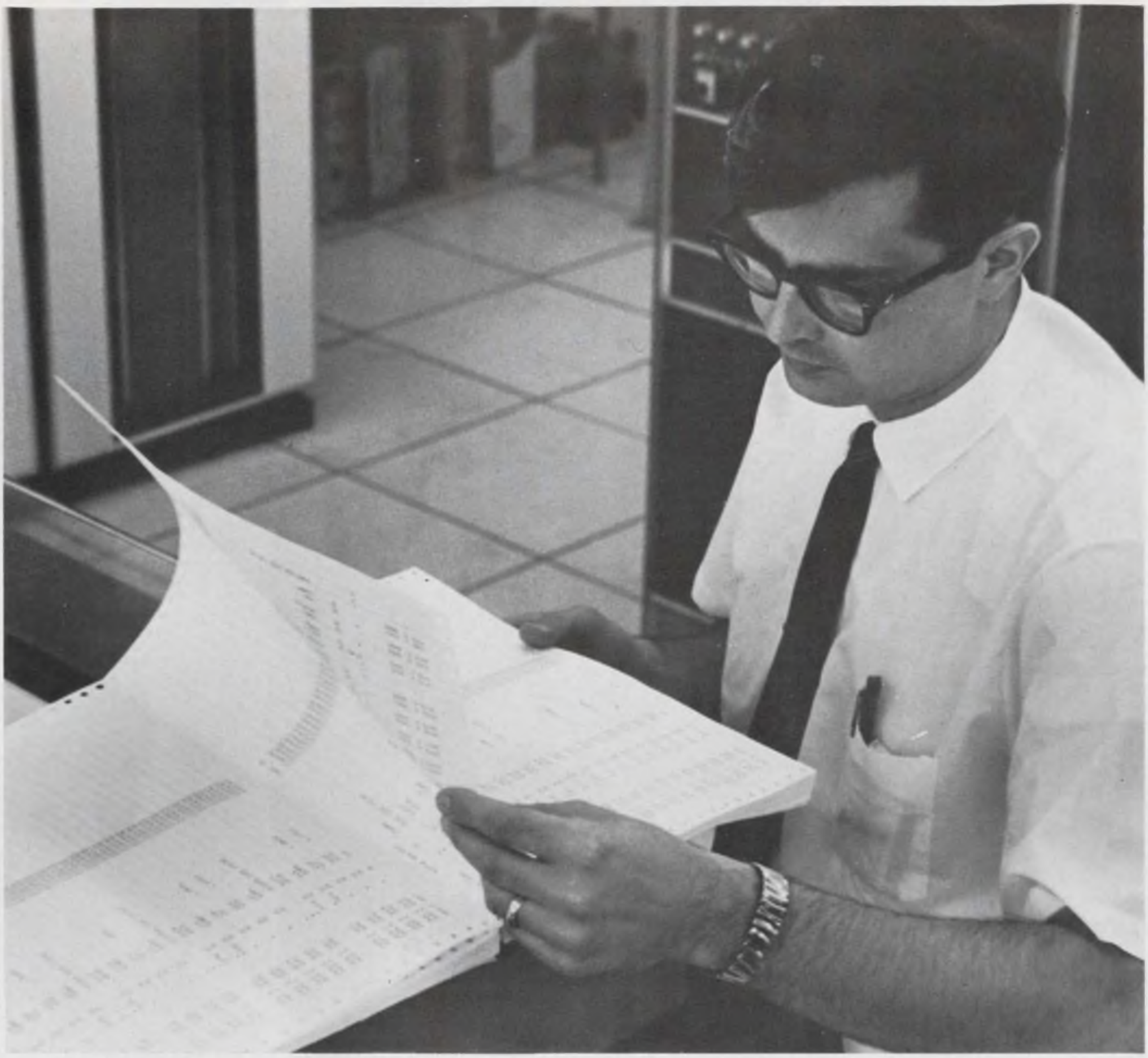
Despite the present widespread use of medical instrumentation, its full potential is still far from fully exploited. This is partly because of the relatively high cost of development and the tendency of many physicians to look on the engineers' "gadgets" with a mixture of wariness and disdain. But the biggest obstacle is the lack of widespread cross-pollination of ideas between the engineering and medical communities. Effective exchange between the two groups is essential if electronic technology is to do all it can for medicine. A good example of what can be done is the bio-medical transfer program of NASA's Technology Utilization Division. Under this program, a NASA team of biological and physical scientists seek out medical problems that might be solved by aerospace-technology developments. And already NASA has solved many such biological problems.

The market for medical instrumentation and data-processing equipment is expected at least to triple by 1975. But where will the ideas, the innovations and the designs for all this equipment come from? The explosive growth will require designers who also know something about the biological sciences. Unless the educational community makes some adjustments, new engineering graduates will not be the answer. At present only a handful of universities offer extensive biomedical engineering programs.

It is probable, therefore, that many designers now devoting their talents to space telemetry, industrial instrumentation and the like will find themselves in years to come designing medical equipment and systems. It might behoove all of us, then, to learn just a little more about the needs and requirements of our doctor friends. Anyone who thinks a pacemaker is a driver at a harness track had better start now.

FRANK EGAN

Technology



Computer-aided circuit design may well have a more far-reaching impact on the tasks of design engineers than any single development since the advent of the transistor. Page 54

Also in this section:

COMPUTER-AIDED DESIGN

Are computers really a designer's best friend?
Read this series and decide for yourself.

Edited by **Joseph J. Casazza,** Technical Editor

Far-reaching in its implications and promise, computer-aided design is already being used in many sectors of the electronics industry. Although still young, this exciting technology is growing rapidly.

Indications of its growth are evident in the conference sessions (WESCON, 1966) and seminars (University of Wisconsin in May and the University of Santa Clara, Calif., last month) devoted exclusively to the topic. So, too, is the birth of small, informal user groups (see Design Directions, ED 20, Aug. 30, 1966, pp. 34-36). The message for the electronic designer is clear: Don't ignore this powerful new technology.

Using the digital computer as a design tool gives the engineer an opportunity to put classical techniques to work with virtually none of the usual manual drudgery. But before the computer will do his bidding, the engineer must perform a few preliminaries. Here are some of them:

- Learn to communicate with the computer. At present this means, at the very least, a working knowledge of FORTRAN (FORmula TRANslation) programing. Ideally, some day we may all be able to write our instructions on the computer's graphic-input tube screen, but much development still remains to be done before this becomes the established practice.
- Learn to state the problem properly. This is vital, if useful and intelligible data are to be obtained from the computer. The approach to a problem must be refined to weed out waste motion, unrealizable specifications, etc. Although most computer programs will let the user know when he has made an error, the wise design engineer can save himself considerable time and strain by ensuring that initial problem statements and formulations are correct.
- Try to find out what others in the field are doing. This is especially important because of the newness of computer-aided design. There is still little communication between users, because of the difficulty of establishing who and where they are. This problem should dwindle as more conference sessions are held and as more information is published in engineering journals.

The four articles presented in this special section are designed to give the reader an insight into computer-aided design. The articles are broad in scope, dealing with feedback system design, circuit design by both large- and medium-scale computers, and the circuit-design programs that are currently available.

Throughout the articles there runs the common theme that computer-aided electronic design is practical and has tremendous potential.

The reader need not be a programer to understand the material, which is written by experts in the field. A casual acquaintance with FORTRAN is certainly helpful but not essential. Once familiar with the capabilities and simple use of such design programs as BASIC, LISA and AMPLI, many designers should be motivated to increase their knowledge of those programing methods that will be of greatest use to them.

Many improvements can be anticipated in computer-aided design in the near future. Perhaps the two most significant developments today are:

- Increased use of time-shared computer systems, enabling relatively small engineering organizations to take full advantage of the modern digital computer.
- Lower cost and greater availability of graphic input/output consoles that allow engineers to communicate with a computer in terms of actual schematic symbols and graphs.

With much new territory to explore, virtually everyone in the industry will eventually feel the effects of the digital computer's contribution to electronic design. *JJC*

Free reprints available

You may obtain a single reprint of the entire special section on computer-aided design by circling 309 on the Reader Service Card.

Here's a powerful design program

that allows the designer to use Laplace transform techniques to check circuit performance.

High-speed computing methods can be applied to complex problems in linear circuit analysis and design with little effort on the part of the engineer. Through a new experimental computer program called LISA (LInear System Analysis Program), the engineer can draw on the useful s-plane, or pole-zero, techniques, without getting lost in a maze of algebraic or programing details.

Laplace transform methods, although powerful tools in linear theory, have been limited in practice by tedious manual calculations and the need for severe approximations to make solutions tractable. In recent years, the digital computer has been applied to remove these restrictions.[1]

LISA was developed as a result of experiments conducted with various programs aimed at solving a matrix equation with terms that are functions of the complex frequency variable s. Other techniques were developed to manipulate transfer functions to obtain solutions in the real-frequency and time domains. To support these methods, programing routines were written, such as those needed to generate matrix equations from a node description of the circuit.

Success with these methods led to the organization of these programs into a tool that can aid the engineer both in analysis and design. LISA, an integrated package of programs connected by a common, easy-to-use language, is the result.[2]

LISA is simple and flexible

The LISA language permits the user to describe his problem in familiar engineering terms, and the simple programing commands can be learned without specialized training in computer techniques. This language is suitable for terminal (i.e., teletypewriter) as well as card input.

The design engineer can apply the program to problems expressed in terms of equivalent circuit diagrams, transfer functions and matrix equations. In addition, basic two-block feedback control systems can be described. Results may be requested as poles and zeros, frequency and transient responses, root locus or sensitivity.

With these alternative forms of input and output, the engineer can apply LISA to a variety of problems, ranging from electronic circuit applications and heat flow to mechanical and servomechanism design problems.

For electronic circuit applications, the program can determine the effects of parameter and topological changes on various parts of the circuit. This characteristic of LISA encourages the engineer to experiment freely with design alternatives. During early design stages, for example, the engineer may want to alter the circuit configuration and examine root locations. At a later stage, his interest may turn to the effect of dominant components. At any time in the development of the design, he can easily jump from the s-plane to the frequency or time domain.

LISA is written in FORTRAN IV for the IBM 7090/94 computer. Although the program is still experimental, it incorporates methods that are general in approach and can be adapted to other types of computers and programing languages.

The flexibility of LISA can be demonstrated through applications that start with an equivalent circuit diagram. The engineer enters the circuit description as values of R, L, C, mutual inductance, initial conditions, independent current sources, and voltage- or current-dependent current sources. The dependent sources are used for active device models such as the Π or T transistor circuits.

From this information, the program automati-

Edward T. Johnson, Senior Associate Engineer, IBM, Systems Development Div., San Jose, Calif.

Author Johnson studies print-out resulting from a design problem being executed on a digital computer.

cally sets up the nodal matrix equation in the complex frequency variable $s = \sigma + jw$. In addition, the engineer defines the functions required by the problem. These may be voltages, voltage ratios, currents, current ratios, impedances, admittances, determinants, cofactors, or any of the common three-terminal, grounded, two-port parameters.

The program can then compute one or more of the following:

- Poles and zeros.
- Variations of the poles and zeros to component variations.
- Locus of roots over a range of values for any component.
- Time response to various driver functions.
- Bode response over a range of frequencies.
- Sensitivity of a function to component variations at a given frequency.

Answers appear as numerical listings or, if applicable, in the form of plots.

The above computations can be approached in several ways.

LISA offers three solutions

Three methods of solving the circuit matrix equation for the unknown function are possible with LISA. Each has its advantages and limitations. The engineer's choice will depend on the relative importance of these factors and the characteristics of his design.

- The first method, POLY, is used to compute polynomial coefficients and find the roots. Calculating speed is an advantage of this method, but coefficient round-off error and overflow problems limit its use to approximately 12 nodes. This method will be illustrated by a design example.
- TRFN, another method, finds the roots directly from the proper determinants by iteration without even forming the coefficients. Round-off error and overflow are considerably reduced at the cost of increasing the computing time in comparison with POLY speeds. TRFN accommodates approximately 25 nodes.
- The third method, called ACCA, works only in the $s = j\omega$, or real-frequency, domain, and roots are not found. However, the method is fast and accurate, and both the Bode response and sensitivity can be computed for circuits containing up to 50 nodes. The ACCA method computes the unknown function for dc circuits by using a single value of ω.

These three alternative methods make it possible for the engineer to check the accuracy of one set of computations against another.

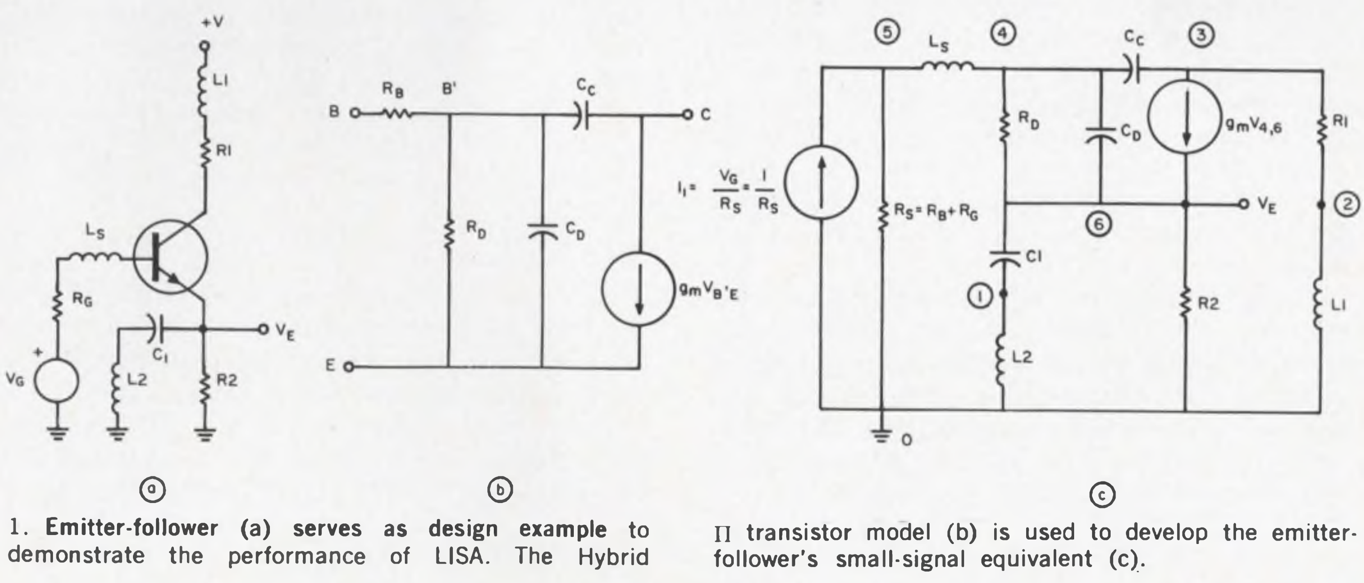
Design problem shows LISA in action

A typical design problem for an emitter-follower circuit illustrates how LISA operates in practice. The engineer starts with a circuit diagram, selects the hybrid-Π as the transistor model for this circuit, and completes the equivalent circuit (Fig. 1). For convenience, the base resistance and generator resistance are combined. In this example, a Norton equivalent circuit is substituted for the voltage source, and $V_G(s)$ is set equal to 1 or to the impulse function. Nodes on the equivalent circuit are numbered for reference, starting with 0 for ground. Symbolic names, such as V1, A or GND, can be used as alternative methods of referring to the nodes.

The engineer assigns values to the circuit components. In this case, he selects scaled values with the following units:

R in kΩ	V in volts	t in ns
L in μH	I in mA	ω in Grad/s
C in pF		

His objective, in this case, is to find the poles and zeros, the magnitude and phase response over a specified frequency range, and the transient response for a given driver function.



1. **Emitter-follower (a) serves as design example** to demonstrate the performance of LISA. The Hybrid Π transistor model (b) is used to develop the emitter-follower's small-signal equivalent (c).

All the program statements required to solve this problem are shown in Table 1. When punched cards are the method of input, each statement represents an individual card. All data are entered in free format—that is, a particular type of information, such as a command word or number, does not have to be restricted to specified columns. The data can appear anywhere on the card, with commas separating the items. The free-format style of LISA reduces the possibility of input errors, is more convenient to use, and allows the program to be readily adapted to input devices other than punched card.

LISA commands (TITLE, COMPUTE, etc.) are placed at the beginning of a statement as shown in Table 1. The TITLE command (Table 1, line 000), for example, is followed by a heading for the output listing. The next command, NOTE (line 001), can be used by the engineer for special reminders, such as the selected scale units. The third command, READ, CIRCUIT, introduces 12 descriptive statements about the circuit (lines 002 through 014). Each component is listed by name with its connection nodes and assigned values.

At this point in the program, LISA sets up the nodal matrix equation:

$$Y(s)\,V(s) = I(s),$$

where $Y(s)$ is the nodal admittance matrix, $V(s)$ the unknown node voltage vector, and $I(s)$ the vector of the sources plus the initial conditions.

The engineer next enters the DEFINE command and describes the unknown transfer function. LISA accepts an unknown function as a FORTRAN-like statement, using the general form:

$$\text{DEFINE, name} = K^*[\pm V(i_1) \pm V(i_2)]^*S^*Z/\text{denominator},$$

where the name is a function term selected by the user; K is a constant; Z is the name of a circuit resistor, capacitor, or inductor; S is the complex frequency variable; and $V(i_1)$ and $V(i_2)$ are circuit voltages at nodes i_1 and i_2. The denominator is identical in form to the numerator, and the two parts are separated by a slash.

For this problem, he assigns the name MS to the function and defines it as the voltage at node 6 (line 015). The engineer can include additional functions by submitting separate DEFINE statements.

The program allows any degenerate (i.e., simplified) form of this expression. Consequently, voltages, voltage gains, currents and a variety of functions can be described in terms of node voltages and circuit resistors, capacitors, and inductors. In addition, a three-terminal, grounded, two-port function is defined by the statement:

DEFINE, PORTS=input node, output node.

Unknown functions can be referred to merely by their assigned names or by their implied two-port names in statements that initiate computing steps. Any of the common two-port names, such as Z11, Y21, or H22, may be given.

For the emitter-follower problem, the decision to compute the function MS has many advantages. Because $V_G(s)$ is set to the impulse function, MS becomes:

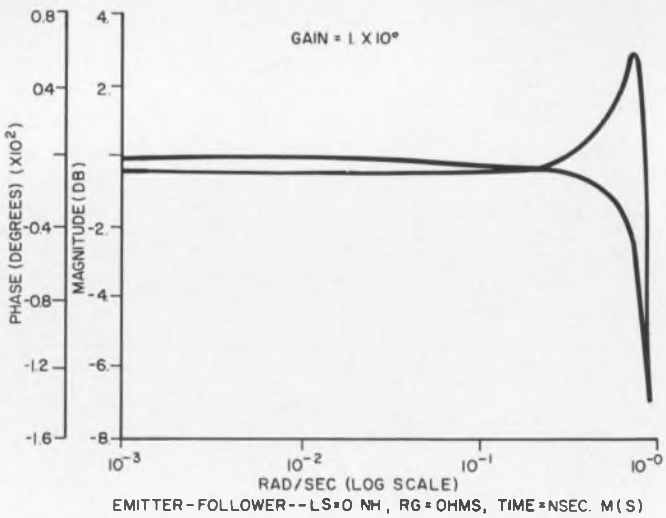
$$MS = V_E(s)/V_G(s) = V_E(s)/1 = V(6) = N(s)/D(s).$$

This function, therefore, represents a voltage ratio for the Bode response, or a voltage for the transient response; and its denominator is the characteristic function for stability studies.

With the command, COMPUTE, POLY, MS, the computer calculates the poles and zeros of the function MS. Output from this computation (Table 2) lists the pole and zero coefficients in descending order and shows the roots. The results,

Table 1. Statements for emitter-follower analysis

```
000  TITLE .   EMITTER FOLLOWER ANALYSIS
001  NOTE   .  SCALE IS K-OHM,UH,PF,NSEC,GIGA-RAD/SEC,VOLT,MA
002  READ   .  CIRCUIT
003       R1, 2 , 3 =  .15
004       L1, 2 , 0 ,  .1
005       R2, 6 , 0 ,  .2
006       C1, 6 , 1 ,  15
007       L2, 0 , 1 ,  .06
008       RD, 4 , 6 ,  .49
009       CD, 4 , 6 ,  60
010       CC, 3 , 4 ,  2.68
011      TGM, 3 , 4 , 6 ,  155.1
012       LS, 4 , 5 ,  .001
013       I1, 0 , 5 ,  20
014       RS, 0 , 5 ,  .05
015  DEFINE,  MS =  V(6)
016  COMPUTE , POLY , MS
017  COMPUTE , BODE , MS
018  DATA , FREQUENCY =  20, 3, .001, RPS
019  PLOT
020  LABEL ,  EMITTER FOLLOWER - W = GIGA-RAD/SEC , T = NSEC ,  MS
021  READ  , DRIVER
022       STEP , 0 , 1.0
023  DATA  , TIME =  0, 80 , .25
024  COMPUTE , TRANSIENT , MS
025  PLOT
026  EXIT
```



2. **Frequency response is plotted by the computer** using data shown in Table 3. The curve shows the Bode response of MS obtained for $s=j\omega$.

Table 2. Computer prints out emitter-follower's poles and zeros for MS

```
            ETJ AMP-BW-1-4   LS INCLUDED , MADE SMALL     SCALED

DENOMINATOR    DEGREE =  9         1.607999999999928D 06        4.171993738775469D 08        2.156315857551004D 09
                                   5.246985160090700D 09        7.556823347392045D 09        4.316465464852453D 09
                                   3.614467120183749D 09        0.                           0.
                                   0.
               ROOTS       REAL PART                          IMAG PART          ITNS    TEST
                     0.                    0.
                     0.                    0.
                     0.                    0.
                   -1.108414643865605D-01  8.346869397855932D-01            8       1
                   -1.108414643865604D-01 -8.346869397855932D-01            1       1
                   -1.177269124880819D 00  1.822899288566771D 00            8       1
                   -1.177269124880819D 00 -1.822899288566771D 00            1       1
                   -2.648344951440168D 00  0.                               2       1
                   -2.542277808088097D 02  0.                               2       1


            ETJ AMP-BW-1-4   LS INCLUDED , MADE SMALL     SCALED

X( 6)          DEGREE =  8         3.215999999999996D 08        1.324674775510202D 09        2.820745496598634D 09
                                   4.614677188208595D 09        2.737124625850357D 09        3.492018140589646D 09
                                   0.                           0.                           0.
               ROOTS       REAL PART                          IMAG PART          ITNS    TEST
                     0.                    0.
                     0.                    0.
                     0.                    0.
                     0.                    1.054092553390536D 00            8       1
                     0.                   -1.054092553389473D 00            1       1
                   -7.500000000000129D-01  1.780124513505184D 00            8       1
                   -7.500000000000129D-01 -1.780124513505184D 00            1       1
                   -2.619013605442175D 00  0.                               2       1
```

after cancellation, are:

$$MS = N(s)/D(s) = 0.8(s-z_1)(s-z_2)(s-z_3)/(s-p_1)(s-p_2)(s-p_3)(s-p_4),$$

where

$p_1 = -0.1108 \pm j0.8346$ $\quad z_1 = -0.75 \pm j1.780$
$p_2 = -1.177 \pm j1.822$ $\quad z_2 = \pm j1.054$
$p_3 = -2.648$ $\quad z_3 = -2.619$
$p_4 = -254.2$

By computing MS in the s-plane, the engineer has immediate information on stability at his disposal. In Table 2 for example, the poles are all in the left half plane, indicating the circuit is stable. The designer can relate MS to the real-frequency domain by setting $s = j\omega$, or he can shift to the time domain by applying residue methods to obtain the inverse of the transform.

The statement COMPUTE, BODE, MS now directs the computer to provide the magnitude and phase of MS over the frequency range given on the DATA card. This card specifies a range of 20 points per decade over three decades, starting at $\omega = 0.001$ Grad/s = 1 Mrad/s. A variety of other point ranges could have been specified, such as 80 points per decade over 10 decades. Computation in Hz is optional. Table 3 shows a partial listing of the results. The PLOT and LABEL commands produce a Bode plot (Fig. 2).

The engineer enters the transient driver with the READ, DRIVER command. He asks for just the step response, beginning with $t = 0$ and with unit height (1.0). LISA actually allows seven basic Laplace transform drivers: impulse, step, ramp, sine, cosine, sinh and cosh. These drivers can be super-imposed to obtain a variety of pulse shapes, which can be periodic.

The DATA, TIME statement supplies the starting time (0 ns), the ending time (80 ns) and the time step (0.25 ns) for the transient response computation. COMPUTE, TRANSIENT, MS and PLOT commands produce a listing of results (Table 4) and a plot of MS vs time (Fig. 3) for the step driver. Since residue methods are used, the partial fraction expansion can also be obtained. Computing time is fast in comparison with numerical integration methods.

The problem ends with the EXIT card. This statement is deferred, however, if the engineer wants to study circuit changes immediately.

Design changes can be evaluated

Let us assume the engineer wants to study the effects of various parameter combinations on stability. With a few more statements, he increases the values of LS and RS and computes the results for each change.

The only statements required to do the additional computation are:

Table 3. Frequency response calculated and printed out using LISA

FREQUENCY	PHASE (DEG)	MAGNITUDE (DB)	MAGNITUDE	LOG FREQUENCY (F/FO)
10.000E-04	-0.024	-0.299	9.661E-01	0.
1.120E-03	-0.026	-0.299	9.661E-01	0.049
1.260E-03	-0.030	-0.299	9.661E-01	0.100
1.410E-03	-0.033	-0.299	9.661E-01	0.149
1.580E-03	-0.037	-0.299	9.661E-01	0.199
1.780E-03	-0.042	-0.299	9.661E-01	0.250
2.000E-03	-0.047	-0.299	9.661E-01	0.301
2.240E-03	-0.053	-0.299	9.661E-01	0.350
2.500E-03	-0.059	-0.299	9.661E-01	0.398
2.820E-03	-0.066	-0.299	9.661E-01	0.450
3.160E-03	-0.074	-0.299	9.661E-01	0.500
3.550E-03	-0.083	-0.299	9.661E-01	0.550
4.000E-03	-0.094	-0.299	9.661E-01	0.602
4.470E-03	-0.105	-0.299	9.661E-01	0.650
5.000E-03	-0.118	-0.299	9.661E-01	0.699
5.620E-03	-0.132	-0.299	9.661E-01	0.750
6.300E-03	-0.148	-0.299	9.661E-01	0.799
7.080E-03	-0.166	-0.299	9.661E-01	0.850
7.950E-03	-0.187	-0.299	9.661E-01	0.900
8.900E-03	-0.209	-0.299	9.661E-01	0.949
10.000E-03	-0.235	-0.299	9.661E-01	1.000
1.120E-02	-0.263	-0.299	9.662E-01	1.049
1.260E-02	-0.296	-0.299	9.662E-01	1.100
1.410E-02	-0.332	-0.299	9.662E-01	1.149
1.580E-02	-0.372	-0.299	9.662E-01	1.199
1.780E-02	-0.419	-0.298	9.662E-01	1.250
2.000E-02	-0.470	-0.298	9.663E-01	1.301
2.240E-02	-0.527	-0.298	9.663E-01	1.350
2.500E-02	-0.588	-0.297	9.663E-01	1.398
2.820E-02	-0.664	-0.297	9.664E-01	1.450
3.160E-02	-0.744	-0.296	9.665E-01	1.500
3.550E-02	-0.836	-0.296	9.665E-01	1.550
4.000E-02	-0.942	-0.294	9.667E-01	1.602
4.470E-02	-1.053	-0.293	9.668E-01	1.650
5.000E-02	-1.179	-0.292	9.670E-01	1.699
5.620E-02	-1.326	-0.290	9.672E-01	1.750
6.300E-02	-1.487	-0.287	9.675E-01	1.799
7.080E-02	-1.673	-0.284	9.679E-01	1.850

Table 4. Print-out shows circuit's transient response

T	F(T)	T	F(T)	T	F(T)	T	F(T)
0.	8.00000E-01	1.0000E 01	9.49459E-01	2.0000E 01	1.00293E 00	3.0000E 01	9.56528E-01
2.5000E-01	6.19049E-01	1.0250E 01	9.74720E-01	2.0250E 01	9.98314E-01	3.0250E 01	9.55336E-01
5.0000E-01	5.25573E-01	1.0500E 01	9.98217E-01	2.0500E 01	9.92570E-01	3.0500E 01	9.54672E-01
7.5000E-01	5.03912E-01	1.0750E 01	1.01904E 00	2.0750E 01	9.86005E-01	3.0750E 01	9.54538E-01
1.0000E 00	5.32764E-01	1.1000E 01	1.03643E 00	2.1000E 01	9.78947E-01	3.1000E 01	9.54909E-01
1.2500E 00	5.91753E-01	1.1250E 01	1.04985E 00	2.1250E 01	9.71726E-01	3.1250E 01	9.55741E-01
1.5000E 00	6.64887E-01	1.1500E 01	1.05892E 00	2.1500E 01	9.64663E-01	3.1500E 01	9.56973E-01
1.7500E 00	7.41496E-01	1.1750E 01	1.06350E 00	2.1750E 01	9.58051E-01	3.1750E 01	9.58531E-01
2.0000E 00	8.15593E-01	1.2000E 01	1.06364E 00	2.2000E 01	9.52151E-01	3.2000E 01	9.60329E-01
2.2500E 00	8.84508E-01	1.2250E 01	1.05957E 00	2.2250E 01	9.47178E-01	3.2250E 01	9.62277E-01
2.5000E 00	9.47440E-01	1.2500E 01	1.05171E 00	2.2500E 01	9.43293E-01	3.2500E 01	9.64282E-01
2.7500E 00	1.00430E 00	1.2750E 01	1.04061E 00	2.2750E 01	9.40604E-01	3.2750E 01	9.66255E-01
3.0000E 00	1.05500E 00	1.3000E 01	1.02691E 00	2.3000E 01	9.39160E-01	3.3000E 01	9.68114E-01
3.2500E 00	1.09911E 00	1.3250E 01	1.01135E 00	2.3250E 01	9.38956E-01	3.3250E 01	9.69784E-01
3.5000E 00	1.13587E 00	1.3500E 01	9.94709E-01	2.3500E 01	9.39930E-01	3.3500E 01	9.71204E-01
3.7500E 00	1.16436E 00	1.3750E 01	9.77753E-01	2.3750E 01	9.41978E-01	3.3750E 01	9.72327E-01
4.0000E 00	1.18372E 00	1.4000E 01	9.61233E-01	2.4000E 01	9.44950E-01	3.4000E 01	9.73121E-01
4.2500E 00	1.19336E 00	1.4250E 01	9.45833E-01	2.4250E 01	9.48669E-01	3.4250E 01	9.73567E-01
4.5000E 00	1.19309E 00	1.4500E 01	9.32156E-01	2.4500E 01	9.52932E-01	3.4500E 01	9.73672E-01
4.7500E 00	1.18322E 00	1.4750E 01	9.20694E-01	2.4750E 01	9.57528E-01	3.4750E 01	9.73445E-01
5.0000E 00	1.16454E 00	1.5000E 01	9.11818E-01	2.5000E 01	9.62239E-01	3.5000E 01	9.72915E-01
5.2500E 00	1.13824E 00	1.5250E 01	9.05766E-01	2.5250E 01	9.66857E-01	3.5250E 01	9.72122E-01
5.5000E 00	1.10585E 00	1.5500E 01	9.02644E-01	2.5500E 01	9.71189E-01	3.5500E 01	9.71114E-01
5.7500E 00	1.06912E 00	1.5750E 01	9.02424E-01	2.5750E 01	9.75063E-01	3.5750E 01	9.69946E-01
6.0000E 00	1.02989E 00	1.6000E 01	9.04955E-01	2.6000E 01	9.78338E-01	3.6000E 01	9.68679E-01
6.2500E 00	9.90039E-01	1.6250E 01	9.09977E-01	2.6250E 01	9.80908E-01	3.6250E 01	9.67371E-01

CHANGE, CIRCUIT, VALUE
LS = 0.05636
COMPUTE, POLY, MS
CHANGE, CIRCUIT, VALUE
LS = 0.2
COMPUTE, PQLY, MS
CHANGE, CIRCUIT, VALUE
RS = 0.1
COMPUTE, POLY, MS

These statements produce computations similar to those seen in Table 2. The results are illustrated in a sketch (Fig. 4) showing the movement of the dominant poles. The critical pole moves to the $j\omega$ axis, then into the right half plane as LS increases. Adding more base resistance stabilizes the circuit.

Many other alternatives could be tried. For example, the engineer could direct the program to compute the locus of the roots over a range of values for RS with the statements:

COMPUTE, LOCUS, MS
DATA, LOCUS = RS, 0.075, 0.1, 0.125, 0.15
PLOT

This input would produce the desired computations and a root-locus plot of the poles and zeros for the selected values of RS. With this information, the engineer could establish the proper design values for stability and other design criteria.

Or, he might determine the effects of component variations on the roots with the statements:

COMPUTE, SENSITIVITY, MS
DATA, SENSITIVITY = 0.05, RS, LS, TGM

These statements will result in new listings of the roots which reflect a 5% increase in the value of RS, LS, and TGM, each taken individually. The word ALL can be used if every component is to be varied. The sensitivity at a single frequency may also be found with similar statements.

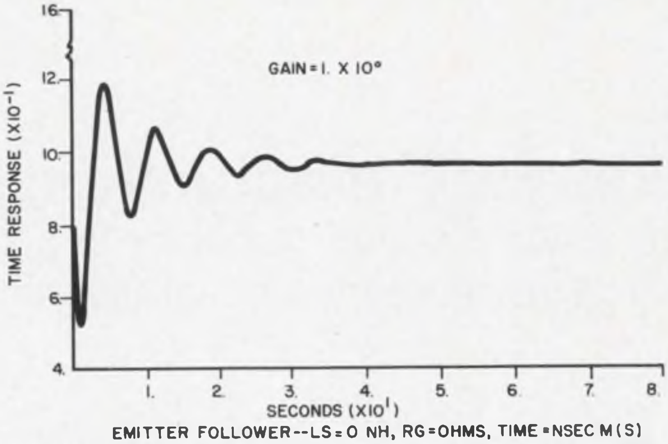
To illustrate how the user directs LISA to change his circuit topology, let us assume that he removes C_c in Fig. 1, and computes the new roots. The statements required for this addition are:

CHANGE, CIRCUIT, TOPOLOGY, REMOVE
CC
COMPUTE, POLY, MS

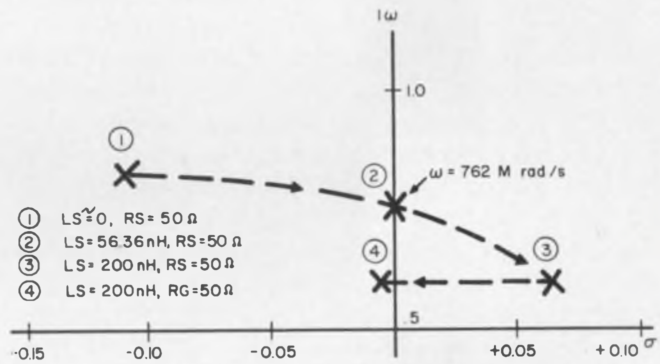
To make further topological changes, ADD and SHORT options are available. The ADD option allows new components to be connected to the original circuit description. Following this command, these components are listed in the same manner as those shown in Table 1.

The SHORT option allows the connection of floating nodes caused by the removal of components, or the option can be used actually to short out components connected to adjacent nodes. Ambiguity is avoided in a change of this type if the nodes are originally assigned symbolic names rather than numbers.

These design capabilities of LISA allow many



3. **The computer provides transient response to unit-step** driver in graphic form as well as in the form of the print-out shown in Table. 4.



4. **Effects of parameter variations on circuit** stability are easily observed with LISA. With only a few statements, the designer can obtain data needed to sketch the movement of dominant poles as both LS and RS are varied.

variations to be made easily in the original circuit, with the result that the effects of certain components may be determined with minimal effort.

For the emitter-follower design, the roots found by the POLY method can be checked against TRFN results. Or, they can be checked indirectly by comparing the magnitude and phase listing produced by ACCA with the results from the poles and zeros for $s = j\omega$.

Many of the device and parameter studies allowed by this program would be difficult or impossible to perform on the bench within a reasonable period of time. By taking over the burden of calculation, LISA permits the engineer to concentrate his abilities on the creative aspects of his job. ■ ■

Acknowledgment:

I want to thank Dr. K. L. Deckert, program leader, for his guidance and significant contributions to all phases of the LISA program.

References:

1. F. F. Kuo, "Network Analysis by Digital Computer," *Proc. of IEEE*, LIV, No. 6 (June, 1966), pp. 820-829.
2. K. L. Deckert and E. T. Johnson, "LISA—A Program for Linear Systems Analysis" (Paper presented at WESCON, Aug. 23, 1966).

Simplify feedback system design

by using a digital computer to perform the tedious steps required by manual techniques.

Next time you're designing a linear feedback system, let a digital computer do the "dog-work" for you. The computer-aided design procedure to be described will deliver more accurate results in less time than standard graphical techniques.

The conventional method of finding the closed-loop response of a linear feedback system is tedious and open to human error. With this method the gain and phase of the sections (low pass, integration, lead-lag, etc.) of the system must be plotted and added graphically. This composite, open-loop response must then be mapped into a Nichols chart to find the corresponding closed-loop response. The computer-aided technique, however, does the required graphical plotting, adding and Nichols mapping precisely and swiftly and then presents the results in both tabular and graphical form.

Defining the problem

Many linear feedback systems can be expressed in the form given in the block diagram of Fig. 1. Here E_1 is the input signal, E_0 is the output signal, and $A(s)$ is a complex function of frequency representing the open-loop transfer function of the system. When the feedback loop is closed by subtracting E_0 from E_1 at the summing point shown in Fig. 1, the closed-loop transfer function is:

$$E_0(s)/E_1(s) = A(s)/[1+A(s)]. \qquad (1)$$

If the open-loop response is known in both gain and phase at a given frequency, Eq. 1 can be used to calculate the closed-loop response at that frequency.

A convenient form of expression for $A(s)$ is the product of a series of first- and second-order transfer subfunctions. Here each subfunction directly represents one of the series of single- and/or double-pole sections from which the over-all transfer function is constructed. A list of the more useful single- and double-pole sections together with their respective transfer subfunctions is given in Fig. 2.

Frederick R. Shirley, Engineer, Electronic Design Dept., Sanders Associates, Inc., Nashua, N. H.

If a transfer function is composed of N sections of the types given in Fig. 2, and if the gain of each section is expressed logarithmically in dB, then the total gain M of the transfer function is:

$$M_{dB} = \sum_{n=1}^{N} 20 \log_{10}|A_n(s)|. \qquad (2)$$

Similarly, if the phase of each section is expressed linearly (in degrees), then the total phase ϕ of the transfer function is given by:

$$\phi_{deg} = \sum_{n=1}^{N} \measuredangle A_n(s). \qquad (3)$$

With the relations of Eq. 2 and 3, the imaginary (I) and real (R) parts of the open-loop transfer funtion may be expressed:

$$\mathrm{I} = 10^{(M/20)} \sin \phi. \qquad (4)$$

$$\mathrm{R} = 10^{(M/20)} \cos \phi. \qquad (5)$$

Therefore the gain (M') and phase (ϕ') of the closed-loop transfer function may be expressed:

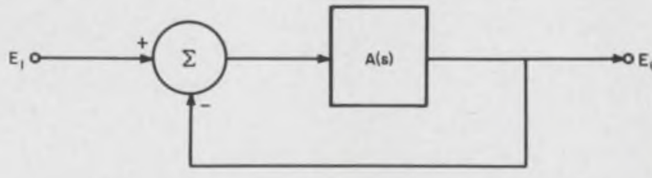
$$M'_{dB} = M - 20 \log_{10}[(\mathrm{R}+1)^2 + \mathrm{I}^2]^{1/2}. \qquad (6)$$

$$\phi'_{deg} = \phi - \tan^{-1}[\mathrm{I}/(\mathrm{R}+1)]. \qquad (7)$$

Equations 6 and 7 form a particularly useful expansion of Eq. 1 because they express the desired closed-loop solution directly in terms of the standard transfer subfunctions of Fig. 2. These equations form the basis for the computer program used to solve a linear feedback system.

The computer program is BASIC

A computer program for calculating the closed-loop transfer function of the feedback system (Fig. 1) is shown in Table 1. The program is written



1. **Feedback system transfer function equations are developed** by means of the block diagram shown. Many linear feedback systems can be represented in this way.

in BASIC (Beginner's All-purpose Symbolic Instruction Code), which is a simplified language used on the Dartmouth teletype time-sharing system. This type of time-sharing system is particularly advantageous to the engineer, because it allows complete control of all aspects of the programing procedure directly from the teletype keyboard.

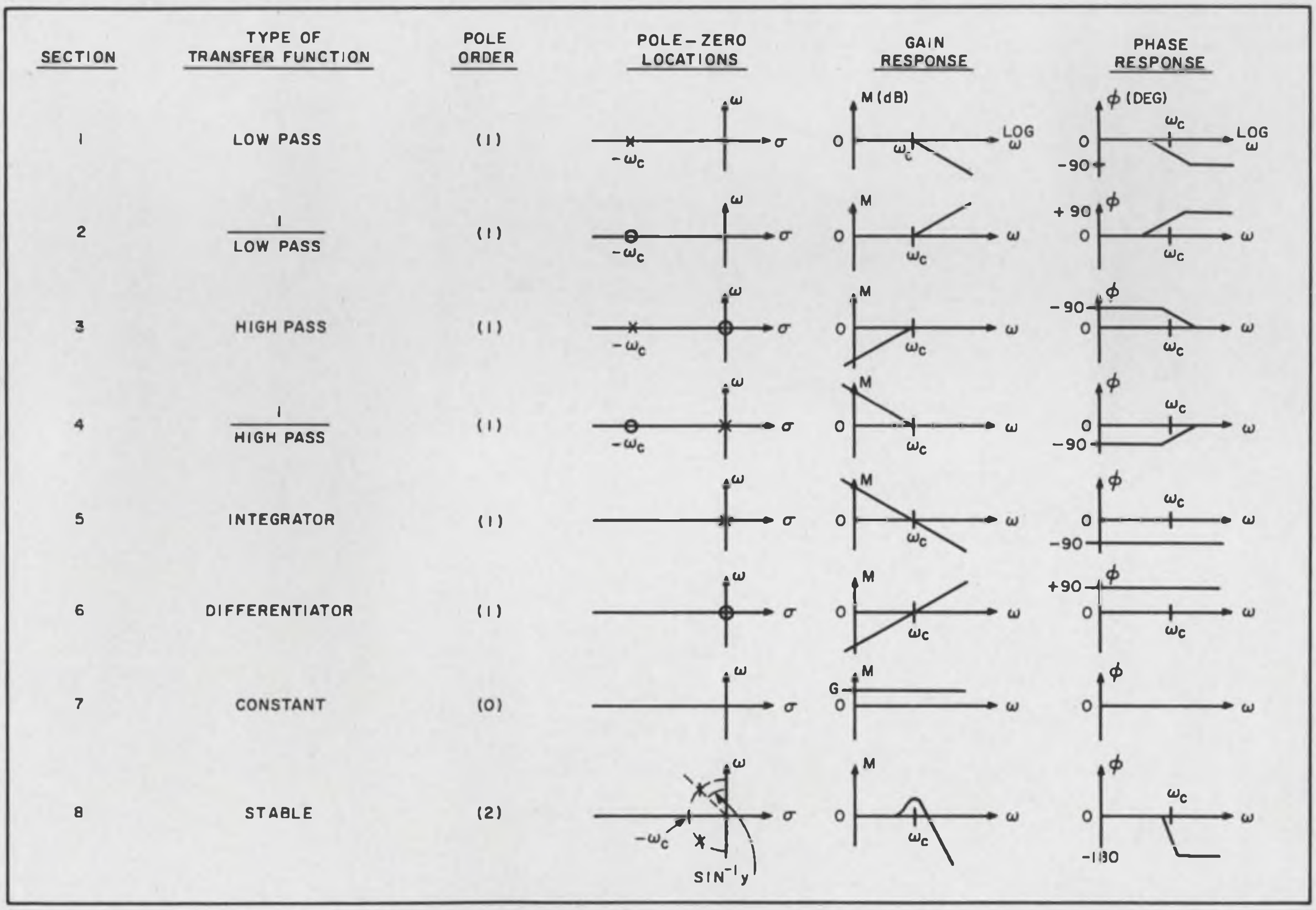
The input format for BASIC requires a line number (0 to 99999) followed by a command word at the beginning of each typed line. The computer interprets each line as an individual statement, and reorders these according to increasing line number. Some of the BASIC command words which are used in the program of Table 1 are listed alphabetically in Table 2.

The program of Table 1 is composed of the following seven parts:

1. Instructions to the user.
2. Data setup.
3. Calculation of the individual section frequency responses.
4. Calculation of the open-loop response.
5. Calculation of the closed-loop response.
6. Print-out of the tabular data.
7. Print-out of the graphical data.

The *instructions to the user* are contained in lines 10 through 44. These statements explain briefly the purpose of the program and the required input format for the user's specific problems. In the execution of the program the computer ignores these statements on every line prefixed with the command word "REM".

The *data setup* is contained in lines 100 through 420. Line 100 is blank (i.e., it line-feeds the print-out one line). Line 110 requests preliminary information on the user's problem—the central frequency and decade range he is interested in, and the number of sections in his open-loop transfer function. Line 115 causes a question mark to be typed, and waits for three numbers to be entered on the teletype by the user. These three numbers are then defined as C, D, and L1 in the succeeding computations in the program. Lines 120-130 form an error routine which prevents the solution of a problem of more than 50 sections, which is the maximum program length—a limit imposed by the available memory room in the computer. Lines 150-190 reserve extra memory room for the variable arrays F (frequency computation points), A (open-loop phases), M (open-loop gains), B (individual section phases), and N (individual section gains). Lines 200 and 210 define the constants π and ln(10) which are used in converting radians



2. **Here are the transfer functions usually encountered** when dealing with linear feedback systems. Also shown are the pole-zero, gain, and phase characteristics of each function.

Table 1. BASIC program aids linear feedback design

```
10 REM     THIS PROGRAM COMPUTES AND GRAPHS THE CLOSED LOOP RESPONSE OF A
12 REM  FEEDBACK SYSTEM WITH UP TO 50 SECTIONS, WHERE EACH SECTION CON-
14 REM  TAINS EITHER A STABLE 2ND ORDER POLE (DAMPING FACTOR >= 0), OR
16 REM  ANY 1ST ORDER POLE.  COMPUTATION IS DONE AT 31 LOG.-SPACED FREQ.
18 REM  POINTS OVER A 2,4, OR 6 DECADE RANGE.
20 REM     WHEN ASKED "CENTRAL FREQ., DECADES, NO. OF SECTIONS?" ENTER
22 REM  3 NUMBERS: C,D,L--WHERE C IS THE CENTRAL FREQ. OF INTEREST: D IS
24 REM  THE NUMBER OF DECADES TO BE COVERED; AND L IS THE TOTAL NO. OF
26 REM  SECTIONS.
30 REM     WHEN ASKED "TYPE, FREQ., GAIN:  NO. N?" ENTER 3 NUMBERS: N1,
32 REM  N2,N3--WHERE N1 IS THE TYPE OF THE NTH SECTION (1=LOWPASS, 2=
34 REM  1/LOW, 3=HIGHPASS, 4=1/HIGH, 5=INT., 6=DIFF., 7=CONST., 8=2ND
36 REM  ORDER); N2 IS ITS CRITICAL FREQ.(HZ); AND N3 IS ITS GAIN (DB)/
38 REM  OR DAMPING FACTOR (FOR 8).
40 REM     TO ELIMINATE THE INDIVIDUAL DATA ENTER EDIT DEL 3060-3160.
42 REM  TO ELIMINATE ALL TABLE DATA ENTER EDIT DEL 3010-3160,3200,3705
44 REM      F. SHIRLEY, SANDERS ASSOC., NASHUA, N.H., 7/8/66
100 PRINT
110 PRINT "CENTRAL FREQ., DECADES, NO. OF SECTIONS";
115 INPUT C,D,L1
120 IF L1 <= 50 THEN 140
125 PRINT "TOO MANY SECTIONS.  TRY AGAIN WITH 50 OR FEWER."
130 GO TO 110
140 PRINT "TYPE, FREQ., GAIN (DB):"
150 DIM F(31)
160 DIM A(31)
170 DIM M(31)
180 DIM B(3,50)
190 DIM N(3,50)
200 LET P = 3.14159265
210 LET E = 2.30258509
220 FOR L = 1 TO D/2
230 FOR J = 1 TO 31
240 READ F(J)
250 LET F(J) = F(J)*C
260 NEXT J
270 NEXT L
280 DATA .100, .117, .136, .158, .185, .215, .251, .293, .341, .398,.464
281 DATA .541, .631, .736, .858, 1.00, 1.17, 1.36, 1.58, 1.85, 2.15
282 DATA 2.51, 2.93, 3.41, 3.98, 4.64, 5.41, 6.31, 7.36, 8.58, 10.0
290 DATA.01,.0136,.0185,.0251,.0341,.0464,.0631,.0858,.117,.158,.215
291 DATA .293, .398, .541, .736, 1.00, 1.36, 1.85, 2.51, 3.41, 4.64
292 DATA 6.31, 8.58, 11.7, 15.8, 21.5, 29.3, 39.8, 54.1, 73.6, 100
300 DATA .001,.0016,.0025,.004,.0063,.01,.016,.025,.04,.063,.1,.16,.25
301 DATA .4,.63,1,1.6,2.5,4,6.3,10,16,25,40,63,100,160,250,400,630,1000
350 FOR J = 1 TO 31
360 LET A(J) = 0
370 LET M(J) = 0
380 NEXT J
400 FOR L = 1 TO L1
410 PRINT " "; "NO."; L;
420 INPUT T, K, G
450 FOR J = 1 TO 31
501 IF T = 1 THEN 1100
502 IF T = 2 THEN 1200
503 IF T = 3 THEN 1300
504 IF T = 4 THEN 1400
505 IF T = 5 THEN 1500
506 IF T = 6 THEN 1600
507 IF T = 7 THEN 1700
508 IF T = 8 THEN 1800
520 PRINT "INCORRECT POLE TYPE.  TRY AGAIN."
530 GO TO 410
1100 LET B(0,J) = -ATN(F(J)/K)*180/P
1110 LET N(0,J) = 20*LOG(SQR(1/(1+(F(J)/K)↑2)))/E + G
1120 GO TO 2000
1200 LET B(0 J) = ATN(F(J)/K)*180/P
1210 LET N(u,J) = -20*LOG(SQR(1/(1+(F(J)/K)↑2)))/E + G
1220 GO TO 2000
1300 LET B(0,J) = ATN(K/F(J))*180/P
1310 LET N(0,J) = 20*LOG(SQR(1/(1+(K/F(J))↑2)))/E + G
1320 GO TO 2000
1400 LET B(0,J) = -ATN(K/F(J))*180/P
1410 LET N(0,J) = -20*LOG(SQR(1/(1+(K/F(J))↑2)))/E + G
1420 GO TO 2000
1500 LET B(0,J) = -90
1510 LET N(0,J) = 20*LOG(K/F(J))/E + G
1520 GO TO 2000
1600 LET B(0,J) = 90
1610 LET N(0,J) = 20*LOG(F(J)/K)/E + G
1620 GO TO 2000
1700 LET B(0,J) = 0
1710 LET N(0,J) = G
1720 GO TO 2000
1800 LET X = F(J)/K - SQR(1-G↑2)
1810 LET Y = F(J)/K + SQR(1-G↑2)
1820 LET B(0,J) = -(ATN(X/G) + ATN(Y/G))*180/P
1830 LET N(0,J) = 20*LOG(SQR(1/((X↑2+G↑2)*(Y↑2+G↑2))))/E
2000 LET A(J) = A(J) + B(0,J)
2020 LET M(J) = M(J) + N(0,J)
2030 NEXT J
2040 FOR J = 1 TO 31 STEP 15
2050 LET B((J+14)/15, L) = B(0,J)
2060 LET N((J+14)/15, L) = N(0,J)
2070 NEXT J
2080 NEXT L
3000 PRINT
3020 PRINT " ", "OPEN LOOP", " ", "CLOSED LOOP"
3030 PRINT "FREQUENCY", "PHASE", "GAIN", "PHASE", "GAIN"
3040 PRINT "HERTZ","DEGREES","DECIBELS","DEGREES","DECIBELS"
3050 PRINT
3060 FOR L = 1 TO L1
3070 PRINT "SECTION NO."; L; ""
3080 FOR J = 1 TO 31 STEP 15
3090 PRINT F(J), B((J+14)/15, L), N((J+14)/15, L)
3100 NEXT J
3110 NEXT L
3120 PRINT
3200 PRINT "COMPOSITE FREQUENCY RESPONSE:"
3210 FOR J = 1 TO 31
3220 LET X = 10↑(M(J)/20)
3230 LET I = X*SIN(A(J)*P/180)
3240 LET R = X*COS(A(J)*P/180)
3250 LET A2 = A(J) - ATN(I/(R+1))*180/P
3260 LET N(0,J) = M(J) - 20*LOG(SQR((R+1)↑2 + I↑2))/E
3300 LET A2 = A2 + 1800
3310 LET A2 = A2 - 180
3320 IF M(J) >= 0 THEN 3400
3330 IF A2 - A(J) <= 90 THEN 3700
3340 GO TO 3310
3400 IF A2 <= 90 THEN 3700
3410 GO TO 3310
3700 REM
3705 PRINT F(J), A(J), M(J), A2, N(0,J)
3710 NEXT J
10000 FOR J = 1 TO 6
10010 PRINT
10020 NEXT J
10025PRINT"                    CLOSED LOOP GAIN (DB)"
10030PRINT"-20      -15       -10       -5        0         5         10"
10040PRINT"+ - - - - + - - - - + - - - - + - - - - + - - - - + - - - - +"
10100 FOR J = 1 TO 31
10110 LET W = INT(2*N(0,J) + .5) + 40
10130 FOR L1 = 0 TO 1
10140 FOR L = 0 TO 4
10150 LET V = W - 6*L - 30*L1
10160 IF V < 0 THEN 11000
10170 IF V > 5 THEN 11000
10200 IF V < 5 THEN 10300
10210 PRINT"     *";
10220 GO TO 12000
10300 IF V < 4 THEN 10400
10310 PRINT"    * ";
10320 GO TO 12000
10400 IF V < 3 THEN 10500
10410 PRINT"   *  ";
10420 GO TO 12000
10500 IF V < 2 THEN 10600
10510 PRINT"  *   ";
10520 GO TO 12000
10600 IF V < 1 THEN 10700
10610 PRINT" *    ";
10620 GO TO 12000
10700 PRINT"*     ";
10720 GO TO 12000
11000 IF L < 4 THEN 11100
11010 PRINT"      ";
11020 GO TO 12000
11100 IF L < 3 THEN 11200
11110 PRINT"  +   ";
11120 GO TO 12000
11200 IF L < 2 THEN 11300
11210 PRINT"      ";
11220 GO TO 12000
11300 IF L < 1 THEN 11400
11310 PRINT"    + ";
11320 GO TO 12000
11400 PRINT"+     ";
12000 NEXT L
12010 NEXT L1
12015 PRINT "+ " F(J)
12020 NEXT J
12025 PRINT
12030PRINT"
12050PRINT"
99999 END
```

and Napierian logarithms (the computer's natural units) to degrees and decibels (the desired print-out units).

In lines 220-301 the computer uses input information C and D to generate 31 logarithmically spaced frequency-computation points. The nested J-loop from 230 to 260 reads the first 31 numbers in the data block (i.e., the data in statements 280-282), multiplies each number by C, and sets the resulting 31 numbers equal to F (J). The over-all L-loop from 220 to 270 operates the J-loop 1, 2, or 3 times depending on whether the value of D is 2, 4, or 6, respectively. If D is equal to 2, the frequency points are determined by the first data block (280-282); if D is equal to 4, the frequency points are recomputed according to the second data block (290-292); and if D is equal to 6, the points are recomputed again according to the third data block (300-301).

In lines 350-380 the initial value of the open-loop phase and gain are set equal to zero in preparation for later computation.

In lines 140, 410 and 420 additional information is requested from the user. For each section in the user's open-loop transfer function, the computer requests the type T, critical frequency K, and gain (or damping factor if T=8) G.

The calculation of the *frequency response for each section* is accomplished in lines 400-1830. Lines 501-508 route the computation of the individual-section phase and gain to one of nine locations: to the appropriate formula pairs in lines 1100-1830 if T is one of the section-type codes given in Fig. 2, or to the error routine in lines 520-530 if T is incorrectly defined. The nested J-loop from 450 to 2030 calculates the phase and gain of the individual section at the 31 frequency-computation points, and the over-all L-loop from 400 to 2080 repeats these calculations for each section in the user's transfer function.

The formula pair for a low-pass section (lines 1100-1120) is typical of the eight sets of formulas in the 1100-1830 calculation portion of the program. In line 1100, B (O, J) is the phase ϕ (ω) of the section for the Jth frequency value, F(J) is the Jth value of frequency, K is the critical frequency ω_c, P is π, and ATN is the arc-tangent function evaluated in radians. Therefore line 1100 is equivalent to:

$$\phi(\omega)_{deg} = -[\tan^{-1}(\omega/\omega_c)_{rad}](180/\pi). \quad (8)$$

Similarly in line 1110, N(O, J) is the gain M (ω) of the section for the Jth frequency value, E is the natural logarithm of 10, SQR is the square-root function, and LOG is the natural logarithm function. Therefore line 1110 is equivalent to:

$$M(\omega)_{dB} = 20\ln\{[1+(\omega/\omega_c)^2]^{-1/2}/\ln 10\}+G_{dB}. \quad (9)$$

The *calculation of the open-loop frequency response* is accomplished in lines 2000 and 2020. The open-loop phase and gain at the Jth frequency value are set equal to their previous values plus the phase and gain of the Lth section. Here it is seen that the initial zero-setting of A(J) and M(J) in lines 350-380 is required to define the starting phase and gain values as zero. After the over-all L-loop (400-2080) has been performed the required L1 times, the values of A(J) and M(J) are the desired sums of the phases and gains of the individual sections according to Eq. 3 and 2.

Table 2. Commands used in feedback design program.

COMMAND	MEANING
DATA	Stores numerical data
DIM	Reserves memory room
END	Terminates all computation
FOR...TO...STEP	Sets up an iteration loop
GO TO	Alters the order of computation
IF...THEN	Allows a computation decision
INPUT	Requests numerical data
LET	Solves a numerical equation
NEXT	Terminates an iteration loop
PRINT	Prints output data
READ	Enters numerical data
REM	Allows remarks to be ignored

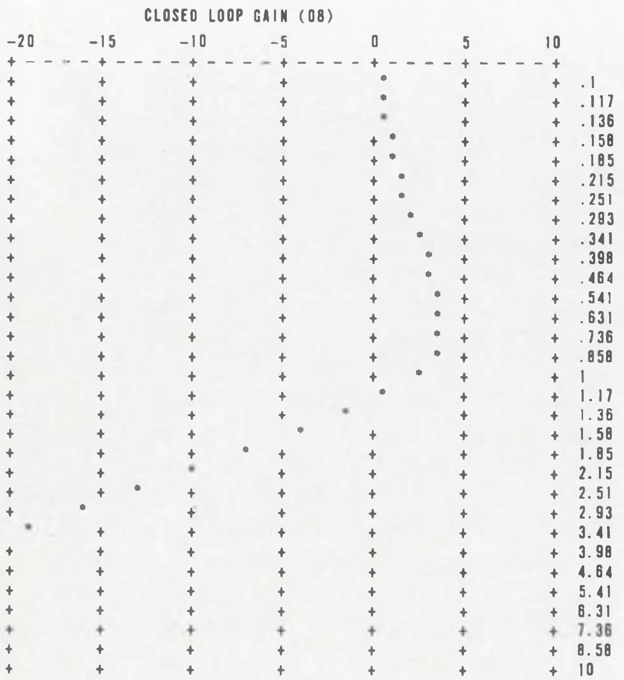
The *calculation of the closed-loop frequency response* is accomplished in lines 3210-3410. Lines 3230, 3240, 3250, and 3260 are directly equivalent to Equations 4, 5, 6, and 7 respectively. However, there is an ambiguity in the closed-loop phase A2 by a multiple of 180 degrees because of the cyclical property of the arc-tangent function. This ambiguity is resolved in lines 3330-3410 by comparison of the close-loop phase with the open-loop phase according to the value of the open-loop gain. For a stable feedback system, if the open-loop gain is non-negative, the closed-loop phase must lie between +90 degrees and −90 degrees, and if the open-loop gain is negative, the closed-loop phase must lie within + and − 90 degrees of the open-loop phase. Therefore, in line 3300 the closed-loop phase is made too large by a multiple of 180 degrees. Then, if the open-loop gain is non-negative, it is reduced 180 degrees at a time in lines 3310, 3320, 3400 and 3410 until it is between + and − 90 degrees. Or, if the open loop gain is negative, it is reduced in lines 3310, 3320, 3330, and 3340 until it is within + and − 90 degrees of the open-loop phase.

Print-out of the tabular data is accomplished in lines 2040-3710. As a means of checking the results, it is convenient to have the print-out divided into two portions: a preliminary print-out giving spot values of the frequency response of each individual section, and a primary print-out giving the open-loop and closed-loop frequency responses of the system. In lines 2040-2070 three values of the phase and gain of the individual sections are stored, and in lines 3060-3110 these values are printed out. Then, in line 3705 the open- and closed-loop system responses are printed out. The REM statement (line 3700) is to provide a forwarding location for lines 3330 and 3400 which is not a PRINT statement such as line 3705. This allows the same flexibility in bypassing the print-out as described in lines 40-42, when only the graphical data are desired by the user. The EDIT DEL statement temporarily removes the indicated line-number blocks from the program.

Print-out of the graphical data is accomplished in lines 10000-12050. Lines 10000-10020 space the graph 6 lines down from the tabular data, and lines 10025-10040 and 12015-12050 print the axes, scales and labels. Line 10110 defines the variable W such that, as the closed-loop magnitude varies from −20 dB to +10 dB, W varies in nearest integer steps from 0 to 60 (i.e., in half-dB steps across the graph grid). Because the BASIC language subdivides each print-out line into six-character regions, it is convenient to define another

COMPOSITE FREQUENCY RESPONSE:

.1	-164.717	27.8465	-.63681	.345785
.117	-162.421	25.2873	-.892853	.46128
.136	-159.999	22.8826	-1.5076	.603359
.158	-157.385	20.544	-2.26386	.781078
.185	-154.5	18.1566	-3.42879	1.01225
.215	-151.669	15.9627	-5.02032	1.27772
.251	-148.778	13.7925	-7.31428	1.59737
.293	-146.043	11.7191	-10.4621	1.95918
.341	-143.646	9.77824	-14.5907	2.34552
.398	-141.637	7.88838	-20.103	2.75529
.464	-140.206	6.08867	-27.1622	3.15371
.541	-139.455	4.34831	-36.1487	3.50476
.631	-139.483	2.84805	-47.4711	3.74073
.736	-140.37	.964465	-61.4345	3.74301
.858	-142.166	-.712783	-77.9068	3.33785
1	-144.906	-2.41337	-96.0372	2.34628
1.17	-148.714	-4.21029	-114.688	.648634
1.36	-153.304	-6.01023	-131.164	-1.52632
1.58	-158.752	-7.90614	-145.616	-4.05302
1.85	-165.344	-10.04	-158.811	-6.94218
2.15	-172.32	-12.2307	-169.849	-9.82744
2.51	-180.045	-14.6697	-180.056	-12.8959
2.93	-188.106	-17.306	-189.38	-16.0484
3.41	-196.124	-20.0882	-197.884	-19.2243
3.98	-204.195	-23.1186	-205.946	-22.551
4.64	-211.924	-26.3083	-213.452	-25.9473
5.41	-219.236	-29.6615	-220.458	-29.4394
6.31	-226.049	-33.1613	-226.969	-33.0289
7.36	-232.304	-36.7776	-232.967	-36.7009
8.58	-237.976	-40.4742	-238.438	-40.4307
10	-243.107	-44.2392	-243.421	-44.2152




```
CENTRAL FREQ., DECADES, NO. OF SECTIONS? 1,2,7
TYPE, FREQ., GAIN (D8):
 NO. 1    ? 5,200,0
 NO. 2    ? 7,1,-46.9
 NO. 3    ? 5,.258,0
 NO. 4    ? 1,2.85,0
 NO. 5    ? 1,174,0
 NO. 6    ? 2,.285,0
 NO. 7    ? 1,2.85,0
```

FREQUENCY HERTZ	OPEN LOOP PHASE DEGREES	GAIN DECIBELS	CLOSED LOOP PHASE DEGREES	GAIN DECIBELS
SECTION NO. 1	:			
.1	-90	66.0206		
1	-90	46.0206		
10	-90	26.0206		
SECTION NO. 2	:			
.1	0	-46.9		
1	0	-46.9		
10	0	-46.9		
SECTION NO. 3	:			
.1	-90	8.23239		
1	-90	-11.7676		
10	-90	-31.7676		
SECTION NO. 4	:			
.1	-2.00956	-5.34356 E-3		
1	-19.3348	-.504242		
10	-74.0925	-11.2423		
SECTION NO. 5	:			
.1	-3.29286 E-2	-1.48035 E-6		
1	-.329281	-1.43481 E-4		
10	-3.28924	-1.43209 E-2		
SECTION NO. 6	:			
.1	19.3348	.504242		
1	74.0925	11.2423		
10	88.3675	30.9066		
SECTION NO. 7	:			
.1	-2.00956	-5.34356 E-3		
1	-19.3348	-.504242		
10	-74.0925	-11.2423		

4. **Here's the computer solution (top) for the feedback system** shown in Fig. 3. Note the ease of reference inherent in this type of print-out. A graphic gain vs frequency plot (bottom) is also part of the print-out, highlighting the value of this computer-aided approach.

variable V in line 10150 which divides W into ten 6-character groups. The nested L-loop (10140-12000) and the over-all L1-loop (10130-12010) print one graph line in ten groups, with the print-out for each determined by the value of V. If V is between 0 and 5 for a particular group, a graph point (an asterisk) is plotted at the correct location by lines 10160-10720. If V is not between 0 and 5 for that group, then a graph grid (a plus sign) is plotted where required by lines 11000-11400.

Sample design illustrates technique

A typical feedback-system (Fig. 3) design problem will serve to demonstrate the computer-aided approach. The specifications for this second-order phase-locked loop are that it have a minimum bandwidth of 1 Hz and an attenuation at 10 Hz of at least 40 dB. With the aid of the computer program of Table 1, the theoretical frequency response of the system can be calculated from the circuit parameters of Fig. 5. In particular, the gain and phase margins of the open-loop transfer function, and the 3-dB bandwidth, 10-Hz attenuation, and resonant rise of the closed-loop transfer function can be precisely determined.

In order to express the system of Fig. 3 in suitable computer format, the open-loop transfer function must be broken down into a series of transfer subfunctions, each of which corresponds to one of the sections of Fig. 2.

The first section is an integrator (type 5), composed of the phase detector and *VCO*, with the transfer subfunction:

$$A_1(s) = (200\ \text{Hz/V})\,(1\ \text{V/rad})\,(2\pi\ \text{rad/s}) = 400\pi/s. \tag{10}$$

The second section is a constant (type 7), composed of the input and output resistive dividers, with the transfer subfunction:

$$A_2(s) = (8.2\ \text{K}/384.2\ \text{K})\,(2.2\ \text{K}/10.4\ \text{K}) = 0.00451. \tag{11}$$

The third section is another integrator (type 5), composed of the 56-kΩ and 560-kΩ resistors and the 1.0-μF capacitor in the operational amplifier circuit, with the transfer subfunction:

$$A_3(s) = 1/(0.616\ \text{M})\,(1.0\ \mu\text{F})\,(s) = 1.62/s. \tag{12}$$

The fourth section is low-pass (type 1), composed of the first 56-kΩ series resistor and 1.0-μF capacitor to ground, with the transfer subfunction:

$$A_4(s) = 1/[1 + 0.056\ \text{M}/(1.0\ \mu\text{F})\,(s)] = 1/(1 + 0.056/s). \tag{13}$$

The fifth section is another low pass (type 1), composed of the 100-kΩ series resistor and the 0.01-μF shunt capacitor to ground, with the transfer subfunction:

$$A_5(s) = 1/[1 + (0.100\ \text{M}/0.01\ \mu\text{F})] = 1/[1 + (10/s)]. \tag{14}$$

The sixth section is a reciprocal low pass (type 2), composed of the second series 56-kΩ resistor and the 1.0-μF capacitor at the operational amplifier input, with the transfer subfunction:

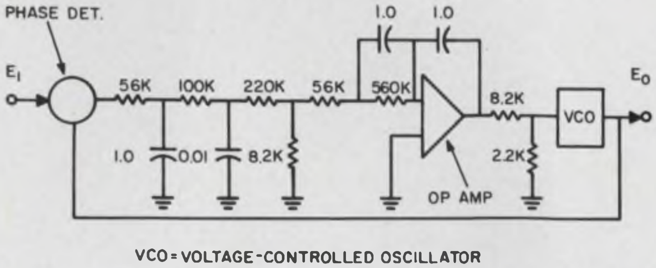
$$A_6(s) = 1 + [0.056/(1.0\ \mu\text{F})\,(s)] = 1 + (0.056/s). \tag{15}$$

The last section is a low pass (type 1), composed of the 560-kΩ resistor and 1.0-μF parallel capacitor at the operational amplifier input, with the transfer subfunction:

$$A_7(s) = 1/1 + [0.560\ \text{M}/(1.0\ \mu\text{F})\,(s)] = 1/[1 + (0.56/s)]. \tag{16}$$

The gain of each of these sections is zero except for section 2, which has a gain of −46.9 dB. The critical frequency in Hz of the integrator sections is the zero-gain frequency, which is 200 for section 1 and 0.258 for section 3. The critical frequency of the constant section is immaterial and is arbitrarily set equal to 1 for section 2. The critical frequencies for the low-pass and reciprocal low-pass sections are the 3-dB corner frequencies, which for sections 4, 5, 6, and 7 are 2.85, 174, 0.284, and 2.85 Hz, respectively.

The computer solution to the problem of Fig. 3 is shown in Fig. 4. Here a two-decade frequency range centered at 1 Hz is selected as the frequency range of interest, and the over-all open-loop transfer function is divided into the seven sections of Eq. 10-16. The preliminary print-out of the individual section data may be used to check the computer calculations of Eqs. 10 through 16 at the 0.1-, 1- and 10-Hz frequency points. The print-out of the composite frequency response shows that the open-loop gain and phase margins are 14.6 dB and 40 degrees, and that the closed-loop 3-dB bandwidth, 10-Hz attenuation, and resonant rise are 1.5 Hz, 44.2 dB, and 3.74 dB, respectively. And for the engineer who likes his data in graphical form, the final print-out gives a Bode plot (dB gain vs logarithmic frequency) of the closed-loop transfer function. ■ ■



3. **Using this sample feedback system,** the design technique discussed in the text can be demonstrated.

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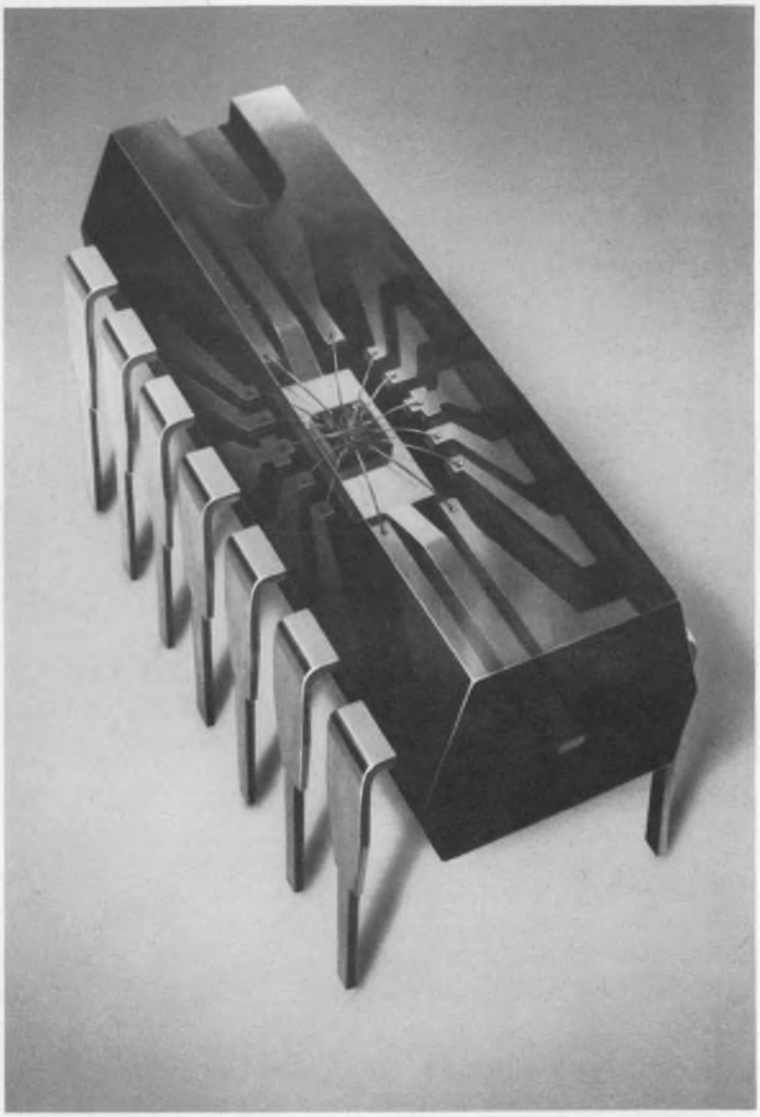

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SN7450N	Expandable Dual AND-OR-INVERT Gate
SN7451N	Dual AND-OR-INVERT Gate
SN7453N	Expandable 2-input 4-wide AND-OR-INVERT Gate
SN7454N	2-input 4-wide AND-OR-INVERT Gate
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SN15833N	Dual 4 Expander
SN15844N	Dual 4 Power Gate
SN15845N	RS/JK Flip-flop
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SN15862N	Triple 2 Nand Gate

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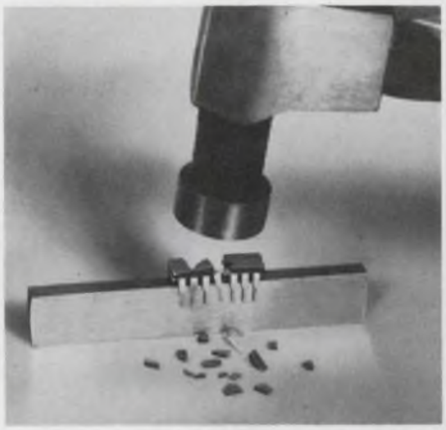

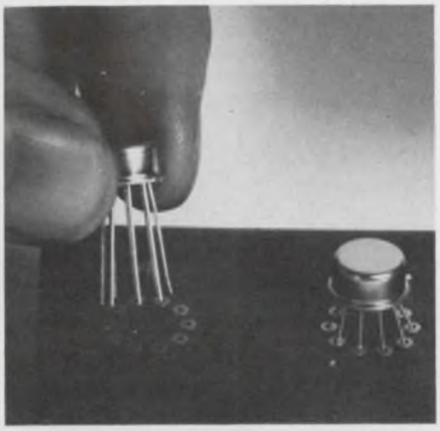

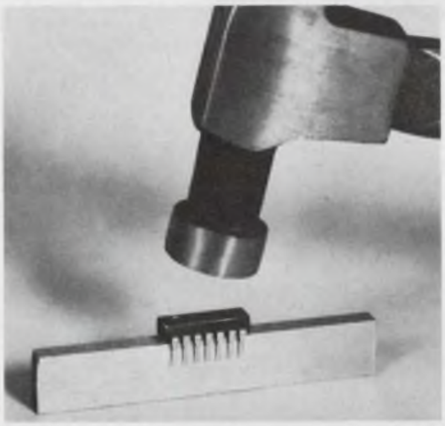

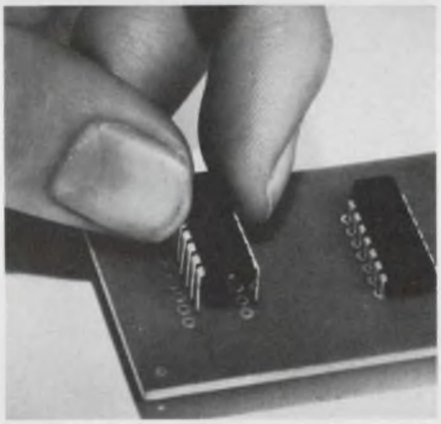

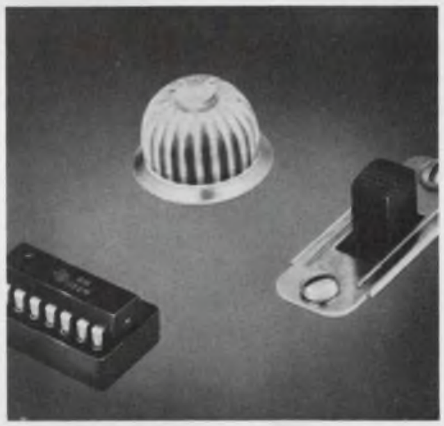

RESISTS SHOCK... TI molded integrated circuits resist impacts that would smash metal packages and shatter ceramic packages as shown in top photo. You benefit from fewer failures in handling accidents and greater reliability in service. The solid molded construction gives extreme resistance to acceleration, vibration and shock as proven in actual test (see opposite page).

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ON READER-SERVICE CARD CIRCLE 35

Need a circuit design program? Why not custom-tailor one to fit your needs? Here's an example that shows you how it can be done.

There are a number of excellent computer programs for circuit analysis now available to the general user.* They have been well documented and work within their defined scope of operation. However, as these programs are major systems best run on larger-scale computers, the total time required is often so excessive as to be impractical for the typical engineering user. Furthermore in using these programs, the engineer tends to lose touch with his circuit because generally he does not know the programed algorithm, the step-by-step procedure followed by the computer for the circuit analysis.

This particular problem tends to be compounded by the fact that any single circuit problem is usually worked on by an entire programing group. This may well lead to further frustrations through lack of communication and end up in the frequently heard complaint by the engineering user that the program is "no good"; it doesn't solve his particular circuit problem. The fact is that frequently some input requirement or other detail has been either garbled or omitted entirely.

In the light of all these problems, the authors saw a need for a circuit-design program that would:

- Be capable of running on a number of different small-scale computers, so that it would be readily available to many users as well as be efficient in terms of running time.
- Demonstrate the features and operation of larger circuit-design programs.

To this end an algorithm was developed to generate a program called AMPLI (Program for Analysis of Amplifier Circuits). AMPLI omits a number of the elaborate automatic-input-setup features found in the major program systems. It has been our experience that the engineering user has no problems in defining these and that the saving in programing effort and time is justified.

In brief, then, the AMPLI algorithm was developed to obtain the frequency response of an electrical circuit composed of conventional circuit elements. The engineering user must define the topological hook-up, including element values and the equivalent circuit model for transistors, and the frequencies of interest. The program in turn develops node voltages which can be used to calculate frequency response, including gain and phase angle. The actual computer program can be readily developed from the detailed algorithm described here by use of one of the higher-order program languages (i. e., those languages closer to plain English), such as FORTRAN II or IV, as opposed to machine language.

Matrix is heart of AMPLI program

The essential information needed by an ac analysis program consists of:

- Control parameters.
- Circuit parameters (independent and dependent).
- Parameter interconnections.

The *control parameters* needed for input to the program are the number of circuit nodes, the number of circuit branches and the number of frequency points at which calculations are to be made. These can be read into the computer on one punched card.

Independent circuit parameters include a listing

*PREDICT—Given a simple topological description, the program solves for the transient response of large, nonlinear electrical circuits. Its output includes listings of computed responses and machine-plotted graphs. It requires initial conditions for capacitors and inductors. Written in FORTRAN II and FAP, it is available for use on the IBM 7090/7094 Series with the approval of the Air Force Weapons Laboratory.

NET-1—From topological circuit description and control statements the program performs a dc steady-state and transient-response analysis of a large class of electrical circuits composed of conventional elements. The program has a built-in Ebers-Moll model for nonlinear devices with provision to alter parameters at check-out. Written in FAP, the program is available for the IBM 7040/44 and 7090/94 Series.

ECAP—The program performs ac-dc and transient analysis of electrical circuits, given a topological description. Many features are available for the dc portion. It is written in FORTRAN II for the IBM 1620.

Fred R. Decker, Manager, and **Augustine J. Welling,** Senior Engineer, Design Analysis Section, Honeywell EDP Division, Waltham, Mass.

of the passive components and independent sources by branch. That is, the value of resistance, inductance, capacitance, source voltage per branch and source current per branch—all of which are put on one card. The direction of branch-current flow has been purposely omitted at this point.

In the large, generalized programs, current direction information is included with the passive elements by indicating the initial and final nodes of a branch. This information is used in the program to generate the node incidence matrix **A** (see Table 1).

Information on feedback and *dependent circuit parameters* (which result from branch interactions and include controlled sources) covers any interaction between the various branches. Two such interactions are mutual inductance and the βi_b factor in the collector branch of a grounded emitter, for example. The direction of the induced disturbance is important and care has to be exercised lest erroneous results occur. Feedback information can be put directly in the **Y** circuit admittance matrix or order n where n equals the number of circuit nodes.

Finally, in AMPLI, *parameter interconnection* information is treated as a separate entity and read into the program. Since the matrix contains only 0, +1, and −1 elements, a FORTRAN format of 40 F2.0 can be used. The result is 40 element locations per card, but only the +1 and −1 elements need be punched. (One card was needed for the circuit problem used later in this article.)

The central program task involves solution of the matrix equation $(\mathbf{A}^t\mathbf{YA})e = \mathbf{A}^t\,(\mathbf{I}-\mathbf{YE})$, which represents the circuit node equations. Vectors **I** and **E** contain the values of the independent sources in each branch. Circuit connectivity information is contained in matrix **A**, while $\mathbf{A}^t$ is the transpose of **A**. All remaining circuit information is contained in circuit admittance matrix **Y**.

Table 1. Explanation of matrix notation

A—node incidence matrix, a matrix containing circuit connectivity information. Elements are 0, +1, −1. The rows of the matrix correspond to circuit branches and the columns correspond to circuit nodes. If a branch current, i, is oriented away from, towards or not connected to a given node j; then $\mathbf{A}(i, j) = (+1, -1, 0)$.

$\mathbf{A}^t$—the transpose of **A**. Rows and columns are interchanged. $\mathbf{A}^t(j, i) = \mathbf{A}(i, j)$.

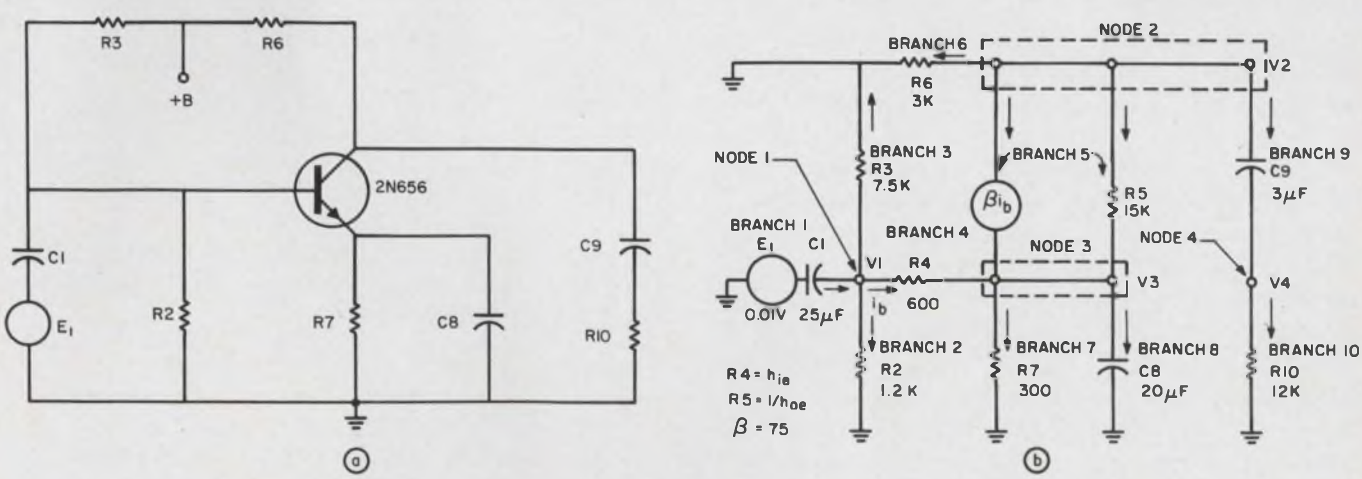
$\mathbf{A}^t\mathbf{YA}$—circuit nodal admittance matrix contains the coefficients of e (node voltages) in circuit nodal equations.

$(\mathbf{A}^t\mathbf{YA})^{-1}$—the inverse of the circuit nodal admittance matrix. Sometimes referred to as the circuit solution matrix, since the solution of $e = (\mathbf{A}^t\mathbf{YA})^{-1}[\mathbf{A}^t(\mathbf{I}-\mathbf{YE})]$.

This information may be considered to be divided into two parts: independent and dependent factors. The independent factors are the values of the circuit passive components and lie on the diagonal of **Y**. Off-diagonal elements of **Y** contain feedback or dependent information, if any.

Once the individual matrices and vectors are set up, straightforward matrix multiplication develops the circuit nodal admittance matrix $\mathbf{A}^t\mathbf{YA}$ and the circuit source vector $\mathbf{A}^t(\mathbf{I}-\mathbf{YE})$. Inverting $\mathbf{A}^t\mathbf{YA}$ with a suitable matrix inversion subroutine and matrix multiplication develops the node voltages: $e = (\mathbf{A}^t\mathbf{YA})^{-1}[\mathbf{A}^t(\mathbf{I}-\mathbf{YE})]$. In actual practice, **Y** would be divided into real and imaginary parts: 1/R and the real terms of feedback would be contained in $\mathbf{Y}_R$; $\omega C - 1/\omega L$ and the imaginary feedback terms would be contained in $\mathbf{Y}_I$. $\mathbf{A}^t\mathbf{Y}_R\mathbf{A}$ and $\mathbf{A}^t\mathbf{Y}_I\mathbf{A}$ would be the results and would require an inversion routine capable of handling a complex matrix.

Once the node voltages are calculated for one frequency, output-to-input ratios can be generated



Analysis of single-stage amplifier (a) demonstrates AMPLI's capabilities. The equivalent circuit (b) is shown labeled with branch and node numbers which are required for data input to the computer.

along with gain and phase data. Repeating the entire process for each frequency of interest essentially completes the program. The entire process can be illustrated by a simple example.

Example illustrates program operation

The following shows how the amplifier circuit in Fig. 1 was analyzed with AMPLI. Steps leading to the equations and node voltages for the circuit of Fig. 1 are given below. The frequency at which the calculations were made is 1000 Hz.

Step 1: The node incidence matrix **A** for the circuit of Fig. 1 is constructed with the method of notation shown in Table 1. To see how these coefficients are obtained, notice that the current in branch 1 (Fig. 1) flows towards node 1: therefore the coefficient −1 (circled) is inserted in the matrix. The remaining terms are obtained in similar fashion and the final result is shown below. The four columns of **A** represent the four nodes, numbered from left to right: the 10 rows of **A** represent the 10 branches, numbered from top to bottom:

$$A = \begin{vmatrix} -1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

Step 2: Transpose **A** to yield:

$$A^{-1} = \begin{vmatrix} -1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & -1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 \end{vmatrix}$$

Step 3: Now the circuit admittance matrix **Y** must be constructed. This matrix contains both real and imaginary terms (i.e., 1/R and $j\omega C$) representing the independent circuit elements shown on the diagonal, and βi_b (75/600 = 0.125 E0), the dependent or feedback element shown as an off-diagonal element. Each term is obtained by finding the reciprocal of the resistance and/or reactance contained in each branch. For example, the uppermost term shown below, j 0.1570 E−1 is simply the reciprocal of the reactance of *C1* at 1000 Hz in branch 1. The "E−1" represents the FORTRAN expression for 10^{-1}; similarly E0=1, E−4=10^{-4}, etc. Remaining terms are applied in similar fashion.

The complete circuit admittance matrix **Y**, containing both real and imaginary terms, is:

$$Y = \begin{vmatrix} \text{j 0.15708 E-1} & & & & & & & & & \\ & \text{0.83333 E-3} & & & & & & & & \\ & & \text{0.13333 E-3} & & & & & & & \\ & & & \text{0.16667 E-2} & & & & & & \\ & & & \text{0.125 E 0} & \text{0.66667 E-4} & & & & & \\ & & & & & \text{0.33333 E-3} & & & & \\ & & & & & & \text{0.33333 E-2} & & & \\ & & & & & & & \text{j 0.12566 E 0} & & \\ & & & & & & & & \text{j 0.18849 E-1} & \\ & & & & & & & & & \text{0.83333 E-4} \end{vmatrix}$$

Step 4: Construct the voltage vector matrix. Since the voltage vector **E** has only one value (i.e., *E1* = 0.01 V) and that is in branch 1, the circuit source vector − $\mathbf{A^tYE}$ becomes:

$$-\mathbf{AYE} = \begin{vmatrix} \text{0.15708 E-3} \\ 0.0 \\ 0.0 \\ 0.0 \end{vmatrix}$$

These four steps constitute all the manual calculations required of the engineer.

After the computer has performed matrix multiplication, according to the program shown in table 2, the real and imaginary parts of the circuit nodal admittance matrix are:

$\mathbf{A^tY_RA}$ (Real components) =

$$\begin{vmatrix} \text{0.26333E-2} & 0.0 & \text{-0.16667E-2} & 0.0 \\ \text{0.125E0} & \text{0.4E-3} & \text{-0.12507E0} & 0.0 \\ \text{-0.12667E0} & \text{-0.66667E-4} & \text{0.13007E0} & 0.0 \\ 0.0 & 0.0 & 0.0 & \text{0.83333E-4} \end{vmatrix}$$

$\mathbf{A^tY_IA}$ (Imaginary components) =

$$\begin{vmatrix} \text{0.15708E-1} & 0.0 & 0.0 & 0.0 \\ 0.0 & \text{0.18849E-1} & 0.0 & \text{-0.18849E-1} \\ 0.0 & 0.0 & \text{0.12566E0} & 0.0 \\ 0.0 & \text{-0.18849E-1} & 0.0 & \text{0.18849E-1} \end{vmatrix}$$

After matrix inversion:

$[\mathbf{A^tYA}]_R^{-1}$ (Real components) =

$$\begin{vmatrix} \text{-0.69199E1} & \text{0.54291E-1} & \text{0.39327E0} & \text{0.54019E-1} \\ \text{0.84639E4} & \text{-0.22102E4} & \text{-0.10249E4} & \text{-0.22108E4} \\ \text{0.25817E2} & \text{-0.49205E0} & \text{-0.35707E1} & \text{-0.49473E0} \\ \text{0.84987E4} & \text{-0.22108E4} & \text{-0.10294E4} & \text{-0.22116E4} \end{vmatrix}$$

$[\mathbf{A^tYA}]_I^{-1}$ (Imaginary components) =

$$\begin{vmatrix} \text{0.59763E2} & \text{0.61309E-1} & \text{0.44479E0} & \text{0.61549E-1} \\ \text{-0.79050E4} & \text{0.14329E3} & \text{0.10267E4} & \text{0.13352E3} \\ \text{0.29206E2} & \text{0.60855E0} & \text{0.44092E1} & \text{0.60636E0} \\ \text{-0.78674E4} & \text{0.13352E3} & \text{0.10221E4} & \text{0.17679E3} \end{vmatrix}$$

Using the preceding results, the computer then produces the node voltages by calculating $e = (\mathbf{A^tYA})^{-1}[\mathbf{A^t(I - YE)}]$:

Node	Node voltages *Real*	Node voltages *Imaginary*
1	−0.93875E−2	−0.10870E−2
2	0.12417E1	0.13295E1
3	−0.45877E−2	0.40553E−2
4	0.12358E1	0.13350E1

Table 2. FORTRAN statements for amplifier analysis

```
TITLEAMFIER
      DIMENSION R(70),RI(70),ELL(70),HI(70),H(70),
      C(70,25),CT(25,70),XAR(70),AI(70),ZR(70),ZI(70),
      BR(25,70),A(25,25),BS(25,70),B(25,25),XVORT(25),
      VOIT(25),HH(70),HC(70),FBR(25,25),VMAG(25),
      WW(35)X,FBI(25,25)
      PRINT 797
  797 FORMAT(34H TRANSISTOR AMPLIFIER DESIGN CHECK//)
      READ 1,N,NBR,LKNO,KW,NX
    1 FORMAT(5I10)
      READ 2,((C(I,J),J=1,LKNO),I=1,NBR)
    2 FORMAT(40F2.0)
      PRINT 3,((C(I,J),J=1,LKNO),I=1,NBR)
    3 FORMAT(//9H C MATRIX,//(4F5.1))
      DO 5 I=1,NBR
      DO 5 J=1,LKNO
    5 CT(J,I)=C(I,J)
      READ 4,(R(I),ELL(I),H(I),AR(I),AI(I),I=1,NBR)
    4 FORMAT(5E15.7)
      READ 62,(WW(I),I=1,KW)
   62 FORMAT(4E20.7)
      READ 61,((FBR(I,J),J=1,LKNO),I=1,LKNO)
      READ 61,((FBI(I,J),J=1,LKNO),I=1,LKNO)
   61 FORMAT(4E20.7)
      QW=180.0/3.14159
      DO 63 I=1,KW
      WW(I)=3.14159*2.0*WW(I)
   63 CONTINUE
      DO 888 L=1,KW
      W=WW(L)
      DO 56 I=1,NBR
      IF(R(I)) 57,58,57
   57 RI(I)=1.0/R(I)
      GO TO 56
   58 RI(I)=0.0
   56 CONTINUE
      DO 7 I=1,LKNO
      DO 7 J=1,NBR
      BR(I,J)=CT(I,J)*RI(J)
    7 CONTINUE
      DO 12 I=1,LKNO
      DO 12 J=1,LKNO
      A(I,J)=0.0
      DO 12 K=1,NBR
      A(I,J)=BR(I,K)*C(K,J)+A(I,J)
   12 CONTINUE
      DO 6 I=1,LKNO
      ZR(I)=0.0
      ZI(I)=0.0
      DO 6 J=1,NBR
      ZR(I)=CT(I,J)*AR(J)+ZR(I)
      ZI(I)=CT(I,J)*AI(J)+ZI(I)
    6 CONTINUE
      DO 66 I=1,NBR
      IF(ELL(I)) 67,68,67
   67 HI(I)=-1.0/(ELL(I)*WW(L))
      GO TO 66
   68 HI(I)=0.0
   66 CONTINUE
      DO 76 I=1,NBR
      HC(I)=H(I)*WW(L)
   76 CONTINUE
      DO 77 I=1,NBR
      HH(I)=HI(I)+HC(I)
   77 CONTINUE
      DO 9 I=1,LKNO
      DO 9 J=1,NBR
      BS(I,J)=CT(I,J)*HH(J)
    9 CONTINUE
      DO 13 I=1,LKNO
      DO 13 J=1,LKNO
      B(I,J)=0.0
      DO 13 K=1,NBR
      B(I,J)=BS(I,K)*C(K,J)+B(I,J)
   13 CONTINUE
      DO 690 I=1,LKNO
      DO 690 J=1,LKNO
      A(I,J)=A(I,J)+FBR(I,J)
      B(I,J)=B(I,J)+FBI(I,J)
  690 CONTINUE
      CALL INVERT(B,A,N,D,DI)
      DO 14 I=1,LKNO
      VORT(I)=0.0
      DO 14 J=1,LKNO
      VORT(I)=-A(I,J)*ZR(J)+B(I,J)*ZI(J)+VORT(I)
   14 CONTINUE
      DO 15 I=1,LKNO
      VOIT(I)=0.0
      DO 15 J=1,LKNO
      VOIT(I)=-B(I,J)*ZR(J)-A(I,J)*ZI(J)+VOIT(I)
   15 CONTINUE
      DO 411 I=1,LKNO
      VMAG(I)=SQRT(VORT(I)**2+VOIT(I)**2)
  411 CONTINUE
      VIN=VORT(1)**2+VOIT(1)**2
      VRT=SQRT(VORT(NX)**2+VOIT(NX)**2)
      EG =VRT/SQRT(VIN)
      DBG=(20.0*ALOG(EG))/(ALOG(10.0)
      IF(VOIT(NX)) 22,99,22
   22 IF(VORT(NX)) 24,999,23
   23 ANG=ATAN(VOIT(NX)/VORT(NX))*QW
      GO TO 80
   24 ANG=(3.14159+ATAN(VOIT(NX)/VORT(NX)))*QW
      GO TO 80
   99 ANG =0.0
      GO TO 80
  999 ANG =90.0
   80 CONTINUE
      PRINT 89,(VORT(I),VOIT(I),I=1,LKNO)
   89 FORMAT(//23H VOLTAGE OUTPUT BY NODE/(2E20.7))
      PRINT 33
   33 FORMAT(//10B, 10H FREQUENCY, 7B,13H VOLTAGE
      GAIN, 12B, 8H DB GAIN, X8B, 12H PHASE ANGLE//)
      PRINT 34, W, EG, DBG, ANG
   34 FORMAT(4E20.7)
  888 CONTINUE
  902 STOP
      END
      SUBROUTINE INVERT(B,A,N,D,DI)
      DIMENSION B(25,25),K(25),P(25),A(25,25),PI(25)
      NN=IABS(N)
      D=1.0                                          15
      DI=0.
      NI=NN+1
      CALL OVERFL(KK)
20    DO 30 I=1,NN                                   22
30    K(I)=I                                         23
      IF(N)420,430,430
  430 I=1
  431 CONTINUE
      I2=NI-I
      PE=0.                                          28
      DO 120 I1=I,I2                                 29
      TPE=ABS(B(I1,1))
      IF(PE-TPE)100,120,120
100   PE=TPE                                         32
110   IP=I1                                          33
120   CONTINUE                                       34
      IF(PE)16,16,10
17    DI=0.
16    D=0.
15    N=0
      RETURN
10    PE=1./B(IP,1)
      D=D*B(IP,1)
      IF(MOD(IP,2))130,130,160
130   D=-D                                           37
160   DO 170 J=2,NN                                  41
170   P(J-1)=B(IP,J)*PE
      P(NN)=PE
190   IP=K(IP)                                       47
      I2=0                                           48
      DO 310 J=1,NN                                  49
      I1=J-I2                                        50
      IF(I2)180,180,340
180   IF (K(J)-IP) 260,250,260                       52
250   I2=1                                           53
      GO TO 310                                      54
340   K(I1)=K(J)                                     51
260   IF(B(J,1))290,270,290
270   DO 280 J1=2,NN                                 57
  280 B(I1,J1-1)=B(J,J1)                             58
      B(I1,NN)=0.                                    59
      GO TO 310                                      60
290   TPE=B(J,1)
      DO 300 J1=2,NN
300   B(I1,J1-1)=B(J,J1)-TPE*P(J1-1)
      B(I1,NN)=-TPE*P(NN)
310   CONTINUE                                       64
      CALL OVERFL(KK)
      GO TO (15,140),KK
140   DO 320 J=1,NN                                  65
320   B(NN,J)=P(J)                                   66
330   K(NN)=IP                                       67
      I=I+1
      IF(I-NN)431,431,350
350   CONTINUE                                       71
      DO 410 I=1,NN                                  72
      DO 400 J=1,NN                                  73
      I1=K(J)                                        74
400   P(I1)=B(I,J)                                   75
      DO 410 J=1,NN                                  76
410   B(I,J)=P(J)                                    77
      RETURN
420   DO 810 I=1,NN
      I2=NI-I
      PE=0.
      DO 450 I1=1,I2
      TPE=A(I1,1)**2+B(I1,1)**2
      IF(PE-TPE)460,450,450
460   PE=TPE
      IP=I1
450   CONTINUE
      IF(PE)19,19,480
480   PER=B(IP,1)/PE
      PEI=-A(IP,1)/PE
      E=D*B(IP,1)-DI*A(IP,1)
      DI=D*A(IP,1)+DI*B(IP,1)
      D=E
      IF(MOD(IP,2))470,470,481
470   D=-D
      DI=-DI
481   DO 600 J=2,NN
      P(J-1)=B(IP,J)*PER-A(IP,J)*PEI
600   PI(J-1)=B(IP,J)*PEI+A(IP,J)*PER
      P(NN)=PER
      PI(NN)=PEI
      IP=K(IP)
      I2=0
      DO 500 J=1,NN
      I1=J-I2
      IF(I2)510,510,520
510   IF(K(J)-IP)530,540,530
540   I2=1
      GO TO 500
520   K(I1)=K(J)
530   PER=B(J,1)
      PEI=A(J,1)
      DO 550 J1=2,NN
      B(I1,J1-1)=B(J,J1)-PER*P(J1-1)+PEI*PI(J1-1)
550   A(I1,J1-1)=A(J,J1)-PER*PI(J1-1)-P(J1-1)*PEI
      B(I1,NN)=PEI*PI(NN)-PER*P(NN)
      A(I1,NN)=-P(NN)*PEI-PI(NN)*PER
500   CONTINUE
      CALL OVERFL(KK)
      GO TO (15,560),KK
560   DO 570 J=1,NN
      B(NN,J)=P(J)
570   A(NN,J)=PI(J)
      K(NN)=IP
810   CONTINUE
      DO 580 I=1,NN
      DO 590 J=1,NN
      I1=K(J)
      P(I1)=B(I,J)
590   PI(I1)=A(I,J)
      DO 580 J=1,NN
      B(I,J)=P(J)
580   A(I,J)=PI(J)
      RETURN
   19 I=NN+1
      GO TO 17
      END                                            79
```

The final circuit nodal admittance matrix **A'YA** can be considered as the superposition of two matrices. If, initially, **Y** contained only diagonal elements (independent parameters), the resulting **A'YA** plus a feedback matrix would yield the final nodal admittance matrix. Both the initial **A'YA** and the feedback matrix would be square, with an order corresponding to the number of circuit nodes. The circuit nodes correspond to the rows of the so-called feedback matrix while the circuit nodes' voltages correspond to the columns. From the example, feedback from branch 4 to branch 5 results in element values of $\pm 75/600$ in locations 2,1, 2,3, 3,1 and 3,3, both in the feedback matrix and the final $\mathbf{A^tYA}$.

Bilateral feedback between two branches affects two off-diagonal elements in **Y** and results in eight elements in $\mathbf{A^tYA}$ if neither branch has a ground. In general:

If Feedback is:	and circuit has:	then the number of elements of **Y** affected is:	and results in $\mathbf{A^tYA}$ elements:
Unilateral	No grounds	1	4
Unilateral	1 ground	1	2
Unilateral	2 grounds	1	1
Bilateral	No grounds	2	8
Bilateral	1 ground	2	4
Bilateral	2 grounds	2	2

An admittance value for an independent, passive, ungrounded component appears in four locations in the $\mathbf{A^tYA}$ matrix. A component connected between nodes 2 and 3 will appear in positions 2,2, 2,3, 3,2 and 3,3. This is just another way of looking at the nodal equations, but it can be helpful in visualizing the nodal admittance matrix.

The transistor y-parameter equivalent circuit may also be used rather than the active model shown in the example. This is useful when transistor high-frequency effects cannot be ignored. A small, flexible program can handle this problem since it is mostly a question of reading in parameter values or devising a simple function describing $y(f)$. Obtaining the transistor y-parameters as a function of frequency, however, is not easy.

To summarize, the algorithm employed in AMPLI will permit the user to develop a computer program to simulate the frequency response of a transistor amplifier circuit. Given an amplifier circuit, the program will generate a frequency analysis with no circuit equations required; the engineer need provide only the circuit mapping, component values and frequencies of interest. Aside from conventional circuit element values, the transistor model with associated parameters is required. Mapping is covered by the connectivity or branch node incident matrix as described.

Next, for each frequency specified, a set of simultaneous equations is set up for each circuit node. Following matrix inversion, the unknown voltages are solved for. Then by equating the first and last node voltage, the over-all gain in dB can be readily determined.

AMPLI is easily modified

In its present form the algorithm could easily be augmented or revised. For example, it would be possible to use any transistor model of interest. Phase angle calculations could be added to the program. Sensitivity analysis could also be added along with a provision for statistical analysis. At this point it would be possible to suggest a large variety of features and output modes. However, these are best dictated by actual user requirements.

Conversion of the algorithm described here to a computer program can be readily accomplished by any program applications group, or, for that matter, by the engineer himself, provided that he has some programing background. The simplicity of the method is demonstrated by the fact that the algorithm was converted to a computer program (FORTRAN II) of less than 150 statements for a computer that included matrix inversion subroutine as shown in Table 2.

Following exploitation of the ac analysis, the engineer would most likely proceed to a dc steady-state analysis, and subsequently a time-domain or transient analysis. But at this point the user might be well advised to use one of the major program systems cited earlier in this article.

Finally, what of the computer programs for circuit analysis that are becoming increasingly available to engineering users? Program distribution centers, exchange groups, both government- and industry-funded, have been set up or are in the process of being set up. These hold great promise for the future.

However, we believe that the engineering user cannot depend entirely on outside sources for circuit analysis programs. Our reasons for this include:

- Compatibility of program languages.
- Incomplete program documentation.
- System operation details.

Also the user, by developing his own competence in this field, will be in a stronger position to evaluate the various program systems offered as well as tackle such undertakings as adding program features or revising the program. ■ ■

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Check design program availability

with this listing of computer programs developed for the design and analysis of electronic circuits.

Granted the availability of a digital computer, the design engineer who intends to use the machine as a design tool must have the necessary "software" (computer program).

To obtain the right software, he must either write his own program or adapt an existing one to his needs.

The first of these alternatives is not always possible, and may not even be desirable. The second is generally the better choice. A representative list of existing computer programs follows.

The programs are arranged in the Table alphabetically, by company or institution. The availability of each program is indicated at the end of each description by one of three letters:

(A) Supply your own blank tape, and the program will be written on it at no charge. Instruction manuals are usually available either at no cost or for a small fee.

(B) The program is available on an exchange basis.

(C) Availability is subject to individual negotiation.

Where possible, a description of the program's capabilities has been provided, together with those computers on which the program may be run.

If a design engineer does not have computer facilities at hand, he may turn to such companies as Design Automation of Lexington, Mass., which will perform batch processing of circuit-analysis problems.

Present programs are not perfect

While a number of powerful and useful programs are available, the relative novelty of computer-aided design implies that a large amount of development work must still be done. Some of the improvements that can be expected in the foreseeable future are:

- Better nonlinear models and more flexible means of insertion. For example, MOS-FETs are not at present properly modeled for transient analysis for a large class of circuits.
- Faster computer running time for frequency analysis problems.
- Partitioning of long computer programs into distinct segments, any of which may be selected from tape or disk files. This reduces the computer core memory requirement, NET-1, for example, a 30,000-word program, is divided into nine such segments. In this time-sharing age, a bulky program occupying the core memory of a computer could reduce the computer's availability for time-shared activities to nil.
- Simpler inputs and outputs, and cheap, simple graphical displays. The aim is to make the computer as easy for an engineer to operate as possible.
- Automatic circuit parameter variation.

In the meantime the electronic designer still has available to him a sizable package of computer programs that will help him to conceive and develop better designs. ■ ■

John Dumanian, Aerospace Technologist, NASA Electronics Research Center, Cambridge, Mass.

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Company	Program	Description
Autonetics 3370 Miraland Ave. Anaheim, Calif. R. S. Miles		The following programs are written in Fortran II and are programed for the IBM 7094. At present they are being rewritten in Fortran IV in one consolidated large program for insertion in the IBM 360 computer. Later another revision will be made into the PL1 language.
	MANDEX WORST CASE METHOD	Performs ac steady-state and/or dc worst-case analyses. It uses circuit equations and requires nominal values and end-of-life limits on parts. It can handle 75 input parameters, 40 output variables and a 40 x 40 matrix. The types of circuits which can be handled are Class-A amplifiers, power supplies, logic circuits (for each state), comparators, switches, flip-flops, etc. (C)
	MOMENT METHOD	Statistical-type program that, when given the mean and variance of individual components, gives the mean and variance of the circuit outputs. The program uses circuit or matrix equations. (C)
	MONTE CARLO METHOD	Statistical program that predicts the output variable for dc, ac or transient inputs. It uses circuit or matrix equations or circuit transfer function. The distributions of all the electronic components must be supplied. The outputs are described by 20-cell histograms. (C)
	VINIL METHOD	Uses piecewise linear equivalent circuits as models and requires drift data. It presents the transfer characteristics (max & min), output characteristic (max & min) and the input characteristic (max & min). It also calculates the stress ratios for failure rate prediction and indicates parameter settings for the worst-case conditions, for digital and linear circuits. (C)
	PARAMETER VARIATION METHOD	Determines the one-at-a-time and two-at-a-time allowable parameter variation before a circuit fails to function. Circuit or matrix equations are used and the nominal value of parameters is required as well as their per cent change. Output schmoo plots determine the safe operating zone. (C)
	SPARC	Performs dc analysis (AEM-1), ac analysis (AEM-2), transient analysis (AEM-3) on the Recomp 11 computer. Equivalent circuit equations or matrices must be prescribed as well as the mean and $\pm 3\sigma$ (σ = standard deviation) components of the circuits. (C)
	SCAN DC	Performs linear and nonlinear static analysis of circuits, with the equations of the circuits presented in matrix form and the components specified by the mean and 3σ values. The output gives nominal solutions and partial derivatives of unknowns with respect to knowns, worst-case values, and the probability of the unknowns being outside specified values. This program permits a more realistic type of statistical analysis than that done by purely worst-case methods as statistical correlations and the averaging effect of random variation in parameters. (C)
	SCAN AC	Performs linear, sinusoidal, dynamic analysis when complex variable equations of circuits are presented along with the mean and $\pm 3\sigma$ values of the components. Families of frequency response curves can be indicated as well as the $\pm 3\sigma$ values of the unknowns versus frequency. (C)
	SCAN TRANSIENT	Performs linear and nonlinear transient analysis given differential equations describing the circuit and data describing components. The output is the system time response. (C)
	CODE	Writes the node voltage equations given a topological description of the circuit and the parameter names and node equations. All circuits except those containing transformers or controlled voltage sources can be handled. (C)

(table continued on p. 78)

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(continued from p. 77)

Company	Program	Description
Bell Telephone Laboratories Murray Hill, N.J. B. J. Karafin	BLODI (Block Diagram Compiler)	Simulates sampled-data systems that are made up of filters, limiters, detectors and other functional blocks which are employed in speech compression systems, television transmission systems, and radar. (C)
	BLODI B	An improved version that will allow the user to define new blocks based on the previously defined types, to code separate, interacting simulation programs, and to define simulation subroutines by symbolic arguments. This as well as other Bell Laboratories programs are being rewritten in the PL1 language. (C)
	CODE-MANDEX	Gives the steady-state ac and/or the dc worst-case from a topological description of a circuit with the nominal values and end-of-life limits of components. The worst-case value of the output variable is compared with the allowable value. (C)
	SPADE	Performs frequency analysis and displays poles and zeros on an s-plane plot. The program requires a set of Laplace-transformed differential equations and nominal parts data. All linear circuits can be analyzed with this program. (C)
	DEE	Performs linear transient analysis given a set of Laplace-transformed differential equations or a rational polynomial in s and the nominal parts data. The maximum degree of matrix-element polynomials is five. The maximum degree of the transfer-function denominator is 23 and the numerator degree must be less than the denominator. The poles and zeros of output variables, the partial fraction expansion and the time response of the outputs are plotted for all circuits. (C)
	SYCATE	Performs failure-mode analysis, given the dc node voltage equations, nonlinear component switching expressions, application curves over operating regions, nominal and drift parameter data, and the range of permissible test-point voltages. This is, at present, a program of limited capability, for it can handle only eight transistors, 12 diodes, and 75 resistors and sources. The output is a table of test-point voltage readings vs failure modes. Any digital or analog circuit that fits can be analyzed. (C)
Bendix Corp. North Hollister Road Teterboro, N.J. Neil V. Hilsen	TRANSFER FUNCTION AND FREQUENCY RESPONSE	Input data are the nodal admittance of the specified circuit if it contains active elements. If the circuit is strictly passive, only the parameters are required. The program yields the transfer functions at any or all points in the circuit, along with the poles, zeros, and frequency response of these functions. The circuit can also be modified for design considerations (worst-case analysis, etc.). The maximum circuit dimensions are 27 nodes and 60 branches. The maximum order of output polynomials is 25. The maximum number of frequencies in each frequency response is 50. The programing is written in FORTRAN II. (C)
	INVERSE LAPLACE TRANSFORM AND TIME RESPONSE	Input data are the numerator and denominator polynomials in the s-domain along with increments of time for the time response. The program yields the inverse Laplace transform in the time domain and the time response. Also available is the time-delayed response. This consists of evaluating the function at a running time and at a delayed time, and then taking the difference. The maximum order of the input polynomials is 25. The time response can be analyzed in a total of four separate sections, each with its own time increments. The program is written in FORTRAN II. (C)
	GATE ASSIGNMENT	Assigns logic elements to flat-packs (modules) with the option of minimum, fixed number, or maximum interconnections between logic elements on the modules. (C)
	LOAD (Load Factor Analysis)	Assures the loading integrity of the circuit elements. Each logic element (gate, flip-flop, etc.) is analyzed for compatibility between load-factor and drive-factor relationships. If an incompatibility is found, additional circuitry is provided either to split the load or help drive the load. If additional circuitry is insufficient, an error message suggests further study or redesign. (C)
	LOGIC DIAGRAM	Generates a tape which contains instructions for a Calcomp or Gerber plotter. The plotter will draw a logic diagram of the switching network which has been synthesized by the NETS program. Military standard 806B symbols are used and drawings prepared in A, B, C or D size. (C)

Company	Program	Description
	TIMING ANALYSIS	Determines the internal states of the switching network for each time interval. Input stimuli and timing data are required inputs. A truth table will be printed out and a timing diagram will be plotted. (C)
	MODULE ASSIGNMENT	Assigns modules to logic cards with the option of minimum, fixed numbers, or maximum interconnections between modules on the logic card. (C)
	PATH ROUTING	Defines the location of paths used to connect module pins to module pins or module pins to terminal pins. In addition, the locations of feed-through holes are determined. (C)
General Electric P.O. Box 2500 Daytona Beach, Fla. E. W. Burdette	COMPILER	Receives input logic equations in the form of the BCD card images, converts these equations to a form usable by the computer, and generates lists (tables in core memory) containing these equations and associated data for use by the NETS program. (C)
	NETS (Network Synthesis)	Processes the compiled form of Boolean equations and reduces them to logical elements which are then assigned to a family of integrated circuit modules. (C)
International Business Machines Greenbelt Space Flight Center Greenbelt, Md. Roger Cliff	ASAP (Automated Statistical Analysis Program)	Performs Monte Carlo analysis on dc currents and voltages of circuits containing transistors and diodes. ASAP handles 50 dependent nodes (other than ground or those connected to a voltage source) and 40 diodes plus transistors. The program, which is a large one, operates on the IBM 7090/94. (C)
	ECAP (Electronic Circuit Analysis Program)	Performs ac-dc and transient analysis of electrical circuits given a topological description of the circuit. Many features are available for the dc portion. Written in FORTRAN II for the IBM 1620. (A)
	PREDICT	Yields the dc and transient response of a general network in a radiative environment. Written in FORTRAN II and FAP (FORTRAN Assembly Program), it permits an optional selection of two integration routines: one is a Runge-Kutta method which yields ±0.01% accuracy; the other is a trapezoidal method which yields ±1% accuracy but with greater numerical stability. The components R, L, C, M are functions of current, voltage or time, and, if the dependence of the sources is allowed to be linear or nonlinear, active devices may be presented. The program is written in FORTRAN II for the IBM 7094 and UNIVAC 1107 computers. It differs from IBM ECAP program in that it does not employ piecewise linear models. SCEPTRE, a newer FORTRAN IV version of this program, is due to be completed in the fall of 1966. (A)
Jet Propulsion Laboratory 4800 Oak Grove, Pasadena, Calif. W. J. Thomas	TAG (Transient Analysis Generator)	A NET-1-like program that performs dc and transient analysis. TAG is written in FORTRAN II and FAP for the IBM 7094. It can handle 100 nodes and 2 or 3 transistors with nonlinear modeling capability. Subroutines such as plotting control and program can be called for by FORTRAN commands. The preprocessor portion generates a FORTRAN program for reuse. It possesses dependent variable stops. Another unique feature is that it employs K. Lock's algorithm for minimum round-off errors.
Los Alamos Scientific Laboratory Los Alamos, N.M. Allan F. Malmberg	NET 1 (Network Analysis Program)	Performs nonlinear dc steady-state and transient analysis for any circuit which can be built from R, L, C, M, voltage sources, junction transistors and junction diodes. Maximum of 200 nodes. Input is circuit schematic. Nonlinear device models are built into the program. Device parameters are fed in from library tape or as a part of the input. Available on IBM 7040, 7044, 7090, 7094 machines. Written in FAP language. (A)
	NET 2	Under development. It will perform all of NET 1 functions plus ac steady-state, Monte Carlo and variational studies, sensitivity analysis. It will include additional nonlinear devices. (A)
Massachusetts Institute of Technology Cambridge, Mass. Prof. M. Dertouzos	CIRCAL I (Circuit Analysis Program)	Can handle linear and nonlinear resistors, linear storage elements, voltage and current sources which are arbitary functions of time. At present, approximately 8 nodes and 12 branches can be handled.
	CIRCAL II	An expansion of CIRCAL I, is capable of accommodating additional elements with faster solution times. (A)

(table continued on p. 80)

(continued from p. 79)

Company	Program	Description
Norden Div. of United Aircraft Norwalk, Conn. Martin Goldberg (NORNAP) Arnold Spitalny (CADIC)	NORNAP (Norden Network Analysis Program)	A nonlinear dc analysis program which is an extension of the dc portion of IBM's ECAP. A nonlinear Ebers-Moll model is set up automatically for transistors and diodes; operating points are determined by iteration of the nonlinear equations. List programs are now being developed or in occasional use. Derating analysis and failure effect analysis routines are being added to NORNAP. (B)
	CADIC (Computer Aided Design of Integrated Circuits)	A man-machine system for rapid design of diffusion and interconnection patterns of new integrated circuits. Experimental version is not available for IBM 7094. CADIC is being converted to IBM 360 with 2250 Display. (C)
Sylvania Electronic Systems West P.O. Box 205 Mountain View, Calif. E.A. Huber Phyllis J. Grossberg	FALEN (Frequency Analysis of Linear Electrical Networks)	Performs with up to 40 nodes. The frequency functions to be calculated are defined by choosing from a prepared set of equations and listing the variables to be used in these equations. Subroutines are used to describe the frequency functions and transistor models; these subroutines may easily be changed to describe models or functions not presently provided. The desired frequency functions are computed in the program by generation of the admittance matrix and partial inversion of it to obtain the voltage needed in the specified equations. The program is written in FORTRAN IV for the IBM 7094. (C)
University of Michigan Ann Arbor, Mich. Alan B. Macnee	FACTOR	Finds roots of polynomials with real coefficients. (A)
	TCHDEL	Finds roots of all-pole transfer function to give a Tschebyscheff approximation to a constant low-pass group delay for a specified percentage ripple. (A)
	RATTCH	Finds zeros of the Tschebyscheff rational function for a specific set of poles. (A)
	LAPLAC	Calculates the step and impulse response of a specified rational function that has simple poles. (A)

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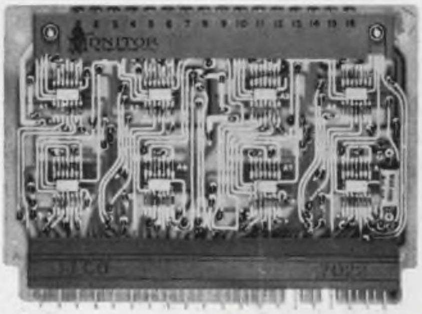

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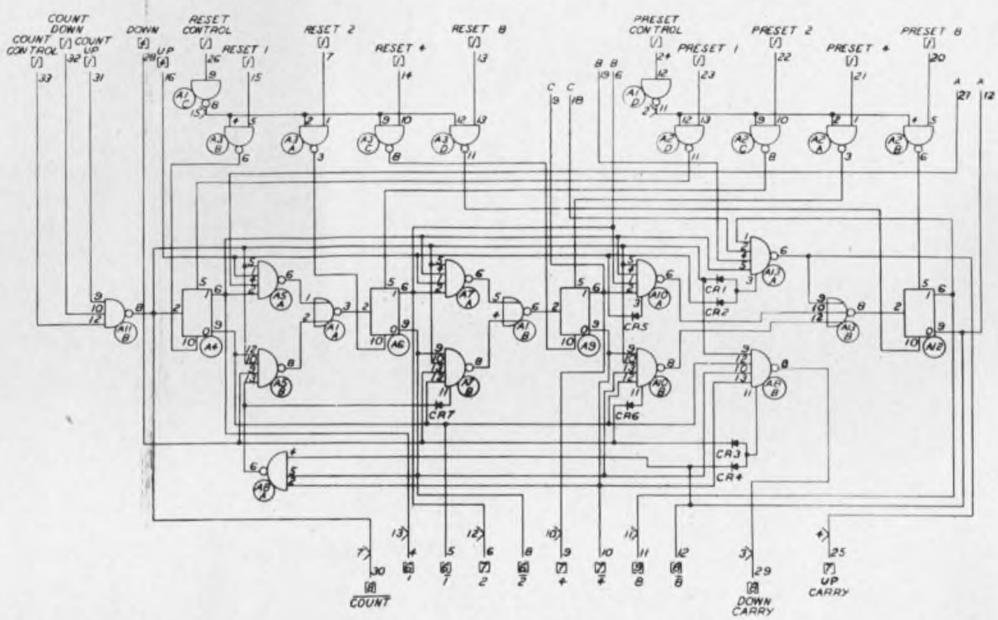

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ON READER-SERVICE CARD CIRCLE 38

Avoid variable-load problems by fitting the power amplifier dissipation accurately to the changing drive needs of the system that you design.

An important consideration in the design of power amplifiers is frequency-dependent load variations; yet they are frequently ignored by many designers. If they are not taken into account, the amplifier may deliver too little drive over one part of the band and too much over the rest. Load variations can cause inefficient operation and possibly destructive overstresses on components—particularly transistors.

Proper design will overcome these problems. The load can be matched to the amplifier at a precise point in the band so as to keep the transistor dissipation to a minimum. The amplifier dissipation can then be analyzed over the entire band. This can be achieved by use of the load-amplifier power dissipation relationships described in this article. A Class-B power amplifier is used in the discussion since this type of amplifier is usually employed in driving high-power complex loads.

Admittance loop opens analysis

A piezoelectric transducer can be taken as a representative example of a varying load. The equivalent circuit of the transducer is shown in Fig. 1a. R_0 and C_0 are the static values of electrical resistance and capacitance, respectively; L_m and C_m are electrical equivalents of the transducer mass and stiffness, respectively; R is the radiation resistance of the transducer.

If an admittance loop (susceptance vs conductance as a function of frequency) is plotted for this circuit, the curve shown in Fig. 1b is obtained. An admittance circle is used because the transistorized driver closely approximates a constant-current source. This makes a Norton equivalent circuit for the configuration more useful in the analysis.

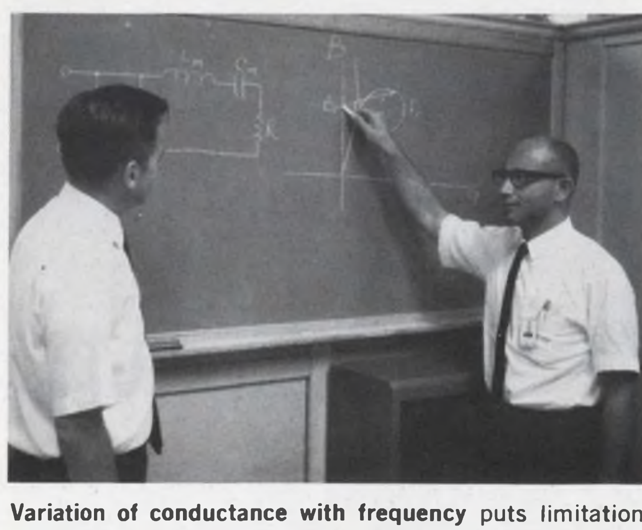
Transducers are usually operated near resonance at the point f_r on the admittance curve. A nominal susceptance, B_0, can be tuned out by means of an inductor. This will have the effect of shifting the curve down so that f_r and B_0 will intersect the horizontal axis at G_0 as shown in Fig. 2. A typical admittance vector **Y** is also shown.

Variations in frequency about the resonance point give rise to a phase-shift, ϕ. Of equal importance is the fact that the real part of the admittance, G, will also change along with the total admittance, **Y**. These variations place severe limitations on the associated Class-B push-pull power-amplifier driver.

Load changes increase dissipation

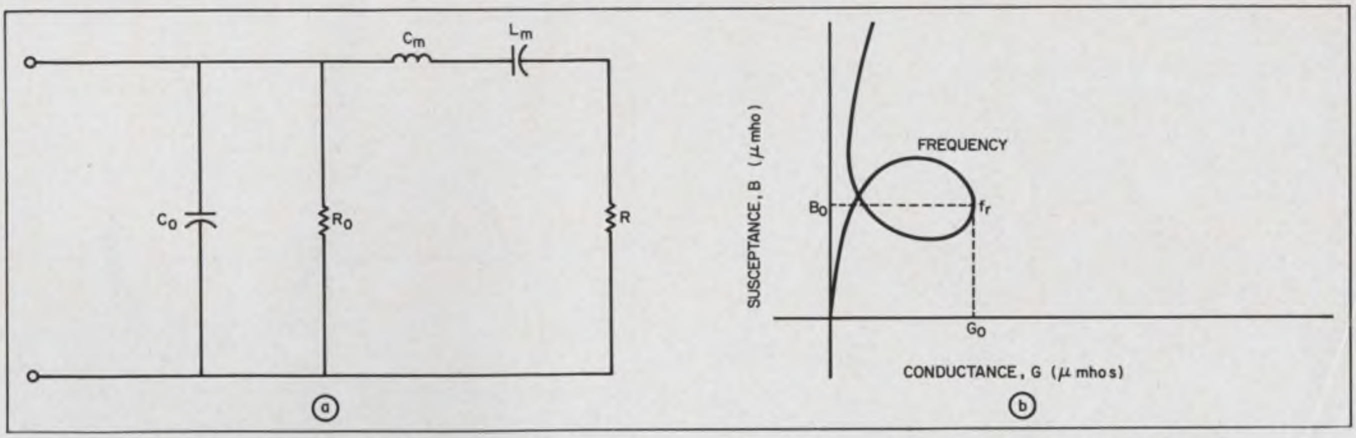
If the amplifier unit is treated as a current-amplifying type (Fig. 3), the power dissipation can be analyzed as a function of the load impedance variations. Variations in output voltage swing as the load impedance changes, and variations in phase angle between voltage and current must be taken into consideration. Note that the output voltage (Fig. 4), as reflected back to the transistor collector, is capable of swinging from V_{cc} to ground for full collector output swing.

While the collector is swinging from the supply toward ground, the transistor's output current



Variation of conductance with frequency puts limitations on the power amplifier driver, Author Bram points out to a colleague.

Jeffry M. Bram, Systems Engineer, Electro-Acoustic Systems Laboratory, Hazeltine Corp., Braintree, Mass.



1. **Piezoelectric transducer,** representative of varying-load for Class-B power amplifiers, has this equivalent circuit (a). Parameters R_o and C_o represent static resistance and capacitance; L_m and C_m are equivalents of transducer mass and stiffness, respectively; R is transducer radiation resistance. Admittance loop (b) shows how susceptance, B, and conductance, G, vary with frequency. Transducers are usually operated near resonance; point f_r.

goes from zero to a maximum current, I, for that stage. The dissipation in that half of the output stage is then the integral of the instantaneous voltage-current products for that half-cycle. During the other half-cycle a similar dissipation occurs in the other half of the output stage. Hence, the total power dissipation in the output stage is twice the dissipation for one half of the sine-wave cycle.

Also, V_{cc} can be reflected back to the output side of the output transformer. It can thus be used with output voltage and current swings in an expression for the total output power of the amplifier. This expression may be written in terms of the maximum-to-actual-rms ratios (voltage and current) for the amplifier dissipation. This will ultimately result in an expression for output stage dissipation which is dependent solely upon:

- The ratio of actual to maximum output voltage, V_{ratio}.
- The ratio of actual to maximum output current, I_{ratio}.
- The division of V_{ratio} by I_{ratio}.
- The phase angle between output current and voltage.

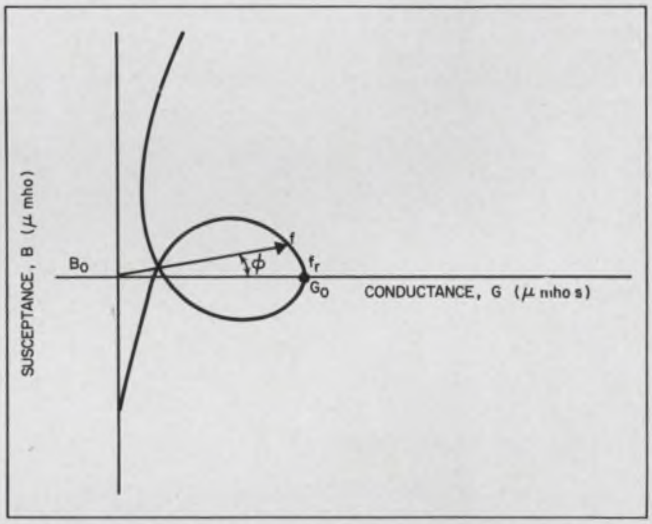
It should be noted that this expression does not take into account losses in the output transformer. These losses must be added to the collector dissipation loss to obtain a total dissipation figure for the output transistors.

Integration yields dissipation figure

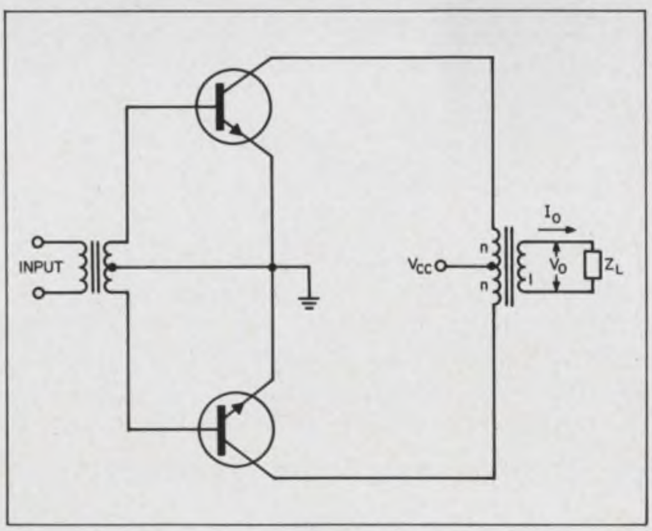
An expression for the dissipated power in the transistors can be derived from Fig. 4 by taking the integral of the instantaneous voltage-current product (over one cycle):

$$P_d = (2/2\pi)\int_0^{\pi} n\, 2^{1/2} I_o \sin \omega t \; [V_{cc} - (2^{1/2}/n) V_o \sin (\omega t + \phi)]\, d\omega t. \qquad (1)$$

In Eq. 1, $\omega = 2\pi f$ and is the frequency in radians



2. **Nominal susceptance** of transducer, B_0, can be tuned out with an inductor. This shifts the admittance loop (see Fig. 1b) so that resonant frequency point f_r intersects the horizontal axis at G_0, the nominal conductance. Vector **Y** represents a typical total admittance value at a frequency f.



3. **Power amplifier** is a push-pull, Class-B, current-amplifying type. As load impedance changes, power dissipation levels are modified.

per second; V_o is the rms output voltage; V_{cc} is the collector supply voltage; I_o is the rms output current; n is the turns ratio from half of the primary to the secondary; and ϕ is the phase angle between output voltage and output current.

Since this is a Class-B, push-pull amplifier, the term $2^{1/2} n V_{o(max)}$ is made equal to V_{cc}. Here $V_{o(max)}$ is the maximum rms output voltage. Therefore Eq. 1 may be rewritten:

$$P_d = (2/\pi) I_o V_{o(max)} \int_0^\pi \sin \omega t [1 - k \sin(\omega t + \phi)] d\omega t, \quad (2)$$

where $k = V_o / V_{o(max)}$.

Using the substitution $\sin(\omega t + \phi) = (\sin \omega t)(\cos \phi) + (\cos \omega t)(\sin \phi)$ and expanding yields:

$$P_d = (2/\pi) I_o V_{o(max)} \int_0^\pi (\sin\omega t - k \sin^2\omega t \cos\phi - k \cos\omega t \sin\omega t \sin \phi) d\omega t. \quad (3)$$

Integrating, evaluating and simplifying Eq. 3 produces:

$$P_d = (1.273 - k \cos \phi) I_o V_{o(max)}. \quad (4)$$

Using the identities $V_{o(max)} = n V_{cc}/2^{1/2}$ and $V_o = I_o/|\mathbf{Y}|$ gives:

$$P_d = [1.273 - 2^{1/2} I_o \cos \phi / (n V_{cc}|\mathbf{Y}|)] n I_o V_{cc}/2^{1/2}. \quad (5)$$

Equations 4 or 5 can be used to calculate the output stage dissipation.

Step-by-step design example

This is how the relationships are used in an actual system. Assume the following parameters are given:

- Power amplifier output — 100 W
- Supply voltage — 28 V
- Admittance at resonance — 10,000 μmhos
- Admittance at the band extremities — 7000 $\angle 20°$ μmhos

The maximum value of V_o occurs at the edge of the band where the admittance is at a minimum. Thus:

$$V_{o(max)} = (P/\mathbf{Y}_{min})^{1/2} = (100/0.007)^{1/2} = 119 \text{ V}. \quad (6)$$

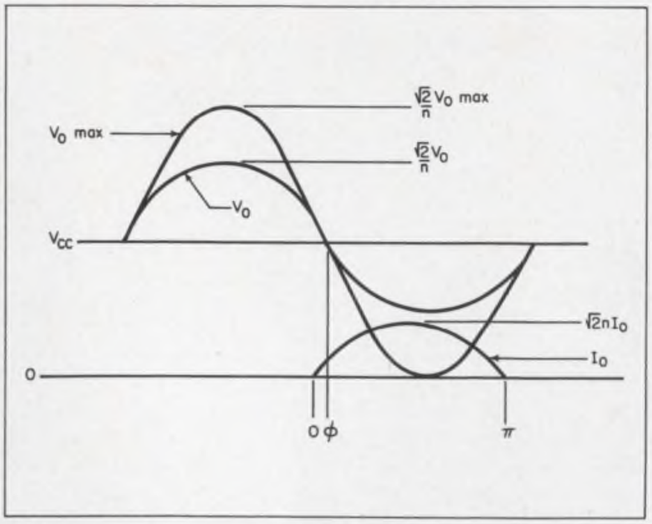
Consequently, n may now be computed:

$$n = 2^{1/2} V_{o(max)}/V_{cc} = 2^{1/2}(119/28) = 6.04. \quad (7)$$

At resonance, to supply 100 watts into an admittance of 10,000 μmhos requires one ampere. At the band edge, the current required by the 7000-$\angle 20°$-μmhos load for 100 watts is 0.858 A. Therefore the dissipated power at resonance may be computed from Eq. 5:

$$P_d = [1.273 - 2^{1/2}(1)(1)/(0.01)(6.04)(28)] (1)(6.04)(28)/2^{1/2} = 51.9 \text{ W}. \quad (8)$$

The dissipated power at the band edge is likewise computed:



4. **Amplifier collector waveforms** for the circuit of Fig. 3 show Class-B operation. Here V_o is the rms output voltage, I_o the rms output current and n the turns ratio.

$$P_d = [1.273 - 2^{1/2}(0.858)(\cos 20°)/(0.007)(6.04)(28)](0.858)(6.04)(28)/2^{1/2} = 31 \text{ W}. \quad (9)$$

If one were to design the amplifier just for operation at resonance, the resulting $V_{o(max)}$ value would be:

$$V_{o(max)} = (100/0.01)^{1/2} = 100 \text{ V}. \quad (10a)$$

This in turn yields:

$$n = 2^{1/2}(100)/28 = 5.06. \quad (10b)$$

Therefore, the dissipated power, computed from Eq. 4 would be:

$$P_d = (1.273 - 1 \cos 0°)100(1) = 27.3 \text{ W}. \quad (10c)$$

From this example it can be seen that the required dissipation varies according to whether the amplifier is designed for proper operation at the band edge or at resonance. If the amplifier is designed to operate at the band edge, at resonance the dissipation is almost double what it would be for a single frequency design at resonance.

Moreover, the dissipation does not include output transformer losses. These must be added to the output transistor losses to obtain a complete result. Also, the expression for power dissipation derived above (Eqs. 4 or 5) is for the entire output stage. So, when the dissipation of each half of the push-pull stage is being calculated, the result should be divided by two.

When computing the maximum dissipation in the output stage, realize that maximum dissipation does not occur at the point of maximum output in a Class-B stage. This fact is made obvious by Eq. 5—by differentiating it with respect to I_o, equating the expression to zero, and then solving for I_o. Doing this shows that the maximum dissipation occurs at 63.7 per cent of the maximum voltage drive for conditions of maximum impedance and zero phase-angle. ■ ■

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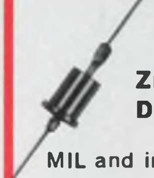

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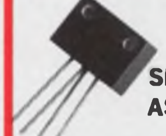

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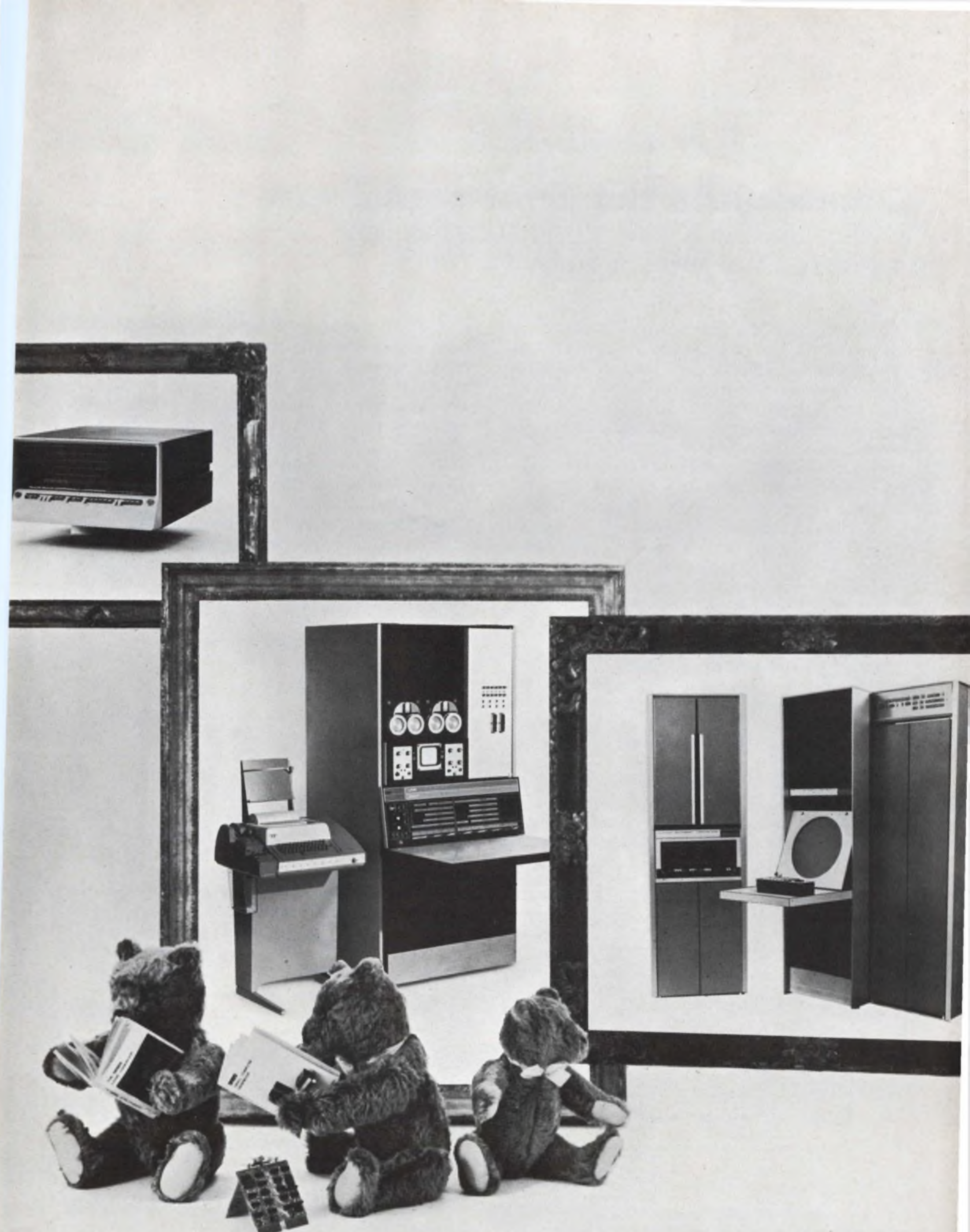


ON READER-SERVICE CARD CIRCLE 40

Demodulate the error signal in FM modulators with a differential network for very stable and broadband operation.

A clever approach to automatic frequency control combines the basically contradictory requirements of stability and wide bandwidth in FM modulators. The design makes the sampling rate independent of the lowest modulating frequency by removing the modulation from the error signal. The result is a modulator with a frequency stability of from 0.005 to 0.001% and a frequency response from dc to 1 MHz.

The conventional automatic frequency control loops used to stabilize voltage-controlled oscillators (VCO), give only an order of magnitude better stability than the oscillator itself. The reasons for this are:

- Use of crystal discriminators for a reference source.
- Drift of dc amplifiers.
- Low loop gains of 20 dB or less.

Mixing techniques improve the stability but create spurious problems and cannot meet wide deviation requirements. At best they tend only to approach the stability of the crystal mixer oscillator.

In a basic afc scheme, shown in Fig. 1, a crystal reference oscillator and a VCO are alternately gated into a frequency discriminator by a gate controlled by the sampling generator. The output of the discriminator has a dc component that represents the center frequency of the discriminator. It also has an ac component, which is a square wave at the frequency of the sample rate, and its peak-to-peak amplitude represents the frequency error between the two oscillators. The dc component is blocked in the ac loop amplifiers. A synchronous detector determines the polarity and magnitude of the error to be corrected by the gain of the loop. In this manner the frequency instability of the discriminator and the drift of the dc amplifiers are eliminated.

The system is limited by the fact that the sampling rate must be about one-tenth of the lowest modulation rate—otherwise errors will be introduced into the loop at low modulation frequencies.

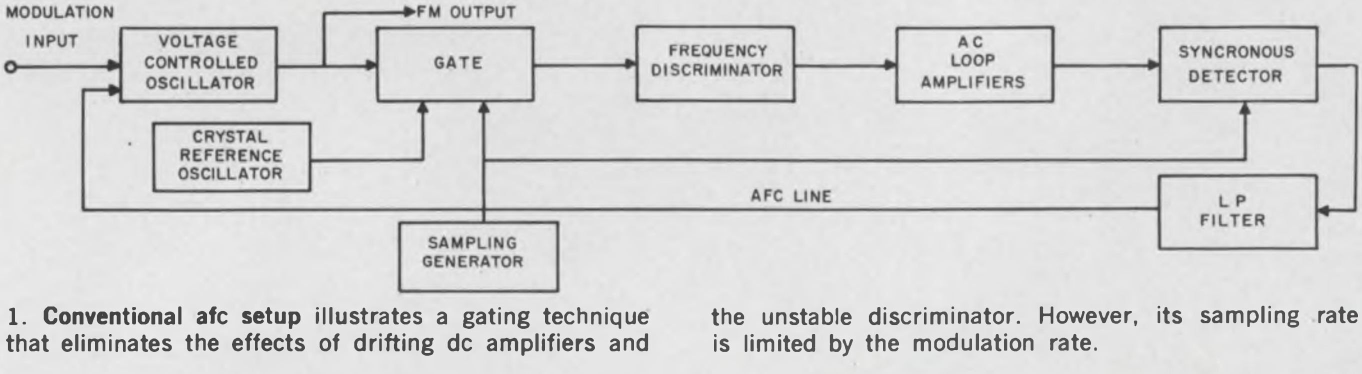
A modified version of this chopper technique allows the sampling rate to be independent of the lowest modulation frequency and, in fact, extends the frequency response down to dc.

Remove modulation from error signal

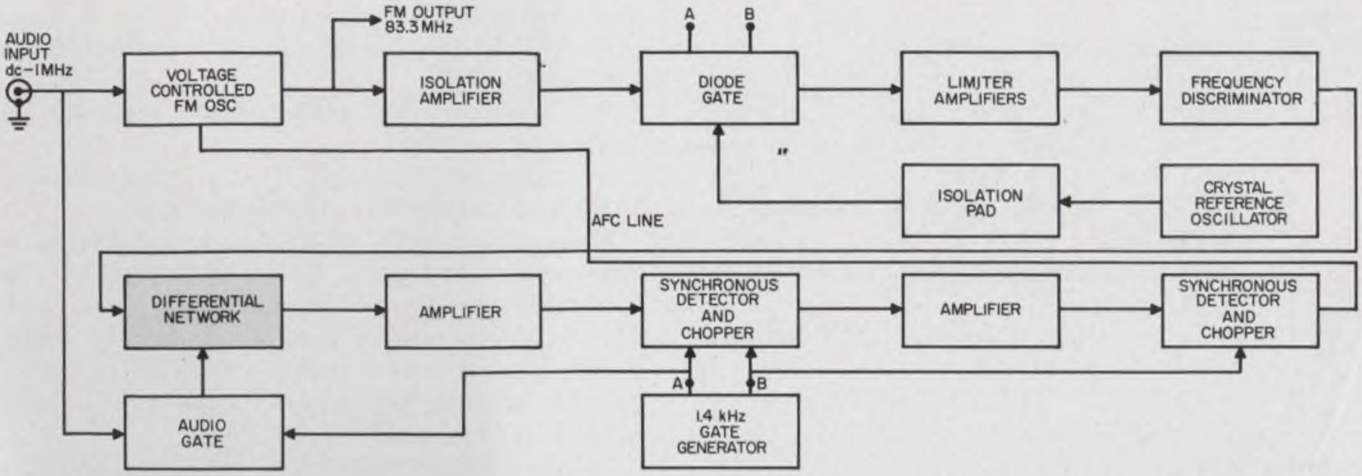
A differential amplifier removes the modulation from the error signal in the FM loop. This step makes the switching rate of the gate generator independent of the system's low-frequency response. The modified block diagram is shown in Fig. 2. Here, as in the basic system, the reference oscillator and the voltage-controlled FM oscillator are alternately gated into the frequency discriminator.

The simple waveforms of Fig. 3 illustrate the manner in which the modulation is removed from the error signal. The two inputs to the differential network are the audio input to the modulator and the sampling output of the discriminator. (The

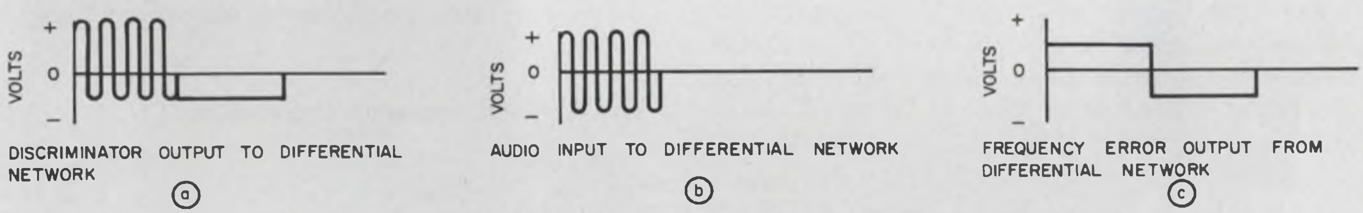
Richard Brounley, Project Engineer, Electronic Communications, Inc., St. Petersburg, Fla.



1. **Conventional afc setup** illustrates a gating technique that eliminates the effects of drifting dc amplifiers and the unstable discriminator. However, its sampling rate is limited by the modulation rate.



2. **Modified chopper scheme** makes the sampling rate independent of the lowest modulating frequency and extends the frequency response to dc. The modulation is removed from the error signal in the FM loop.



3. **The two inputs to the differential network** (a and b) yield the ac error signal (c). The discriminator's output (a) displays the frequency of each oscillator in terms of a dc voltage as it is gated into the limiter-discriminator.

audio gate passes the audio signal during the time the FM oscillator is being sampled.) The differential network is adjusted so that the algebraic difference between the two signals is zero, which essentially eliminates the effect of modulation on the signal from the discriminator.

Once the modulation has been removed from the error signal, it is amplified and fed into a synchronous detector and a chopper that filter it and reconvert it to an ac signal.

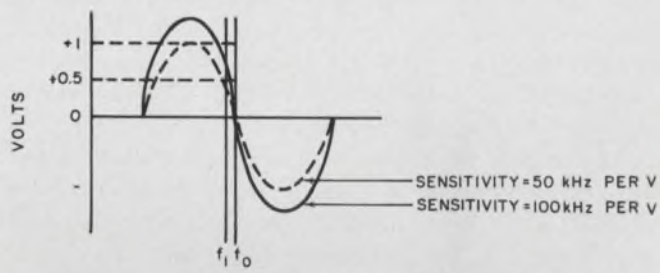
Then a final synchronous detector and low-pass filter provide the correction voltage, porportional to the error signal, to the FM oscillator. The gain of the loop is nominally set at 60 dB and will, therefore, reduce the open-loop error of the FM oscillator by a factor of 1000:1.

Limiting gives rise to frequency errors

Ideally, the frequency is unaffected by discriminator drift owing to the ac coupling. However, imperfect limiting induces a frequency error that does depend on the discriminator drift.

The effect of imperfect limiting may be illustrated with Fig. 4. No frequency error will be produced when the loop is closed, if both oscillators and the zero point of the discriminator are all the same frequency (f_0 in Fig. 4) when the loop is open.

However, if the center frequency of the discriminator drifts, a square wave is generated when the loop is open. Since the closed loop sees this as a difference in frequency between the two oscillators, the frequency of the FM oscillator will be changed.



4. **Inadequate limiting** introduces drift-sensitive frequency errors. The error is the result of discriminator drift, not of the difference in amplitudes.

This process may be illustrated with a numerical example. Assume that one oscillator produces a discriminator sensitivity of 100 kHz per volt and the other, 50 kHz per volt. If the discriminator drifts, the frequencies of the two oscillators may be represented by f_1 in Fig. 4. As a result, a square-wave voltage of 0.5 V peak-to-peak is generated. Since the closed loop detects this as a 50-kHz frequency drift of the FM oscillator, the oscillator's frequency will be changed by 50 kHz. Therefore the drift of the discriminator must be minimized by extremely good limiting and by reduced level variation between the two oscillators. The error generated by the drift of the discriminator can be expressed in the following form:

$$fe = \Delta f VE/L, \qquad (1)$$

where

fe = frequency error (hertz),

Δf = discriminator sensitivity (hertz/volt),

V = expected discriminator drift ($\pm$volts),

E = difference between input levels of the two oscillators $= (E_1 - E_2)/E_1$, where E_1 is the higher input level and E_2 is the lower input level,

L = degree of amplitude-variation reduction by limiters.

Typical numbers for a developed modulator are:

$\Delta f = \pm 500{,}000$ hertz/volt,

$V = \pm 0.5$ volt ($-28°C$ to $+85°C$),

$E = (1-0.8)/1 = 0.2$,

L = 300 to 1, or 50 dB.

Therefore, $fe = \pm 166$ hertz.

At 83 MHz, this error results in an additional frequency tolerance of about $\pm 0.00025\%$. Because of the high-gain afc loop, the corrected free-running oscillator frequency error is also about $\pm 0.00025\%$. The total worst-case tolerance of the modulator is the sum of these two errors plus the reference oscillator error of $\pm 0.0015\%$, or $\pm 0.002\%$.

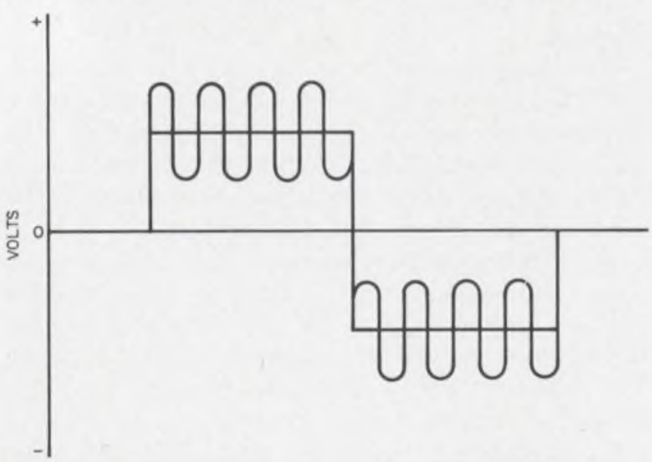
50-dB isolation is advisable

If the outputs of the two oscillators are not fully isolated during the error-sampling time of the loop, frequency errors can occur. The beat interference between the two oscillators appears superimposed on the error signal before being detected by the synchronous detector (Fig. 5).

If the interference is not large enough to saturate the loop amplifiers, very little frequency error results. It is even possible to phase-lock the FM oscillator and the reference oscillator.

If the interference does saturate the loop amplifiers, a frequency offset appears and leads to a symmetrical control of the FM oscillator's frequency drift.

Adequate interference suppression may be



5. **Insufficient isolation** between the FM and the reference oscillator causes a beat signal to appear superimposed on the error signal. This beat influences the detector and so introduces frequency errors.

achieved through the following steps:

- Provide adequate decoupling between the two oscillators.
- Ensure at least 50-dB on-to-off ratio for the diode gate.
- Isolate by at least 50 dB the other coupling paths and be careful with packaging.

Since telemetry systems characteristically require low incidental FM, the output of the modulator must have switching currents and beat-interference effects reduced or completely eliminated. This is again primarily an interference problem and requires essentially the same consideration as that discussed above.

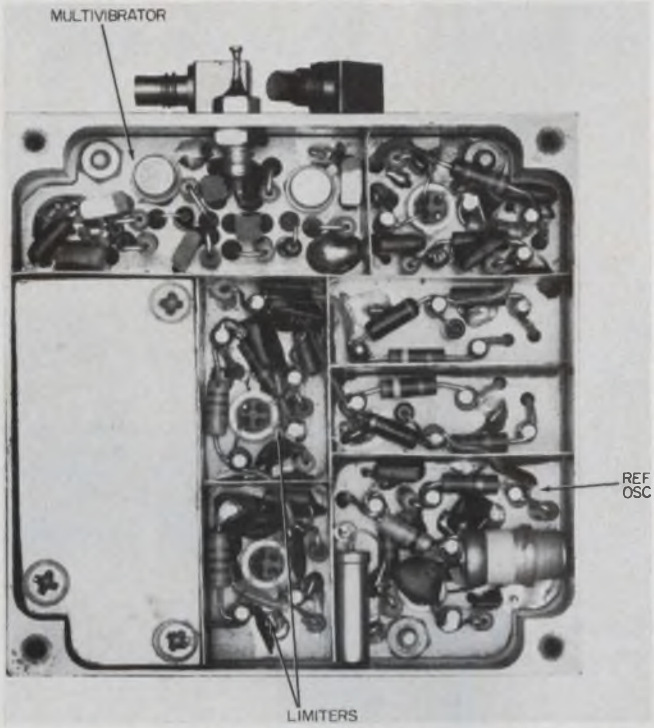
Isolation between the FM oscillator and the diode gate must be maintained or the impedance change of the gate will be reflected as incidental FM. About 80-dB isolation is needed to decrease this incidental to a value below the normal oscillator noise.

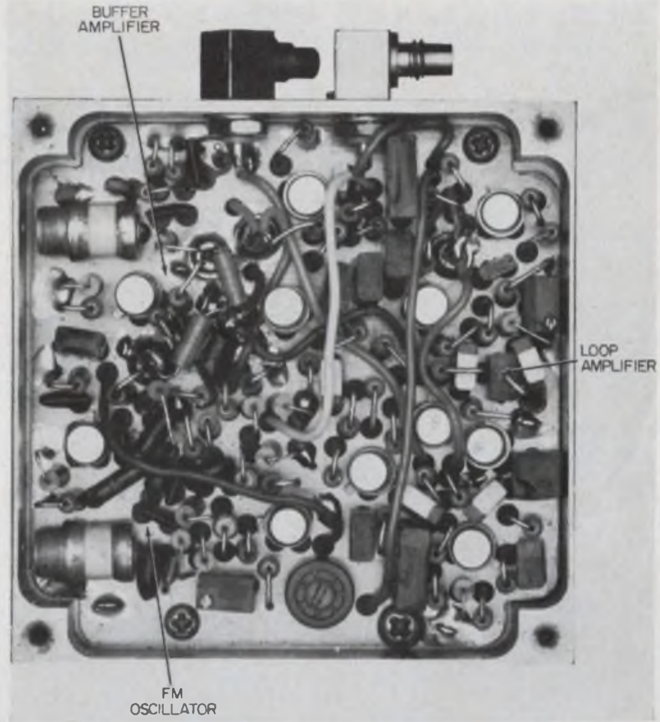
The beat from imperfect cancellation

The beat effect discussed here is not the same as the beat interference already mentioned. It is the beat between the modulation frequency and the gate generator rate. This beat would not exist if perfect cancellation were possible, but in practical operation it is always present in some degree. It is caused by an odd number of half cycles of the modulating frequency at the output of the differential network during the FM sample time. The average value of these odd half cycles changes at a rate which is equal to the difference between the two frequencies and thus creates this beat effect. The effect can occur when the modulating frequency is near the sample rate or any of its odd harmonics.

The amplitude of the beat is a function of the difference between the modulation and gate generator rates, the peak deviation, the low-pass filter bandwidth and the degree of cancellation achieved ahead of the loop amplifiers. With a cancellation of 40 dB, the beat is only about 1% of the peak deviation with a low-pass filter having a time constant of five seconds. The beat can increase to 10% of the peak deviation, when the degree of cancellation drops with temperature variation. The odd harmonics and subharmonics have a lower average value for their odd number of half cycles, and the beat effect is considerably less than at the sample rate.

The best solution is to use a time constant of about 200 seconds in the low-pass filter. This restricts the modulation frequency range for which the beat can occur to within a few cycles of the sample rate. Unfortunately, this makes the turn-on time about two minutes, because the capacitor in the low-pass filter must charge from zero to a positive bias voltage on the afc varactor





6. **Modulator,** built according to the circuit of Fig. 2, performs as a frequency source for telemetry transmitters in both the vhf and uhf regions. The frequency of the gate generator is set at 1.4 kHz.

diode. This problem has been solved by shunting a silicon diode across the series resistor in the low-pass filter. The shunt diode permits the low-pass filter capacitor to charge very quickly during initial turn-on. Thereafter it acts as a peak detector with a long discharge time constant. No beat interference of any consequence is then observed or measured under any operating condition.

Other sources of errors

If the amplifier ahead of the synchronous detector and chopper circuit becomes saturated during the FM oscillator time period because of imperfect cancellation, a frequency offset can occur. Therefore, the levels of the system must be established so as to prevent this.

Any square wave, introduced at the sample rate into the loop by the audio gate, the synchronous detectors, loop amplifiers, and so on, will result in frequency errors. The degree of error depends on the magnitude of the square wave and the point at which it occurs in the loop. For instance, a particularly sensitive point is at the input to the first-loop amplifier. For this reason the audio gate employs a simple insulated gate field-effect transistor series switch which has virtually no leakage to the output from the switching voltage on the gate.

A modulator, built according to the design approach described (Fig. 6), has been operating as an integral part of a modularized S-band telemetry transmitter capable of delivering 5 watts of average power.

The frequency of the gate generator is set at 1.4 kHz to minimize the size of the audio components. This selection also allows very high loop gain because of the wide separation between the cutoff frequency of the low-pass filter at the output of the loop, and the loop carrier or sampling rate.

The reference oscillator uses a fifth overtone crystal at 83.3 MHz and is typically stable within $\pm 0.0015\%$ over a temperature range of $-28°C$ to $+85°C$. No temperature compensation techniques are needed to achieve an over-all stability of $\pm 0.002\%$ from the modulator over the same temperature range in production quantities. Center frequency is unaffected by modulation at deviations up to ± 100 kHz and with rates from 1 hertz to 1 MHz. The dc response and hence the center frequency is affected by the degree of cancellation held over temperature and is specified at ± 1.5 dB.

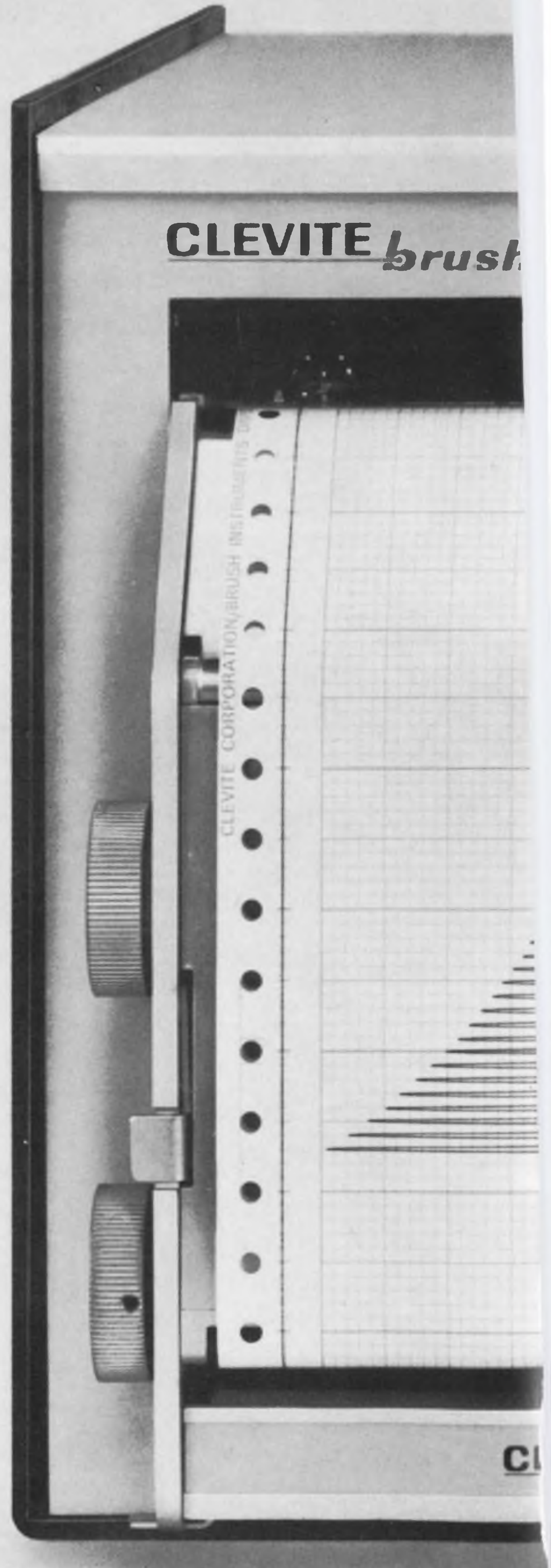
With the above parameters, the frequency at which the beat is of significance is 1.4 kHz ± 25 hertz; the maximum beat occurs at 1.4 kHz, where it is a dc voltage whose magnitude depends on the phase of the two frequencies.

The frequency stability of the S-band transmitter is $\pm 0.002\%$, its frequency response is from dc to 1 MHz (± 1.5 dB loss). The transmitter operates with a distortion of 1% and an incidental FM of ± 5 kHz. The deviation is ± 2 MHz and the temperature range is from $-28°C$ to $+85°C$. ■ ■

Acknowledgement:

The author wishes to express his gratitude to Mr. Neville Downs and Mr. Ralph Looney for their assistance in developing the modulator.

Announcing the Brush Mark 250, first strip chart recorder for the perfectionists of the world.



Shown approx. 76% of actual size with 1 μv preamplifier RD 4215-70; event markers optional.

Meet the fastest, most accurate strip chart recorder on record: The new Brush Mark 250. When you read about all the features you'll know why we call it the first recorder for the perfectionists of the world!

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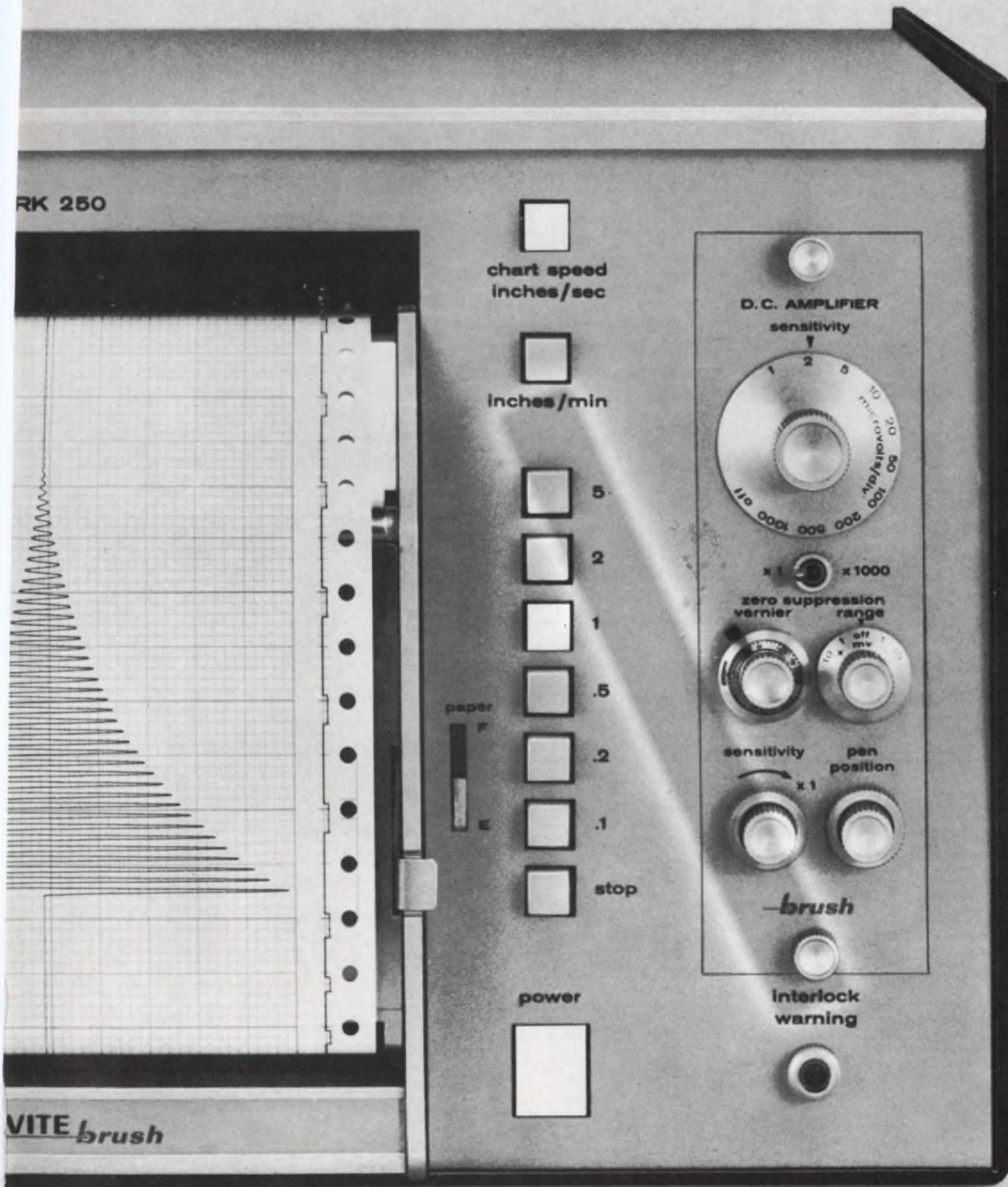


The Brush Mark 250

First recorder for perfectionists

ON READER-SERVICE CARD CIRCLE 248

Convert complex numbers to absolute values and angles graphically. The approach is very useful in analyzing transfer functions and complex impedances.

A simple, graphical approach provides quick, accurate answers in calculations of the magnitudes and angles of transfer functions and complex impedances.

Consider the circuit shown. Its complex impedance, Z_i, is equal to $R+sL2$. The transfer function has the form:

$$\frac{e_o}{e_i}=\frac{R+sL2}{R+s(L1+L2)}=\frac{Z_i[R-s(L1+L2)]}{R^2+|s(L1+L2)|^2} \quad (1)$$

To illustrate the use of the graph, assume that R is equal to 3 and both $|sL1|$ and $|sL2|$ are equal to 10. To find the magnitude and the angle of Z_i:

- Put 3 on either scale A or B; draw a horizontal line (line a); read off 9 from scale C.
- Do the same for 10; read off 100 from scale C (line b).
- Add 100 and 9; mark the point for 109 on scale C; draw a horizontal line and read off the intersection from scale A or B (line c). The value at this point, 10.7, is the magnitude of Z_i.
- Put 3 on scale A and 10 on scale C; read off the angle of Z_i: $\theta=73°$ (line d).

The transfer function is found in a similar manner. The procedure is repeated for $R-s(L1+L2)=3-j20$. The result is $20.2\ \underline{/-81.5°}$. The value of $R^2+|s(L1+L2)|^2$ is 409.

The numerator of Eq. 1 is a product of two terms—$10.7\ \underline{/73°}$ and $20.2\ \underline{/-81.5°}$. To perform the multiplication:

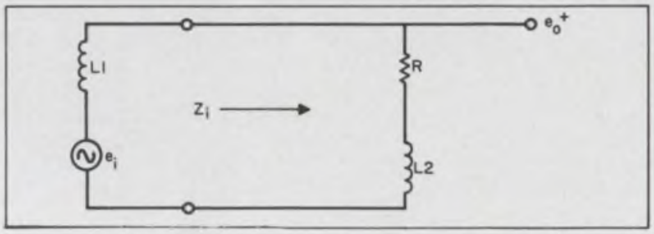
- Put 20.2 on scale A and 10.7 on B; connect these two points; read off the value at the intersection with C: 217 (line e).
- Put 217 on scale C, 40.9* on A; connect these two points; read off the value at the intersection with B: 5.3 (line f). The correct answer is $5.3\ (10)^{-1}$.

The angle of the transfer function is simply the sum of the two angles: $73°-81.5°=-8.5°$. Hence:

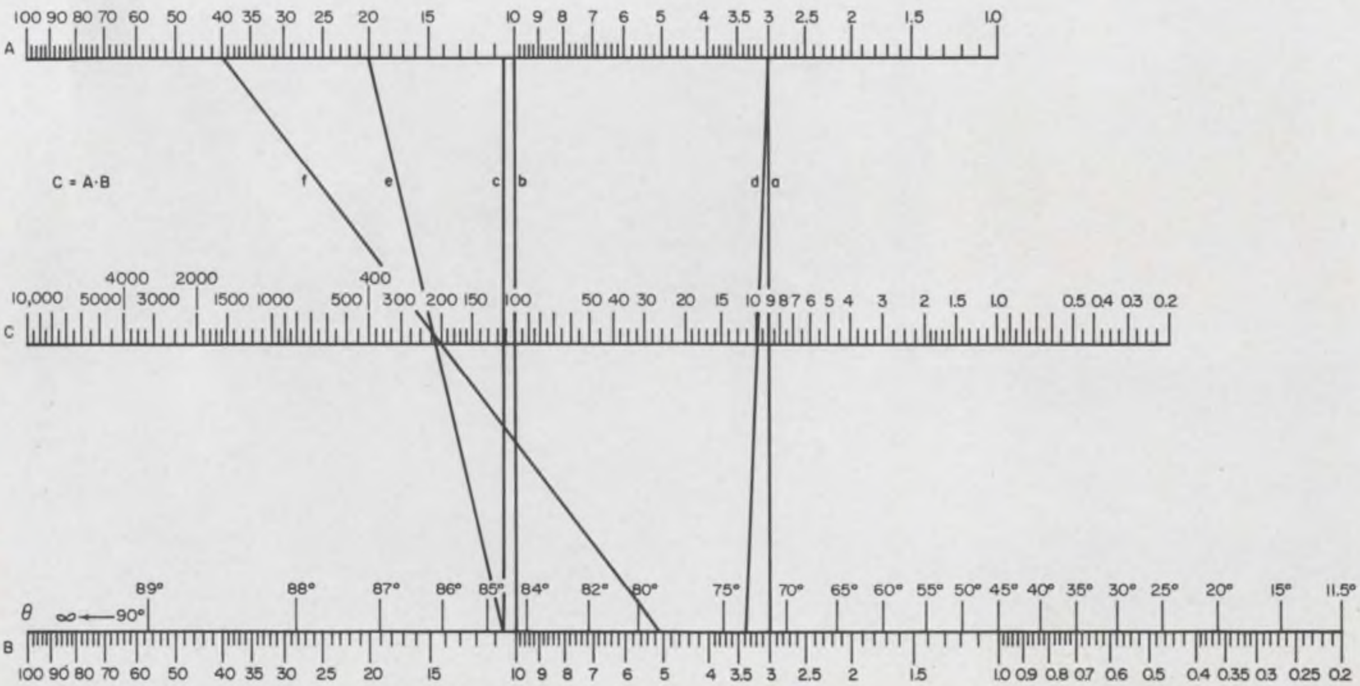
$$e_o/e_i=0.53\ \underline{/-8.5°}.$$ ■ ■

*Numerical values exceeding the ranges of the scales may be divided or multiplied by factors of 10.

Thac Mac, Research and Development Engineer, Allen-Bradley Co., Milwaukee



Simple RL circuit is used to illustrate the graphical approach to transfer functions and complex impedances.



PROGRESS REPORT

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Counter Bore .295 ± .002
I.D. .249 ± .003
Length Ground .150 ± .002

O.D. .418 ± .002
Length .600 ± .005

Center Hole I.D. .258 - .259
Grinding on 5° Angle leaving
.258 - .259 dimension
.032 ± .005 long

Length .760 ± .005
Thickness .050 $^{+.005}_{-.000}$
Counter Bore Depth .008 $^{+.003}_{-.000}$

Length .500 ± .003
Shank O.D. .235 $^{+.000}_{-.005}$
Hole .139 $^{+.006}_{-.000}$

O.D. .604 ± .005
I.D. .510 ± .005
Thickness .040 ± .005
Wall Thickness .047 ± .0015

Thickness .030 ± .002
I.D. .060 ± .001
Two Holes .020 ± .002
Hole Center .054 ± .002
O.D. .273 ± .001 Ground

O.D. .220 ± .002 Square
Thickness .030 ± .002
Counter Bore Depth .025 $^{+.005}_{-.000}$
Counter Bore Dia. .175 ± .002

Diameter .027 ± .002
O.D. .153 ± .003
Width .044 —.003

Length .220 ± .005
Rib Width .026 ± .001
Overall Width .101 ± .001

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More than ten years of growth in this field have given us a lot of know-how. We have not been able to meet all the requirements of all designs but our batting average continues to rise. One recent design which we cannot illustrate was an AlSiMag 614 alumina ceramic .277" (+ .000, — .004) square and with a thickness of .043" ± .003 with an array of holes with a diameter of .012" ± .001 on .023" HC (leaving a .011" wall between holes).

Marked progress has been made in two other areas. Note the tolerances on the four hole tube illustrated in the lower left. This gives an idea of precision attainable in extruded ceramics. Progress also is being made on precision metallizing. Metallize patterns are screened with lines as thin as .007" and as close as .007". Much closer tolerances are practical with our photoetch process.

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Parts illustrated approximately actual size.

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Counter Bore .008 Minimum

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Boss O.D. .400 ± .005
Counter Bore Depth .020 $^{+.005}_{-.000}$

O.D. .250 Square
Wall Thickness .015 ± .002
Thickness .018 ± .001

O.D. .636 ± .007
Thickness .046 $^{+.002}_{-.000}$
Hole .042 $^{+.002}_{-.000}$

Thickness .032 ± .002

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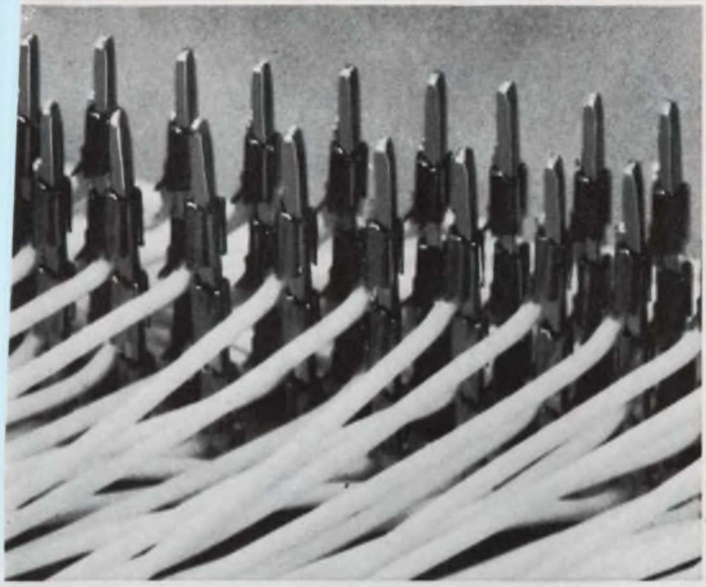

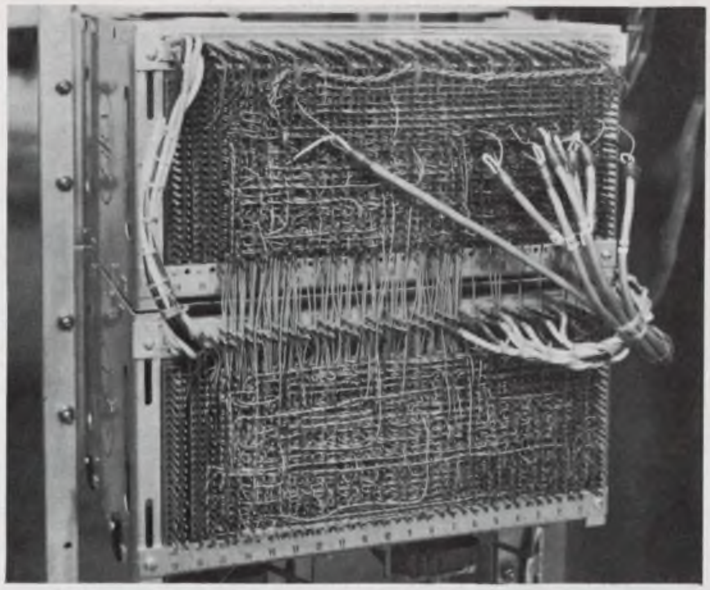

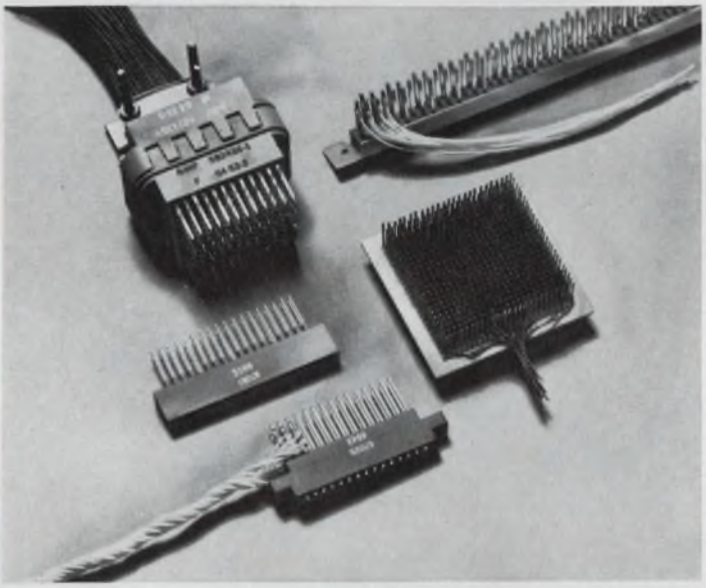

blocks, bus bars, cable connectors, junction blocks, relay blocks, and other devices. Furthermore, large-scale wiring of these products may be accomplished by mounting them on a panel and programming the TERMI-POINT machine for high-speed automatic wiring.

Besides the speed, density, and versatility of this wiring method, it offers an unusual degree of reliability. The reason for this is AMP's special post presents relatively large contact surfaces which are wiped clean by the wire held by the TERMI-POINT clip as the post is terminated. The resulting connection is highly resistant to the effects of corrosion, vibration, and temperature extremes. It is held with a high retention force which exceeds the yield strength of the wire itself, yet the post plating remains undamaged and the wire may be used again.

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If you plan to enlarge or improve your present wiring facilities, we suggest a comparative study of this new technique at your earliest convenience. Write or call today for a demonstration; or ask for information about the TERMI-POINT products which interest you most. Find out how this versatile new method can boost your future production!

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ON READER-SERVICE CARD CIRCLE 43

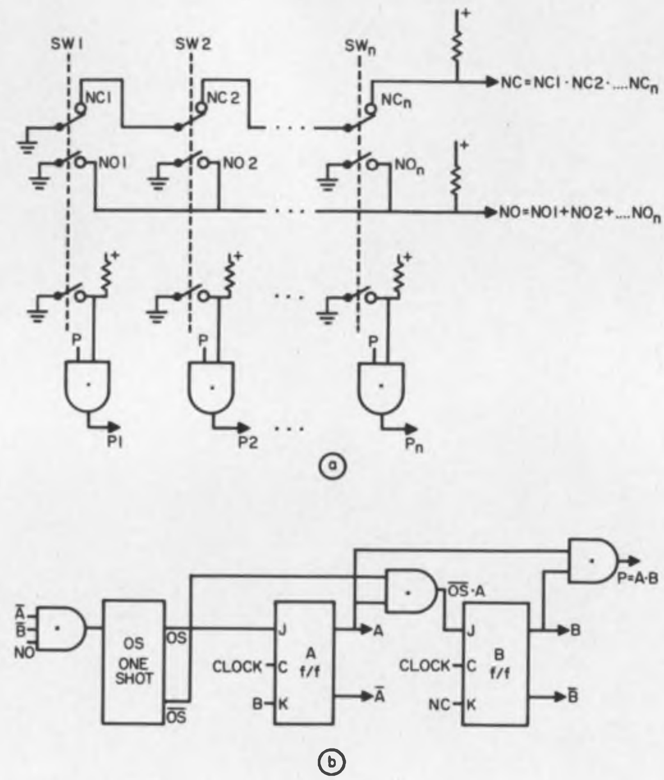
Eliminate switch contact bounce with this simple logic design

When a mechanical switch is used as an input to a digital system, contact bounce will almost always be present. Many times it is necessary for the input signal from the switch to produce a single one-clock-period-long pulse which is used by the digital system to initiate a sequence of events. When contact bounce is present, however, several pulses may be generated, or possibly a pulse may be generated that is longer than the specified one clock-period. In either case, a number of difficulties may ensue. The use of RC networks on the switch contacts tends to reduce contact bounce, but it never fully or reliably eliminates the problem.

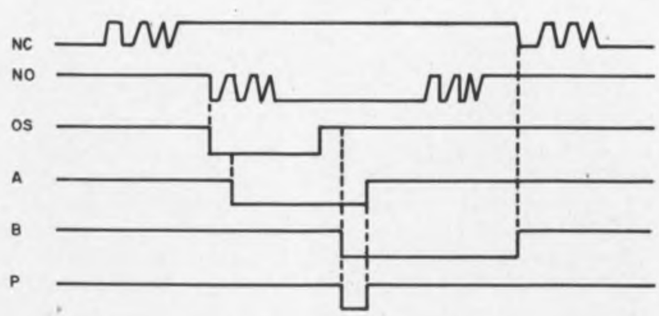
Logic techniques can be used to generate a pulse one clock-period long regardless of any contact bounce present. This approach allows a number of switches to time-share a single bounce-suppression circuit.

The logic mechanization diagram is shown in Fig. 1 and the waveforms are shown in Fig. 2. The switches $SW_1 \ldots SW_n$ in Fig. 1a contain three sets of contacts which are the break-before-make type. As shown in Fig. 2, these switches have contact bounce; however, since the normally closed contact (NC) is broken before the normally open contact (NO) is made, the contact bounce on the NC side stops before contact bounce on the NO side starts. In the waveforms of Fig. 2 a logic "one" (or "true") is indicated when the waveform is low and a logic "zero" (or "false") is indicated when the waveform is high. Similarly, in Fig. 1, a logic "one" is present when a signal level is at ground and a logic "zero" when the signal level is at $B+$.

In order to allow the switches to share the single bounce suppression circuit shown in Fig. 1b, the first set of contacts of $SW_1 \ldots SW_n$ in Fig. 1a is connected together to produce a "true" signal for as long as all the switches remain released. The logic equation for this condition is: $NC = NC_1 \cdot NC_2 \cdot \ldots NC_n$. The second



1. **Contact bounce can be eliminated** using the logic circuitry shown. Pulse P, shown in (a), is generated by the circuits shown in (b).



2. **These waveforms result** when any switch is depressed.

set of contacts is connected to produce a "true" signal when any of the switches are depressed. The logic equation is: $NO = NO_1 + NO_2 + \ldots NO_n$. When any of the switches is depressed, a one-shot pulse (OS) is initiated. This pulse, which is about 15 ms long (depending on the switch in use), lasts long enough to eliminate any contact bounce coming from the NO contact

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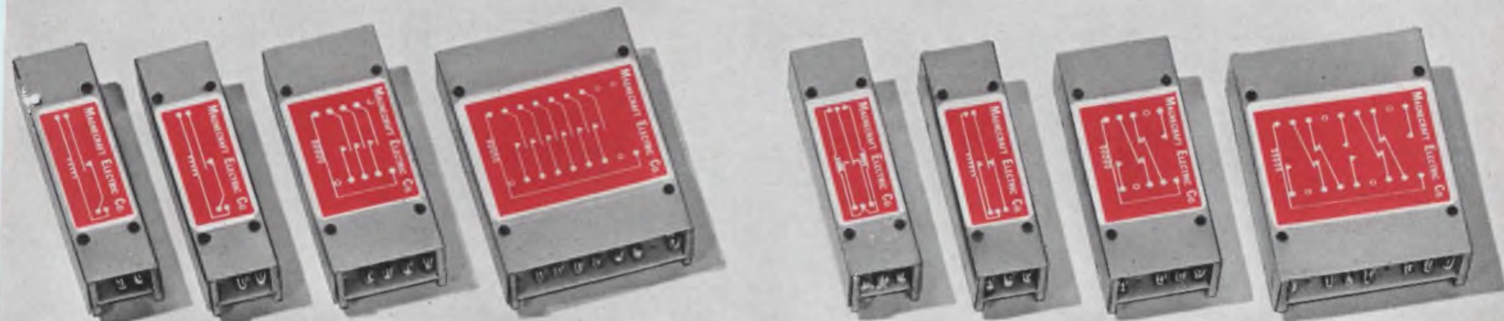
Low Profile, MPC Package, Standard Size, Printed Circuit Reed Relays



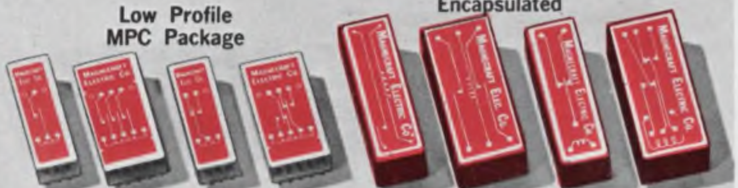
102RMPC SPST-NO 3 ampere POWER | 102MPC SPST-NO | 102MPC 3PST-NO | 102MPC 6PST-NO | 103LMPC SPDT Magnetic Latching | 103MPC SPDT | 103MPC DPDT | 103MPC 4PDT

Encapsulated, Standard Size, Printed Circuit

102PC SPST-NO | 102PC DPST-NO | 103PC SPDT | 103PC DPDT

Miniature Printed Circuit Reed Relays

Low Profile MPC Package | Encapsulated



101MPC SPST-NO | 101MPC 3PST-NO | 104MPC SPDT | 104MPC DPDT | 101PC SPST-NO | 101PC DPST-NO | 104PC SPDT | 104PC DPDT

Mercury-Wetted Printed Circuit Reed Relays

Standard Size Low Profile MPC package

Miniature Encapsulated

133MPC SPDT | 132MPC SPST-NO | 131PC SPST-NO | 131PC DPST-NO

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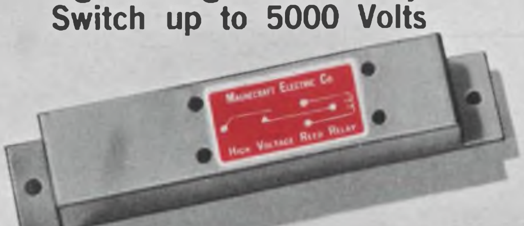
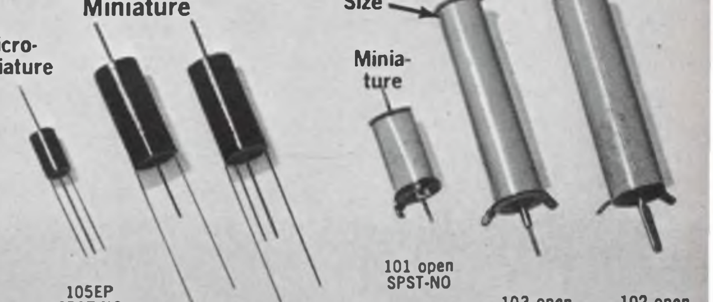


Class 102V SPST-NO

Dry Reed Relays with Axial Leads



105EP SPST-NO | 101EP SPST-NO | 104EP SPDT | 101 open SPST-NO | 103 open SPDT | 102 open SPST-NO closure. After this time period has elapsed, a pulse, P, is produced by the circuitry shown in Fig. 1b. P is then "ended" with the third set of $SW_1 \ldots SW_n$ contacts to produce output pulses P_1 to P_n, which select one of n possible sequencing operations. Since only one of the switches is depressed, only one of the output pulses will go "true" and, consequently, only one of n possible operations can be selected.

The logic equations producing P after a switch is depressed and the NO putput reaches a true steady state are as follows:

$$OS = NO \cdot \bar{A} \cdot \bar{B} \qquad BJ = OS \cdot A$$
$$AJ = OS \qquad BK = NC$$
$$AK = B \qquad P = A \cdot B$$

The waveforms are shown in Fig. 2. A one-shot (OS) Fig. 1b, is initiated when any NO contact is made. The A f/f (A flip-flop) is set by OS. (The set side of the A f/f is indicated as AJ.) Then, after the time period generated by OS is finished, the B f/f is set and P goes "true." P remains "true" until one clock-time later when the A f/f is reset by B. The $\bar{B}$ term prevents the one-shot from being reinitiated by contact bounce from the NO contact when the switch is released. When the switch is released, its NC contact is made and the B f/f is reset, enabling the process to begin again.

Norton Markin, Senior Engineer, Bendix-Pacific, North Hollywood, Calif.

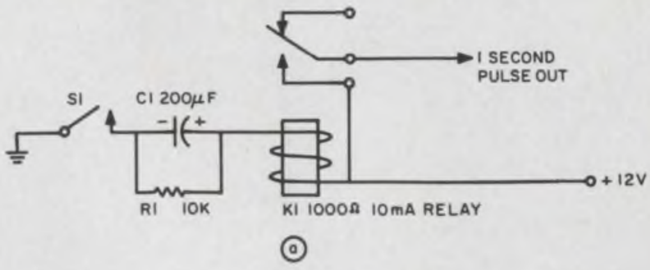
VOTE FOR 110

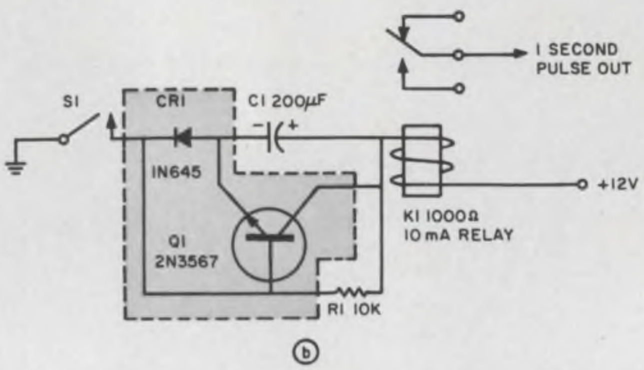
Transistor-diode combination improves pulser operation

An inexpensive transistor-diode combination increases the ability of a simple pulsing circuit to generate pulses of varying widths.

A frequently used pulsing circuit is shown in (a). Pulse characteristics are determined by *C1* and *K1*. Often only a form-A (i.e., spst normally open) contact is available at *S1* for actuation, so that circuit reset is accomplished by paralleling *C1* with *R1*. The reset time, determined by *C1* and *R1*, may be made less by reducing *R1*, but this is possible only when the value of *R1* is greater than that resistance value which will hold *K1* operated and prevent delivery of the required pulse.

An inexpensive way to overcome this problem appears in (b). Operation of *S1* reverse-biases *Q1*, owing to the drop across *CR1*, and *C1* is essentially shunted by *R1*, which is too large to hold *K1*, after *C1* is charged. When *S1* is opened, *CR1* is reverse-biased, allowing *R1* to deliver base current to *Q1* from its collector potential. *Q1* conducts and rapidly discharges *C1* as if it were





Improved operation can be obtained from the simple pulsing circuit (a) by the addition of a transistor-diode combination (b) which allows greater variation of pulse widths.

seeing a resistor of $R1/h_{fe}$ across it. For all practical purposes, the circuit is ready immediately for another timing cycle.

This arrangement may be used to advantage in isolated or floating circuits, since no external power source is required.

Elbert S. Kennedy, P. E., Leawood, Kan.

VOTE FOR 111

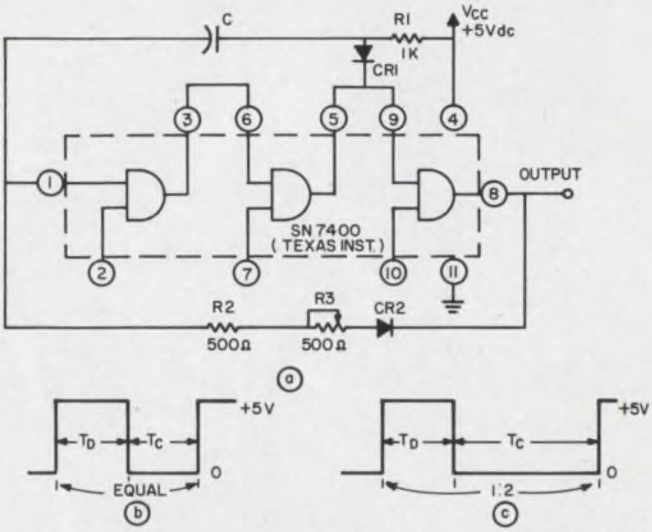
Square-wave generator uses IC NAND gate

With one IC NAND gate and a couple of passive components, a small square-wave oscillator may be built to work in the 1-hertz-to 5 kilohertz range. Since this clock generator is physically compatible with integrated logic circuits, it is easy to locate it close to the logic circuitry and alleviate pulse degeneration problems.

Distortion limits the frequency of this design (Fig. 1a), but within the range the waveform is fairly good with a rise of time of less than 100 ns. With an added buffer or drive stage at the input point (pin 1), however, it should be possible to extend the operating frequency even higher than 5 kHz.

For very low frequencies, electrolytic capacitors can be used reliably. Two miniature 47-μF capacitors were used in parallel to achieve a 1-Hz pulse.

The charge time for C (T_C) is dependent on the values of $R1$, $R2$, $R3$, the source impedance of the



1. **Square-wave generator** (a) uses charge and discharge paths of capacitor C as timing elements. With R3 shorted, the output is symmetrical (b). As R3 is increased, the symmetry is affected and the pulse is slowed down (c).

NAND gate output (pin *8*), and the resistance of *CR2*. Potentiometer *R3* provides a 2-to-1 frequency change for any specific capacitor. However, since it operates only on the charge path, it affects the symmetry of the output. In Fig. 1b, with *R3* shorted out, the output is symmetrical. In Fig. 1c, with *R3* all the way in, the OFF time of the pulse is twice as long as the ON time. The discharge time for C (T_D) is determined by the value of source impedance of the NAND gate output (pin *5*) and the input impedance (pin *1*).

C. Joseph Buttemeier, Senior Engineer, Litton Guidance & Controls Systems Div., Woodland Hills, Calif. VOTE FOR 112

Balanced load, tight regulation with SCR-Zener circuit

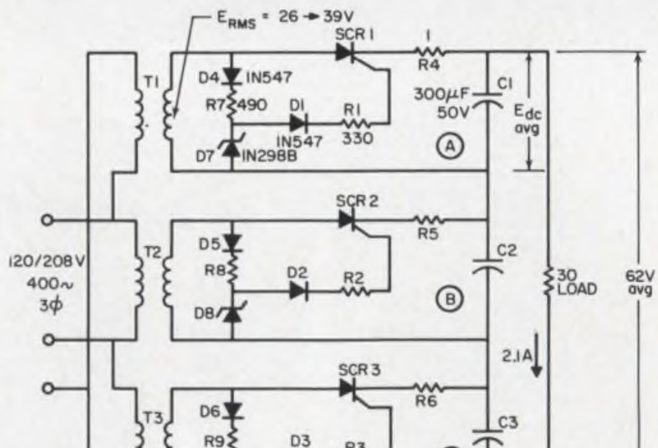
Balancing the load on a multiphase power source is achieved easily with this straightforward rectifier-voltage regulator circuit. Intended primarily for use as a preregulator for three-phase power sources, not only does the circuit serve as the main system rectifier but the SCRs (2N689) are also used for regulation. Finer regulation can be obtained by following this circuit with a series-type regulator.

When the upper terminal of the secondary of *T1* (as viewed in the diagram) becomes sufficiently positive with respect to its lower terminal, Zener diode *D7* breaks down to provide a reference potential at the junction of current-limiting resistor *R7* and diode *D7*. This reference voltage is applied through direction-determining diode *D1* and current-limiting resistor *R1* to the gate electrode of silicon-controlled rectifier *SCR1*. Since *SCR1* is switched ON when its control voltage is less than its gate voltage and is switched OFF when its control voltage is greater than its gate voltage, the upper rectifier circuit *A* tends to keep the voltage across its output capacitor, *C1*, at a constant value. Each of the SCR rectifier circuits, *B* and *C*, which are energized by the secondary windings of *T2* and *T3*, respectively, charges its respective output capacitor, *C2* or *C3*, in a similar manner. The three capacitors in series discharge through the load resistor providing a regulated output voltage.

The load across the individual phases of the polyphase source may be balanced by adjustment of the output time constant of the SCR circuits by means of varying the values of either their respective output capacitors or their respective series resistors *R4*, *R5* and *R6*, or both, for a given load resistance.

The main advantage is that the power drawn from each phase of the primary source is the same, and thus a balanced load is achieved. A secondary advantage is that the power drawn is about the same at low-line voltage as at high-line voltage. (The circuit was originally designed to handle a 60% swing in line voltage, [145 V-270 V]). In other words, the circuit is almost a constant power input device independent of line voltage.

Other advantages are: three-phase equalization



E_{RMS} VOLTS	$E_{dc_{avg}}$ VOLTS	E_{avg} (LOAD) VOLTS
26.0	21.0	62.0
30.0	21.0+	62.0
34.0	21.2	62.0
38.0	21.8	62.0
39.0	21.8	62.0

Good output voltage regulation is easily obtained with this circuit. The voltages shown indicate the effectiveness of this multiphase rectifier-regulator. All single phase circuits use the same values of components.

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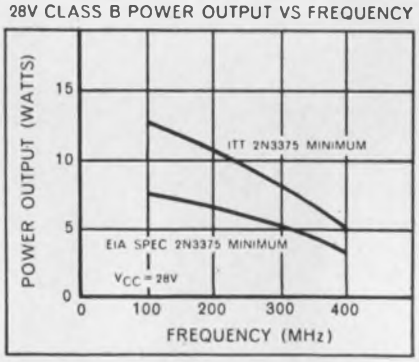

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of phase loading using a minimum number of parts for a maximum change in the three primary voltage; capacity to feed reasonably high current loads; and the facility of the single-phase version to be adapted inexpensively to regulate dc for any electronic application requiring a maximum change in the primary ac voltage (transmitters, receivers, test equipment, etc.).

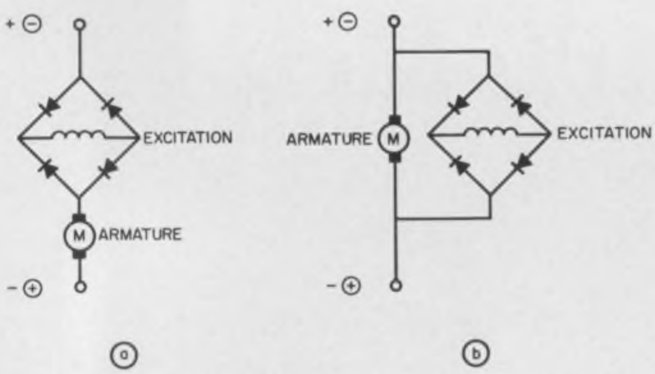
Daniel Rosenthal and Herbert E. Hawlk, Design Engineers, RCA, Camden, N. J.

VOTE FOR 113

Diode bridge saves wires in motor-reversing systems

Two, not four, wires are needed to reverse the rotation of a motor, if a diode bridge is employed.

Often, small shunt or series dc motors are used for remote-controlled equipments. To change the direction of rotation, the conventional circuit requires four leads—two for the armature with a fixed polarity and two to stop polarity of the excitation.



Only two wires are needed to reverse the rotation of a series motor (a) or a shunt motor (b) when a diode bridge is employed.

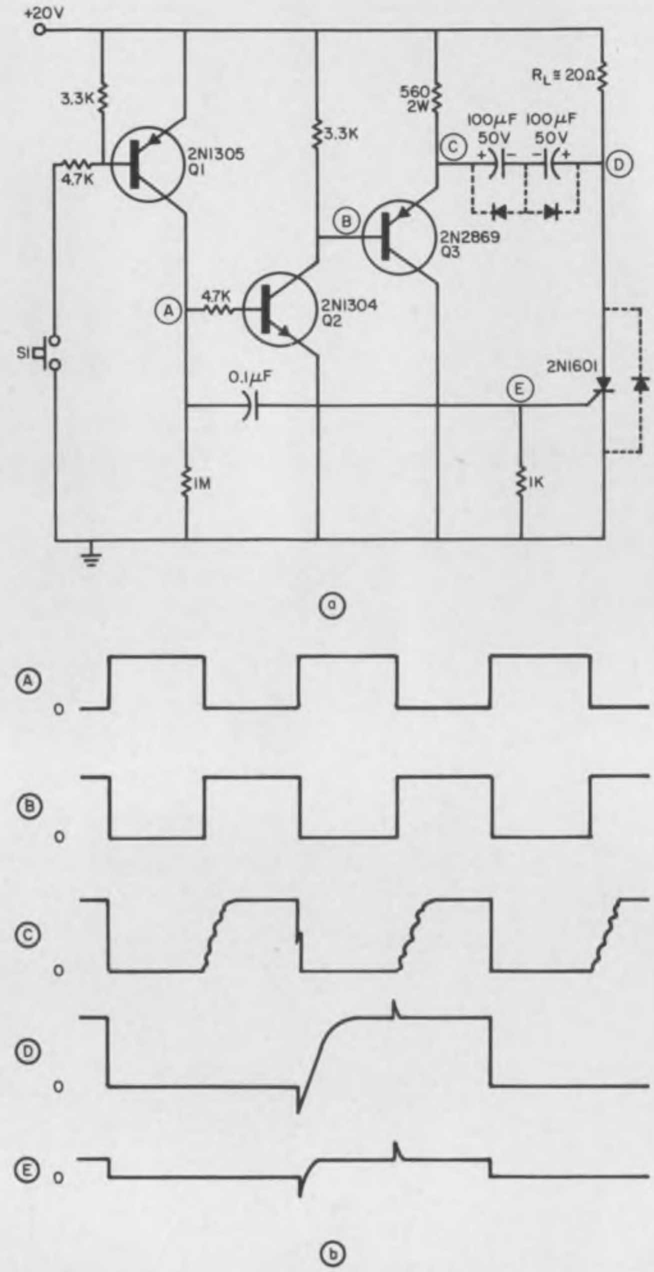
With a diode bridge (see schematic) only two wires are necessary. When the polarity of these two wires is changed, the armature current changes direction, but not the excitation current. The motor, however, will reverse its direction of rotation.

Gottfried Irminger, Design Engineer, Wettingen, Switzerland.

VOTE FOR 114

One-sided flip-flop uses only one SCR

A one-sided flip-flop, driven by a switch-generated trigger, can easily be built with a single SCR. Its current-handling capability is reasonably large; its components are inexpensive.



One-sided flip-flop uses SCR and three bipolar stages (a). Output frequency (at D) is half that of input frequency (b). Optional diodes (dotted) may be used for peak clipping and reset of electrolytics.

In the circuit (see schematic) the SCR is being commutated; *Q3* is a charging stage, and *Q1* and *Q2* provide the triggering-buffering functions. The optional diodes (shown dotted) may be added to clip negative spikes and to reset the back-to-back electrolytics.

Output current capabilities may be further increased by using "bigger" SCR and *Q3* stages. This, however, entails larger commutating capabilities and less emitter resistance in *Q3*. A further liability is the possible degradation of the frequency response. Circuit action is iniated by grounding the base-leg of *Q1* by way of switch *S1*.

Jack H. Still, Project Engineer, American Lava Corp., Chattanooga, Tenn.

VOTE FOR 115

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Bits and Pieces

Wisdom and levity, well-developed fruits of frustration, will rarely be found, except in bits and pieces.....

Esoteric obscurity

The present report is an admonitory expostulation by a panel of eminent psychologists who have been designated to conduct an investigation into the feasibility of implementing an optimal increment in the degree of obfuscation in defense reports. It has been averred in cognizant circles that recognized techniques have circumstantiated that the degree of operational utility envisioned for certain ancillary defense projects is minimal, if not altogether suppositious. To obviate the possibility of a budgetary recession, it seems to be indicated that means should be devised to make the appreciation of the inherently nonutilitarian nature of the aforementioned projects as recondite as possible.

Heretofore the panel has convened only a minimal number of times, but considerable progress has already been made toward elaboration of procedures and establishment of basic principles. Recapitulation of its work demonstrates that seven fundamental principles of obfuscation obtain:

- Utilization of Anglo-Saxon language units of deficient letter count should be deprecated insofar as more suitable polysyllabics of Latin or Greek origin can be substituted.
- Euphuistic periphrasis and employment of complex and compound syntax should be encouraged, since it has been determined by a study of behavioristic significs that, when the reader observes ambiguities in the relation between verbal form classes, a comparatively high parameter of confusion results.
- Fustian recourse to archaic and obsolescent word forms will inculcate an impression of erudition and scholarship.
- Excessive verbosity in the form of concatenations of sonorous phrases of negligible import is highly commended.
- The passivity of verbal voices is an auxiliary ploy that engenders opacity.
- Infusion of alphabets other than roman, interspersed with technological nomenclature which should be neither semantically defined nor elucidated by terminological redundancies, will promote turbidity.
- **Never write as you speak!** People might just be able to understand you, and then you're really in trouble. After all, what *are* you trying to say?

V. D. Landon
Princeton, N. J.

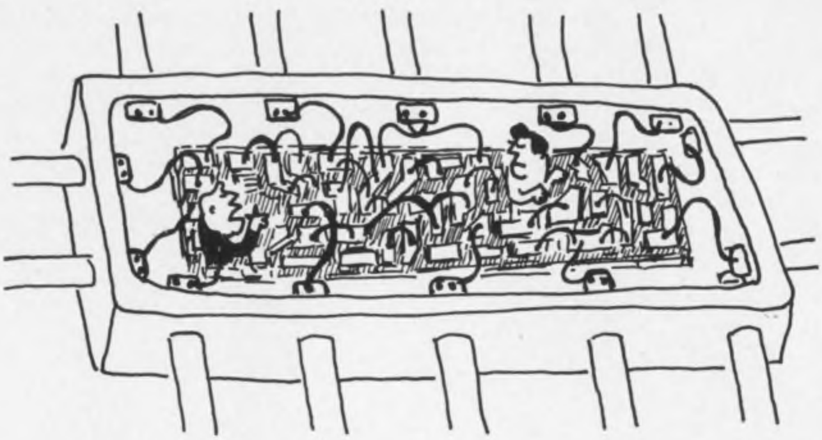
Have you got a contribution? We'll compensate. Be it a letter, commentary, puzzle, cartoon, or cartoon idea, send it along to: RC, Electronic Design, 850 Third Ave., New York, N. Y. 10022.

Managing change

How are your managerial instincts? Success demands dynamism, dynamism begets change and change creates resistance. Do you give conscious thought to this problem when you institute changes? As stated by Dr. Gordon L. Lippitt, president of Leadership Resources, Inc., here are some of the reasons why people resent change:

- When purpose is not clear. Mystery and ambiguity cause anxiety.
- When they are not involved in the planning. On the other hand, we're all usually ready to follow our own suggestions.
- When the change is made for purely personal reasons. Loyalty is great, but action requires a purpose and a goal.
- When habit patterns are ignored. A group of people who eat lunch together will resent changes that alter their relationship.
- When there is fear of failure. For instance, if penalties for nonfulfillment are implied or stated—demotion, loss of job, etc.
- When there is poor communication. Though a change may affect only one or two persons out of a group of ten, all members of the group need to be advised in order to maintain group cooperation.
- When excessive work pressure is involved. Often these pressures are the result of short-sighted work plans.
- When the rewards for changing are, in human terms, outweighed by the costs.
- When there is no obvious benefit from the change. There is always the attitude, typically human, that is reflected by the question, "Why rock the boat?"

(continued on p. 112)



"Hey Joe, you sure you wired the emitter to R1?"

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Bits and Pieces CONTINUED

Next time you're thinking of making some changes, keep these points in mind and see if the waves made by your changes can't be reduced to ripples.—**RC**

If you learn, you earn. This is particularly true in the engineering profession, according to a study by the National Society of Professional Engineers.

The study, based on a survey of 1960 engineering graduates from the University of Illinois, found that without exception the increase in an engineer's salary is more dependent on education than experience.

The survey showed that the 319 engineers who took jobs immediately after graduation now average $818 a month. The 66 with master's degrees in a technical field earn an average $893 a month, while three with doctorates average $900.

"Although advanced sophistication and circuits may lead to efficient instruments, their basic measuring principles must be soundly founded. Most of these were conceived a half-century ago."

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". . . professors, preoccupied with their personal prestige and fortified by their intellectual competence, are inclined to look down their noses at the most pedestrian efforts of the working Industrial Engineer. Without detracting from their important role in developing the minds of our youth, I think educators are generally out of place in the industrial world. Their theories, some quite obscure, have not been honed and sharpened by contact with the realities of running a profitable business. There is something about the generation of action . . . that requires a realistic bed-rock approach not in harmony with lofty pronouncements or impressive equations.

"If these idealists had to work with people rather than ideas, they would soon find a variety of reactions that defies a precise, mathematical-oriented solution . . . They have a place in the field but in the average plant which can support an Industrial Engineering department of, say, twenty engineers, the right proportion would be, in my opinion, one technically competent theorist to nineteen agressive, take-charge, shirtsleeve type of operator who will set some realistic objectives and get them done."

Taken from "The Emerging Role of the Industrial Engineer," a paper by R. H. Bavier, of Bavier, Bulger and Goodyear, management consultants, this statement appears particularly appropriate within the electronics industry, where a good many engineers and engineering managers would sympathize with Mr. Bavier. The complete paper appears in the August/September issue of the IEEE Engineering Management Newsletter.—**RC**

Fold here, staple and Mail.

University surveys indicate:

STARTING SALARIES OF ENGINEERS ARE DECEPTIVELY HIGH

By James M. Jenks

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

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

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

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

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

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

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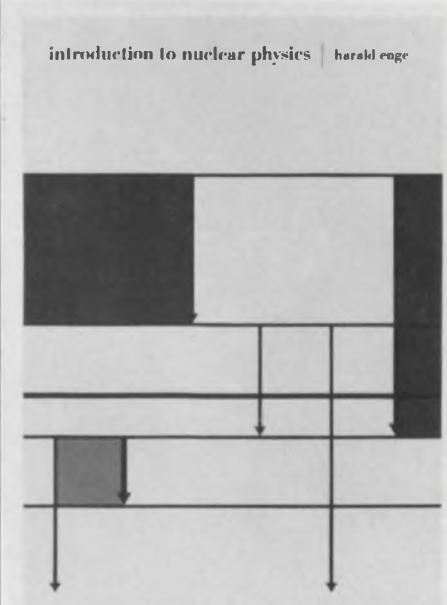
Book Reviews



Nuclear physics

Such topics as two-body problems, proper ties of stable nuclei, nuclear models, disintegration of unstable nuclei, nuclear reactions, nuclear power and elementary particles are covered in this book on low-energy physics.

For a given topic the experimental facts are presented first, followed by theory. Experiment and theory are then compared. For example, the Hofstadter experiment which measures the nuclear radius using high-energy electron scattering or diffraction is described. The experimental results are likened to those of the less complex Rutherford experiment in which nuclei are bombarded with alpha particles. Then the formula for distribution of the charge density in the nucleus and theory are given and compared to Hofstadter's experimental results.

The recent and typical experiments chosen to illustrate the various theories are not necessarily historical firsts. In organizing the material for this book no attention is paid to the historical development of the subject.

Some knowledge of electricity and magnetism and elementary wave mechanics is helpful for a full understanding of the book. One appendix contains a brief but thorough review of wave mechanics

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for those uncertain of their proficiency in this subject. Other appendices cover ion-beam focusing and dispersion in electric and magnetic fields, barrier penetration, time dependent perterbation theory and matrix diagonalization.

A number of problems are given at the end of each chapter. One or two problems in each section considered more difficult are intended as "term problems."

Introduction to Nuclear Physics. Harald A. Enge (Addison-Wesley Publishing Co., Inc.: Reading, Mass.). 582 pp. $12.75.

—*Genevieve Adee*

Test probes

This is an introductory book intended to provide a basic background to modern electronic probes and their uses. It explains how they operate and what they can be expected to do. It provides information about the circuitry, construction, basic functions, and applications of the most common types of test probes found in the field today. You will find illustrations to guide you in improving your knowledge of test equipment.

ABC's of Electronic Test Probes, Rudolf F. Graf, (Howard W. Sams & Co., Inc., Indianapolis, Ind.) 128 pp. $2.25

Switching theory

The techniques and theory for the design and analysis of switching circuits are given in two volumes. Their theoretical framework explains the switching theory from both engineering and mathematical points of view.

Volume 1 covers extensively functional decomposition, multiple output design, the application of techniques developed for relay-contact networks, cubical representation and the connection of Boolean algebra to group and lattice theory.

Topics in Volume 2 include regular depressions, incompletely specified sequential machine state minimization, and asynchronous and speed independent circuit theory.

Switching Theory. Raymond E. Muller (John Wiley & Sons, Inc.: New York). 2 vols.

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Crystal growth and structure

A book on crystals, their growth and structure is one in a series of Westinghouse Search Books. It describes the arrangement of molecules, atoms and electrons within various crystals and other solids and discusses how the lattice formations determine physical and chemical properties. Imperfections in crystals are examined, and diagrams and illustrations show crystal formation.

Crystals: Perfect and Imperfect. A. Bennet, D. Hamilton, A. Maradudin, R. Miller and J. Murphy (Walker and Company: New York). 237 pp. $5.95.

Basic microwave principles

An explanation of the principles underlying modern microwave technology begins with wave phenomena, considering electromagnetic waves both in free space and interacting with matter. A discussion of reflection, refraction and diffraction provides the basis for the introduction of antenna theory and a description of antenna types.

Treatment of the transmission line theory and the effects of obstacles and apertures in waveguides is provided, as is a consideration of microwave component design. Mathematical aids are included where needed, but a knowledge of calculus is not required.

Basic Microwaves. Bernard Berkowitz (Hayden Book Company, Inc.: New York). 167 pp. $5.95.

Power supplies

Methods and circuits for controlling power supply outputs, including the latest innovations are included in this book. Contains numerous diagrams for open-loop regulated supplies, closed-loop regulators, and open-loop circuits using zener diodes. Written for anyone who designs and services regulated power supplies.

Design and Operation of Regulated Power Supplies, Irving Gottlieb (Howard W. Sams & Co., Inc., Indianapolis, Ind.) 144 pp. $3.25

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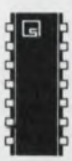

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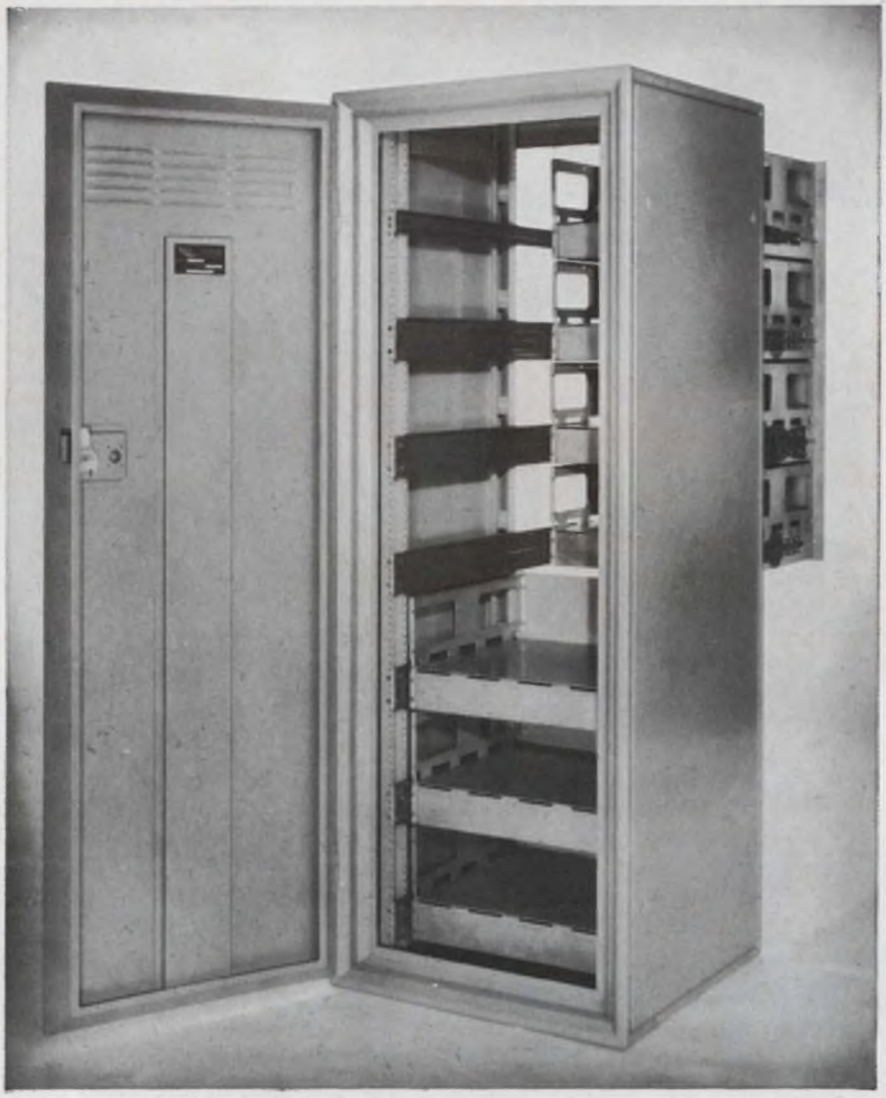

Bibliographical guide

This second volume of Electronics is a bibliographical guide from 1959 to December 1964. It lists directly the major works in the literature of electronics: the authoritative textbooks, the survey articles, reports on main conventions and conferences, and papers in which significant advances have been reported. The aim has been to provide a means by which any paper in the literature of electronics may be located. Emphasis is given to recent trends in the design of electronic equipment such as color television and computer memory.

Electronics a bibliographical guide-2, C. K. Moore, Royal Radar Establishment, UK, K. J. Spencer, H. Q. Library, Ministry of Aviation, U. K. (Plenum Publishing Corp., New York) 411 pp. $18.00

Junction transistors

The principle purpose of this book is to explain the properties of transistors and to show how their behavior can be described in a way equitable for circuit analysis. Written for students of engineering and physics this text presents more adanced ideas about transistor operation and also explains the operation and characterization of junction transistors to a point from which detailed circuit analysis and design can be undertaken.

Junction Transistors, John J. Sparkes, Senior Lecturer in Communications, Imperial College, London (Pergamon Press) 249 pp. $3.95

Design approach to electronic devices

This text, geared to students, discusses the operation, modeling and application of active devices with emphasis on semiconductor devices. The relation of Bode plots to the pole-zero analysis and the development and use of the piecewise linear model are covered. Each chapter contains a summary and problems of circuit design. Included are a list of symbols and quantities and data sheets on semiconductor devices.

Electronics. Roy H. Mattson, (John Wiley & Sons, Inc., New York) 620 pp. $12.95.

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Bandwidth (unity gain)	MHz	7	15	6
Voltage gain		2,700	2,700	50,000
Offset voltage	mV	2.0	2.0	2.0
Offset current	nA	80	400	80
Thermal drift	μV/°C	5	5	5
Output swing	V_{P-P}	21	21	9
Power consumption	mW	90	160	90
Common mode rejection	db	100	100	100
Power supply rejection	db	80	80	80
Input bias current	μA	0.4	1.2	0.4

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Space communications

Here under one cover is a compact, yet thorough and informative treatment of virtually every aspect of space communications systems. Divided into two parts, Fundamentals and Applications, the book begins with a chapter covering the motion and dynamics of a space vehicle. Proceeding through discussion and explanation of the environmental and reliability considerations involved in space communications system design, the propagation and noise problems involved, the authors conclude the Fundamentals section with a chapter devoted to types of space communications links and their design.

The second part, Applications, provides an interesting treatment of existing systems, their requirements and their performance. Appendices provided at the end of the book contain data related to system requirements, test plans, reliability, estimates, performance criteria, etc.

Throughout all parts of the book, the authors have emphasized the systems characteristics of space communications. In keeping with this systems concept, a large part of the material in this work is devoted to showing how the electronic systems which serve communications functions can be integrated with other electronic, thermal, mechanical and optical systems to satisfy requirements for a given space mission.

(continued on p. 128)

BOOK REVIEWS

(continued from p. 126)

Planned as both a text and a reference, the book succeeds on both counts. Practicing engineers as well as students will find it a useful addition to their libraries.

Space Communications Systems, Richard F. Filipowsky, Eugen I. Muehldorf (Prentice-Hall, Inc., Englewood Cliffs, N. J.) 575 pp.

Control systems

Collections of papers given at a USSR Conference on Automatic Control and Computer Engineering are given in two volumes. They cover both analog and digital computing techniques.

Volume 1 examines problems of developing and applying resources of computer engineering in the automatic control of manufacturing processes. Examples for using computer system design and the automation of manufacturing processes are included.

Volume 2 deals with the dynamics of control systems containing computers. Non-linear theory of oscillations are examined, as are theories of impulse systems and of vibrational smoothing of non-linear characteristics of automatic control systems.

Automatic Control and Computer Engineering. V. V. Solodovnikov, ed. (Pergamon Press: New York). 2 vols.

Using oscilloscopes

Latest methods for using an oscilloscope for faster, more proficient servicing, are included in this book. Tells how to make waveform tests and how to analyze the waveforms produced by defective circuits. Much of the book is related to television set testing, covering the various sections of both black and white and color TV sets in detail. Charts are found for some of the common circuits. The use of square waves to evaluate circuits and components is also explained. For each test described, information is included on equipment needed, connections required, procedure, and test evaluation. Includes many illustrations and waveforms.

101 Ways to Use Your Oscilloscope, Robert G. Middleton, (Howard W. Sams & Co., Inc., Indianapolis, Ind.) 192 pp. $2.95

Say you started out to design a hi-rel regulator that would replace bulky DO-7 and 13 cans.

But still deliver at commercial prices.

First you'd tap management for quite a few kilobucks and a room full of the best brains.

Then, after both were spent, you'd find you'd developed a thermally-grown, oxide-passivated, silicon wafer. With brazed leads. Snug fitting slugs. And exclusive hermetic seal.

And you'd pass the word along that it'd take more heat and current than the old metal cans.

Now what?

You'd expand the line and wind up with twenty-eight each HW 1 watt or HM 400 mw micro-glass, micro-miniature regulators that you could deliver in a week.

Which is what we did right here.

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A Division of Hoffman Electronics Corporation, Hoffman Electronic Park, El Monte, California 91734

ON READER-SERVICE CARD CIRCLE 61

These three NIXIE® tubes will fill 80% of your digital-readout requirements

STANDARD RECTANGULAR — MINIATURE RECTANGULAR — LOW-COST SIDE-VIEWING

The most popular readout ever made—Type 8422. Combines *readability* (maximum viewing distance of 30 feet), *compact* size (0.6" character in a 1.0" x 0.8" end-reading rectangular envelope) and *high reliability* (MTBF of 1 million hours at 90% confidence level). Also available in a decimal-point version, Type B-59956. For high-density packaging (0.7 cu. in.) and minimal instrument height, it's the choice of virtually every important manufacturer of digital instrumentation.

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Our new side-viewing NIXIE tube, Type B-5440. Combines *long-life* (average life of 600,000 hours) with *low cost* ($4.95 in 1000 quantity). Tube has low profile and narrow width for minimum panel-area opening (you can line them up on less than 0.80" centers), and its new socket is especially designed for pc-board mounting. Independently-operable decimal points are optional at slight extra cost (Type B-5441).
Call or write for full information.

See us at ISA Booth 1320
See us at NEREM Booth 1B69-70
See us at Fall Joint Computer Conference Booth 835-37

(and we've got the NIXIE tubes for that other 20%, too!)

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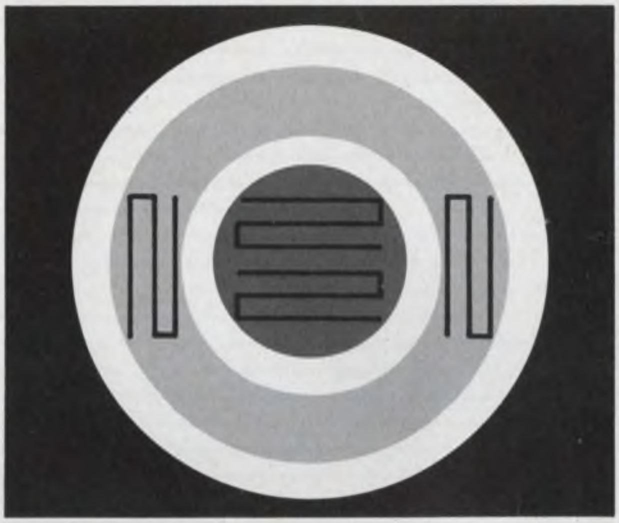
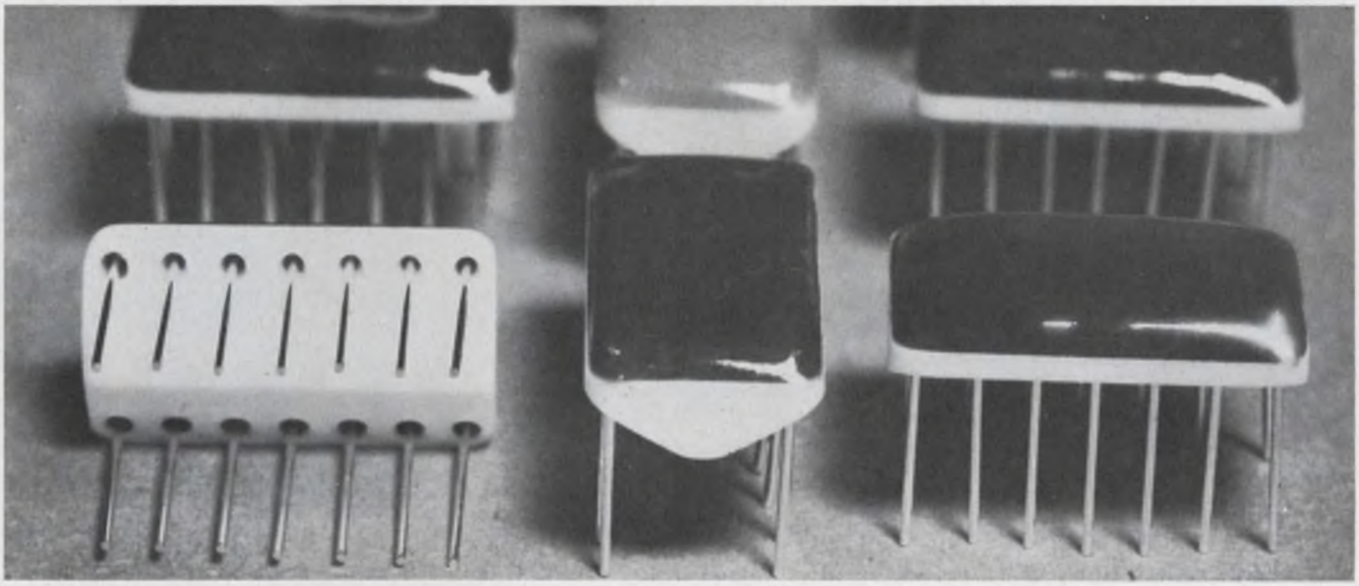
Burroughs Corporation / ELECTRONIC COMPONENTS DIVISION
PLAINFIELD, NEW JERSEY 07061

Products

Power FET "on" resistance drops to 4 Ω while transconductance hits 150,000 μmho. Page 132



Monolithic pressure sensor uses a single silicon crystal as its diaphragm. Page 166



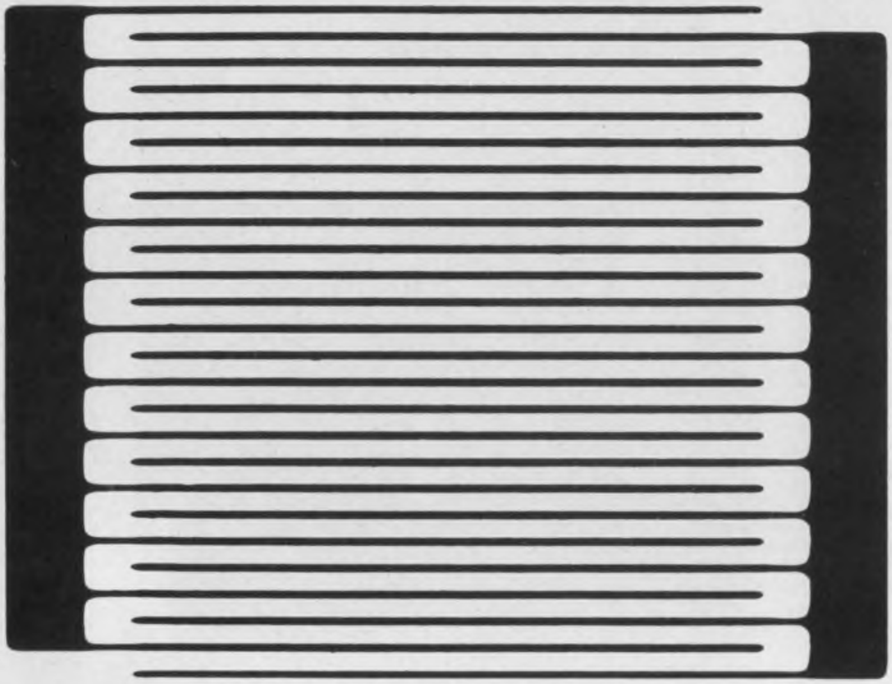
Epoxy DTL circuits in dual in-line package cut costs. The series consists of gates, J-K flip-flops, buffers, line drivers, expanders and inverters. Page 136

Also in this section:

Epoxy transistors in TO-18 can for low-cost, high-speed switching. Page 134

4-bit storage registers operate in BCD or biquinary mode. Page 138

Circuit test board uses stainless steel springs to secure components. Page 158



Power FET "on" resistance reaches a new low

Two series of silicon n-channel field-effect transistors boast the lowest "on" resistance of any currently available device. The CP650 series of power and switching FETs and CM650 series switching FETs have maximums of 5 and 4 Ω respectively. Previous lows, achieved by Texas Instruments, have been in the 20-Ω range for their switching FETs. In addition, transconductances (g_m) reach 150,000 μmho, drain currents (I_{DSS}) are 1.2 A and theoretical gain-bandwidth product is 1.5 GHz.

Low drive power requirements make the CP650 attractively for use in power supply regulators. As an RF amplifier (2 to 30 MHz), the CP650 has exhibited a dynamic range exceeding 140 dB. As a switch (CP652), the low R_{DS} and high-speed ($T_{on}/T_{off} < 20$ ns driven from 50 Ω) make these FETs suitable for high-speed D-to-A converters, core drivers or even low-current SCR replacements. Low leakage currents (I_{GSS} is less than 3 nA) coupled with inherent FET zero offset voltage suggest solid-state relay applications. Other applications include inverters and current sources.

Other specifications include maximum capacitances of 20 pF gate-to-source and gate-to-drain. Breakdown voltages are 20 V.

The CP650 is packaged in a copper-base TO-5 can with the gate connected to case. The package dissipates 9 W at 25°C case. (The FETs should be useable up to 5 W at 800 MHz). The 25-channel device is an interdigitated design having a large active area with a total equivalent gate length of less than 1.5 in. The chip itself measures 40 x 40 mils.

The CM series of switching FETs has basically the same specs. Dissipation is only 400 mW derating at 2.3 mW/°C. Peak gate current is 100 mA and peak drain current is 400 mA. Drain currents are specified at 100 and 150 mA. Both devices have an operating and storage junction temperature range of −65 to 200°C.

P&A: $26 to $42 (CP series), $25 to $48 (CM series), (1 to 99); November. Crystalonics Div., Teledyne Inc., 147 Sherman St., Cambridge, Mass. Phone: (617) 491-1670.

Circle No. 117

Diff-amp transistor

Differential base current drift of the A607 and A608 differential amplifier transistors is 1.5 nA/°C. With a differential voltage drift of 5 μA/°C, the A607 offers high gain stability against changes in current drain. Total variation in h_{FE} for collector currents from 10 to 100 μA is 3 dB. Packaged in TO-5 cans, these transistors offer increased amplifier sensitivity and linearity.

Amperex Electronic Corp., Slatersville, R. I. Phone: (401) 762-9000.

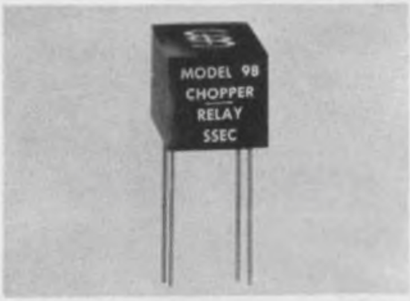
Circle No. 118

Laser chips

Operating at liquid nitrogen temperatures under pulsed conditions, these gallium arsenide phosphide laser chips are available at any wave length between 6500 and 8300 Å with spectral halfwidth of about 8 Å. The chip is mounted on a TO-46 solid Kovar header. Output is typically 0.5 W at 25 A with a 50-ns pulse and a repetition rate of 75 pps. Threshold currents are less than 15 A.

P&A: $13 to $19.50; stock. Monsanto Co., 800 N. Lindbergh Blvd., St. Louis. Phone: (314) 993-1000.

Circle No. 119



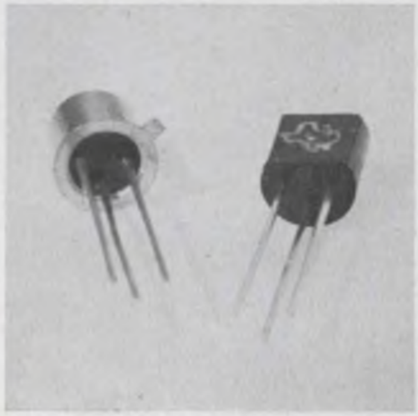
Chopper-relay

This inertialess chopper-relay can be driven from dc to 5 kHz with complete isolation between either drive terminal and contact terminals. Noise is 25 μV and dynamic range can be extended from ±75 μV to ±20 V. Alternate application of a polarized or ac square wave causes the device to act as an spst chopper. Two units may be connected to form an spdt chopper or switch.

Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. Phone: (213) 785-4473.

Circle No. 120

ON READER-SERVICE CARD CIRCLE 63 ➤



TO-18 epoxy transistors

A family of one-piece plastic-encapsulated silicon transistors is packaged with leads in a standard TO-18 pin-circle configuration. Initial devices with the 100-mil diameter pin-circle include a family of complementary npn/pnp, high-speed low-level switches. Type numbers 2N4418 and 2N4419 (2369), 2N4420 (3014), 2N4421 (706), 2N4422 (3646 and 3013) and 2N4423 (2894) are direct plug-in replacements for the metal-can units shown in parentheses. Since no lead-forming is necessary, the transistor can be mounted flush on PC boards. Package height is 185 mils. Leads are silver-plated nickel.

P&A: $0.45 (2N4419); stock. Texas Instruments Inc., 13500 N. Central Expressway, Dallas, Texas. Phone: (213) 235-3111.

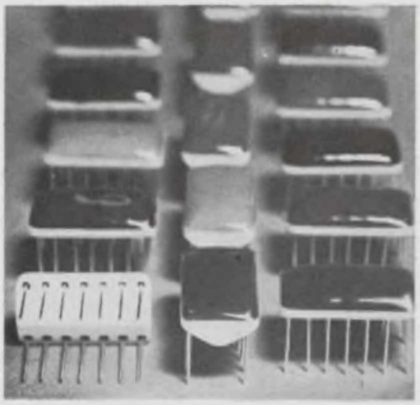
Circle No. 121

Low-noise MOSFET

A new single-gate MOSFET, the 3N128, is designed for vhf amplifiers, mixers and oscillators. It is also suited for use in low-frequency amplifier applications requiring a transistor having high-power gain and very high input impedance. In addition, the MOS process makes possible a feedback capacitance of 0.2 pF max. The 3N128 is an N-channel, depletion-type silicon device with a transconductance ranging from 5000 to 7300 μmho. Typical power gain is 18 dB and noise figure is 4 dB at a drain current of 5 mA, a drain-to-source voltage of 15 V and a frequency of 200 MHz.

RCA, Electronic Components and Devices, Harrison, N. J. Phone: (201) 485-3900.

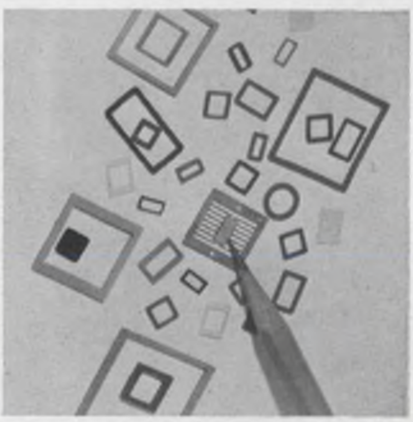
Circle No. 122



Epoxy DTL ICs

Epoxy DTL circuits, designated the E-line, are standard 930 series DTL circuits in a dual in-line package. The family consists of gates, buffers, line drivers, and expanders. The J-K flip-flops have a typical toggle rate of 24 MHz. Special packaging features include standard 100-mil center-to-center spacing between round kovar leads and standard 300-mil spacing between lead ranks.

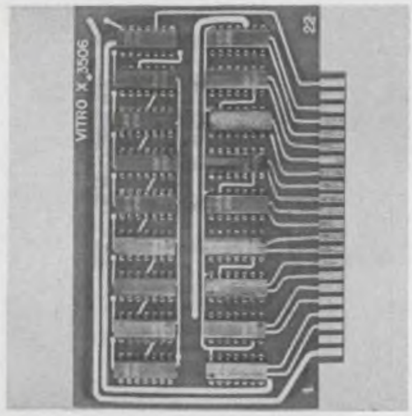
Price: $1.40 to $2.80 (100 to 1000). Microelectronics Div., Philco Corp., 2920 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-2966. *Circle No. 123*



Preformed glass frames

Preformed glass frames for sealing alumina or Kovar bases to their Kovar leads are offered. The preformed frame introduces a finite amount of sealing glass and can be shaker loaded into the sealing jigs. The frames are available in custom sizes with 0.02-in. minimum thickness and ranging from 1/4 x 1/8-in. up to 0.98-in.^{2}.

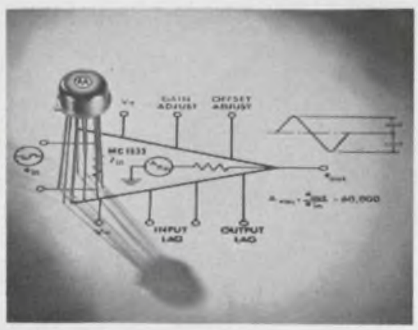
P&A: $10 to $400/M, 5 to 8 wks. Glass Beads Co., P. O. Box 266, Latrobe, Pa. Phone: (412) 537-7791. *Circle No. 124*



Microcircuit modules

High-density logic modules can accommodate up to 18 removable microcircuits on a single card. All boards have been standardized for positive NAND logic functions at a voltage swing from 0 to 3 V. The DTL devices used have individual circuit speeds up to 10 MHz and equipment speeds above 5 MHz. Boards can be custom built.

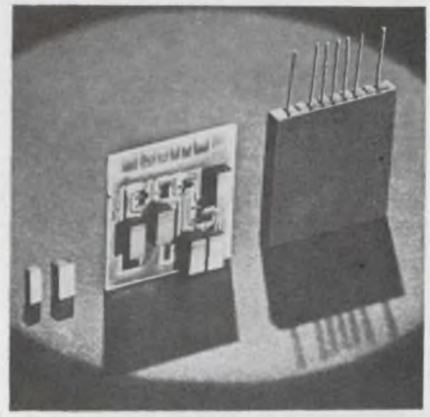
Vitro Electronics, 919 Jesup-Blair Dr., Silver Spring, Md. Phone: (301) 585-1000. *Circle No. 125*



IC op-amp

Designed for use as a summing amplifier, integrator or amplifier with operating characteristics as a function of external feedback components, this op-amp has open loop voltage gain of 40,000 min and 60,000 typical. Average temperature coefficient of input offset voltage is typically 3 μV/°C from 25 to 125° C and 5 μV/°C from −55 to 25°C. Input offset voltage is 5 mV max adjustable to zero by an external resistor. Full output voltage swing is ±12 V min with a ±15-V supply and 10-kΩ load.

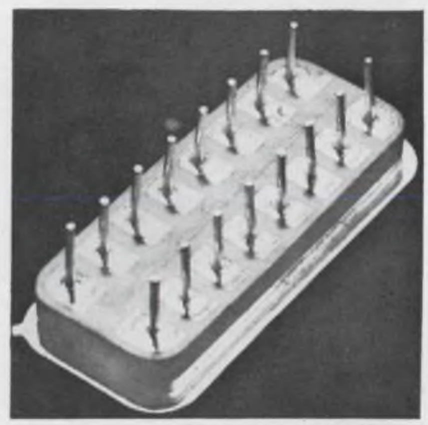
P&A: $34 (over 100); stock. Motorola Semiconductor Products Inc., Box 944, Phoenix. Phone: (602) 273-6900. *Circle No. 126*



Chip capacitor

Made of alternate layers of ribbon glass and dielectric material, fused into a monolithic chip, these miniature chip capacitors are metallized on the ends and can be soldered directly to the conductor on a substrate. The 0.19- x 0.95- x 0.08-in. version has a range of 0.012 to 0.051 μF. Working voltage is 50 Vdc from −55 to 125°C. Worst case capacitance change from accelerated life testing is 2% max for the lower capacitance values and 10% max for the higher values.

Corning Glass Works, Corning, N. Y. Phone: (607) 962-4444. *Circle No. 127*



16-pin header assembly

A 16-pin dual-in-line header assembly for complex function ICs is designated HA-1496. The package is a high-temperature brazed construction using 95% aluminum oxide. Closure is made by capacitance discharge welding.

P&A: $250 (set of 25 with covers and flanges); 6 to 8 wks. Mitronics Inc., 132 Floral Ave., Murray Hill, N. J. Phone: (201) 464-3300. *Circle No. 128*

ON READER-SERVICE CARD CIRCLE 66 ➤

Relay shipments rescheduled again?
Next time call Leach!

One week delivery. That's a promise. At least on standard units. Even our new SERIES K for example. Here's a 10 amp 4PDT polarized relay offering maximum capabilities for the most severe aircraft, missile and aerospace applications. And we have built up an inventory to cover your requirements.

The SERIES K holds size and weight to an absolute minimum without sacrificing operating characteristics. It will withstand 100g shock, 30g, 70 to 3000 cps vibration, meets Mil-R-6106E and has a temperature range of $-70°$ to $+125°$C. Operate and release time is less than 15 milliseconds including bounce. Yet it measures only 1.000″ x 1.015″ x 1.015″ and weighs less than 2.5 ounces. Need one? A dozen, a hundred? Even a thousand? Then call us today. You'll have them. Right on time.

Leach Corporation, Relay Division, 5915 Avalon Boulevard, Los Angeles, California 90003
Phone (Area code 213) 232-8221
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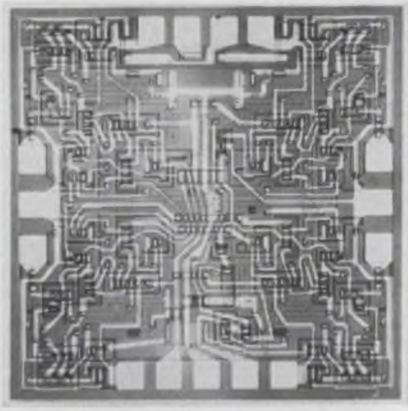
LEACH



4-bit storage registers

Two monolithic silicon sub-systems, a 4-bit decade counter/storage register (S1289A) and a 4-bit binary counter/storage register (S1281A), incorporate four J-K flip-flops and 13 gates. Equivalent discrete component count is 160. The S1280A may be used in either the BCD or bi-quinary mode to provide the square wave output for frequency synthesis. This flexibility results from the incorporation of separate divide-by-two and divide-by-five functions on the chip. The S1281A contains separate one- and three-stage binary counters which may be cascaded by external connections to obtain a four-stage binary counter. The unit therefore provides division by 2, 4, 8 or 16. Both feature strobed single-ended parallel entry capability and are offered in a plastic dual-in-line plug-in package.

P&A: $14.40 (100-up); immediate. Signetics Corporation, Sunnyvale, Calif. Phone: (408) 739-7700.

Circle No. 129

Thermoelectric modules

A "building block" for temperature control applications, this thermoelectric module has flat surfaces, parallel to ±1/2 mil. The metalized ceramic construction provides internal thermal stresses approximately 1/2 that of copper and 1/4 that of aluminum capped modules of the same size. The unit will pump 67 Btu/h max and provides an unloaded temperature differential of 65°C max when operated at 9 A and 4 V. The G9-65 measures 1.25 x 1.25 x 0.21 in.

EG&G, Inc., 160 Brookline Ave., Boston. Phone: (617) 267-9700.

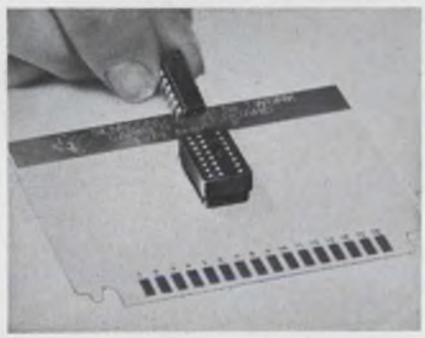
Circle No. 130

Wirewound networks

Available as voltage dividers, D-to-A ladder networks or other configurations, the smallest of these resistor networks measures 0.14- x 0.3- x 0.6-in. This unit will hold 6 resistors ranging from 0.1 Ω to 100 kΩ each with standard tolerance of 1% to 0.05%. Minimum lead spacing is 0.1-in. along the length with 0.05-in. minimum from edge of package to center of lead. Ribbon leads are available for IC compatibility.

Tri-King Industries, Inc., 8933 Quartz Ave., Northridge, Calif Phone: (213) 882-1500.

Circle No. 131



IC test board

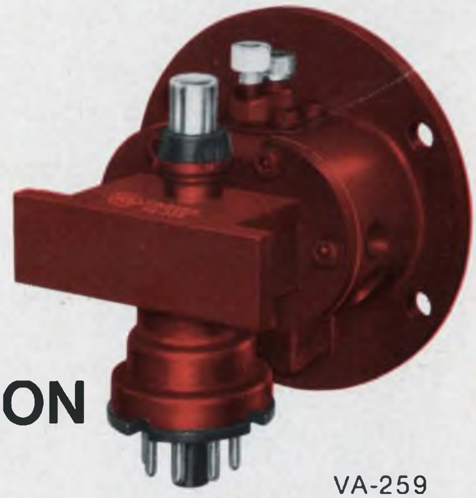
For the testing and operation of plug-in and in-line ICs, the "Pin Pack Test Board" will mate with standard 18-position edge connectors with contacts on 0.156-in. centers. Devices with up to 16 lead positions on 0.1-in. centers with round, square or rectangular leads can be accepted. Model MPC 6 has two rows of 8-lead sockets and will accept only the TI package. MPC 8 has three rows of 8-lead sockets and will accept all popular packages up to 16 leads.

Texas Instruments Inc., Metals & Controls Div., 34 Forest St., Attleboro, Mass. Phone;: (617) 222-2800.

Circle No. 132

VA-244
SERIES

VARIAN KLYSTRONS FOR RELIABLE, MICROWAVE COMMUNICATION SYSTEMS



VA-259
SERIES

One railway microwave communication system uses 1,636 of these two Varian klystrons and, over a recent 24-month period, accumulated 1,000 years of experience with less than one day of down time (including <u>all</u> failures).

For more complete information, write
Palo Alto Tube Division, Executive Offices,
611 Hansen Way, Palo Alto, California.
In Europe: Varian A.G., Zug, Switzerland.
In Canada: Varian Associates
of Canada, Ltd., Georgetown, Ontario.

varian

Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 68

Meter relay

This horizontal line contactless meter relay employs a light-sensitive switch that provides positive on-off control and continuous reading above and below set-points. The relay provides either single (high or low) or double set-points, with high and low set-points adjustable over full scale length. Accuracy is 2% and repeatability is 0.3% with maximum dead band of 1%.

General Electric Co., 40 Federal, West Lynn, Mass. Phone: (617) 598-6000.

Circle No. 133

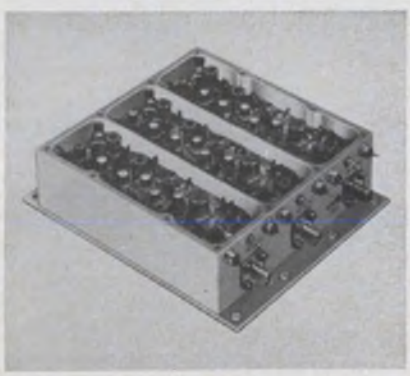
Interval meter

Frequency, period, multiple period, time interval, ratio, multiple ratio and count can be measured with this six-digit in-line frequency time interval meter. The 10-MHz unit can "self-check" itself on all operational functions. Sensitivity is 100 mV and the input impedance is 1 MΩ.

P&A: $1525; 30 days. Northeastern Engineering Inc., 130 Silver St., Manchester, N. H. Phone: (603) 622-6485.

Circle No. 134

IF amplifier



Measuring less than 7 in.^{3} per channel, this three-channel IF amplifier is phase-and gain-matched. The unit has a 30-MHz center frequency, 10-MHz bandwidth and 13-dBm max linear output. Gain is 90 dB and gain control is 60 dB. Noise figure is 2.5 dB and, over agc and range of −55 to 71°C, phase match is ±2.5° and gain match is ±1 dB.

P&A: from $99 per channel; 4 to 8 wks. RHG Electronics Lab., Inc., 94 Milbar Blvd., Farmingdale, N. Y. Phone: (516) 694-3100.

Circle No. 135

Capacitance tester

Employing tunnel diodes and epoxy IC logic elements, this capacitance tester has a direct reading digital display with 3 in-line digits. Range is 0.1 to 99.9 pF with optional ranges and output functions available. Measurement time is less than 500 ms and the frequency at which capacitance is determined is 1 MHz.

P&A: $1295; stock to 4 wks. Continental Device Corp., 12515 Chadron, Hawthorne, Calif. Phone: (213) 772-4551.

Circle No. 136

Charge amplifier

Consisting of charge converters and signal conditioning amplifiers, this charge amplifier measures input signals from 4 x 10^{-3} to 100,000 pC without signal clipping. The converters change charge to voltage which is then amplified by the signal conditioning stage. Line-isolated individual power supplies eliminate ground loops and built-in filters reject undesired high frequencies. Frequency response is within ±5% from 5 Hz to 30 kHz with no filter.

Unholtz-Dickie Corp., 2994 Whitney Ave., Hamden, Conn. Phone: (203) 288-3358.

Circle No. 137

Spectrum analyzer

When used with communications receivers for narrow-band high-resolution analysis, this spectrum analyzer serves as a band-pass monitor with an input center frequency of 500 kHz. Sweep width is variable from 0 to 100 kHz or 0 to 2 kHz with afc. Sweep rate is 0.1, 1 or a variable 1 to 30 Hz. Bandpass amplitude response is ±10% and variable resolution is 10 Hz to 2.7 kHz.

Probescope Co., Inc., 211 Robbins La., Syosset, N. Y. Phone: (516) 433-8120.

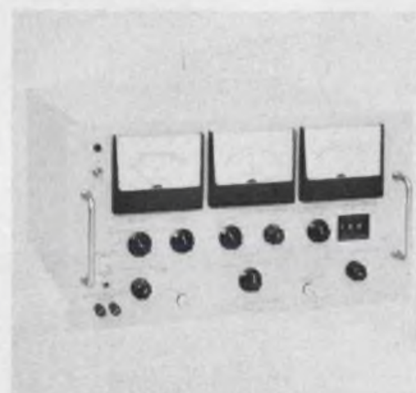
Circle No. 138

Ac/dc meter

Available for ac mA/A or ac voltage measurements, this thermocouple ac meter has ±0.5% accuracy in the horizontal position. The magnetically shielded units employ wire-wound resistors of ±0.05% accuracy. The ac mA-ammeter has a range of 0, 10, 20, 50, 100, 200 and 500 mA ac/dc at 1.5 V and 0, 1, 2 and 5 A ac/dc. The ac voltmeter has a range of 0, 2, 5, 10, 20, 50, 100, 200 and 500 V at 143 Ω/V.

Price: $250 (ac mA/A); $300 (ac voltmeter). Triplett Electrical Instrument Co., Bluffton, Ohio. Phone: (419) 358-5015.

Circle No. 139

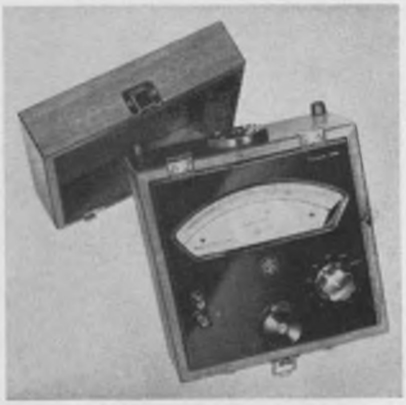


Envelope delay unit

Covering a 30- to 750-kHz range, this unit measures delay distortion of the carrier frequencies. This instrument has crystal-controlled reference delays in 10-μs steps up to 200 μs for use in offsetting time delay. Resolution is 0.05 dB. The most sensitive scale is 2 μs full scale with 0.1-μs calibrations. The instrument has transformed-coupled output and input at 135 Ω.

Price: $8100. Wiltron Co., 930 East Meadow Dr., Palo Alto, Calif. Phone: (415) 321-7428.

Circle No. 140

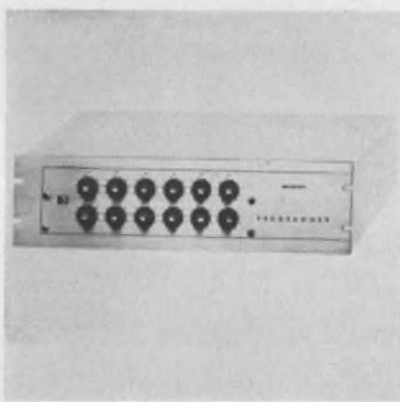


True rms microammeter

With a low full-scale range of 50 μA this true rms microammeter has eight ranges from 0.05 mA to 10 mA. The unit achieves 0.05% full scale accuracy for irregular waveforms having crest factors in excess of 4 and square waves up to several kHz. Repeatability is better than 0.1%. The instrument responds to inputs to 500 kHz with a ±0.5% full-scale accuracy at the most sensitive ranges.

Greibach Instruments Corp., 315 North Ave., New Rochelle, N. Y. Phone: (914) 633-7900.

Circle No. 141



Drum programer

Precise dial adjustment of individual step times is provided by this programer. The unit offers repeat accuracy of ±2%. Plug-in drum pins can quickly modify the program. Standard time ranges available include 0.2 to 10 s, 1 to 100 s and 0.1 to 10 minutes per step. Twelve steps are provided. Output load capacity is 15 A (resistive) at 120 Vac. Operating voltage is 120 Vac (nominal).

ESNA, Agastat Div., 1027 Newark Ave., Elizabeth, N. J. Phone: (201) 352-2900. *Circle No. 142*

Miniature probe

For portable and general purpose scopes in the dc- to 33-MHz range, this 10X attenuation probe can be compensated for scope or plug-in unit input capacitances of 15 to 47 pF. Risetime of the probe is 5 ns, input resistance is 10 MΩ and input capacitance is 11.5 to 14.5 pF. Voltage rating is 500 Vdc, ac peak or dc and ac peak combined. Peak-voltage derating is necessary for cw frequencies above 6 MHz—typically 105 V at 30 MHz.

P&A: $27; Oct. Tektronix, Inc., Box 500, Beaverton, Ore. Phone: (503) 644-0161.

Circle No. 143

Selective null detector

This tunable null detector has a sensitivity of 1 μV for full-scale meter deflection, a frequency range of 15 Hz to 100 kHz and 5 to 10% bandwidth. It can be used as a sensitive detector in bridge balancing and as a low-noise preamp for increasing the sensitivity of scopes and VTVMs. The output amplifier has a linear or logarithmic response. Input impedance is 50 kΩ to 1 MΩ depending on gain control. Output impedance is about 300 Ω in series with 5 pF. Maximum output is about 1 V rms.

International Telephone & Telegraph Corp., 320 Park Ave., New York. Phone: (212) 752-6000.

Circle No. 144

SINGLE REJECTION CAVITY TYPE DIPLEXER—COMPARABLE TO A PACK OF REGULAR SIZE CIGARETTES IN SIZE

DOUBLE REJECTION CAVITY TYPE DIPLEXER

New Ultra-Compact UHF antenna diplexers

for use in the 2.2 to 2.3 GHz frequency range

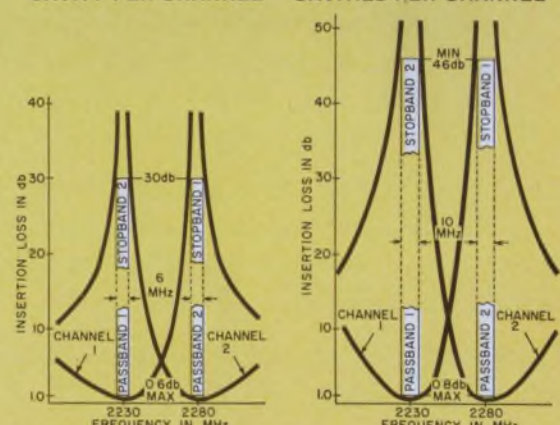
■ Allen-Bradley high frequency laboratories are pioneering the development of antenna multiplexers for use at ultrahigh frequencies. The two diplexers for the 2.2 to 2.3 GHz band shown above are representative of Allen-Bradley's high frequency capability. These diplexers are rugged—designed to withstand acceleration of 15 G's; shocks of 100 G's (1 msec.); and vibration of ±10 G's (30-2000 Hz). They're hermetically sealed for use at unlimited altitude and are stable over the temperature range from −50° to +170°F. The power handling capacity per channel is 20 watts.

Allen-Bradley engineers will be pleased to work with you. Please write: Allen-Bradley Co., 1344 South Second Street, Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Ltd. Export Office: 630 Third Avenue, New York, N. Y., U.S.A. 10017.

TYPICAL RESPONSE CURVES

WITH ONE REJECTION CAVITY PER CHANNEL

WITH TWO REJECTION CAVITIES PER CHANNEL



ALLEN-BRADLEY
QUALITY ELECTRONIC COMPONENTS

965-1AB

ON READER-SERVICE CARD CIRCLE 74

RF ratiometers

Reflection coefficient or vswr are measured by these RF ratiometers without the use of slotted lines. The ratio of incident and reflected signals is calibrated in % reflection coefficient and/or vswr. Reflection coefficient ranges are 0.1, 0.3 and 1% full scale. Accuracy is ±1%. The RF signal source employed is modulated at 1000 Hz with an output of 50 mW nominal. The model 101 covers a 215- to 450-MHz range and model 102 covers a 450- to 960-MHz range.

Chrysler Corp., Huntsville, Ala. Phone: (205) 842-4710.

Circle No. 145

5-MHz counter/display

Employing silicon ICs, this bidirectional counter/display also counts in reverse at any rate between 0 and 5 MHz. The unit accepts quadrature or pulse input signals. Sine waves may range from 1 to 30 V p-p and square waves may have p-p amplitudes of 500 mV to 15 V. Optional axis-crossing detection modules multiply encoder resolutions by factors of 1, 2 and 4 (depending on system requirements).

P&A: $1095 to $1695; 6 wks. Janus Control Corp., 296 Newton St. Waltham, Mass. Phone: (617) 891-4700.

Circle No. 146

STEP IN THE RIGHT DIRECTION WITH KEARFOTT STEPPER MOTORS

The logical step is to think of Kearfott for a wide variety of permanent magnet and variable reluctance stepper motors.

You get— • High Speed • High Quality • High Reliability • Variety of Stepping Angles • Non-resonant VR types which need no external electrical or mechanical damping devices.

It's even more logical when you're looking for logic components. Ask for Kearfott's completely transistorized driver and logic circuits— • Rugged • Compact • Lightweight • Easily Mounted • Wide Operating Temperature Range • Pulse Shapers and Inverters Available.

Or how about these special stepper motors, which are typical of Kearfott's forward thinking in design— • Separable Rotor & Stator Stepper Motor for Gimbal Drive Applications • Special Stepper Motor for Space Applications.

Now look at the wide variety of standard steppers we offer:

PERMANENT MAGNET AND VARIABLE RELUCTANCE STEPPER MOTORS

TYPE	SIZE	HOLDING TORQUE (in. oz.)	MAXIMUM STEPPING RATE (steps/sec.)	TOTAL POWER INPUT (watts)	WINDING RESISTANCE (ohms)	PHASING SEQUENCE TABLE NUMBER (for ccw rotation)	WEIGHT (oz.)	STEPPER MOTOR PART NUMBER	LOGIC-DRIVE CIRCUIT PART NUMBER
P.M. 90° Step Angle	5	.2	270	4.9	160	2	.7	CJ0 0191 750	C70 3531 301
	8	.6	320	5.2	600	1	1.5	CM4 0191 007	C70 3531 001
	8	.6	320	4.4	180	2	1.5	CM4 0191 012	C70 3531 301
	11	1.8	220	7.0	450	1	2.9	CR0 0191 750	C70 3531 001
	11	2.0	250	7.8	200	2	2.9	CR4 0191 002	C70 3531 302
	15	4.5	125	13.0	65	2	8.0	CT4 0191 001	C70 3531 302
P.M. 45° Step Angle	11	1.5	400	7.1	220	1	3.0	CR0 0193 750	C70 3531 001
	15	3.5	220	13.0	60	2	8.0	CT0 0193 750	C70 3531 302
	18	6.0	270	13.0	60	2	13.0	CV0 0193 750	C70 3531 302
V.R. 15° Step Angle	8	.5	1000	6.3	250	1	1.5	CM4 0192 001	C70 3531 104
	11	1.1	700	7.1	220	3	2.9	CR0 0192 750	C70 3531 201
	11	1.6	600	7.1	110	4	2.9	CR4 0192 001	C70 3531 402
	15	6.5	660	17.0	90	1	8.0	CT0 0192 750	C70 3531 103
	18	8.5	600	23.0	70	1	13.0	CV0 0192 750	C70 3531 103

NOTE: Operating voltage for all units is 28 volts dc. Temperature range for all motors is —54°C to +165°C (ambient + temp. rise). Duty for all units is continuous.

STEPPER MOTOR DRIVER AND LOGIC ELECTRONICS

PART NUMBER	OUTPUT SEQUENCE	CURRENT OUTPUT MAX./LEG (amp)	DC POWER REQ. (+ volts)	NEGATIVE BIAS REQ. (— volts)	INPUT PULSE POLARITY*	INPUT PULSE AMPLITUDE (volts)	INPUT PULSE RISE TIME (μ sec max.)	PULSE WIDTH (μ sec min.)	WEIGHT (oz.)	TEMPERATURE RANGE (°C)	TYPICAL KEARFOTT MOTOR
C70 3531 001	Table 1	.2	28	12	Negative	15 to 30	5	10	2.0	—55 to +125	CR0 0193 750 CM4 0191 007
C70 3531 002	Table 3	.2	28	15	Positive	2.3 to 15	10	10	1.8	—55 to +95	CR0 0192 750
C70 3531 004	Table 3	.5	28	None	Negative	3 to 15	5	10	2.8	—55 to +125	CR0 0192 750
C70 3531 101	Table 1	.2	28	12	Positive	2.5 to 6	5	10	3.0	—55 to +125	CR0 0193 750
C70 3531 102	Table 1	1.0	28	12	Negative	2.5 to 6	5	10	3.5	—55 to +125	Multiple Loading (e.g. up to 5 CR0 0193 750 in parallel)
C70 3531 201	Table 3	.2	28	12	Positive	2.5 to 6	5	10	2.2	—55 to +125	CR0 0192 750
C70 3531 103	Table 1	.5	28	12	Negative	2.5 to 6	5	10	3.5	—55 to +125	CT0 0192 750 CV0 0192 750
C70 3531 301	Table 2	.2	28	12	Negative	2.5 to 10	5	10	3.5	—55 to +125	CM4 0191 012
C70 3531 302	Table 2	1.0	28	12	Negative	2.5 to 10	5	10	4.5	—55 to +100	CT4 0191 001 CT0 0193 750
C70 3531 401	Table 4	.2	28	12	Negative	2.5 to 10	5	10	3.5	—55 to +125	Reduced Power (drives CR0 0192 750, for reduced torque applications)
C70 3531 402	Table 4	1.0	28	12	Negative	2.5 to 10	5	10	4.5	—55 to +100	CR4 0192 001
C70 3531 104	Table 1	.2	28	12	Positive	2.5 to 6	5	10	3.0	—55 to +125	CM4 0192 001

*Pulses with polarity reversed from that specified will also drive circuits, but with trigger occurring on trailing edge.

NOTES: 1. Units can be operated over a limited temperature range without applying a negative bias. Details on each unit will be supplied on request.
2. Units also available which do not require a negative bias supply. Part numbers available on request.

ELECTRICAL PHASING SEQUENCES

TABLE 1

Step	Yel.	Wht.	Red	Blk.
1	0		0	
2	0			0
3		0		0
4		0	0	
1	0		0	

TABLE 2

Step	Yel.	Blk.	Wht.	Red
1	0			
2		0		
3			0	
4				0
1	0			

TABLE 3

Step	Red	Blk.	Yel.
1	0	0	
2		0	0
3	0		0
1	0	0	

TABLE 4

Step	Red	Blk.	Yel.
1	0		
2		0	
3			0
1	0		

"O" designates polarity of dc supply voltage.

Send for new stepper motor catalog and wall chart describing these motors in greater detail.

KEARFOTT PRODUCTS DIVISION
GENERAL PRECISION INC.
AEROSPACE GROUP
LITTLE FALLS, NEW JERSEY

ON READER-SERVICE CARD CIRCLE 76

Digital voltmeter

An accuracy of 0.1% plus 1 digit is characteristic of this digital voltmeter. The unit compares input voltage to an internally-generated voltage from a zener reference diode and resistors. The unit has a floating input. Input impedance is 10 MΩ on all ranges. The instrument has five manually-selected ranges from 100 mVdc to 1000 Vdc full scale.

P&A: $595; 60 days. Hewlett-Packard 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000.

Circle No. 147

Audio voltage standard

This convection-cooled audio voltage standard offers variable output from 1 mV to 1011 V. An internal oscillator provides full frequency coverage from 50 to 10,000 Hz. Basic absolute accuracy is ±0.035%. Model 631 is capable of 10 VA of power with less than 0.1% distortion. A three-digit voltage deviation system permits calibrated plus and minus offsets at any voltage setting.

P&A: under $6500; 60 days. Holt Instrument Laboratories, Oconto, Wis. Phone: (414) 834-2222.

Circle No. 148

MIL-T SPEC LACING TAPE isn't right for every harness job!

- **GUDEBROD sells plenty of it (Gudelace 18) —but makes 172 other* tapes too!**

- Tapes for high temperatures, burnproof tapes, tapes for outer space and vacuum use.

- Tapes for heavy cabling and for small units, color coded tapes.

- They all tie tight. Ask about them.

*And they all exceed MIL-T performance requirements

Saturn rocket inertial guidance stabilized platform produced at The Bendix Corporation's Eclipse-Pioneer Division. Wiring laced with Gudebrod Tape.

With every advancement in electronic technology, for every new electronic application there is need to review your harnessing practices and materials. If your harness department is struggling to make-do with the lacing tape they have always used—they may be wasting time and money as well as heading for rejects. Gudebrod has pioneered in producing special tapes—for particular applications, and to meet customer's specifications. Available at Gudebrod is a stock of 173 types of lacing tape—and a wealth of harnessing information. Why not consult with Gudebrod!

GUDEBROD CABLE-LACER

The first hand tool engineered for wire harnessing. Handle holds bobbins, feeds tape as needed, grips tape for knotting. Speeds, eases harnessing. Pays for itself in time saving.

Area Code 215, WA 2-1122

GUDEBROD BROS. SILK CO., INC.

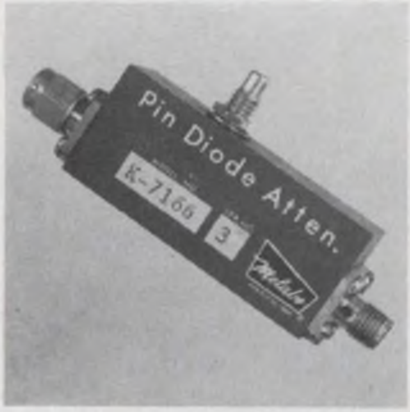
FOUNDED IN 1870

Electronics Division

12 SOUTH 12th STREET, PHILADELPHIA, PENNSYLVANIA 19107

ON READER-SERVICE CARD CIRCLE 78

Pin diode attenuator

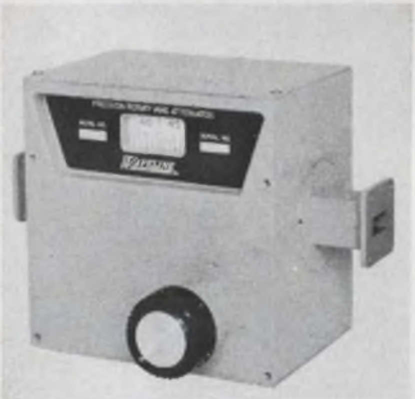


Providing 80 dB or more attenuation across the 1- to 8-GHz range, this pin diode attenuator has a minimum attenuation typically 2 dB. The component handles 250 mW avg or 100 W peak. Vswr is typically 2 for minimum attenuation and about 10 at full attenuation. Bias required for maximum attenuation is −100 mA at about 3 V.

Availability: 30 days. Melabs, 3300 Hillview Ave., Stanford Industrial Park, Palo Alto, Calif. Phone: (415) 326-9500.

Circle No. 149

Rotary vane attenuator



Readout is provided with this X-band rotary vane attenuator by a calibrated stainless steel tape which is viewed through a readout window. The window has dual index lines to reduce parallax error. Accuracy is ±2% of the reading or ±0.1 dB whichever is greater from 0 to 50 dB and ±3% of the reading from 50 to 60 dB. Vswr is 1.15 max and insertion loss is less than 1 dB.

Waveline, Inc., Box 718, West Caldwell, N. J. Phone: (201) 226-9100.

Circle No. 150

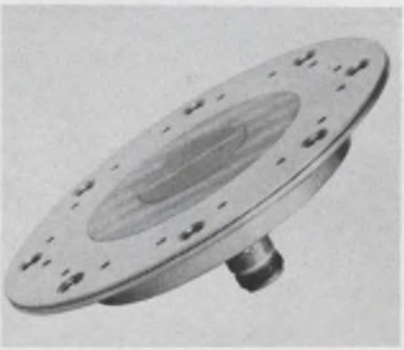
30-W TWT

Output of 30 W in the 3.6- to 4.2-GHz band is provided by this TWT. The tube is for 1800-channel microwave links. With a typical gain of 43 dB at a working output of 20 W, saturated output is 30 W. The unit operates in a periodic permanent-magnet mount. Incorporated in the mount are RF input and output waveguide connections, deflection and matching adjustments, tube ejection control at either end of the mount and a convection cooler.

ITT Corp., 320 Park Ave., New York. Phone: (212) 752-6000.

Circle No. 151

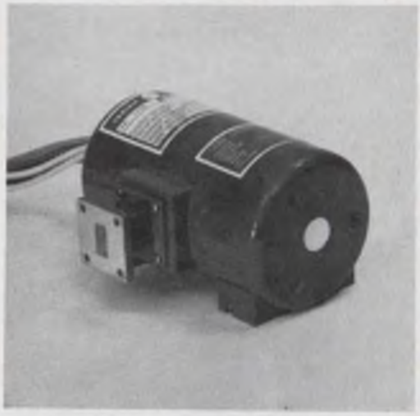
S-band antenna



Designed for airborne flush-mounting applications, this 14-oz antenna operates over the 2200- to 2300-MHz telemetry band with a vswr of 1.5 max. The radiation pattern of this annular slot antenna is similar to a dipole with linear polarization perpendicular to the plane of the aperture. An N connector jack is provided for input.

L. P. Associates, Inc., 11830 West Pico Blvd., Los Angeles. Phone: (213) 477-2762.

Circle No. 152

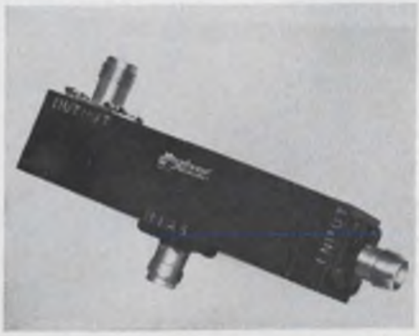


Ku-band BWO

Delivering 50 to 100 mW over a 14- to 17- GHz tuning range, this backward-wave oscillator tube is magnetically shielded and permanent-magnet focused. This 4-lb convection-cooled unit is 3 in. in diameter and 6 in. long. Frequency adjustments are made by varying the helix voltage. The voltage-versus-frequency curve is exponential and continuous.

P&A: under $1500; 60 days. Varian Associates, 611 Hansen Way, Palo Alto, Calif. Phone: (415) 326-4000.

Circle No. 153



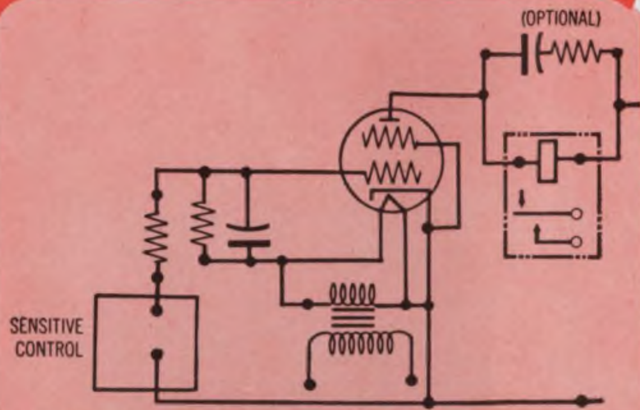
Limiter-attenuator

This high-power limiter-attenuator provides receiver protection over the 2.2- to 2.3-GHz range with an insertion loss of 1 dB max, flat leakage of 50 mW and recovery time of 500 ns. Peak power is 1 kW and average power is 10 W. Applications include tracking, target detection and navigational radar. This component functions effectively as a controlled variable attenuator which increases the dynamic range of the overall radar system.

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

Circle No. 154

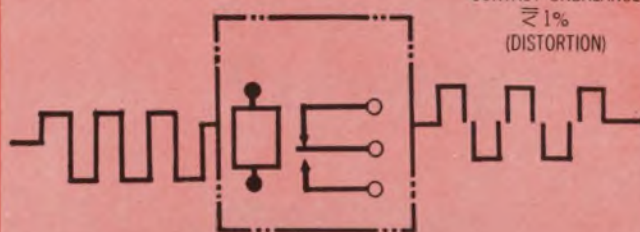
New Mercury Relay Applications From Adlake



MERCURY
DISPLACEMENT
RELAYS

Small Currents Control "Heavy Duty" Load Relay

In applications having extremely sensitive controls, this circuit illustrates how very small currents are capable of controlling an Adlake "Heavy Duty" load relay. Resistive loads of 35, 50 or 75 amperes at 120 volts, 60 cycles, are easily met up to 44 operations per minute. 100 ampere loads at the rate of 6 operations per minute.



MERCURY
WETTED
CONTACT
RELAYS

Ideal for Data Transmission or Tele-Typing

Adlake Polar Relays—Form C—are ideal for data transmission or tele-typewriting where a series of equal length impulses represent an alpha-numeric character or function. Baud rates up to 120 are available with Contact Unbalance —Distortion — of 1% or less including transition. Transition time is normally 200 microseconds or less.

Backed by sound research and disciplined engineering, Adlake applies the industry's broadest line of mercury displacement and mercury wetted relays to the creative solution of design circuit problems. However unique or special your application, Adlake can assist you in developing it. For prompt, personal and knowledgeable attention to your relay needs, contact the one source that is the complete source in the mercury relay field. Contact Adlake today for catalog and further information.

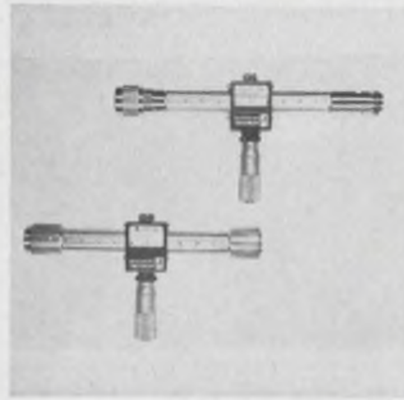
Adlake SINCE 1857

THE ADAMS & WESTLAKE COMPANY

Dept. 1106 • Elkhart, Indiana 46514 • Phone (A.C. 219) CO 4-1141

WINDOWS & CURTAIN WALLS • DOORS & ENTRANCES • TRANSPORTATION EQUIPMENT • MERCURY RELAYS • CONTRACT MANUFACTURING

ON READER-SERVICE CARD CIRCLE 79

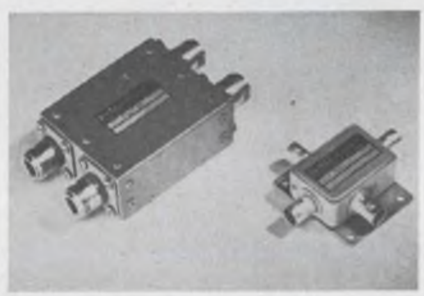


Coax slide screw tuners

Available with either 7 mm or type N connectors, these resettable tuners can be used over the 12.4- to 18-GHz band. The units tune out reflections in a system or match individual components with a vswr of up to 5. They consist of a coax line section with a sliding carriage upon which an adjustable probe is mounted. The sliding carriage is aligned by teflon guides riding in a slot milled along the bottom length of the coax section.

Price: $295 to $345. Weinschel Engineering, Gaithersburg, Md. Phone: (301) 948-3434.

Circle No. 155



Hybrid junctions

Four-port networks featuring 40- to 50-dB isolation typically, these broadband hybrid junctions provide continuous coverage from audio to microwave freqencies. Vswr is 1.35 max and insertion loss is 0.3 dB max. Power applied to any of the ports is split equally between two other arms while the fourth arm is isolated. The three units of the series cover 200 to 400 MHz, 250 to 500 MHz and 500 to 1000 MHz. All three have impedance of 50 Ω and amplitude balance of ± 0.15 dB.

Price: $195. Merrimac Research & Development Inc., 517 Lyons Ave., Irvington, N. J. Phone: (201) 371-1616.

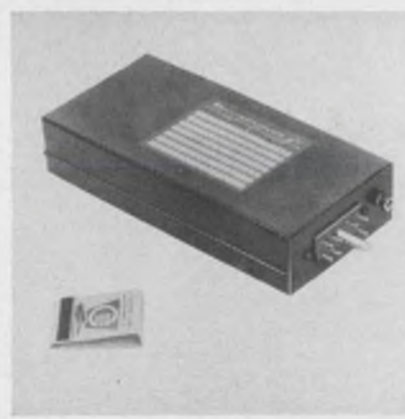
Circle No. 156

Bench power supply

Regulation of 0.02%, 2-mV ripple and noise, 10-mV/day drift and 30-μs transient response are features of this bench power supply. The unit incorporates two independent outputs rated at 0 to 32 V and 0 to 300 mA and variable current limiting from 30 to 250 mA. Separate 58- to 400-Hz power transformers and regulator circuits keep the two outputs independent and free from mutual interference as load currents or voltages change.

Availability: stock to 3 wks. Analog Devices, 221 Fifth St., Cambridge, Mass. Phone: (617) 491-1650.

Circle No. 157



Switching regulators

Dc to dc switching regulators supply power for integrated circuits. They provide zero-up voltages from 10 to 250 Vdc, with power capabilities from 15 to 1500 W. Overvoltage protection is built in with a 65% efficiency. Special packaging can be provided.

Technipower Inc., 18 Marshall St., South Norwalk, Conn. Phone: (203) 866-9245.

Circle No. 158

Voltage regulated supply

A voltage regulated power supply provides up to 300 mA over a range of 1.25 to 30 Vdc. Load regulation is ±0.5% or 50 mV and line regulation over a range of 105 to 125 V is 10 mV. Output impedance is 0.2 Ω at 1 or 10 kHz. Full load ripple is 1 mV rms.

P&A: $98; stock. Acopian Corp., Easton, Pa. Phone: (215) 258-6149.

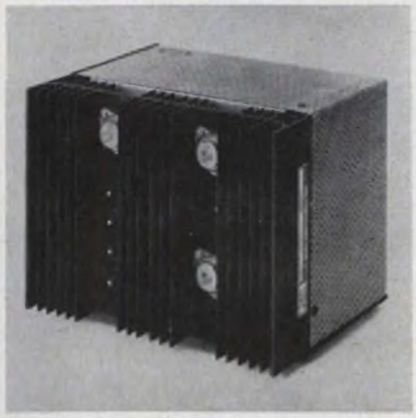
Circle No. 159

Triple output supply

Hybrid tube and transistor circuitry completely protects this supply against shorts, overloads and high temperatures. Model 2909 is fully transistorized except for the series regulators. It features one filament output and three simultaneous dc outputs, each separately metered. One is fully adjustable from 0 to 500 at up to 0.2 A. A continuously adjustable bias supply and a fixed 300-V, 0.05-A auxiliary bias source can extend the main output to 800 V.

Price: $465. Deltron Inc., Wissahickon Ave., North Wales, Pa. Phone: (215) 699-9261.

Circle No. 160

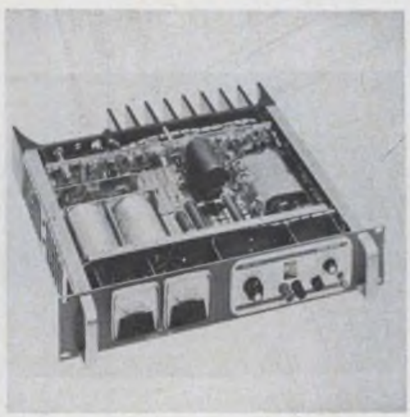


Modular power supplies

All-silicon supplies are available with outputs from 0 to 400 Vdc at 0.1 to 20 A in 11 different case sizes. All models are available with either 0.5% or 0.01% regulation. All regulation and control circuitry is mounted on a plug-in PC board. Automatic overload and short protection, remote programing and remote sensing are standard. Heat sinking is not needed up to 71° C.

ACDC Electronics Inc., 2979 N. Ontario St., Burbank, Calif. Phone: (213) 849-2414.

Circle No. 161

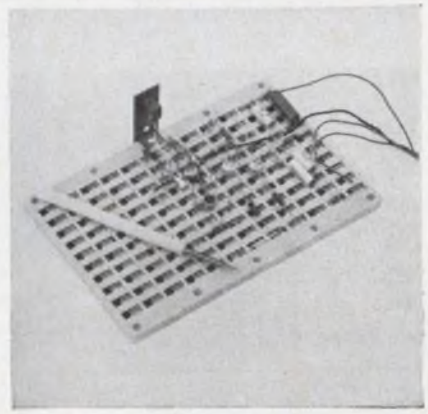


Voltage/current supply

This dc power supply can be used alternatively as voltage regulated power supply or as current regulated power supply, simultaneously offering current-limiting or voltage-limiting capabilities. The unit has an output of 0 to 36 V and 0 to 5 A with an input of 4 A. Constant load and line voltage is 0.005% or 0.5 mV and 0.01% or 1.0 mW. Constant current load is 1 mA/V change in output and 1 mA in constant current lines.

Price: $330. NJE Corp., 20 Boright Ave., Kenilworth, N. J. Phone: (201) 272-6000.

Circle No. 162

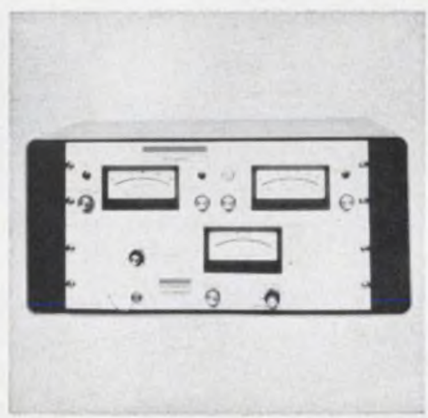


Test circuit board

"Springboard," a solderless experimental circuit board, permits addition or removal of components without damage to leads. The board incorporates 120 ten-turn stainless steel springs that hold the components and act as connectors. All springs are electrically isolated, but several may be joined with jumpers if required. The boards measure 4-3/4 x 7-1/4 x 5/16-in.

Barry Instrument Corp., 10804 Kaylor St., Los Alamitos, Calif. Phone: (213) 430-4913.

Circle No. 163



Charge sensor

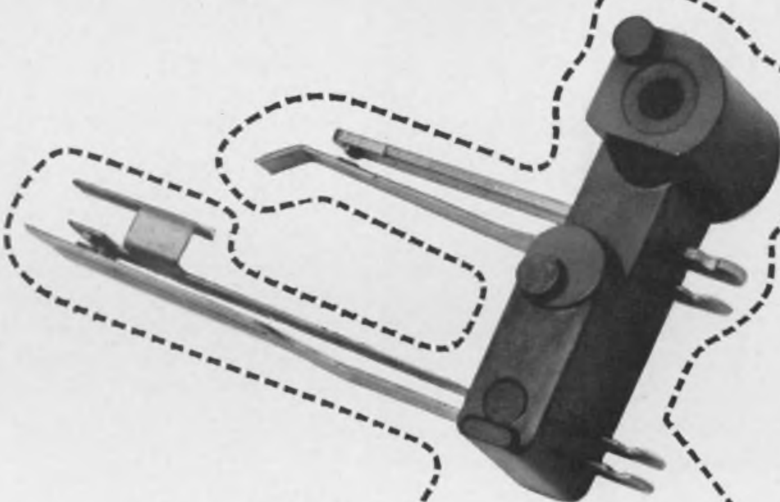
Electrostatic charges on paper and plastic insulating materials are detected and measured by this charge sensor. This unit also measures charge acceptance and rate of charge decay under light or dark conditions. An integral calibrated light source permits studies to be performed on rates of light or dark decay. The electrometer used has a sensitivity of 300 pA full scale and measures voltages from 10 mV full scale.

The Victoreen Instrument Co., 10101 Woodland Ave., Cleveland. Phone: (216) 795-8200.

Circle No. 164

Any material that can help Western Electric cut down its phone bill must be something.

Something called Plaskon Epoxy.



This phone dial relay switch used to be molded of soft-flow phenolic. Now it's made of a stronger, more versatile Plaskon® epoxy molding compound. Because of that, Western Electric was able to eliminate an expensive metal flange with no loss of strength. And at a substantial saving, considering the millions of parts that were made.

They were also able to use the existing molding equipment for the job.

Plaskon epoxies have excellent dimensional stability. They cure fast and shrinkage is often less than one percent. And because of great electrical insulation value, applications are numerous.

Allied Chemical has an extensive line of epoxy molding compounds, including DAP, phenolics and alkyds. Whatever your application requires, one of them should work best—and most economically. Call your Plastics Division representative for more information. Or, mail the coupon, and start saving right away

Gentlemen:
I'd like to know more about the complete line of Plaskon epoxy molding compounds. Please send me your technical brochure.
ED-10

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POST OFFICE BOX 365
MORRISTOWN, N. J.

Allied Chemical

ON READER-SERVICE CARD CIRCLE 88

Small-scale digital computer offers high speed

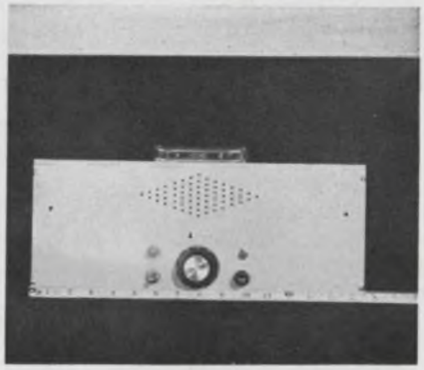
Suited for a wide range of scientific applications, the model 640 digital computer employs input/output and interrupt features designed especially for improving operations in hybrid and special computer-based systems. Utilizing monolithic integrated circuitry, the machine operates with a fixed, 16-bit instruction and data word, plus protect bit. A protected core memory, with up to 32,768 word storage capacity 1.65-μs cycle time, a repertoire of 62 instructions, a multilevel interrupt capability and a capacity for communications with up to 64 peripheral devices also are featured. Maximum I/O rate is 1.2-million 8-bit bytes per second.

Options to the basic computer include expansions for teletype equipment, a direct memory-access channel, and memory expansions from the basic 4k words to 8k, 16k or 32k. Peripheral equipment available includes: low-cost, mass storage disk memory—up to 1/4-million words; a 300-line-per-minute line printer, high-speed paper tape punch and reader units with 120 and 300 characters-per-second capabilities, respectively; a card reader—400 cards per minute, a 100-card-per-minute, column binary card punch; a magnetic tape unit—36-kHz transfer rate.

Symbolic assembler, FORTRAN (ASA Standard), linking loader, debug, update, bootstrap, operations interpreter and other hybrid programing systems are available in the 640 software program.

P&A: less than $30,000; Feb. (including software), Electronic Associates Inc., W. Long Branch, N. J. Phone: (201) 229-1100.

Circle No. 165



Laser system

Capable of emitting 30 J at 1.06 microns or 15 J at 6943 Å, this head and power supply has a pulse duration of about 1 ms with a permissable repetition rate of 2 ppm at maximum energy. The head can be remotely operated up to 50 ft from the control unit. Power supply charge time is about 8 s. The controls may vary the output energy from the minimum of threshold to the maximum output.

Price: $4965. Maser Optics, Inc., 89 Brighton Ave., Boston. Phone: (617) 254-7880.

Circle No. 166

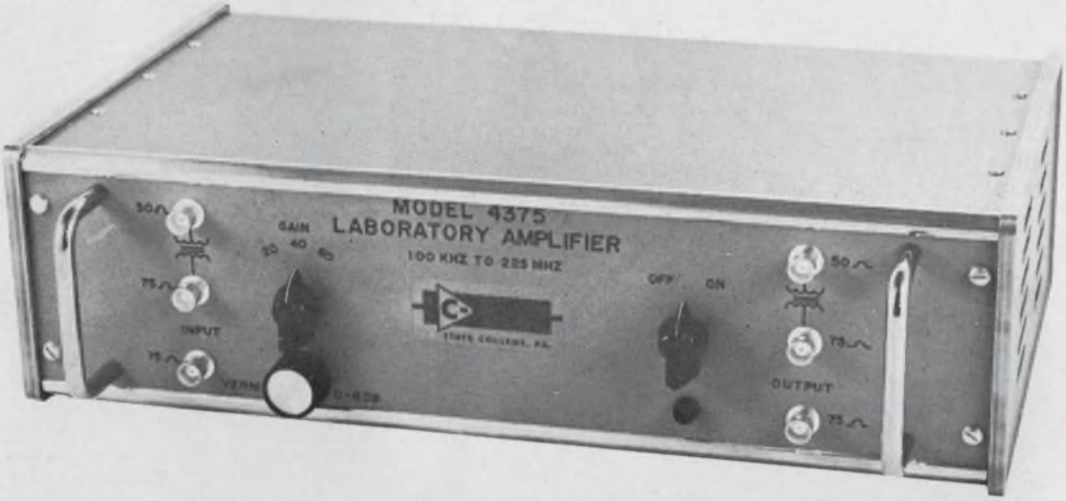
Scanning receivers

Model SR-9A scanning receiver continuously scans from 1.5 to 30 MHz, model SR-9B scans from 30 to 300 MHz and model SR-9C scans from 300 to 1000 MHz. RF preselection and swept local oscillators which are tuned by a self-contained sweep generator give the receivers a high spurious-free dynamic range. Frequencies are received on three separate up-conversion superheterodyne units packaged together and driven by a common sweep generator and power supply.

HRB-Singer, Inc., Science Park, State College, Pa. Phone: (814) 238-4311.

Circle No. 167

✶ HIGH OUTPUT: 15 VOLTS P-P INTO 75 OHMS
✶ WIDE BANDWIDTH: 100 kHz TO 225 MHz



A new definition of capability: C-COR's Laboratory Amplifier

SPECIFICATIONS

3 DB PASSBAND:
100 kHz to 225 MHz

FLATNESS: MODEL 4375-S
±0.5 db, 1 MHz to 220 MHz

OUTPUT CAPABILITY:
15 volts p-p, ±7.5 volts into 75 ohms; 12 volts p-p, ±6 volts into 50 ohms; 360 mw, 25 dbm for 1 db compression

PULSE RESPONSE, MODEL 4375-P:
Rise time, 2 ns
Fall time, 2 ns
Overshoot and ringing, less than 5%

INPUT IMPEDANCE:
50 or 75 ohms, selectable

INPUT VSWR:
1.5/1 typical

OUTPUT IMPEDANCE:
50 or 75 ohms, selectable

OUTPUT VSWR:
2.0/1 max to 175 MHz,
3.0/1 max to 220 MHz

GAIN:
20, 40, or 60 db (fixed steps)
Vernier control 0 to 6 db

NOISE:
30 uv rms equivalent input

CONNECTORS:
BNC

OPERATING TEMPERATURE RANGE:
−20° C to +50°C

POWER REQUIRED:
105 to 125 V, 50-60 cps; 25 watts

PRICE:
$995.00 f.o.b. factory, any model. Specify Model 4375-S for sine wave or 4375-P for pulse
For relay rack mounting, order Model 1375-S or 1375-P

HIGH Z PROBE:
$125.00 Model 3691, sine wave, BW 10 hz-200 MHz, Model 3691A, pulse response, 2 ns rise time

C-COR now announces a long awaited amplifier: the Model 4375, for laboratory or systems use, which features wide bandwidth and high output. The 4375 is a compact, solid state unit. It utilizes C-COR's unique solid state distributed amplifier circuitry in the output stage to provide the high capability. The gain is switchable in steps of 20, 40, and 60 db by use of attenuators at the input. In addition, a 6 db continuously variable gain control is provided. This unit serves well as either a general signal amplifier, (or preamplifier) or as a fast rise time pulse amplifier. Orders are now being filled on this unit. To insure fast delivery, why not call us or your nearest C-COR rep. today?

C-COR®

C-COR Electronics, Inc.

60 DECIBEL ROAD • STATE COLLEGE, PENNA. 16801 • PHONE 814-238-2461

ON READER-SERVICE CARD CIRCLE 90

Data multiplexer

This STEP/SCAN data multiplexer uses a sampling switch with stepper-motor drive. The stepper motor can be programed to drive past or to dwell on data points. One standard STEP/SCAN multiplexer provides up to 540 input data channels. Ten multiplexers can be combined into a coordinated system. Standard scanning rate is 100 channels/s. Contacts are rated at 10 mA, 10 Vdc with a resistance of 1 Ω max.

Fifth Dimension Inc., Route 206 Center, Princeton, N. J. Phone: (609) 924-5990.

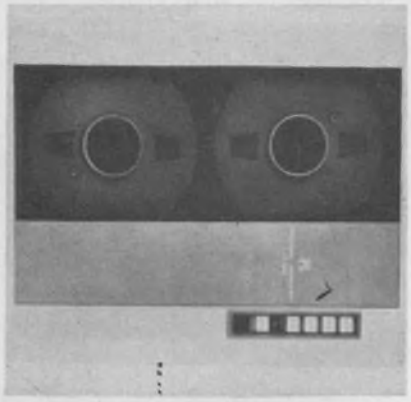
Circle No. 168

Ssb transceiver

Operating on four channels from 2 to 18 MHz, this single sideband transceiver has 100-W peak envelope power. The unit can provide transmission and reception for compatible AM and cw telegraph signals. Frequency of operation is controlled by crystals. Except for three vacuum tubes in the transmitter section, the transceiver is transistorized throughout. It operates on either 115/230 Vac, 50 to 60 Hz, 13.75 or 27.5 Vdc.

Wilcox Electric Co. Inc., 14th & Chestnut, Kansas City, Mo. Phone: (816) 231-0700.

Circle No. 169



Digital recorder

As an incremental recorder, this unit will write packing densities of 200, 556 and 800 bits/in. at 0 to 300 characters/s and read 200 and 556 bits/in. at 0 to 300 characters/s. As a high-speed synchronous recorder, the unit will search both forward and reverse at 37.5 ips and write in the forward direction at the same speed. This incremental digital recorder has automatic vertical and horizontal generation of parity in the write mode.

Price: $6000. Precision Instrument Co., 3170 Porter Dr., Palo Alto, Calif. Phone: (415) 321-5615.

Circle No. 211

Digital data reader

This digital data reader can reduce 10,000 data points/day for output to such devices as key punches or paper tapes. The unit features X and Y readout with SCR-driven variable speed circuits and manually-selectable 14- or 22-position readout. Also provided are six fixed digits and full range zero shift, automatic polarity, time index multipliers and readout sequence interlocks. A keyboard gives additional digital data input and paper transport.

Gerber Scientific Instrument Co., Box 305, Hartford, Conn. Phone: (203) 644-1551.

Circle No. 212

10-kW transmitter

A high-frequency independent sideband transmitter automatically tunes and loads in 15 s max. Model 7500 is rated at 10 kW average and 10 kW peak envelope power and is designed for low distortion service in the 2- to 3-MHz band. Tuning is in 100-Hz increments. Accuracy and stability are 0.01 ppm/day. The unit will transmit four 3-kHz ISB or two 6-kHz ISB signals. Third order distortion products are 40 dB below a one-tone signal at full power output.

Litton Industries, New Rochelle, N. Y. Phone: (914) 636-1620.

Circle No. 213

Calculator storage option

The Mathatron "auxiliary program storage" option can be added to the manufacturer's basic calculator for increased speed, capacity, and operational efficiencies. The auxiliary results in a total of 480 steps of program memory and 48 individually addressable storage registers. Each of the registers has one extra digit added to allow 2-digit addresses where necessary. Each stores a sign and 11 digits consisting of 9 digits and a 2-digits power of 10 exponent. The program memory is organized in 10 banks or loops of 48 steps. Storage register reference requires 3 steps.

Mathatronics Inc., 257 Crescent St., Waltham, Mass. Phone: (617) 894-0835.

Circle No. 214

S-band TV transmitter

This solid-state S-band transmitter can be used with TV equipment having 75-Ω input impedance. It produces 20 mW at 2280 MHz with an undistorted bandwidth of ±9 MHz. The unit operates on 28 W. An input signal of 1.4 V p-p drives the transmitter to a frequency deviation of 18 MHz. Signal response is flat within 1 dB for frequencies from 5 to 10 MHz. Housing is in a sealed aluminum-magnesium casting.

Brown Engineering Co., Inc., Huntsville, Ala. Phone: (205) 532-1336.

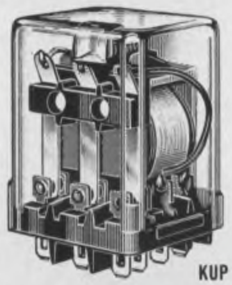
Circle No. 215

NEW! *Four problem-solving P&B relays . . . all immediately available at factory prices from leading electronic parts distributors*

CH

Solid State Time Delay Relays for as little as $17.50

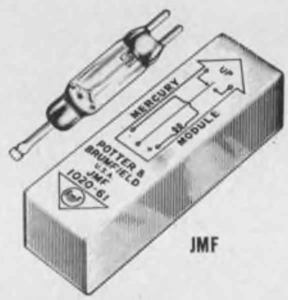
Here is a practical cost saving answer to many timing applications in the range of 1.0 to 180 seconds. You can save up to 60% on relay cost. They're available for AC or DC, knob adjustable, and accuracy is +10% over a −10°C to +55°C temperature range and include an internal 10 amp DPDT relay.



KUP

Versatile KUP relay can be a cost-saving answer to your plug-in relay problem

Save up to $2.00 each over similar relays with octal-type plugs. Get greater reliability, too. Relay has quick connect/solder terminals. Nylon socket (sold separately) rated for 10 amperes. One to three poles. Cover is heat and shock resistant lexan. For DC or AC operation.



JMF

The answer to billions of trouble free operations and speeds up to 1 millisecond

Mercury-wetted contact relay modules give you fast response, reliability, high sensitivity and extremely long life. Designed for printed-circuit mounting. Has SPDT, break-before-make (Form C) contact arrangement for single-side-stable or bi-stable operation.

JR

Reed Relays may replace expensive solid state devices

In many applications JR reed relays may be used in place of more expensive solid state devices over which they have one basic advantage . . . they are not subject to inadvertent switching by line transients.

For applications where fast operate time, low power and long life are required. Their high sensitivity and compact size recommend them for data processing, computer equipment, logic circuitry, for voltage or current sensing and various other types of control circuits.

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

They're all in this new Stock Catalog 100. Free from your electronic parts distributor. Ask for your personal copy today.

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Export: AMF International, 261 Madison Avenue, New York, New York

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ON READER-SERVICE CARD CIRCLE 94

Pressure sensor uses single silicon chip

An accurate and stable pressure sensor is made out of a single piece of semiconductor material. This monolithic solid state sensor utilizes the piezoresistive effect, in which the semiconductor changes resistance when strained. In the "Semiducer," the "diaphragm" is a single crystal of silicon, and the piezoresistive elements are diffused directly into its surface. Overall accuracy is within 0.4% of full scale. Ranges are 0 to 10 through 0 to 500 psia or psig. Low level output is 0 to 30, 40, 50 and 100 mV and high level output is 5 Vdc with optional electronics. Input and output impedance are 1000 Ω ±10% at 22°C.

Giannini Controls Corp., 1600 S. Mountain Ave., Duarte, Calif. Phone: (213) 359-9141.

Circle No. 216

Thermistor

Packaged in a borosilicate sleeve sealed on each end to molybdenum plugs, this thermistor features a positive temperature coefficient of 0.7%/°C. Linear resistance curve is between −55 and 125°C. The device can retrace its resistance vs temperature curve within a ±2° tolerance. The unit is available in 32-Ω values ranging from 10 Ω to 2.7 kΩ, in both 5% and 10% tolerances.

P&A: $2.80 (100-5000); stock. Texas Instruments Inc., 13500 N. Central Expwy., Dallas. Phone: (214) 235-3111.

Circle No. 217

Phase generator

The constant-amplitude phase shift produced by this phase generator may be continuously varied between 0 and 360°. The resulting phase-shift is indicated in degrees on a dial face. Absolute accuracy is within 30 minutes of arc. Phase accuracy and zero position are unaffected by loads from open circuit down to 10 kΩ. Input is 115 V, 400 Hz and output is variable from 0 to 35 V by means of a 10-turn pot.

P&A: $550; 4 wks. Theta Instrument Corp., Saddle Brook, N. J. Phone: (201) 843-6060.

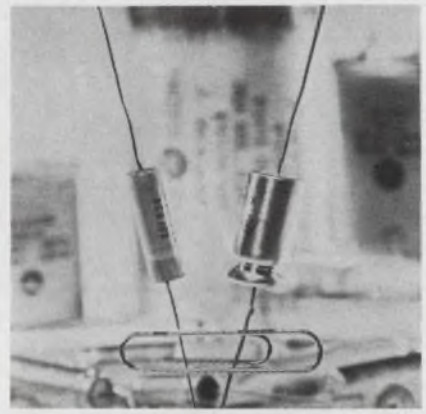
Circle No. 218

MV-to-current converter

Input signal spans ranging from 0 to 2 mV to 0 to 50 mV are converted into output ranges of 1 to 5, 4 to 20 or 10 to 50 mA by these dc amplifiers. Any incremented output range from 0 to 50 mA or 30 Vdc is available. The units feature 0.1% accuracy and 0.5-μV/°C stability high-and-low impedance input windings and input, output and power isolation are provided.

Airpax Electronics Inc., P.O. Box 8488, Ft. Lauderdale, Fla. Phone: (305) 587-1100.

Circle No. 219

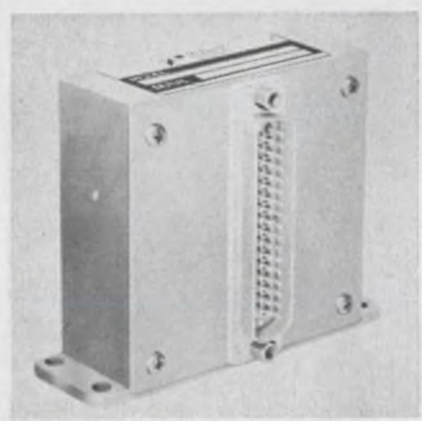


Wet-slug capacitor

Supplied in polar form with insulated metal cases these capacitors have an operating range from −55 to 85°C and meet military vibration requirements of 2000 Hz, 15-G acceleration. Available in four tubular case sizes, the units have ratings from 6 to 60 V and range from 3.3 to 450 μF. The units are suitable for filtering, bypass and coupling circuits.

General Electric, 392 S. Stratford Rd., Winston-Salem, N. C. Phone: (919) 725-9777.

Circle No. 220



Commutators

Using thin-film monolithic ICs, these high-level commutators/multicoders have an over-all accuracy of better than ±0.1%. Back current is virtually eliminated by using FETs as switches (0.1 μA nominal). The 2-pole 90-channel/pole unit is about 18.5 in^3 and the 30-channel unit is about 10.5 in.^{3} Offset is ±5 mV max. The series is available with one or two poles and IRIG, PAM and PDM output format.

Teledyne Telemetry Co., Dyna-Plex Div., Box 341, Princeton, N. J. Phone: (609) 452-2550.

Circle No. 221

E. C. C. heat shrinkables are recognized under UL component file E39100.

Feed them:

New Insultite SR-350 eats up shock, strain, and vibration like only a semi-rigid, irradiated polyolefin can. It combines superior dielectric characteristics with high structural strength.

Insultite FP-301, on the other hand, has a flexible polyolefin appetite that devours mil-spec applications. Quickly. Totally.

SR-350 meets classes 3 and 4 of MIL-I-23053A and NASA MSFC 276A. FP-301 meets classes 1 and 2.

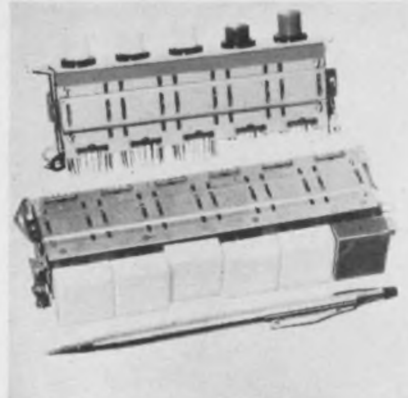
Both feature high abrasion resistance, superior voltage standoff and excellent dielectric characteristics.

Both SR-350 and FP-301 shrink at a better than 2 to 1 shrink ratio when heat is applied.

Insultite SR-350 and FP-301 come in a variety of sizes and colors. White, black, red, blue, and yellow, all easily printed for identification purposes, and clear where visual inspection is important. New SR-350 is available from 3/64" to 1" ID. FP-301 comes in sizes from 3/64" to 4" ID.

Whatever your insulation problem, think shrink with the Insultites. We offer commercial, military grade, flexible and semi-rigid tubing, heat-shrinkable end caps, and exclusive meltable inner-wall tape. Write today for free samples. (Specify diameters, please.)

ELECTRONIZED CHEMICALS CORPORATION
A subsidiary of High Voltage Engineering Corporation
Box 57, Burlington, Massachusetts, Area Code 617-272-2850

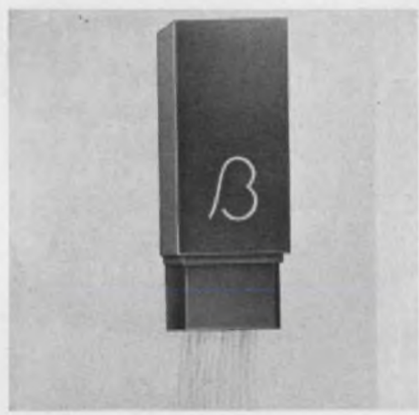


Pushbutton switches

Either illuminated or non-illuminated, this line of switches provides six pdt contacts and round or square buttons that can be mounted in parallel rows. Life expectancy of the switches is 10^6 operations. These units can be provided for momentary contact, push-lock, push-release, inter-lock, and all lock. Contact ratings for a non-inductive load are 1 A at 30 Vdc or 0.5 A at 60 Vdc.

American Zettler Inc., 697 Randolph Ave., Costa Mesa, Calif. Phone: (714) 540-4190.

Circle No. 222



Time delay relays

A timing range of 0.05 s to 22 minutes is provided by these time delay relays for any fixed time. Accuracy is ±5% for all conditions of temperature or voltage. The relays are available as 2 A resistive and 1 A inductive at 28 Vdc, 10 A resistive and 5 A inductive at 28 Vdc or 110 Vac at 400 Hz. Solid-state circuitry is rated at 150 mA max, 20 mA min at 28 Vdc ±5%, 2 V drop max. The relays meet MIL-R-5757D.

Betamite Electronic Devices, 7001 West Imperial Highway, Los Angeles. Phone: (213) 673-5058.

Circle No. 223

Foil-dielectric trimmers

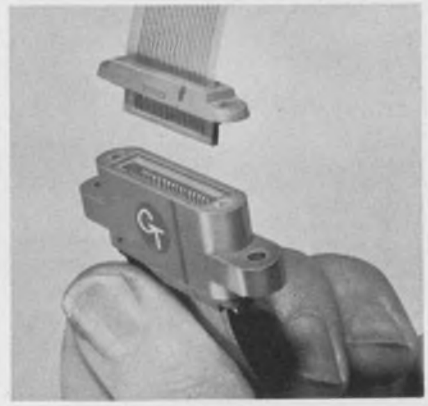
Available in ratings of 5, 10, 20 and 60 pF, these trimmers have a working voltage of 50 Vdc max and 360° rotation. Operating torque is less than 150 g-cm. The units can operate at frequencies above 100 MHz. The trimmer dielectric consists of thin polyethylene foils having high isolation resistance even under humid conditions. Both the foils and vanes are closely stacked on a plastic base having high vibration resistance.

Amperex Electronic Corp., Hicksville, N. Y. Phone: (516) 931-6200.
Circle No. 224

Miniature relay

For up to 2-A multiple switching, this relay offers 2-, 4-, and 6-pole types for operation from 5-Vdc sources. Gold-plated contacts are rated for 10^6 operations at maximum load at 28 Vdc or 115 Vac resistive. Mechanical life is 10^8 operations. The units have applications in communications and data processing equipment, measuring instruments, process controls, recording devices and alarm systems.

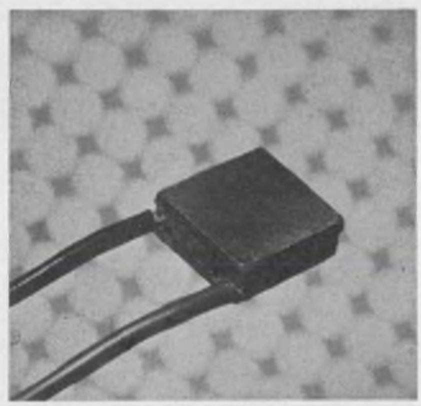
Sigma Instruments Inc., 170 Pearl St., Braintree, Mass. Phone: (617) 843-5000. *Circle No. 225*



Cable connector

Flat cable connectors eliminate insertion force against the surface of the conductor. The male plug enters the female portion of the connector without deflecting the contacts. The carrier block with its raised lead edge protects the front edge of the flat cable. As the cover cap is pressed into place the carrier block is moved forward and up, bringing the cable conductor into contact with the lug. Center-to-center spacing is 0.05-in.

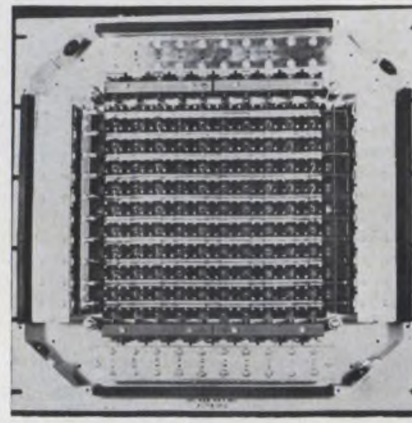
Price: $2 to $10. G.T. Schjeldahl Co., Hwy. 3, Northfield, Minn. Phone: (507) 645-5633.
Circle No. 226



Component cooler

For temperature control and cooling of small components, this thermoelectric module has a loaded heat pump capacity of 3.9 W max. Requiring an input of 9A, the unit has an unloaded temperature differential of 65°C. PC techniques applied to metalized ceramic end caps give electrically insulated module surfaces a higher breakdown voltage, improved cooling capability and rapid response.

P&A: $24; stock. EG&G, Inc., 160 Brookline Ave., Boston. Phone: (617) 267-9700. *Circle No. 227*



Switching matrix

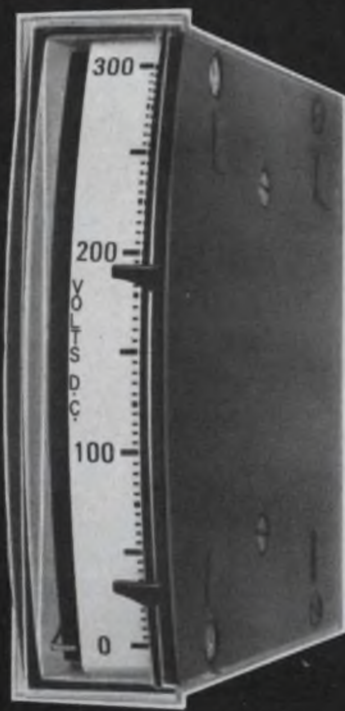
Requiring no wiring of contacts, this switching matrix has random or sequential switching. Two or more input points may be selected simultaneously by energizing the contact bar to move perpendicularly to the actuator bar. This action positions a bifurcated contact against a stationary input connector pin. Crosstalk is −80 dB at 4 kHz and capacitance is 1.5 pF.

P&A: $650; 5 to 10 wks. McKee Automation Corp., 7315 Greenbush Ave., N. Hollywood, Calif. Phone: (213) 983-1193. *Circle No. 228*

Plastic-film capacitors

The series L plastic-film extended-foil capacitors store from 25 to 1500 J in tubular cans at 5 kV. The units weigh from 5 oz to 14 lbs. The series M capacitors operate to 65°C at rated voltage (85°C with derating) at 12% less energy density than series L. Both series discharge at up to 50,000 A. Pulse repetition rates range to 100/s within their respective temperature ratings. The capacitors are rated from 2.5 to 10 kV.

Maxwell Laboratories, Inc., Box 20508, San Diego, Calif. Phone: (714) 281-8146. *Circle No. 229*



THIS IS A COMPLETE CONTROL METER

(ACTUAL SIZE)

PARKER

MINITROL

Not only the most compact, but also the simplest, fastest-acting, most rugged and dependable yet to reach the market.

Minitrol ER35 (above), with 3⅛″ scale, is ⅞″ thin and 4½″ deep, handles up to 300 MA at 100 V internally — thanks to the unique PARKER etched-coil movement and the new contactless, mirrorless, prismless all-solid-state photo switching. Modules for high-density monitor/control applications assemble 22 abreast in a 19″ rack.

Surface-mounting models (right) have the same self-contained switching and brilliant performance in cases also ⅞″ thin.

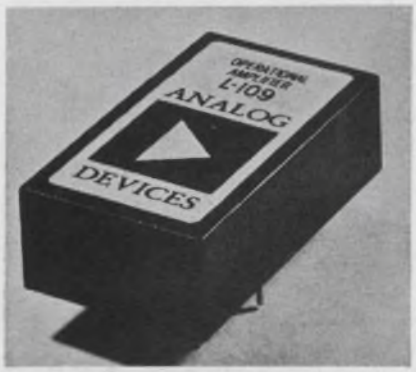
Ask for Bulletin M-5.

SR35/3½″ SURFACE-MOUNTING

SBR35 & 45/3½″ & 4½″ SURFACE-MOUNTING

PARKER **INSTRUMENT CORP.** 200 HARVARD AVE / STAMFORD, CONN 06904 / (203) 325-4361 / TWX 710-474-3390

ON READER-SERVICE CARD CIRCLE 102

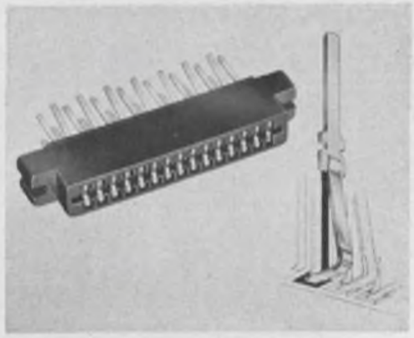


20-mA op-amp

Output of ± 10 V and 20 mA is characteristic of this dc differential op-amp. Open loop gain is 150,000 and gain-bandwidth product is 1.5 MHz. Voltage drift is 20 $\mu V/^\circ C$ and drift at each input is 1.5 $nA/^\circ C$, max. Differential current drift is 0.5 $nA/^\circ C$, slew rate is 1.2 $V/\mu s$ and overload recovery time is 1 ms. The unit has ± 20-nA offset, ± 10-V common mode rating and 20-kHz full response.

P&A: $55; stock. Analog Devices, 221 Fifth St., Cambridge, Mass. Phone: (617) 491-1650.

Circle No. 230



PC board connector

This PC board connector has preloaded cantilever contacts with closely controlled gap uniformity. Contact pressure is independent of PC board insertion depth. The connector is available with selective gold plating which concentrates the gold in the contact area. Selective application of tin or tin-lead coating is optional. Comb contact formation permits simultaneous insertion of contacts for consistency of assembly and increased speed.

Price: $0.01-1/4 /contact. Cinch Mfg. Co., 1026 S. Homan Ave., Chicago. Phone: (312) 632-2000.

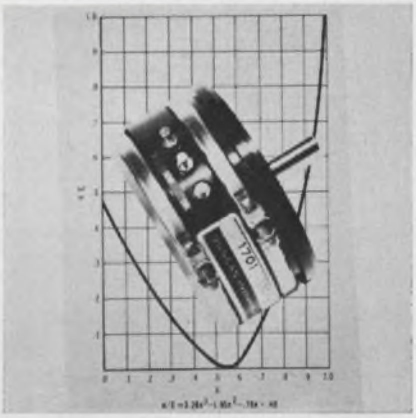
Circle No. 231

Frequency standard

Designed as a clock source for digital industrial control, this miniature flat pack frequency standard has a square wave output. The device operates over the 10-kHz to 3-MHz range. Stability from 200 kHz to 3 MHz is $\pm 0.001\%$. A crystal-controlled oscillator generates the primary frequency. Oscillator output is buffered and shaped for positive triggering of the binary that ensues. An internal voltage regulator stabilizes output frequency.

Robinson-Halpern Corp., 5 Union Hill Rd., West Conshohocken, Penn. Phone: (215) 825-1300.

Circle No. 232

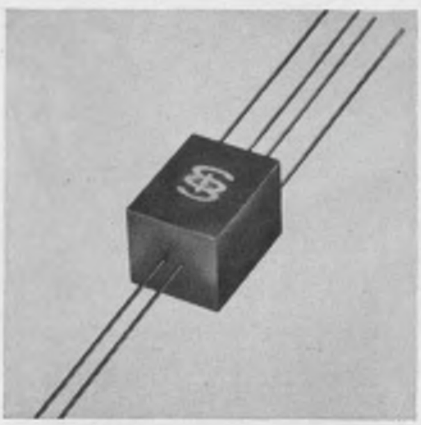


Nonlinear pots

This family of nonlinear pots features low-noise windings, dual whisker in V-groove slip-ring design and a low-inertia rotor. A digital computer analyzes mathematical and graphical data defining the desired output function of the pot. This design information is used to program servo-controlled winding machines which produce the variable-pitch winding to meet the specified function.

Duncan Electronics Inc., 2865 Fairview Rd., Costa Mesa, Calif. Phone: (714) 545-8261.

Circle No. 179



Bistable latching relays

These polarized dc latching reed relays contain a single coil of reversible polarity which transfers the contacts to either of two stable states. A symmetrical magnetic latching design holds the contact open or closed for model 7051 (spdt) and closed for model 8051 (spst) until a reverse input changes contact state.

P&A: $43 (model 8051), $48 (model 7051); stock. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. Phone: (213) 785-4473.

Circle No. 180

Solid-state relay

This solid-state relay has a range of 0 to 100 μAdc with a set-point scale calibrated in increments of 1 μA. Input resistance is 100 Ω for the entire current range and load rating is 1 A at 117 V, 60 Hz. Response time is 200 ms, accuracy is ±2% under reference conditions and repeatability is typically ±0.5%. Breakdown voltage is 500 Vac and common mode rejection is 250 Vdc max.

P&A: $175, stock. Weston Instruments, Inc., 614 Frelinghysen, Newark, N. J. Phone: (201) 243-4700.

Circle No. 233

Encoder devices

Nine new encoders include optical, magnetic and contacting types available with modifications. The line includes a size 31 gray code with a 5-million turn life, a high-reliability size 11 binary X, an optical incremental encoder, a size 23, 360-count and multi-360 turn encoder for use with IC logic, a magnetic encoder, an 8-digit per turn, self-selecting size 18 with a life of 7-1/2 million turns and a bi-polar, noise-free 100-million turn contacting encoder.

United Aircraft Corp., Norden Div., Norwalk, Conn. Phone: (203) 838-4471.

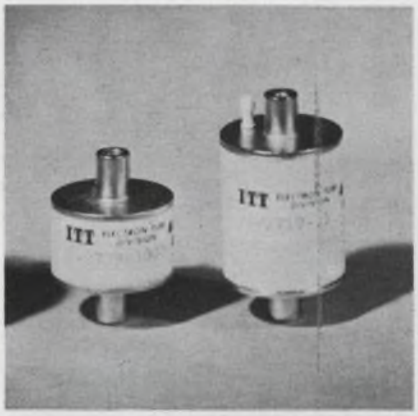
Circle No. 234

Positive TC thermistor

An increase in resistance with temperature to up to 50% of instantaneous value/°C is exhibited by this thermistor. Made from doped barium titanate, the device may be used up to 170°C. The switching point is a function of the material and does not change with time. Thermistors with switching temperatures in 10° increments are available from 55 to 165°C.

Pennsylvania Electronics Technology, Inc., 1397 Frey Rd., Pittsburgh. Phone: (412) 351-0890.

Circle No. 235

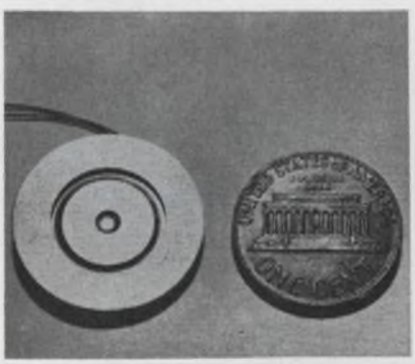


Spark-gap protectors

This line of ceramic-metal spark-gap protectors present a very high impedance until break-down impedance drops to a few ohms. These gaps are usable for high-voltage energy transfer with minimum switch dissipation. Type F-2709 gaps have breakdown voltages between 400 and 8000 V. Surge currents range to 3000 A and energy to 40 J. Type F-2719 gap has a standard breakdown of 400 V and handles peak currents of 25,000 A at 2.5 C to 200 A at 200 C.

ITT Corp., 320 Park Ave., New York. Phone: (212) 752-6000.

Circle 236



Pressure transducer

Air turbulence and pressure on surfaces are measured by this transducer. The unit has a pressure range of from 0 to 4 psig with a maximum overpressure capability of 10 psig. Output is 1000 Ω nominal (at 25°C). Temperature coefficient is 1%/°F, linearity is ±1% (terminal), repeatability is 0.1% and hysteresis is 0.3% max. The sensing element is a nickel alloy.

Mechmetals Corp., 11431 Joanne Pl., Culver City, Calif. Phone: (213) 870-5671.

Circle 237

Position transducer

Formed by depositing the resistive material onto a copper mandrel, this linear position transducer has essentially infinite resolution. Model 178 has typically 100-Ω noise level, ±300 ppm/°C max temperature coefficient and 5% resistance tolerance. Independent linearity is ±0.5% with power rated at 1.5 W/in. at 40°C. Operating range is −55 to 125°C with an insulation resistance of 50 MΩ.

Bourns Inc., 6135 Magnolia Ave., Riverside, Calif. Phone: (714) 684-1700.

Circle No. 238

Xenon flashtube

With internal trigger probes and a semi-flat top, this xenon flashtube has flash rates up to 600 pps and pulse duration of 15 μs or less. In single flash operation the input per flash is 5 J max. Long term average input rating is 7 W. These flashtubes are available in aircooled, helical, bifilar, annular or U-shaped designs. Applications include laser stimulation, flash photolysis and medical research.

EG&G Inc., 160 Brookline Ave., Boston, Mass. Phone: (617) 267-9700.

Circle No. 239

Glass reed relay

Insulation resistance of this relay exceeds 1 x 10^{14} Ω at 90 Vdc. This relay occupies 0.02 in.^{3} and has an operating time of 0.4 ms max. Release time is 0.018 ms max, shock is 50 G and vibration is 50 G at 2000 Hz. Coil power is 60 to 70 mW sensitive and 160 to 230 mW non-sensitive, contacts are rated 7 W, 125 mA and open contact capacitance is 0.1 pF.

Availability: 4 to 5 wks. Wheelock Signals, 273 Branchport Ave., Long Branch, N. J. Phone: (201) 222-6880.

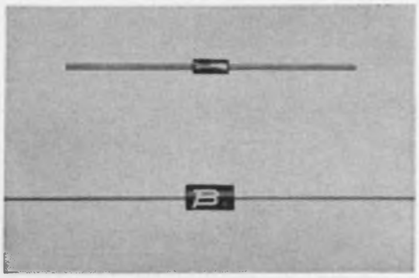
Circle No. 240

FET buffer amplifier

Differential and common mode input of 10^{10} Ω is combined with input offset of ±0.2 nA and 100-dB open-loop gain in this FET op-amp. The amplifier will deliver ±10 V at 10 mA from dc to 100 kHz and has a unity gain bandwidth of 1 MHz. Slewing rate is 5 V/μs. In the unity gain non-inverting circuit, model 1557 draws 0.2 mA from the source. Flat response is maintained with up to 1000 pF load.

P&A: $110; stock to 3 wks. Burr-Brown Research Corp., 6730 S. Tucson Blvd., Tucson. Phone: (602) 952-1111. *Circle No. 241*

GUARDIAN/SOLENOIDS

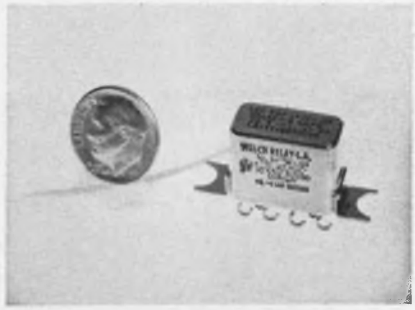


Micromin capacitor

Encased in a high-temperature plastic molded body, this capacitor measures 0.1 x 0.2 in. and has a terminal strength of 5 lbs. It meets environmental conditions of MIL-C-11015C. The gold-plated nickel leads are weldable and solderable. Capacitance range is 10 to 10,000 pF and tolerances of 10% and 20% are available. Operating temperature range is −55 to 150°C, insulation resistance is 100 GΩ at 50 Vdc and power factor is 2.5% max.

Bourns, Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

Circle No. 242

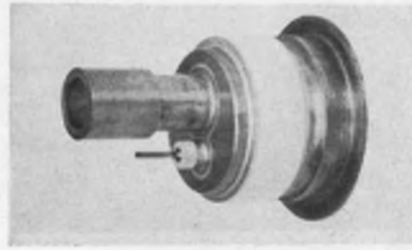


Magnetic latch relay

Four internal diodes for steering and suppression are included in this relay. Flux, gas and humidity contamination are eliminated. The relay has an 18-V pull-in and 2-A dpdt contact ratings. Both 90- and 140-mV sensitivities are available in 8-, 9- or 10-pin headers. The unit can withstand 30-G vibration and meets MIL and NASA specs. The relay is all welded internally and welded to its can.

Welch Relay Co., Inc., 1871 S. Orange Dr., Los Angeles, Calif. Phone: (213) 933-9542.

Circle No. 243



Ceramic SCR housing

For encapsulating power or control rectifiers ranging from 16 to 500 A, this housing consists of a glazed alumina (ceramic) body brazed to a Kovar cap and an oxygen-free copper flange. The knife-edge seal permits flange yield during welding preventing stresses from being transmitted to the ceramic-to-metal joint. A ceramic-to-metal seal supports a small copper gate-lead tube which is welded to the gate wire.

Price: $3.50 (in 25,000 lots). Ceramics International, 39 Siding Pl., Mahwah, N. J. Phone: (201) 529-2800.

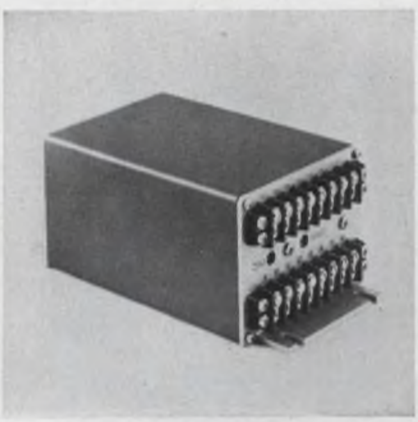
Circle No. 244

Solid-state oven

A fixed temperature operating environment for crystal or solid state components is provided by this oven. The unit employs an ac or dc adjustable proportional temperature control. Externally made adjustments over a range of 20°C are accurate within 0.1°C. Units are available from 6 to 120 Vac or 12 to 28 Vdc using 10 W. Cavity dimensions are 0.665 x 1.09 x 1.062 in.

P&A: $125 (1 to 10); 30 days. Electronic Research Co., 10000 W. 75 St., Overland Park, Kansas. Phone: (913) 631-6700.

Circle No. 245



Dc to ac converter

Offering linearity of better than 0.025% full scale, this converter has an output frequency directly proportional to the input voltage. Four input ranges from 10 mV to 10 V full scale have a 10-kHz full scale output for each range. The housing consists of a flange-mounted case with barrier strip screw terminal connectors for input and output. Adjustment pots give zero and range control.

P&A: $350; 3 to 4 wks. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, Calif. Phone: (213) 782-9527.

Circle No. 246

2-W RF load resistor

A short cylindrical film resistor as the center conductor of a matched tractrix housing gives this 2-W RF load resistor a vswr of 1.04 from dc to 1 GHz, 1.06 from 1 to 2 GHz and 1.1 from 2 to 4 GHz. The compact terminations are designed for 50-Ω transmission lines. They weigh 2 oz max. Model 8010 (female N connector) is 1-1/2 in. long and model 8011 (male N connector) is 1-5/8 in. long.

P&A: $20; 60 days. Bird Electronic Corp., 30303 Aurora Rd., Cleveland. Phone: (216) 248-1200.

Circle No. 247

Tunable analog filter

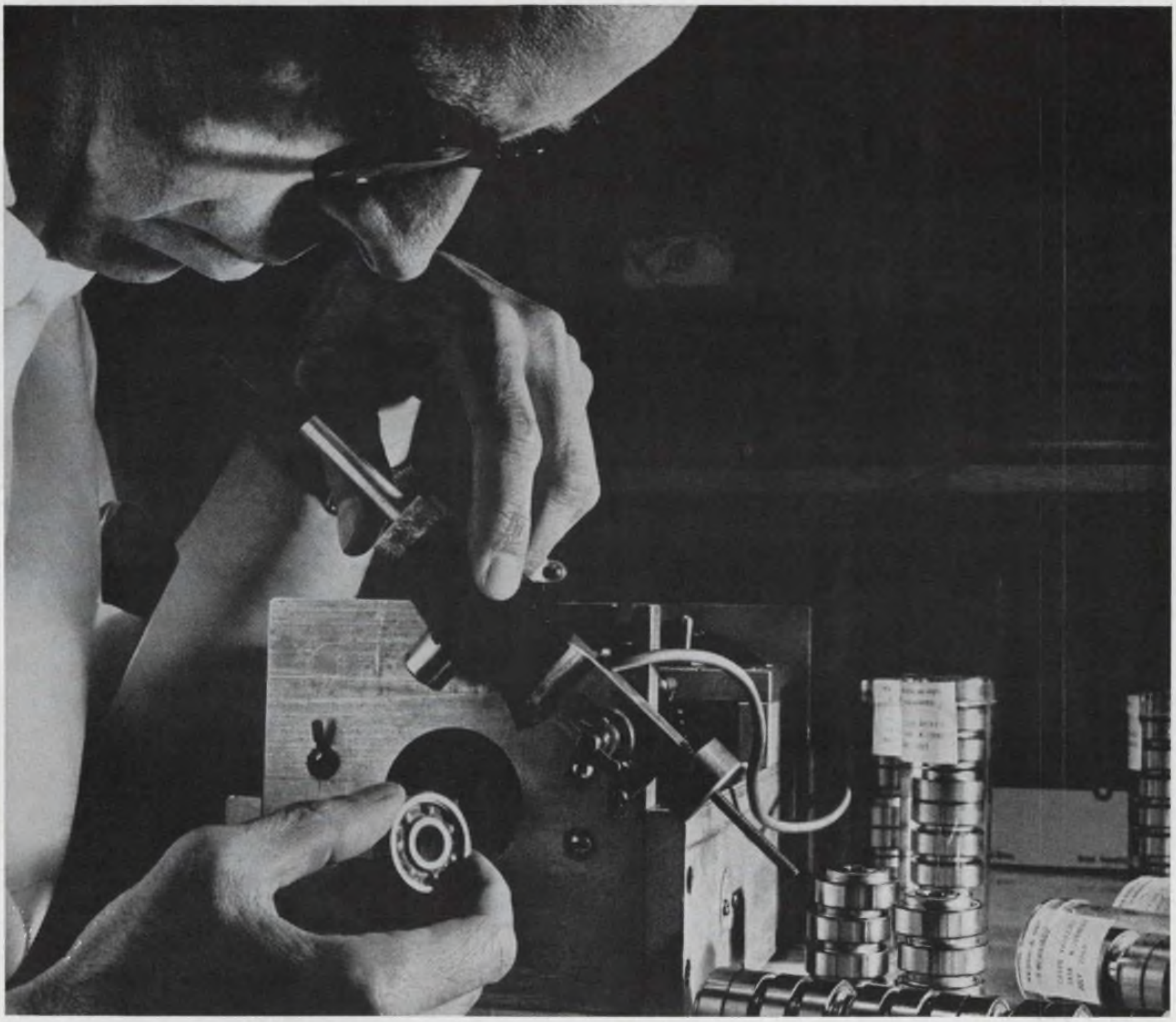
A tuning range from 20 Hz to 2 MHz is handled in analog form by this tunable bandpass device. The instrument behaves as a cascade of low-pass and high-pass filters with 4-pole Butterworth response. Both high and low stop bands attenuate at 24 dB/octave. Nominal passband gain is unity. Cutoff accuracy is ±5% of indicated frequency, high-pass or lowpass.

Spectrum Instruments, Inc., Box 474, Tuckahoe N. Y. Phone: (914) 779-8111.

Circle No. 249

Why does Bodine test motor bearings electronically?

—to be sure Bodine Motors run quietly.



Ball bearings that create objectionable vibration and audible noise have a tough time finding their way into the Bodine motors which power your products. Our special electronic ball bearing tester helps weed out such potential noisemakers.

We purchase only low-noise motor bearings manufactured to special specifications. And we choose suppliers with great care.

But still, we test incoming bearings . . . for even slight variations in ball bearing manufacture can create undesirable noises in fractional and subfractional horsepower motors. Bodine motors must run quietly.

Checking for potential noisemakers is only one of many ways we control Bodine motor quality. Our controls begin with design, extend through production, through run-in and final inspection.

Doesn't your product deserve a controlled-quality motor? A Bodine motor.

Bulletin S-2E describes over 300 stock types and sizes from 1/2000 to 1/6 hp. Write Bodine Electric Co., 2528 W. Bradley Place, Chicago 60618.

BODINE fractional / horsepower MOTORS
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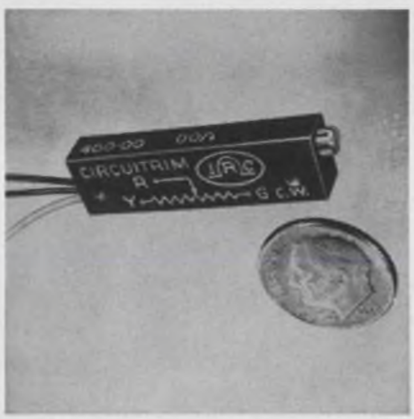
Speed Inquiry to Advertiser via Collect Night Letter
ON READER-SERVICE CARD CIRCLE 191

7-mm connectors

Operating at up to 17 GHz, this family of 7-mm connectors, adapters and assemblies has a vswr of 1.037. At 17 GHz the 50-Ω connector has an insertion loss of 0.028 dB max. RF leakage of a mated pair is below the signal inside the coax line by a ratio greater than 120 dB. Direct current resistance of a pair is 1 mΩ max or the inner contact and 0 Ω for the outer contact. Electrical length variation of a pair is 0.002 in. max.

Amphenol Corp., 33 E. Franklin St., Danbury, Conn. Phone: (203) 743-9272. *Circle No. 250*



10-Ω to 50-kΩ trimmers

Meeting MIL-R-27208, this line of rectangular trimmers includes wirewound units. All trimmers have a one-piece corrosion-resistant shaft and wiper block system which isolates electrical elements. Teflon-insulated leads extend from the diallyl phthalate cases. Rated at 1 W at 70°C, the units are available from 10-Ω to 50-kΩ with ±5% tolerance.

P&A: \$3.56 (100 lots); 4 wks. IRC Inc., 401 N. Broad St., Philadelphia. Phone: (215) 922-8900. *Circle No. 251*

Comparator/relay

Capable of functioning directly from low-level transducers or logic levels, this comparator/relay provides 1/2 A and 220 V. Relay contacts have a 1-ms max operating time from 1-pW signal inputs. Sensitivity is 300 μV and input impedance is 400 kΩ. Using differential inputs the unit becomes a comparator which can trigger from 300-μV differentials with 500-μV repeatability. Input varies from microvolts to 8 V max.

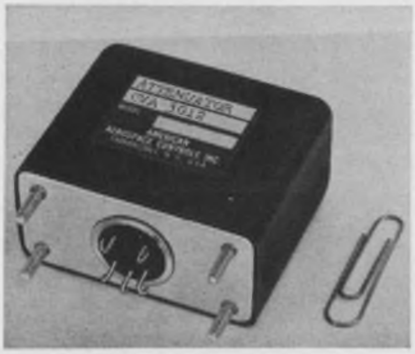
P&A: $35 to $39.80, (1 to 9); stock. Data Device Corp., 240 Old Country Rd., Hicksville, N. Y. Phone: (516) 433-5330.

Circle No. 252

High-G accelerometer

Weighing 13 gm, this accelerometer has a linear response up to the 100,000-G shock level. The low stress level of the sensor material, even at full-scale shock loads, eliminates sensitivity hysteresis and results in good repeatability. The unit operates from 2 Hz to 15 kHz and from −65 to 250°F. Charge sensitivity is 0.03 pC/G and internal capacitance is 115 pF.

Endevco Corp., 801 S. Arroyo Pkwy., Pasadena, Calif. Phone: (213) 795-0271. *Circle No. 253*

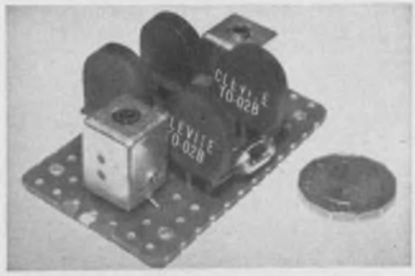


Variable attenuators

Used for remote volume or gain control circuits, this line of infinite resolution and noiseless attenuators has control current from 0 to 10 mAdc to 0 to 40 mAdc. This current produces a voltage attenuation change of 6 dB. Each resistor in the attenuator circuit is rated at 500 Ω nominal. The attenuator circuit is rated for dc or ac to 10 V.

P&A: $69.50 (1 to 9); 4 wks. American Aerospace Controls Inc., 129 Verdi St., Farmingdale, N. Y. Phone: (516) 694-5100.

Circle No. 254



Crystal filters

Provided with input and output matching transformers, type PF1 crystal filter has skeleton construction. Frequency is 457, 465 or 470 kHz ±1 kHz. Bandwidth is 2.5 kHz at 6 dB and 9 kHz at 40 dB and insertion loss is about 5 dB. Type PF2, lacking matching transformers, has a frequency of 459, 467 or 472 kHz ±1 kHz. Bandwidth is 3 kHz at 6 dB and 10 kHz at 40 dB and insertion loss is about 5 dB.

Price: $12.50 (PF1), $10.50 (PF2). Elliott Electronics, 3 Sandgate Ave., Tilehurst, Reading, Berkshire, England.

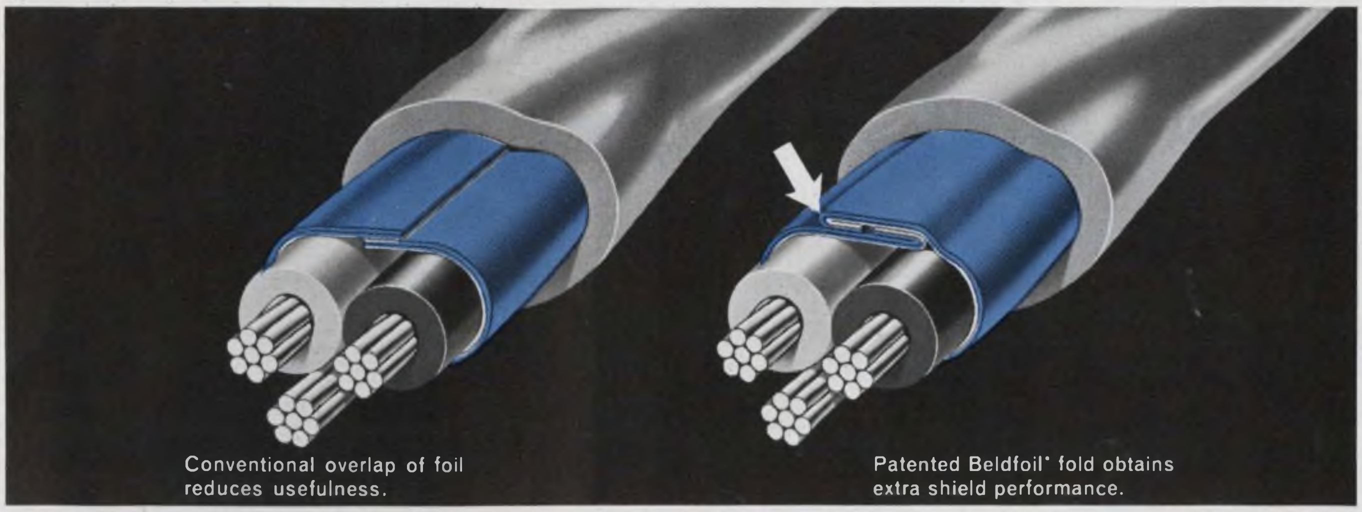
Circle No. 255

Translatory pots

Translatory potentiometers are capable of handling power levels to 1 W per inch of stroke. Standard resistances range from 100 Ω to 40 kΩ/inch. This resistance is varied as the pot's shaft is slid into or out of the unit's housing. Both linear and nonlinear outputs are available. Both single or dual resistance elements with separate contact brushes and terminals are offered. Housings are anodized aluminum. Stroke lengths from 1/2 inch to 16 inches are standard.

E. W. Bliss Co., Gamewell Div., 1238 Chestnut St., Newton, Mass. Phone: (617) 244-1240.

Circle No. 256


Conventional overlap of foil reduces usefulness.

Patented Beldfoil* fold obtains extra shield performance.

It's in the fold!

By Frank Timmons, Chief Engineer, Electronics Division, Belden Manufacturing Company

There are a number of cables on the market today which utilize Mylar† Aluminum Shielding to eliminate noise, hum and cross-talk. These cables have been developed to meet the needs of equipment engineers who have found that standard braided and spiral shields are inadequate in reducing pick-up and transmitted noise.

There is a big difference in the various cables available . . . and the big difference is in the manner by which the Mylar Aluminum Shielding is applied to the cable. The cable which does the most effective job of eliminating noise, hum and cross-talk uses a unique, patented wrapping process that "folds back" one or both edges of the Mylar Aluminum Shielding. It provides "total shielding" and was introduced in 1957 by the Belden Manufacturing Company under the trade name, "Beldfoil."

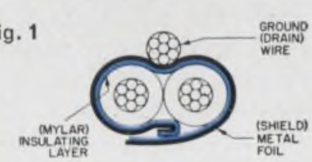
It is evident that many interested persons do not completely understand the manner in which Mylar Aluminum Shielding is used in the manufacture of Beldfoil cable. Therefore, Frank Timmons, Chief Engineer of the Electronics Division at Belden's Richmond, Indiana plant answers some of the more frequently asked questions, and points up some of the more important benefits offered by Beldfoil.

Q. *You talk about a patented process wherein the Mylar Aluminum Shielding is folded back . . . on one or both edges. Just how is this done?*

A. First, let us define Mylar Aluminum Shielding . . . it is a lamination of Mylar insulation film from 0.0005" to 0.001" thick and aluminum foil of .00035" to .001" thickness, applied spirally around the shielded conductor or conductors to give 100% shield coverage.

In some instances the wires are wrapped with the metal foil on the outside as shown in the cross-sectional drawing Fig. 1.

Fig. 1



Note the heavy black line showing the foil edge folded back so that a full layer of Mylar "bonus insulation" is provided between the conductors and the foil shield, increasing the reliability of the cable.

Cables to be used at radio frequencies, or sensitive to radio frequency interference, may need the fold shown in Fig. 2. This fold creates a metal-to-metal connection which eliminates any possible inductive effect, and makes the shield the electrical equivalent of a solid aluminum tube.

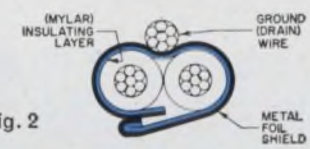


Fig. 2

Shields shown in Fig. 1 and 2 are used for cables with one pair of conductors.

For cables carrying multiple pairs of conductors, a different technique is used. On each pair, the aluminum foil is placed on the *inside*, with the Mylar layer on the *outside* (See Fig. 3). This is important because if the aluminum surface were on the outside we would have random metallic contact between the shields on the different pairs of wires. This would permit the voltages existing on one shield to generate currents in the adjacent shield, creating a transfer of energy or cross-talk between circuits.

Note that the outer edge of the shield is folded to tuck the edge of foil out of the way where it cannot short to the adjacent shield.

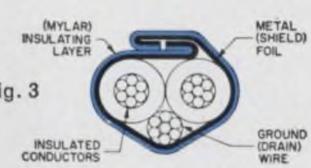


Fig. 3

The inner fold again provides the electrical equivalent of a solid aluminum tube. Belden calls this combination of two folds in one shield a "Z" fold because an end view of the unwrapped tape looks like the letter "Z".

Q. *How much signal isolation results between pairs, when aluminum foil is on the inside, and Mylar layer outside?*

A. This type of construction obtains isolation of more than 100 db between pairs, per thousand feet of cable, at 10 Kc. The short-circuited tape shield makes the cable quite suitable for use at frequencies ranging from audio to RF.

Q. *Do any contact-resistance problems arise between the drain wire and the aluminum foil shield on Beldfoil?*

A. No. Belden design and field service experience on millions of cable-feet in wide service environment have proved this point of reliability.

Q. *Can Beldfoil shields be used over small single conductors as well as over large complex cables?*

A. Yes. Belden applies it on groups from .050" to 1.25" OD.

Q. *Design engineers are constantly faced with miniaturization problems. What about the size of Beldfoil shielded cables?*

A. Beldfoil definitely reduces the diameter of multi-conductor cables . . . in some instances by as much as 66⅔%. The small diameter provides design engineers with extra conduit space, extra raceway, extra console and rack space.

Q. *How can I determine which type of shield I should choose for a given cable?*

A. Belden application engineers are available for engineering assistance. Or, you can obtain preliminary printed information by writing to Belden Manufacturing Company, Advertising Department, P.O. Box 5070-A, Chicago, Illinois 60680.

Belden

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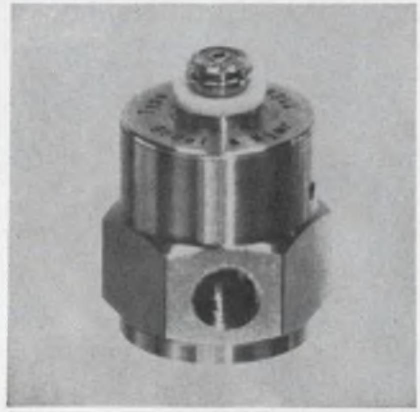
*Belden Trademark Reg. U.S. Pat. Off. †duPont Trademark

ON READER-SERVICE CARD CIRCLE 197

Accelerometer



Vibration measurements at temperatures to 1000°C with water cooling are made by this accelerometer. Nominal sensitivity of 16 mV/G and nominal capacity of 1000 pF provide a range of 2 to 10,000 Hz and acceleration range of 0.01 to 2000 G with appropriate signal conditioner and accelerometer mounting.

P&A: $105 to $155; stock. B&K Instruments, Inc., 5111 West 164th St., Cleveland. Phone (216) 267-4800. *Cricle No. 257*

Rack/panel connector

This shell-less square rack/panel connector accommodates 34 crimp snap-in removable 5-A contacts plus 5 snap-in coax high-power and/or high-voltage contacts. The 5-A contacts accept #20, 22 or 24 AWG wire. The coax contacts have crimp or solder termination. High-voltage and high-power contacts for solder termination are also snap-in removable.

ITT Cannon Electric, 3208 Humboldt St., Los Angeles. Phone: (213) 225-1251.

Circle No. 258

Flame-proof resistor

When overloaded up to 100 times rated power this tin-oxide low-power resistor will not burn. Designed for TV circuitry, the resistors will open instead of burning. An overload of 10 times rated power applied for 5 s causes a 5% resistance change. Rated at 2, 3, 4, 5, 7 and 10 W, the units have tolerances of 1, 2, 5 or 10%. Temperature coefficient is ±200 ppm from −55 to 150°C.

Availability: November. Corning Glass Works, Corning, N. Y. Phone: (607) 962-4444. *Circle No. 259*

Vacuum feedthroughs

Bakeable to 450°C, these ceramic-metal vacuum feedthroughs come with integral internal connectors and a standard MS connector. The units operate electrical devices or multiple-filament evaporation sources during vacuum processing or testing. They can also supply power to resistance heaters or sublimation or evaporation filaments. Ratings are 50 A/pin, 1 kV pin-to-pin and 2 kV pin-to-ground.

Varian Assocs., Vacuum Div., 611 Hansen Way, Palo Alto, Calif. Phone: (415) 326-4000.

Circle No. 260

Binding posts

One 1/4-in. No. 32 nut mounts this pre-assembled binding post. A low-loss polyamide body insulates stud, providing a 5000 Vdc break-the stud, providing a 5000 Vdc breakdown at 15 A. Capacitance to a 1/8-in. panel is 3 pF. Insulation resistance is 200 MΩ min after MIL-T-5422B humidity test. Front projection is 25/32 in. open and 21/32 in. closed. The self-captivated fluted thumb nut cannot work loose.

E. F. Johnson Co., Waseca, Minn. Phone: (507) 835-2050.

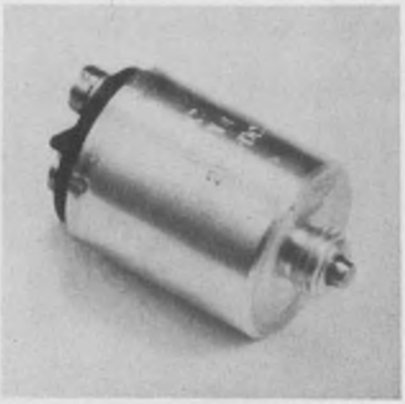
Circle No. 261

Crystal can relay

Type HF half-size crystal can relay is designed for low level to 2-A switching. Contact arrangement is two form C (dpdt) with bifurcated contacts. Standard 26.5-Vdc coil has resistance of 1250 Ω, operate sensitivity of 160 mW and nominal voltage power requirement of 560 mW. Operate time at nominal voltage is 4 ms max and bounce is 2 ms max at low level and 1 ms max at high level rating.

C. P. Clare & Co., 3101 Pratt Blvd., Chicago. Phone: (312) 262-7700.

Circle No. 262

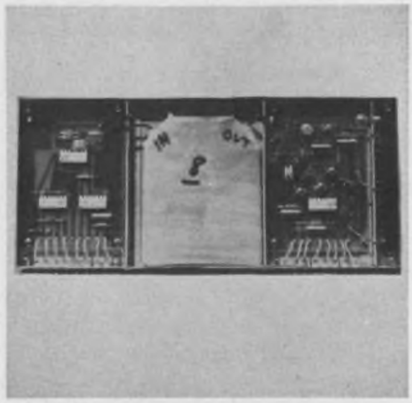


Miniature solenoid

This continuous-duty solenoid pushes 1 lb at 0.05-in., 2 lbs at 0.025-in. or 3 lbs at 0.01-in. stroke. The 52-gram device measures 1.25-in. long. Operating range is 65 to 200°F. The unit uses 0.6 A max. Voltage range is 18 to 30 Vdc.

P&A: $10 (1 to 4), $5 (over 1000); stock. IMC Magnetic Corp., 570 Main St., Westbury, N. Y. Phone: (516) 334-7195.

Circle No. 263

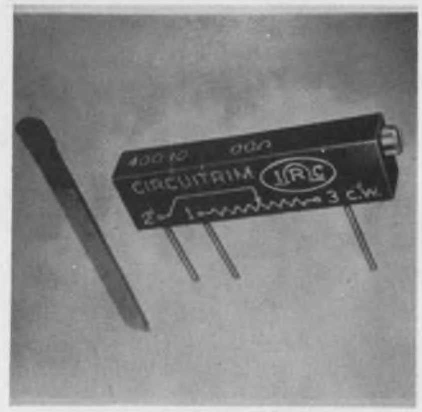


Glass memory modules

A delay line and input-output circuitry are combined in this glass memory module for increased stability and reliability. Data rate is 9 Mbits/s, storage is up to 1600 bits and delay time is 200 μs. These memories are made of glass having zero nominal temperature coefficient of time delay.

Corning Glass Works, Bradford, Pa. Phone: (814) 362-5571.

Circle No. 264

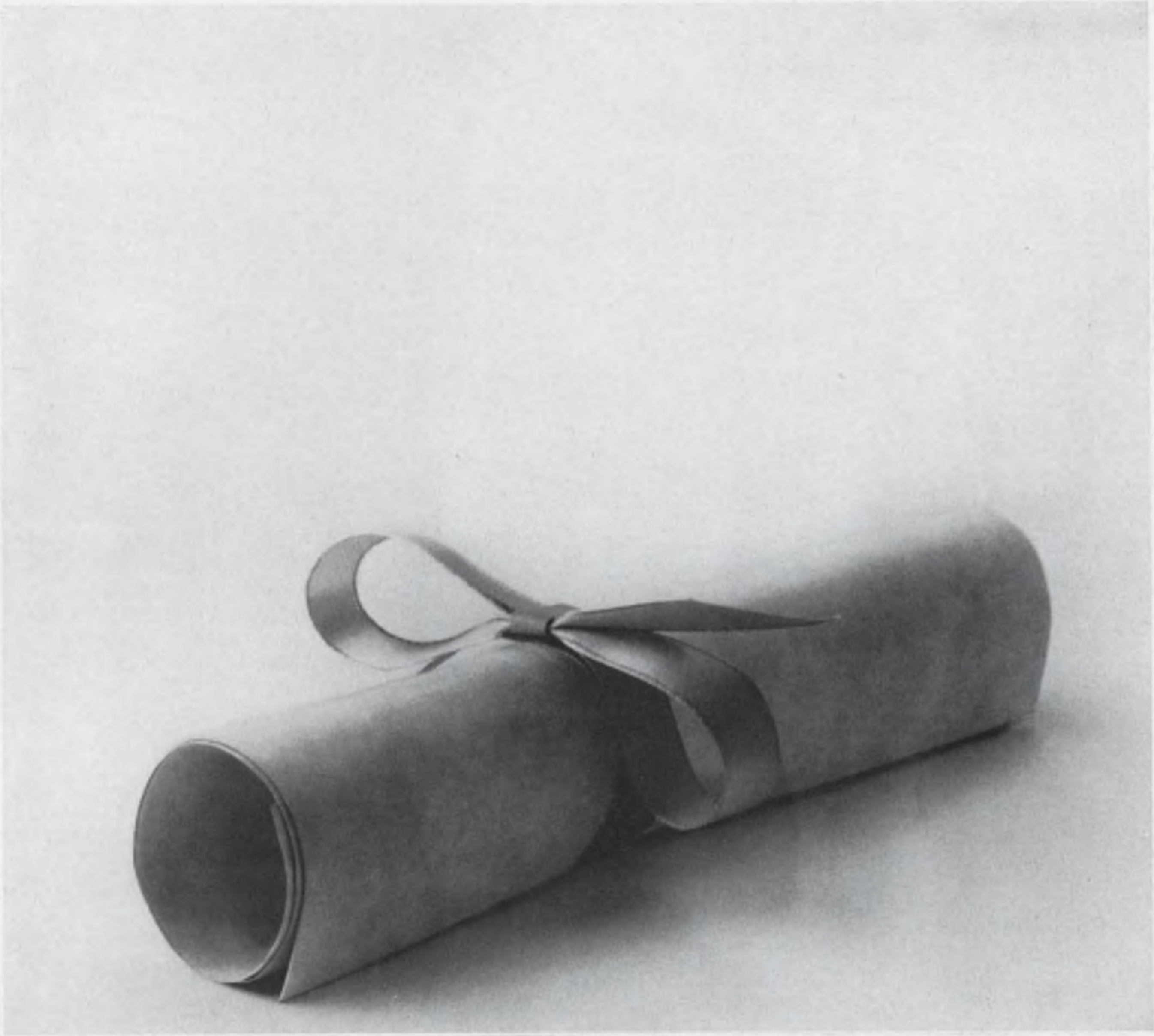


Wirewound trimmers

These rectangular wirewound trimmers with in-line PC pins have diallyl phthalate cases with epoxy seals for very good humidity-proof characteristics. The units are available with resistance values from 10 Ω to 50 kΩ and ±5% tolerance.

P&A: $3.56 (100 lots): 4 wks. IRC, Inc., 401 N. Broad St., Philadelphia. Phone: (215) 922-8900.

Circle No. 265



It's only a beginning.

MIT says career engineers should spend 10% of their time keeping up with new technology. IBM agrees. Whatever degree you hold, you can't afford to stop learning.

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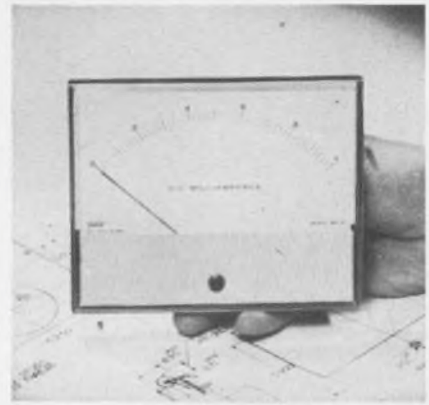
ON CAREER-INQUIRY FORM ON PAGE 111, CIRCLE 910



Dc panel meters

These 5-1/2-in. dc panel meters are available as voltmeters, millivoltmeters, ammeters, milliammeters and microammeters with front-panel or bezel mounting. Ammeters feature a standard 50-mV drop. All meters are pivot and jewel or suspension construction. Standard accuracy is 2% and best accuracy is 1/2%. Either magnetic or nonmagnetic panel standard calibration may be used. Breakdown voltage is 5 kV.

Availability: stock. Triplett Electrical Instrument Co., Bluffton, Ohio. Phone: (419) 358-5010.

Circle No. 266

Crystal oscillators

Frequency stabilities of ±1 ppm over a range of −40 to 70°C and ±2 ppm from −55 to 85°C without an oven are characteristic of these temperature-compensated crystal oscillators. This stability is accomplished by a compensation network which has a voltage variable capacitor and thermistors with computer-selected values. Units are available in a range of 3 to 20 MHz.

P&A: $250; 8 to 10 wks. Bulova Watch Co. Inc., 61-20 Woodside Ave., Woodside, N. Y. Phone: (212) 335-6000.

Circle No. 267

Monitor control

Combining functions of an op-amp, differential amplifier and solid-state switch, this monitor control module accepts two separate inputs with a voltage differential as low as 10 mVdc or ac to control solid-state output switching to over 200 Hz. Impedance of each input is 2 MΩ. Common mode rejection is 60 dB at dc and 50 dB at 60 Hz.

Price: $167.75. Maytronics Inc., P.O. Box 460, Colorado Springs, Colo. Phone: (303) 636-1301.

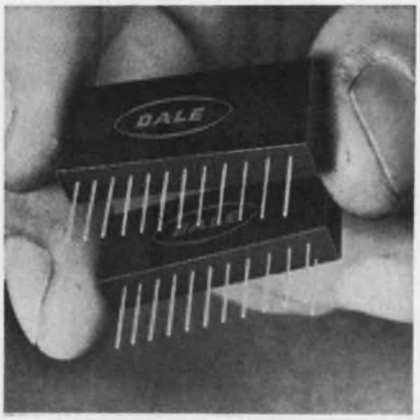
Circle No. 268

Passive low-pass filter

Measuring 2-1/4 x 2 x 3-1/16 in., this passive low-pass filter has a maximum linear phase response from its cutoff frequency to three times its cutoff frequency. Minimum overshoot is less than 2% and insertion loss is 2 dB max. The unit is available with cutoff frequencies from 1 to 200 kHz and provides attenuation of 60 dB min in the stopband to 1 MHz.

P&A: $185; stock to 30 days. Guillemin Networks Inc., 170 Brookline Ave., Boston, Mass. Phone: (617) 536-5810.

Circle No. 269

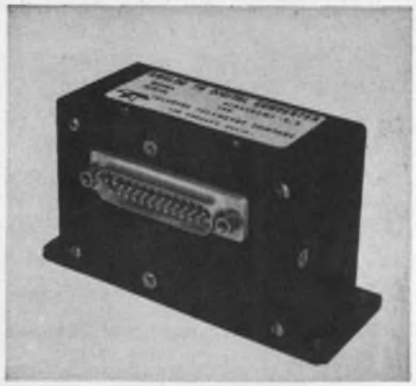


Ladder networks

Containing wirewound resistance elements, these ladder networks can be used as voltage attenuators or digital-to-analog converters in computer systems. Resistors are packaged in matched sets and meet MIL-R-26 and -93. They are available from 0.1 to 2 W each and from 0.1 Ω to 500 kΩ. Resistors can be matched to within 0.005% and have a standard tolerance of 0.02% min.

Dale Electronics, Inc., Columbus, Neb. Phone: (402) 564-3131.

Circle No. 270

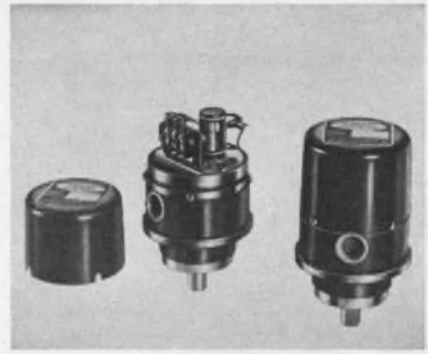


A-to-D converters

Using thin-film monolithic ICs, this series of analog-to-digital converters provides up to 10-bid resolution on analog inputs with overall accuracy from ±0.4 to ±0.1%. Series 610 is available with internal clock or provisions for slaving to an external clock, 0- to 5-V unipolar and bipolar operation and word conversion rates from 1 to 50 kHz.

DynaPlex Div., Teledyne Telemetry Co., Aerospace Div., Box 341, Alexander Rd., Princeton, N. J. Phone: (609) 452-2250.

Circle No. 271

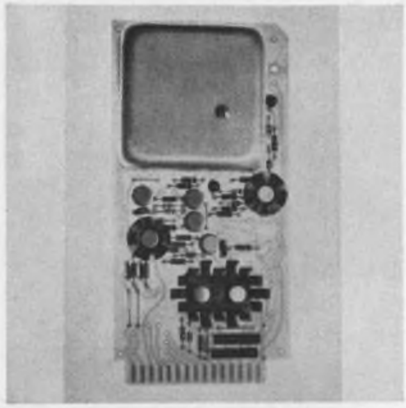


Feedback sensor

Capable of withstanding large mechanical stresses, these feedback sensors have input to potentiometer ratios of 2:1, 1:1 or 1:2. Using single or multi-turn precision pots provides for input ranges from 1/2 to 20 turns for full pot range. Units are rated at 1 and 10 kΩ. Because the unit has a servo clamp mounting, the cover need not be removed for trimming and adjustment of the resistance value.

Jordan Controls Inc., 5607 W. Douglas Ave., Milwaukee. Phone: (414) 461-9200.

Circle No. 272



100-mA dc op-amp

An output of 100 mA at ±10 V, 50 mA at ±20 V or 20 mA at ±110 V is provided by this dc op-amp. Input impedance is 100 GΩ shunted by 6 pF and dc gain is 10^6. Output slewing limit is 20 V/μs. A guard driver neutralizes cable capacitance at the summing node to cut ac error. These all-silicon amplifiers are direct-coupled and therefore free of chopper noise and intermodulation distortion.

P&A: $140 to $180; stock to 60 days. Newport Laboratories, Box 2087, Newport Beach, Calif. Phone: (714) 540-4914.

Circle No. 273

Op-amp has 40-V swing

Dc gain of 150,000, output of ±10 mA and output drive of ±20 V is provided by this dc differential op-amp. This unit features 1.5-MHz gain-bandwidth, 20-kHz full power output and 1.2-V/μs slewing rate. Drift is 20 μV/°C, offset is 20 nA max at 25°C and current drift is 1.5 nA/°C max from −25 to 85°C. Typical uses occur in multiplier and log circuits where non-linear feedback is used.

Price: $65. Analog Devices, 221 Fifth St., Cambridge, Mass. Phone: (617) 491-1650. *Circle No. 274*

Metal film resistors

Rated at 0.1 W, these metal film resistors have temperature coefficients of ±10, 25, 50 and 100 ppm/°C and resistances from 10 Ω to 3 MΩ. The units have a protective covering and special end cap construction for high moisture and environmental protection. Measuring 0.25 x 0.095 in., the resistors are suitable for miniaturized equipment utilizing either conventional wiring or PC boards.

Pyrofilm Resistor Co., Inc., 3 Saddle Rd., Cedar Knolls, N. J. Phone: (201) 539-7110.

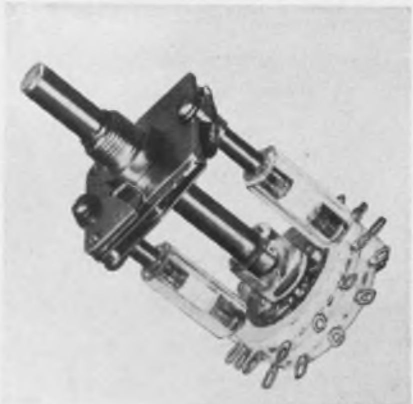
Circle No. 275

Transducer amplifier

This transducer amplifier and bridge source uses 28 Vdc ±10% at 50 mA and provides constant amplitude square wave bridge excitation adjustable from 4.5 to 5.5 V. Designed to accommodate bridges with impedance from 200 to 500 Ω, the unit gives 0- to 5-Vdc output from a 2-kΩ source for inputs having factors of 2 to 12 mV/V. Response is flat ±5% from dc to 2.5 kHz.

Pioneer Magnetics Inc., 1745 Berkeley St., Santa Monica, Calif. Phone: (213) 393-0136.

Circle No. 276

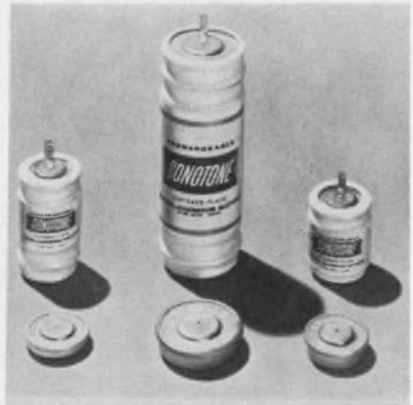


Selector switches

An insulation resistance of 10^5 GΩ min is provided by these selector switches with polycarborate insulated shaft extensions and spacers. The isolated portion of the circuit can be floated up to 10 kV above ground. Shaft extensions are available in 3/8- to 1-7/8-in. lengths. Spacer length is 13/16 in.

Chicago Telephone of California Inc., 1010 Sycamore Ave., S. Pasadena, Calif. Phone: (213) 255-7186.

Circle 277

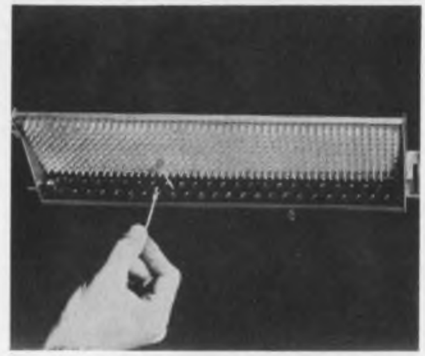


Ni/Cd disc cells

A safety vent cover built into this disc cell provides protection from charging malfunctions. Sintered, rather than pasted, positive and negative plates are used. Three models are rated at 225 mA-hr, 150 mA-hr and 500 mA-hr. When the cells are improperly used, the cell vents release internal gasses and operation resumes.

Sonotone Corp., Elmsford, N. Y. Phone: (914) 592-9600.

Circle 278

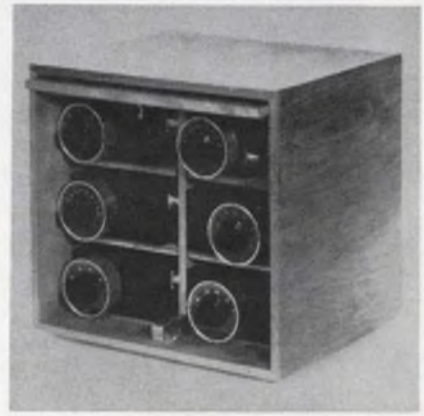


Terminal block

Capable of accommodating 1000 connections, 500 on each side, this solderless connecting block has mounting holes spaced at 15-1/8 in. Male tabs for snap-on solderless terminals are spaced 5/16 in. apart. The tabs are set in a 14-1/2-in. glass-laminate epoxy insulating base. The base has 13/32-in. holes for use as a fanning strip for the terminated wires.

The Thomas & Betts Co., 36 Butler St., Elizabeth, N. J. Phone: (201) 354-4321.

Circle 279

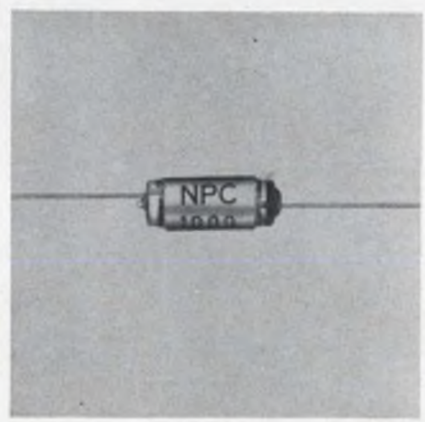


Bandpass filter kits

These tunable bandpass filter kits provide continuous frequency coverage from 48 MHz to 4 GHz. Each kit contains five or six iris-coupled bandpass filters. The capacitively tuned 0.05-dB Chebischev cavity filters have a 3-dB bandwidth of 5% and a tuning range of one octave. They are available in 3-or 5-section designs for 30-dB form factors of 3 and 1.8 respectively. Accuracy is ±1% of center frequency.

P&A: $2000 to $3000; stock. Telonic Engineering Co., Box 277, Laguna Beach, Calif. Phone: (714) 494-7581.

Circle No. 280

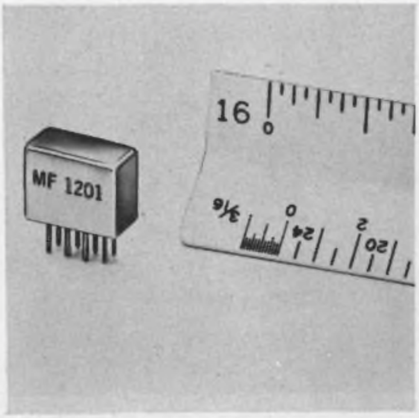


Film capacitors

Available in capacitance ranges from 5 to 25,000 pF, these polystyrene film capacitors have a temperature coefficient of ±50 ppm/°C. Type L is rated at 160 wvdc and type H is rated at 630 wvdc. Capacitance tolerance is ±2.5%, capacitance stability is 0.3% max and power factor is less than 0.03%. Q is 3000 min at 1 MHz at 25°C.

Nucleonic Products Co., Inc., 3131 E. 12th St., Los Angeles. Phone: (213) 268-3464.

Circle No. 281



Crystal can relay

Two dpdt contacts are provided by this crystal can relay. The standard 26.5 Vdc coil is rated at 1500 Ω. Operate sensitivity is 125 mW and nominal voltage power requirement is 470 mW. For low-level applications the unit is rated at 10,000 miss-free operations min. Operating time at nominal voltage is 8 ms max including bounce. The relay withstands vibrations of 20 G peak acceleration, 10 to 2000 Hz and shock of 65 G half sine wave, 11 ms ±1 ms duration.

C. P. Clare & Co., 3101 Pratt Blvd., Chicago. Phone: (312) 262-7700. *Circle No. 282*

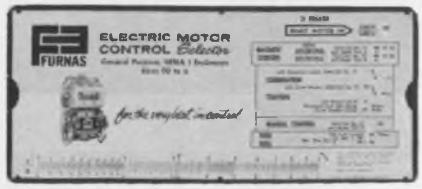
Voltage divider

Reading accuracy to ±0.5% at up to 100 kV is provided by this high voltage divider. Total resistance is 100 MΩ resulting in a 1-mA circuit loading at maximum voltage. Each resistor is electrostatically shielded to minimize corona effects. Tap points are 1, 10, 100 and 1000 V. The divider may be used with digital or other null balance readout instruments.

Beckman Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J. Phone: (201) 239-6200.

Circle No. 283

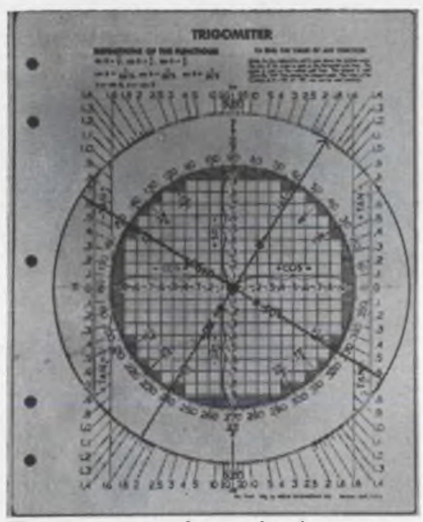
Design Aids



Motor control selector

For single- and three-phase, 110, 220- and 440-V general purpose NEMA 1 enclosure motors, this slide chart aids in specifying motor controls. Reversing and nonreversing magnetic starters, disconnect switches, circuit breakers, heater coils, manual starters and wire sizes are read out for motors rated at 1/2 through 400 hp. For a given fuse, circuit breaker, and wire rating, full load current is also specified. A unique pricing scale calculates discounts ranging from 5 to 50% for list prices ranging from $5 to $1000. For convenience, standard C and D scales are incorporated. Furnas Electric Co.

Circle No. 284



Trigonometric calculator

One setting of the dial of this calculator gives sine, cosine, tangent and contangent of any angle from 0 to 360° with sign. Without changing the setting, the same functions for 180° or ±90° are shown. In addition, the "Trigometer" enables transforming any of the trigonometric functions into the terms of any of the other functions. The 8-1/2 x 11-in. Mylar laminated calculator is punched to fit standard looseleaf notebooks.

Available for $4.50 from Hoyle Engineering Co., 25408 W. Main St., Barstow, Calif.

Microwave receiver rule

For any receiver noise bandwidth from 50 Hz to 30 MHz and noise figure from 0 to 50 dB, sensitivity can be read in dBm with this microwave receiver slide chart. Resultant vswr can also be calculated for a vswr of load between infinity and 1.1 and for a sum of backward and forward loss from 0 to −40 dB. In another window dBm can be calculated for any voltage between 1 μV to 1 V and resistance from 25 to 300 Ω. The reverse side of the chart contains C, D, A and L scales for convenience. Also included is a scale which gives percentage of power reflected for any vswr from 1 to 10. LEL Div., Varian Associates.

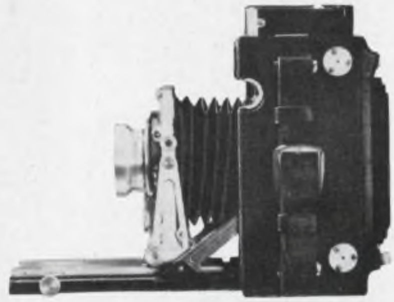
Circle No. 285

TDR calculator

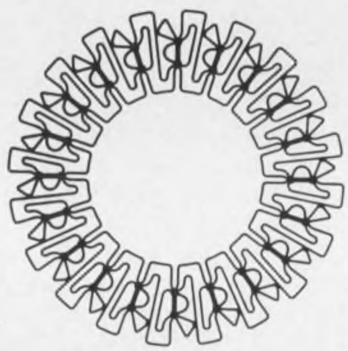
A forty-page application note on cable testing with time domain reflectometry accompanies this TDR calculator. The slide rule itself simplifies the techniques to the point where transmission line formulas are needed only for extreme accuracy. The distance/time scale converts electrical length to the metric and English units of distance, modified by the propagation velocity of the line used. The vswr/reflection coefficient scale converts to vswr for resistive discontinuities. Those discontinuities of a finite length are treated as complex impedances and calculated with the Smith chart in the booklet. The impedance scale calibrates the 1-cm markings of the CRT graticule to Ω, and may be based on any impedance on the slide rule. Hewlett-Packard, Colorado Springs Div.

Circle No. 286

TAKE A POWDER



TAKE A PICTURE



MAKE A PART

Photofab® process holds tolerances on intricate parts to ±0.0005″

Flat components with oddball configurations and close tolerances are no longer production bugaboos, thanks to Magnetics' new photoetching process, Photofab®. This process delivers precision replicas in pilot or production quantities from nearly any magnetic or specialty alloy.

First, Magnetics' powder metallurgy capability develops an alloy strip with uniform magnetic and electrical properties from an exact blend of powdered metals. After the strip has been cold rolled to the specified thickness, it is then photoetched into any configuration that can be drawn on paper.

Frets, rotors, stators and head laminations are just a few of the parts which can be produced by this process—especially effective when material thicknesses of less than 0.001″ are involved.

Consistent high quality in metallic properties, and reproducibility that meets your most exacting specifications are guaranteed by Magnetics Inc. The savings in days and dollars invested are, of course, tremendous.

Write Magnetics Inc., Butler, Pa. 16001, for more information on Photofab® (Dept. ED-103), or for data on custom blended alloys (Dept. ED-104).

MAGNETICS inc. ®

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New Literature

Introduction to telemetry

"Introduction to Telemetry" includes definitions of technical terms, history and applications, telemetry techniques and equipment requirements. Techniques covered include FM/FM, PAM, PDM and PCM. Equipment requirements are discussed for signal conditioners, subcarrier oscillators, transmitters, RF amplifiers, antennas, preamps, multicouplers, receivers, discriminators, data display, magnetic tape recording, and data processing. International Electronic Research Corporation.

Circle No. 287

Stepping motors

A stepping motor which directly converts digital pulse inputs to analog shaft output motion, is described in this 12-page booklet. Sigma Instruments, Inc.

Circle No. 288

Axial lead component design

An 8-page manual, "Board design Guidelines for Axial Lead Components," considers machine assembly of axial lead devices. Board, hole and spacing considerations are discussed and specifications, insertion lead forms, component locations and wire control beneath the PC board are fully covered. The brochure is complete with schematics. Universal Instruments Corp.

Circle No. 289

Switch catalog

This 44-page catalog covers rotary, thumbwheel, pushbutton, slide and special application switches. Construction details, engineering data, dimensional diagrams and specifications are given. In addition, a chart gives a cross-reference of competitive and MIL switches. The catalog also covers complete design information and application, offers sample switch kits, shows a sample detailed layout sheet and shows how to design special switches from standard switch components. Standard Grigsby Co.

Circle No. 290

Power magnetics design

A rapid, explicit, step-by-step procedure for power transformer and inductor design using ferrite cores is given in this reference. Fundamental considerations, such as relationships between flux density and effective permeability, core loss vs frequency, flux density, and temperature, are discussed in conjunction with typical curves. Design procedures, including full mathematical treatment, are then separately explored. A full set of core-group charts and curves provides complete technical characteristics, dimensions, and winding data for over 100 standard ferrite cores suitable for power magnetics applications. Ferroxcube Corporation of America. *Circle No. 291*

Magnetic cores

Fundamental factors affecting the selection and use of electrical steels are presented in this 32-page manual. Dealing specifically with steels for magnetic cores, emphasis is placed on how stresses effect magnetic properties and surface insulation. Data on the classification of electrical steels, core loss, lamination thickness, mechanical properties and factors in grade selection are included. Armco Steel Corp.

Circle No. 292

IC and transistor hardware

Transistor and integrated circuit sockets, holders, bushings and pads are described in this 6-page bulletin. Complete dimensional specifications and engineering drawings for 12 types of sockets, 22 types of holders, 15 types of bushings and nine types of pads are given. The line is designed to accommodate components in TO-5 and TO-18 size cans with three to 12 leads. Sealectro Corp.

Circle No. 293

Semiconductor cooling

Two catalogs on semiconductor cooling cover natural convection heat sinks, circuit board heat sinks, thermal retainers, mounting insulators, thermally conductive adhesives, thermal joint compounds, open airflow cooling assemblies, closed airflow cooling packages, liquid cooled plates, heat sink extrusions and special assemblies. The first catalog covers heat sinks for milliwatt to high-power semiconductors while the second covers standard commercial and military forced convection assemblies and liquid cooled plates. Wakefield Engineering Inc.

Circle No. 294

Pulse transformer packages

This 4-page data sheet describes and illustrates 17 pulse transformer packages. It covers four-pin square packages, round, rectangular, radial lead and flat pack packages, as well as open construction transformers. Contemporary Electronics.

Circle No. 295

Vibration control

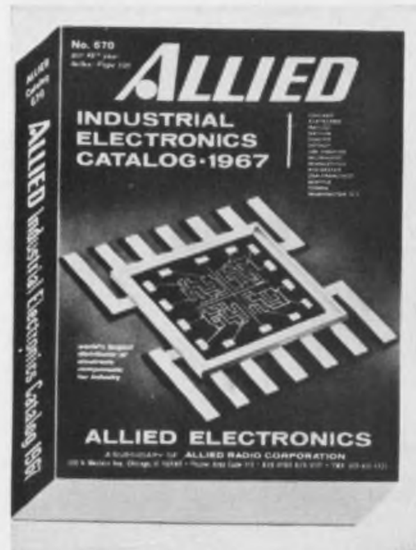
"Built-in Damping" covers the theory and the design method for structural damping applications. Two application examples are included. The 16-page reprint considers vibration control with integrally damped laminates. Lord Manufacturing Corp.

Circle No. 296

SCR control circuits

Seven single and three phase (half- and full-wave) circuits used in SCR control are diagramatically pictured in this bulletin. Cross referenced to these circuits are the various models which are applicable to the circuits. These include card-mounted as well as enclosed units. Also cross referenced are normal pulse output units and hard firing units for high di/dt applications. The bulletin shows the firing pulses for all models, lists conduction angles, sensitivity, prices, model numbers and other information to aid in mating firing circuits and SCRs. The back page defines the general terms used in the industry such as snap-on, conduction angle, speed of response and on-to-off ratio. Firing Circuits, Inc.

Circle No. 297



Industrial electronics

The 1967 edition of Allied's catalog is designed for use by engineers, purchasing, research and maintenance people. The 548-page catalog lists over 60,000 electronic components, communications gear, sound and allied equipment produced by more than 600 manufacturers. 89 pages of semiconductors and IC devices include an enlarged section of additional specs to provide a reference and cross-indexed price guide of the products of major semiconductor manufacturers. Allied Electronics Corp.

Circle No. 298

ABCs of polymers

The basic principles of polymer chemistry and an assessment of plastic's use in the future is detailed in this 12-page nontechnical guide. The booklet covers the molecular structure of polymers and explains their cohesive qualities, size and crystallinity. Mechanical, thermal, optical, electrical and chemical properties are covered. Ferro Corp.

Circle No. 299

Pulse terminology

What is a pulse and how is it defined? "The New Pulse" includes 45 basic pulse definitions, most of which are illustrated. It is believed that these definitions not only approximate what most time domain practitioners think these words mean, but are unambiguous, rigorous and mathematically defensible. E-H Research Laboratories.

Circle No. 300

EASTMAN 910® Adhesive...

bonds carbide to magnesium in seconds

Speed is what business machines now have plenty of. IBM's 084 card sorter, for example, sorts 2,000 cards/minute—up 500% from the original design. Essential to higher speed was redesign of sorter's picker arm (the object that looks like a safety razor in the photo). Once carbon

steel, arm is now hollow magnesium faced with carbide. A bond formed *in seconds* with one drop of EASTMAN 910 Adhesive joins the two materials, holds up in wet grinding, takes 2,000 impacts/min.

EASTMAN 910 Adhesive will form bonds with almost any kind of material without heat, solvent evaporation, catalysts, or more than contact pressure. Try it on your *toughest* bonding jobs.

For technical data and additional information, write to Chemicals Division, Eastman Chemical Products, Inc., subsidiary of Eastman Kodak Company, Kingsport, Tennessee. EASTMAN 910 Adhesive is distributed by Armstrong Cork Company, Industry Products Division, Lancaster. Pa.

There is no adhesive like EASTMAN 910® Adhesive

SETS FAST—Makes firm bonds in seconds to minutes.

VERSATILE—Joins virtually any combination of materials.

HIGH STRENGTH—Up to 5,000 lb./in.^{2} depending on the materials being bonded.

READY TO USE—No catalyst or mixing necessary.

CURES AT ROOM TEMPERATURE—No heat required to initiate or accelerate setting.

CONTACT PRESSURE SUFFICIENT.

LOW SHRINKAGE—Virtually no shrinkage on setting as neither solvent nor heat is used.

GOES FAR—One-pound package contains about 30,000 one-drop applications. (Or in more specific terms, approximately 20 fast setting one-drop applications for a nickel.)

The use of EASTMAN 910 Adhesive is not suggested at temperatures continuously above 175°F., or in the presence of extreme moisture for prolonged periods.

See Sweet's 1966 Product Design File 8a/Ea.

Now available! EASTMAN 910 Surface Activator
When certain surface conditions inhibit rapid bond formation, use of EASTMAN 910 Surface Activator is suggested to restore the rapid polymerization of EASTMAN 910 Adhesive.

Here are some of the bonds that can be made with EASTMAN 910 Adhesive

Among the stronger: *steel, aluminum, brass, copper; vinyls, phenolics, cellulosics, polyesters, polyurethanes, nylon; butyl, nitrile, SBR, natural rubber, most types of neoprene; most woods.* Among the weaker: *polystyrene, polyethylene (shear strengths up to 150 lb./sq. in.).*

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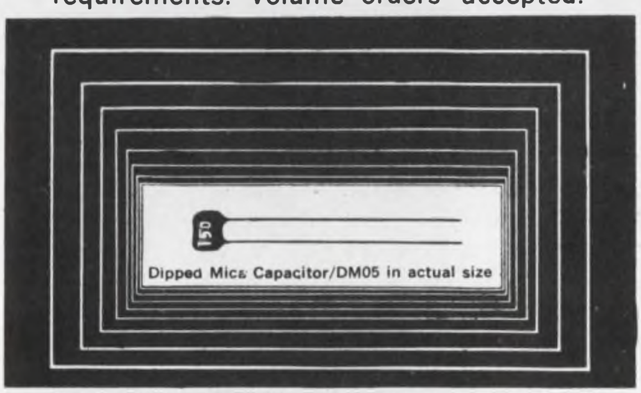
ANOTHER WORLD'S SMALLEST

Soshin's Dipped Mica Capacitors/DM05

Developed by SOSHIN ELECTRIC, the only mica capacitor maker in Japan with MIL-C-5C qualifications. This newest and its bigger brothers will meet all your requirements. Volume orders accepted.



Dipped Mica Capacitor/DM05 in actual size

Types	Max Allowable Capacitance (pf)			Dimension (mm)								
Standard	100 WV	300 WV	500 WV	100 WV			300 WV			500 WV		
				L Max	W Max	T Max	L Max	W Max	T Max	L Max	W Max	T Max
DM 05	200	130	–	7.0	5.0	3.5	7.0	5.0	3.5	–	–	–
DM 10	440	390	330	8.5	5.5	3.5	8.5	5.5	3.5	8.5	5.5	3.5
DM 15 (CM05)	2000	1200	510	13.0	11.0	6.5	12.5	10.5	6.0	12.0	10.0	5.5
DM 19 (CM06)	10000	6800	5100	18.0	15.0	8.5	18.0	15.0	8.0	17.5	15.0	7.5

For further information, write to

SOSHIN **SOSHIN ELECTRIC CO., LTD.**
18-18, Nakamagome 1-chome, Ohta-ku, Tokyo, Japan
Cables: SOSHINCAPACITOR TOKYO

ON READER-SERVICE CARD CIRCLE 886

GOOD FORTUNE AND PROSPERITY AWAIT ENGINEER ORDERING E-T POTS

E-T ⅞" 10-turn precision pots:

- cost $4.50 or less, in production quantities
- meet or exceed existing, accepted specifications
- resistance range from 25 to 250,000 ohms
- linearity tolerance ± 0.25% (special to ± 0.05%)
- life expectancy (shaft revolutions) 2,000,000
- operating temperature range −55°C to +125°C

Want more details? Write or phone the company that gives you more for your money in quality, price and world-wide delivery . . .

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MFRS. OF LINEAR AND NON-LINEAR PRECISION POTENTIOMETERS SINCE 1959

ON READER-SERVICE CARD CIRCLE 887

TV equipment

This cable antenna TV equipment catalog gives specs, photos and prices for over 200 products. A section on engineering, construction and financing services available is included. Ameco, Inc.

Circle No. 301

"Don't Disturb" sign

For the engineer constantly bothered in the lab by prowlers searching for test equipment for their own projects, this "DON'T DISTURB TEST SET UP" sign has a "Holy Experiment" theme. This multi-colored 6 x 12 in. sign will attract enough attention to your set-up so that all who see it will know that it should not be disturbed. Trygon Electronics, Inc.

Circle No. 302

Wire and cable guide

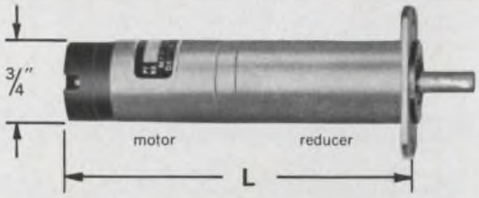
This 20-page booklet gives technical data on the company's line of wire and cable. A section containing tables with weight comparisons between light wall insulation and conventional insulation is given. The booklet also has technical data including wire formulas for resistance and impedance calculations for electrical conductors and coax cable. A table presents nominal diameters, cross-sectional areas, weight and resistance of different hardness copper wires listed by AWG sizes. Inso-Electronic Products Inc.

Circle No. 303

Random vibration testing

A 34-page booklet compares sine wave, wide band random and narrow band random vibration testing. An electrical analog of a mechanical test specimen was used for the comparison. Theoretical and actual test results are compared with a discussion of optimum operating procedures. B&K Instruments, Inc.

Circle No. 304



¾" GEARHEAD MOTOR

Now you can get up to 300 oz. in. torque from a precision miniature gearmotor only ¾" in diameter. Globe's Type SD permanent magnet d.c. motor with integral planetary gearhead provides 19 standard ratios, wound for 4 to 50 volts. Armatures can be wound to produce any speed-torque combination within the capacity of the motor. Can meet environmental and other applicable portions of MIL-M-8609. Request Bulletin SDG.

Speed Reduc. Ratio	Max.Cont. Torque Oz. In.	L
14.58	3.0	2³⁹⁄₆₄
22.08	4.5	
33.28	7.0	
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84.11	14	
127.1	21	
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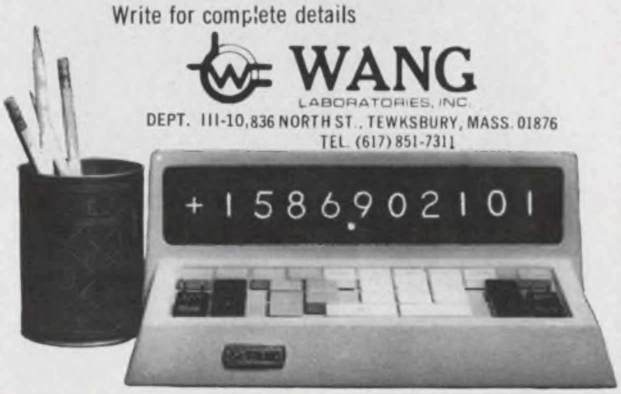

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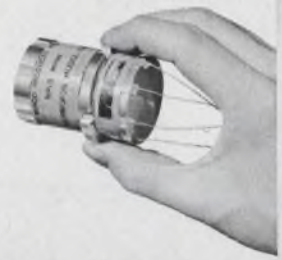

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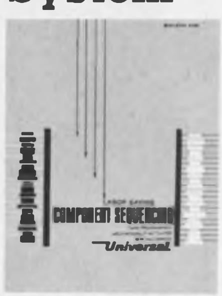

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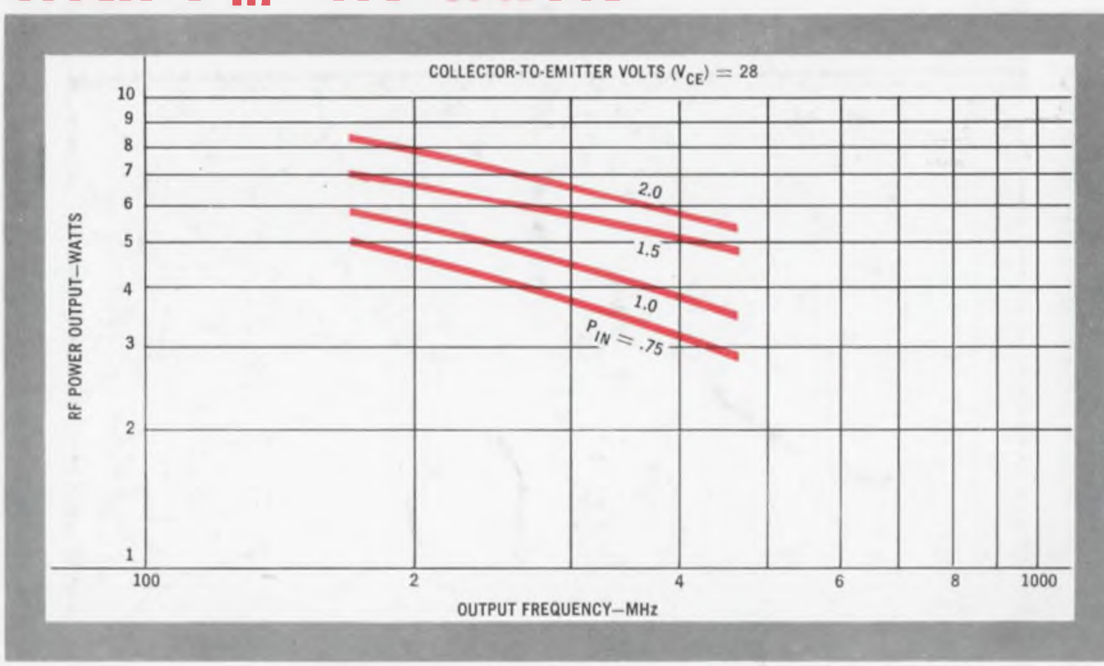

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