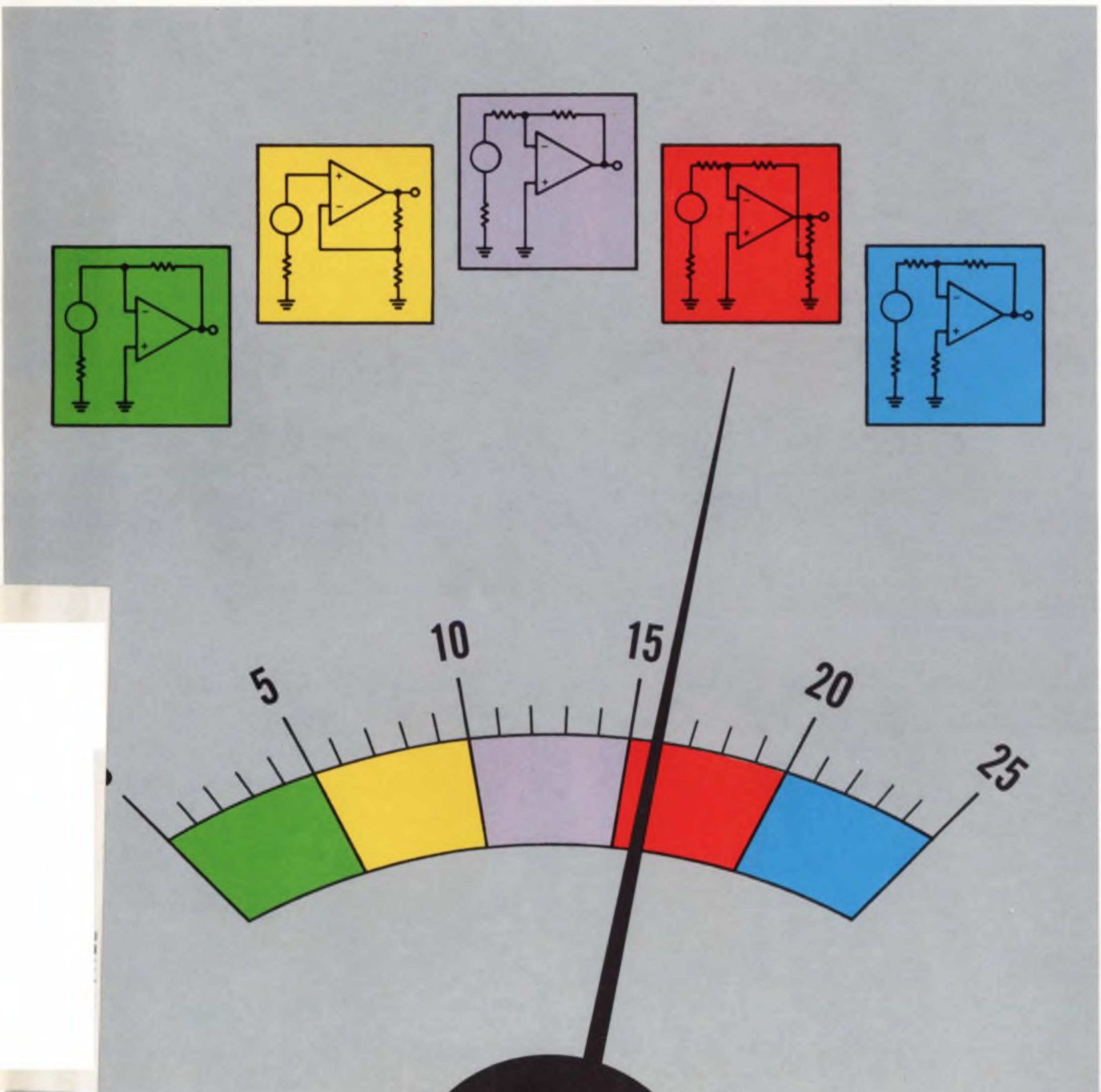
Electronic Design 18
VOL. 18 NO. 18
FOR ENGINEERS AND ENGINEERING MANAGERS
SEPT. 1, 1970

Pick the right op amp for your precision dc measurement. But be careful: A unit with a low voltage drift may surprise you with current-drift errors. And the right choice for a low-impedance circuit may be all wrong when the impedance is high. Listen to an expert's advice on amplifier selection in the article on p. 54



What's a 500 kHz plug-in doing in a 100 MHz mainframe?

Increasing its versatility, that's what!

When you need 100 μV sensitivity, rather than 100 MHz bandwidth, HP's new dual-channel 1806A plug-in lets your 180 Scope System do the job. With the 1806A, the versatile 180 Mini-Giant becomes a powerful tool for measuring and analyzing low-level signals up to 500 kHz.

A 100 μV/div deflection factor lets you see beyond the surface of a signal – to detect ripples, discontinuities and harmonics invisible at less sensitive levels. To get the most out of the 100 μV sensitivity, drift is typically <50 μV/hr, CMRR is 100 dB, noise is <20 μV tangential at full BW – and a pushbutton lets you limit bandwidth to 50 kHz, when you need to.

For applications where you need high-bandwidth capabilities, there are a host of other plug-ins for the versatile 180 System. There's a 50 MHz, 5 mV/div plug-in for only $695. 100 MHz with 10 mV/div and 50Ω input, $1200 (10 M$\Omega$ active probe, $95 extra).

Other available plug-ins include: a differential/dc-offset amplifier, a 4-channel amplifier, and a 35 ps time-domain reflectometer that doubles as a 12.4 GHz sampler.

Today, oscilloscope technology is at a crossroads. The HP direction points to getting the best, now, at a low price – with assurance of increased measurement capabilities down the road, using existing mainframes. The new 1806A plug-in is the latest example of this approach at work.

To see the 180 System, call your local HP field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

080/15

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INFORMATION RETRIEVAL NUMBER 245


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Electronic Design 18

VOL. 18 NO. 18

FOR ENGINEERS AND ENGINEERING MANAGERS

SEPT. 1, 1970

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Cover: Designed by William Kelly, assistant art director

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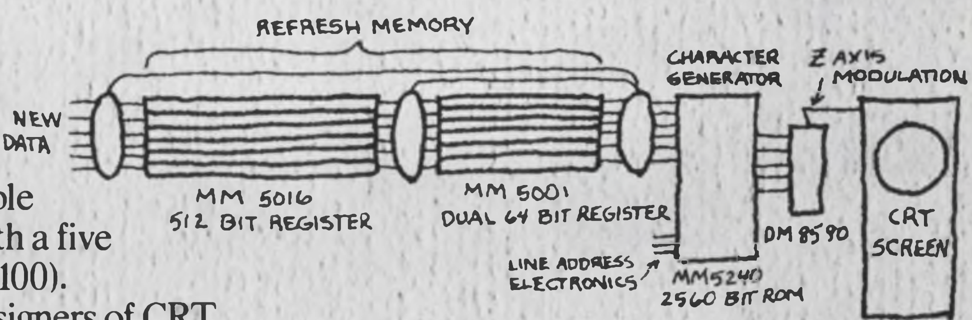
82,501 copies this issue.

National sells MOS than Fairch TI and Signetics

Guess which one is selling shift registers at a penny a bit.

more
ild, Motorola,
combined.



Who else?

National just came out with the MM5016, a bipolar compatible 512-bit dynamic shift register with a five dollar price tag (in quantities of 100). The MM5016 should interest designers of CRT refresh memories, radar delay lines or fast access drum memories. And engineers looking for a small and stable replacement for glass and magnetostrictive delay lines.

Now guess who's selling 600ns ROM's.

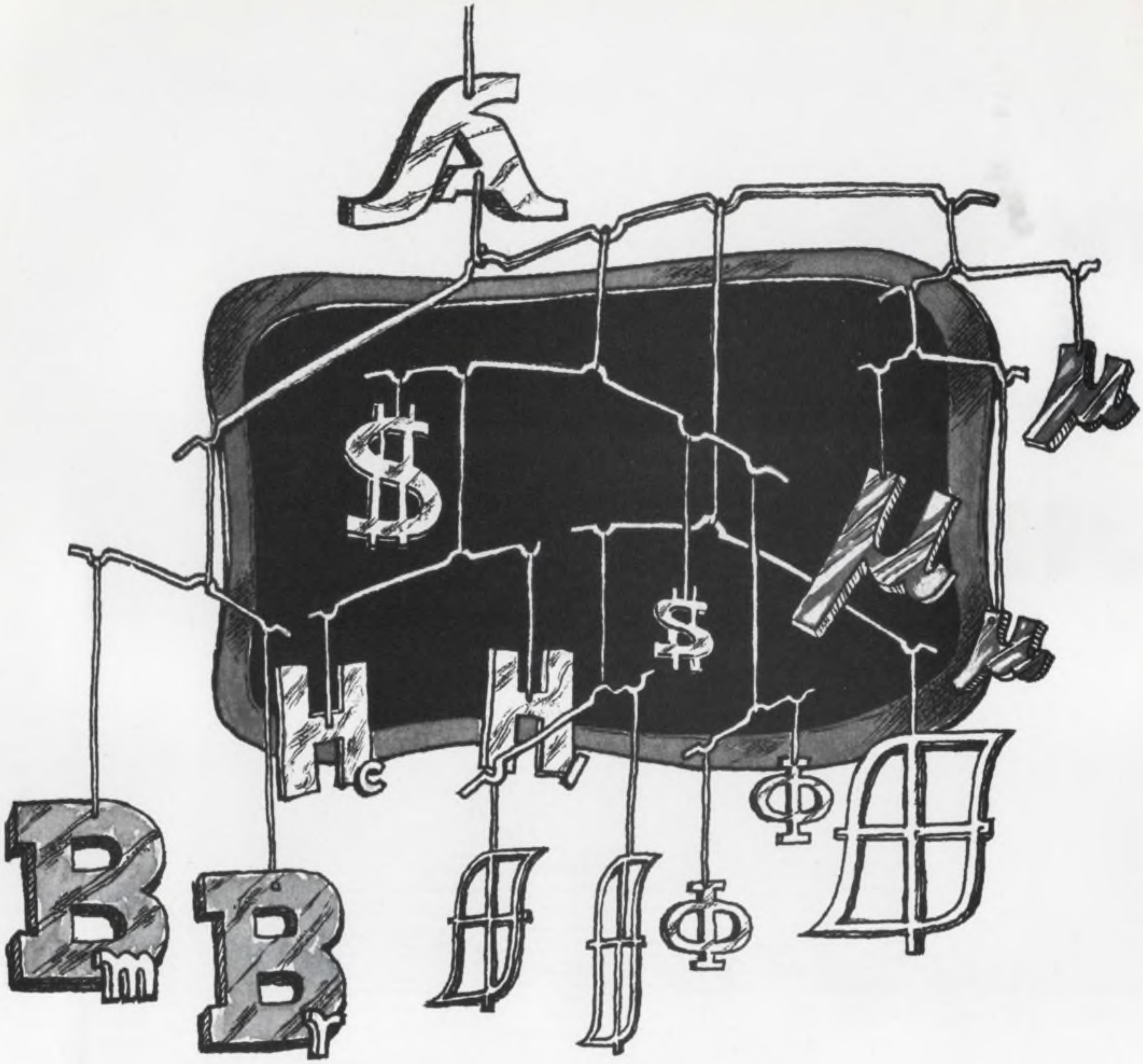
National again. We just introduced the MM5240, a bipolar compatible, 2560 bit character generator that offers you off-the-shelf standard fonts in addition to its blazing speed. We've priced the MM5240 at $30.00 (in quantities of 100) and now await orders from people involved in character generation, random logic synthesis, micro-programming and table look-up.

What else?

Well, National recently introduced still another MOS, the MM5001. The MM5001 is a dual, 64-bit dynamic shift register. Like the MM5016 and the MM5240, it's bipolar compatible. It costs just $10.80 (in quantities of 100), and you'll find the MM5001 handy in a variety of data handling and computer type applications.

All three of National's new MOS products have application in CRT refresh memories. We've written an application brief to give you all the details. The brief awaits you now at your National distributor. So do the products. National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051/Phone (408) 732-5000, TWX (910) 339-9240.

National



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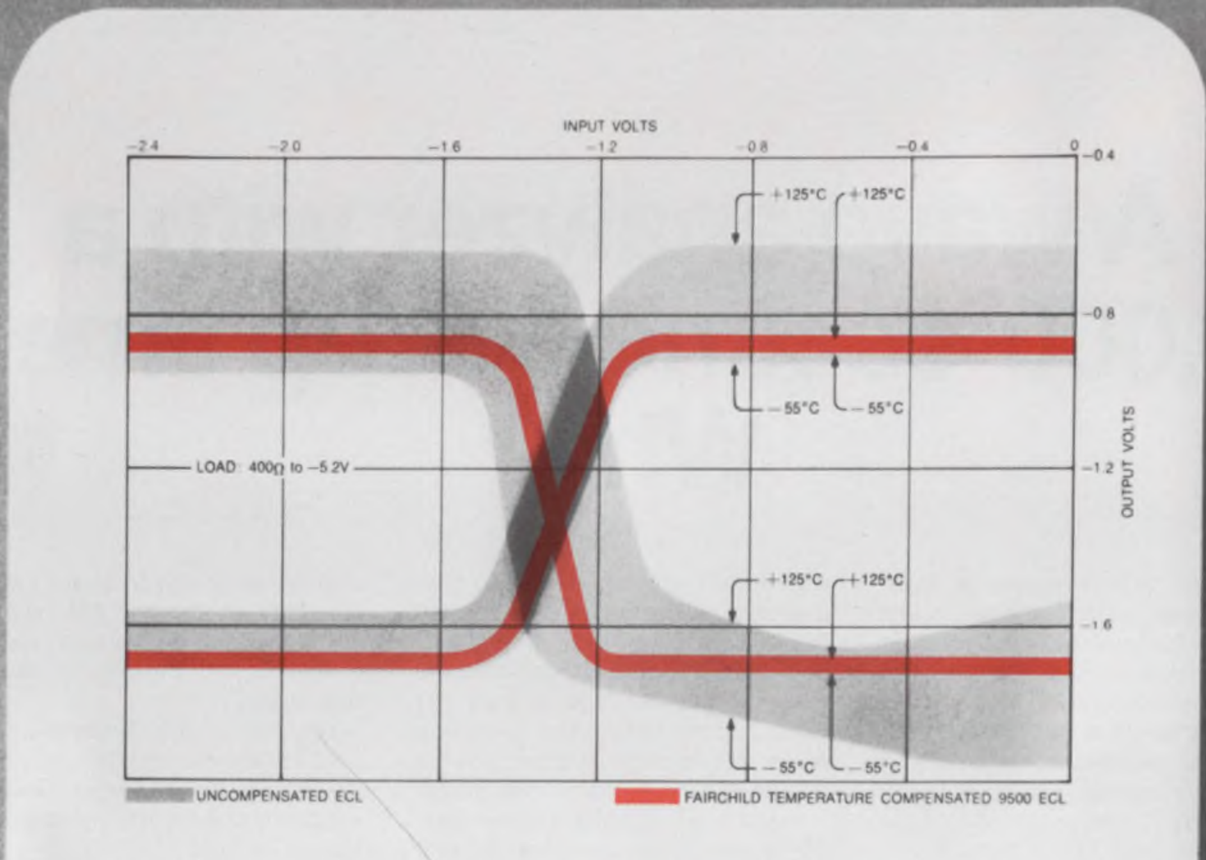

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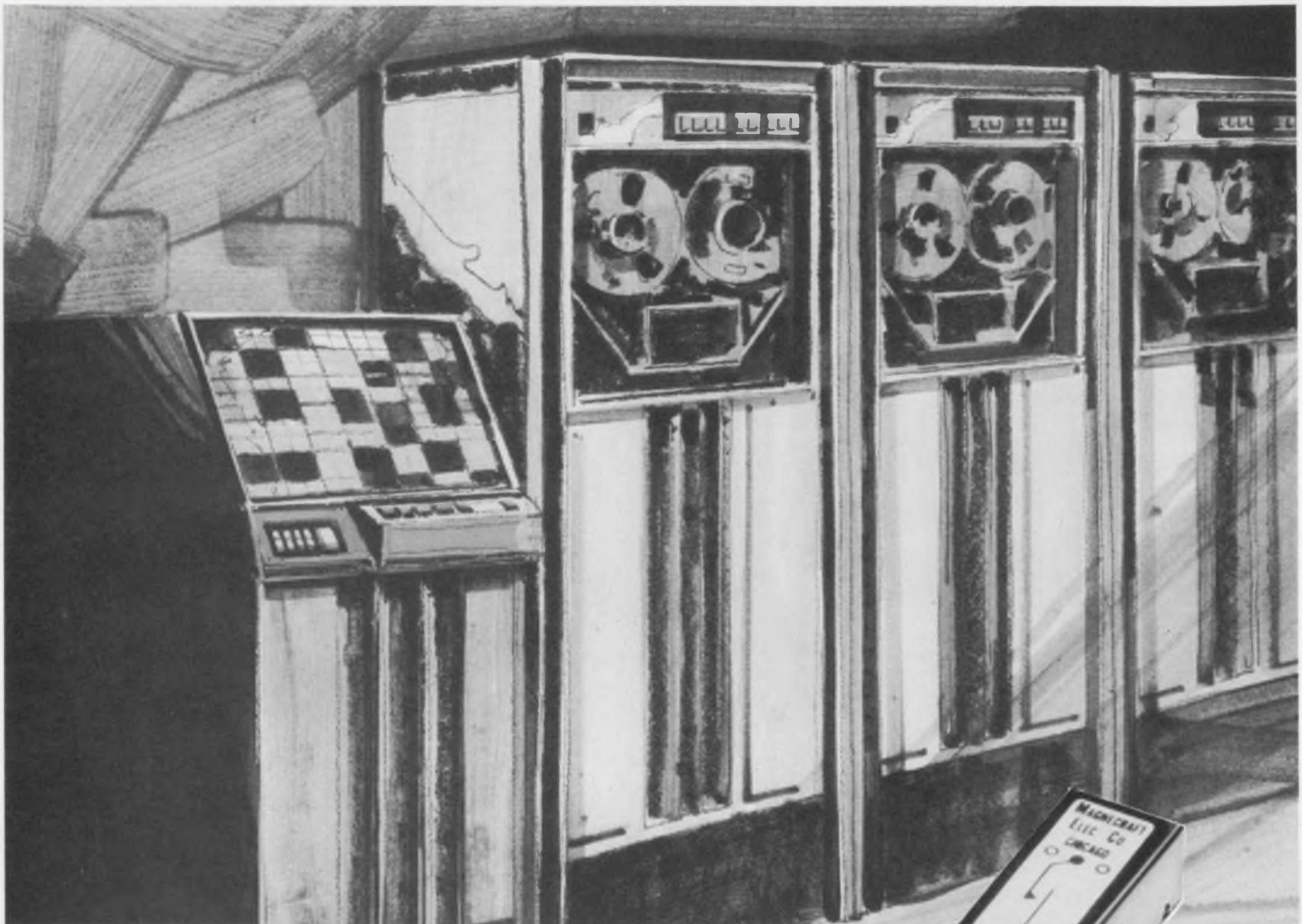
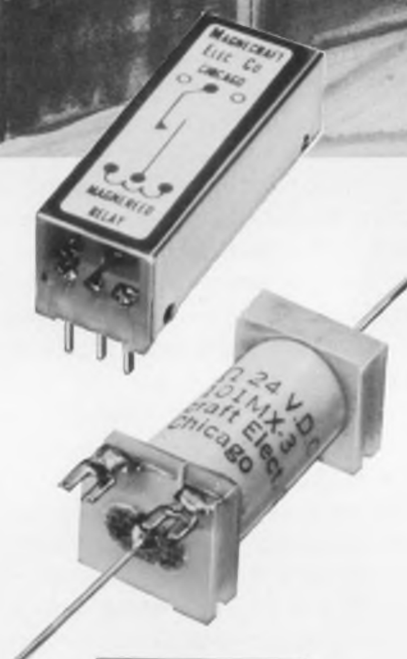


NEW! IC COMPATIBLE REED RELAYS

Let Magnecraft relays work, while your integrated circuits think...



Our new IC compatible reed relays offer total isolation of the integrated circuit. These relays are capable of switching higher voltages, for example a neon lamp readout, while operating at the low input voltage of the IC, 2.5 volts or 5.0 volts.

Best of all, Magnecraft stocks the IC compatible reed relays for immediate delivery. They're priced right, too—as low as $1.54 in 1000 quantities and even lower for larger quantities.

Contacts are rated 10 VA at 0.5 amp max. or 100 VDC max. resistive load with a configuration of SPST-NO (1 form A), and 3 VA at 0.25 amp or 28 VDC max. resistive load with a configuration of SPDT (1 form C). Two package designs for mounting are available: in-line axial leads; and low profile printed circuit type.

For all the facts on the new IC relays and Magnecraft's 512 other in-stock relays, send for our new Stock Catalog No. 271.

See our product data in EEM

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See us in Booth #6122 at Production Engineering Show.

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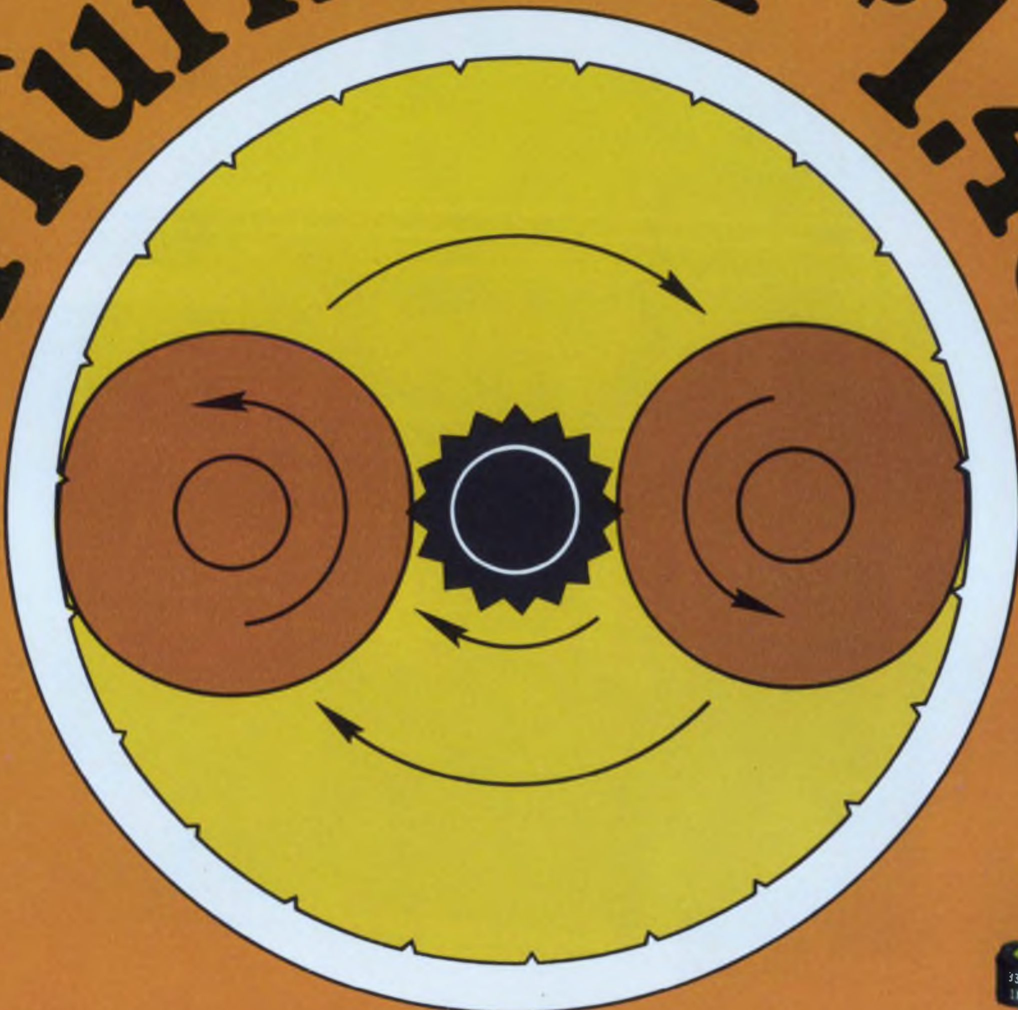
4 Turns for $1.46



• MODEL
3339

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the smallest low-price multi-turn potentiometer on the market.

You can be four times as sure of balancing critical circuitry with this new cermet trimmer, Model 3339. Why? An ingenious drive mechanism (patent pending) gives you four mechanical turns to traverse the element.

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All for only $1.46 in 1,000-piece quantity.

Call or write your nearest Bourns sales office for more data on this new multi-turn in single-turn package size (.30″ dia. x .25″ high). Also available in a side adjust model.

In stock at Bourns distributors nationwide.

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Designer's Calendar

SEPTEMBER 1970						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

For further information on meetings, use Information Retrieval Card.

Sept. 21-24
International Conference on Engineering in the Ocean Environment (Panama City, Fla.). Sponsor: IEEE. Lewis Winner, 152 W. 42nd St., New York, N. Y. 10036.

CIRCLE NO. 403

Sept. 23-24
Electron Device Techniques Conference (New York City). Sponsor: IEEE. Mayden Gallagher, Hughes Res. Labs., 3011 Malibu Canyon Rd., Malibu, Calif. 90265.

CIRCLE NO. 404

OCTOBER 1970						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Oct. 7-9
Allerton Conference on Circuit & Systems Theory (Monticello, Ill.) Sponsors: IEEE, Univ. of Illinois. G. Metze, Univ. of Illinois, Urbana, Ill. 61801.

CIRCLE NO. 405

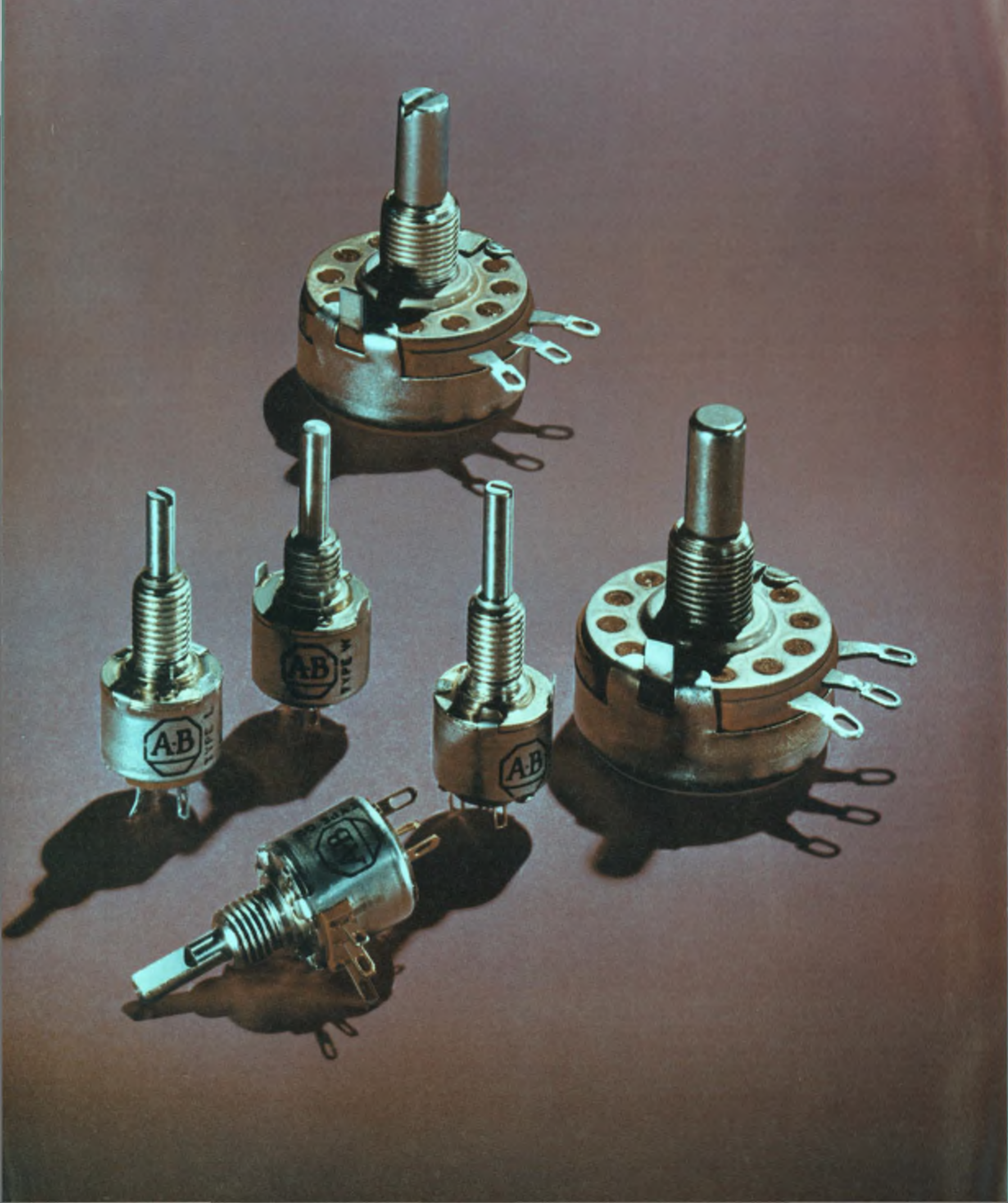
Oct. 13-15
International Telemetering Conference (Los Angeles). Sponsors: International Foundation for Telemetering, et al. J. Wayne Matthews, c/o Electronic Resources, 4561 Colorado Blvd., Los Angeles, Calif. 90030.

CIRCLE NO. 406

INFORMATION RETRIEVAL NUMBER 11

◄ INFORMATION RETRIEVAL NUMBER 10

Fight noise pollution



with this quiet family.

Hot Molding with Allen-Bradley's exclusive technique, gives these composition variable resistors an unusually low noise level. And importantly, this low noise level actually decreases in use. Under tremendous heat and pressure the resistance track is molded into place. A solid element with a large cross-section is produced.

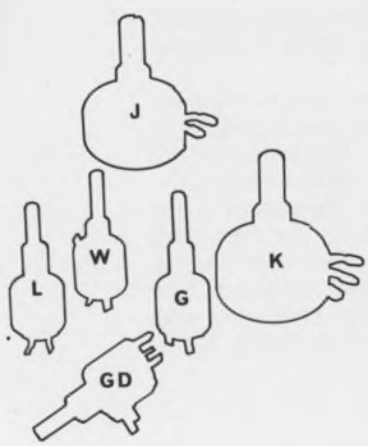
This important Allen-Bradley difference means better short-time overload capacity and a long operating life. Control is smooth, resolution almost infinite. These variable resistors are ideal for high frequency circuits. Why should you trust the performance of your designs or your reputation to anything less than Allen-Bradley quality? Use the most thoroughly "field tested" (over 20 years) variable resistors available today. Quantity stocks of popular types J, G, W and GD available for immediate delivery from your appointed A-B industrial electronics distributor.

For information write: Marketing Department, Electronics Division, Allen-Bradley Co., 1201 South Second Street, Milwaukee, Wisconsin 53204. Export office: 1293 Broad Street, Bloomfield, N. J. 07003, U.S.A. In Canada: Allen-Bradley, Canada Ltd., 135 Dundas Street, Galt, Ontario.

SPECIFICATIONS

	TYPE J— STYLE RV4	TYPE K	TYPE G— STYLE RV6	TYPE L	TYPE W	TYPE GD
CASE DIMENSIONS	5/8" deep x 1-5/32" dia. (single section)	5/8" deep x 1-5/32" dia. (single section)	15/32" deep x 1/2" dia.	15/32" deep x 1/2" dia.	15/32" deep x 1/2" dia.	35/64" deep x 1/2" dia
POWER at + 70°C	2.25 W	3 W	0.5 W	0.8 W	0.5 W	0.5 W
TEMPERATURE RANGE	−55°C to +120°C	−55°C to +150°C	−55°C to +120°C	−55°C to +150°C	−55°C to +120°C	−55°C to +120°C
RESISTANCE RANGE (Tolerances: ±10 and 20%)	50 ohms to 5.0 megs	50 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs
TAPERS	Linear (U), Modified Linear (S), Clockwise Modified Log (A), Counter-Clockwise Modified Log (B), Clockwise Exact Log (DB). (Special tapers available from factory)					
FEATURES (Many electrical and mechanical options available from factory)	Single, dual, and triple versions available. Long rotational life. Ideal for attenuator applications. Snap switches can be attached to single and dual.	Single, dual, and triple versions available. Long rotational life.	Miniature size. Immersion-proof. SPST switch can be attached.	Miniature size. Immersion-proof.	Commercial version of type G. Immersion-proof.	DUAL section version of type G. Ideal for attenuator applications. Immersion-proof.

ALLEN-BRADLEY



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Specifications provided for every *pulse-rated* toroid include pulse inductance, volt-microsecond product, and temperature behavior under pulse conditions.

Parylene-coated *pulse-rated* toroids in sizes and specifications to suit your design requirements are now available for off-the-shelf delivery. Want some? We welcome the opportunity to send you samples. And hot-off-the-press spec sheets. And to consult with you about your design problems. Write Indiana General, Electronic Products, Keasbey, N. J. 08832.

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INFORMATION RETRIEVAL NUMBER 14 ►

We've got the dope on 26 companies at Spring Joint.

Twenty-six companies were in on it. They didn't breathe a word.

You wouldn't either, if you had something special going for you to give you lower development costs, quicker start-up, and more competitive pricing.

We won't tell you who these companies were.

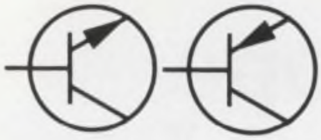
But we will tell you their secret.

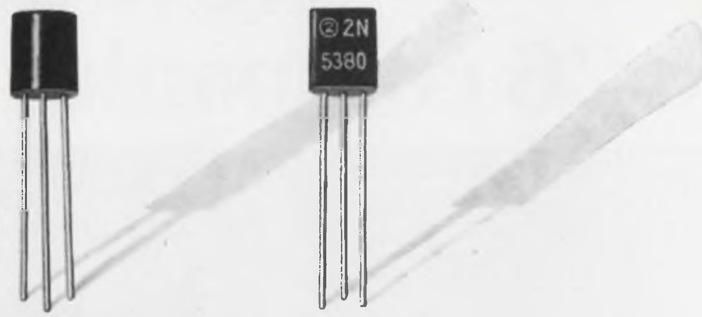
Every one of them utilized advanced, off-the-shelf MOS circuits from the same source—Electronic Arrays.

Fifteen of these 26 companies were less than three years old, which points out that EA's broad line of off-the-shelf MOS registers, ROMs, Read/Write RAMs and logic arrays are especially suited to companies needing low-cost product development and sure-fire delivery.

Now that we have your ear, we'd like to keep you clued in. Whisper the password—MOS—to your EA distributor or representative. Or write directly to the source: Electronic Arrays, Inc., 501 Ellis Street, Mountain View, Calif. 94040. (415) 964-4321.

electronic arrays, inc.





GOOD NUMBERS TO KNOW: 2N5381 2N5383

REPLACE OLD 2N3904 and 2N3906 PLASTIC TRANSISTORS AND GAIN 3 WAYS. 360 mW P_D vs 310. T_J (max) =150°C vs 135. TO-18 PINNING.

These two new Sprague plastic transistors give you 20% more power dissipation, 15° C higher junction temperature, and industry standard TO-18 pinning when used as direct electrically interchangeable replacements for 2N3904 and 2N3906.

The 2N5381 and 2N5383 are two of twenty new TO-18 pinned plastic transistors from Sprague. Check the replacement chart, then make your move. Sprague industrial distributors have stock. The sales offices listed below can supply samples. Call them now. Or get complete specifications by writing Technical Literature Service, Sprague Electric Company, 347 Marshall Street, North Adams, Mass. 01247, or use the reader service number below.

OLD NUMBERS	NEW SPRAGUE TYPES	OLD NUMBERS	NEW SPRAGUE TYPES
2N3903	2N5380	MPS6514	TPS6514
2N3904	2N5381	MPS6515	TPS6515
2N3905	2N5382	MPS6516	TPS6516
2N3906	2N5383	MPS6517	TPS6517
2N4123	TP4123	MPS6518	TPS6518
2N4124	TP4124	MPS6519	TPS6519
2N4125	TP4125	MPS6520	TPS6520
2N4126	TP4126	MPS6521	TPS6521
MPS6512	TPS6512	MPS6522	TPS6522
MPS6513	TPS6513	MPS6523	TPS6523

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INFORMATION RETRIEVAL NUMBER 15

Highlighting
THE ISSUE

To measure a dc voltage to within 0.1% when it's across a fairly low impedance is no great feat. The cheapest reasonable monolithic IC operational amplifier can do the job. But when an accuracy of 0.001% is needed and the source impedance is on the order of hundreds of kilohms, some very interesting and subtle problems can arise.

To make the optimum choice of an amplifier for a given precision measurement, the drift characteristics of the various types of op amps should be considered, along with the nature of the source. Only when both factors are taken into account can a wise decision be made.

Page 54

If test results justify it, present incandescent lights in Air Force jet cockpits will give way to EL phosphor panel displays.

An EL lamp consists of a light-emitting phosphor sandwiched between two electrodes. The green EL light—emitted when the proper voltage is placed across the electrodes—is filtered to make it white.

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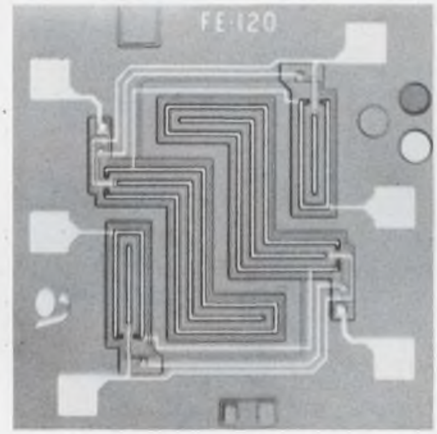

Consisting of npn and pnp bipolar and field-effect types, two new series of monolithic dual transistors offer superior temperature tracking and high current gain at low costs.

One series of bipolar dual transistors exhibits typical tracking (base-voltage differential drift) of 3 $\mu V/^{\circ}C$ and a typical base-voltage differential of 2 mV.

Another series of dual FETs exhibits tracking of 1 $\mu V/^{\circ}C$ over the temperature range of -55 to $+125^{\circ}C$, a gate-to-source breakdown voltage of 30 V, source transconductance of 2 μmhos and gate-to-gate breakdown voltage of over 60 V.

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News Scope

Microwave scanning may replace vhf landing systems

WASHINGTON, D.C. — Elimination of the present problem-ridden vhf instrument landing systems and ultimate replacement with C and Ku-band microwave scanning-beam systems is the aim of a new Government committee: the Microwave Landing System National Planning Group. Headed by Alexander B. Winick, chief of the navigation division of the Federal Aviation Administration's research and development service, the committee includes members from the Departments of Transportation and Defense and the National Aeronautics and Space Administration.

Committee objectives, according to Winick, are the development, test, and acceptance of a new microwave system—as yet undefined—that will be compatible with both civil and military aircraft requirements.

The prime reason for substituting a microwave system for the present landing system is to eliminate false, off-course signals generated by reflections from buildings and structures on the airport, and from planes flying overhead.

The microwave system is also superior in that interference between two or more of them is minimal. The systems as projected could be placed as close as 750 feet from each other, permitting simultaneous landings on parallel runways.

The only real problem at the higher frequencies is attenuation from heavy rain, but FAA officials say that this can be solved by using the C-band as the primary-system frequency with guidance in both azimuth and elevation. For landing in zero-visibility weather, short-range Ku-band equipment would provide precise guidance in elevation, down to flare-out, touchdown and rollout. Signals from the scanning system would be fed to the autopilot system, as with today's method of operation.

Research and development on both C-band and Ku-band systems is planned over the next five years at a cost of about $27 million. Current cost goal for the complete system is about $500,000.

Computer helps restore Caruso's fuzzy voice

The voice of Enrico Caruso has been successfully separated from the vibrations of early recording equipment by a signal processing technique developed at the University of Utah, Salt Lake City. Using a computer, researchers estimated the reverberation of the acoustic system originally used to record the voice. Then recorded sound waves of Caruso's voice were digitized and fed into the computer, which reprocessed them to remove the reverberations.

The restored voice was then re-recorded. The results sound like a much younger Caruso, who is much nearer the listener than in the original recording and sings with a much wider dynamic range.

Dr. Thomas Stockham Jr., associate professor of engineering who spearheaded the work, points out that although the digitally "restored" voice sounds far more natural than the original recording, the process does not replace high frequencies that were not picked up in the first place. He plans therefore to improve the sound still more by extrapolating the missing frequencies from the known "signature" of Caruso's voice.

Dr. Stockham speculates that recording companies may someday use computer programs to retrieve the true sounds of recordings that contain unwanted reverberations—such as voice recordings in large convention halls where engineers cannot control the acoustics.

2 conferences to explore environmental problems

Growing interest in the use of electronics to solve environmental problems is reflected in two conferences planned this fall: the IEEE International Conference on Engineering in the Ocean Environment, Sept. 21-24 in Panama City, Fla., and the 25th National Conference of the Association for Computing Machinery, Sept. 1-3 in New York City.

The IEEE meeting features several sessions on "Monitoring Techniques in Coastal Waste Management." The panels were organized by Dr. Russell Keim, executive secretary of the Committee on Ocean Engineering in the National Academy of Engineering, Washington, D. C.

"This area," says Dr. Keim, "has long been the province of civil, mechanical and chemical engineers

News Scope CONTINUED

who developed systems for measuring physical, chemical and biological aspects of ocean wastes and ocean environment."

Now, he adds, there is a pressing need for electronic engineers to join in designing measuring systems at reasonable cost.

A massive problem, Dr. Keim points out, is the tremendous amount of data gathered that must be monitored and evaluated.

In agreement with Dr. Keim is Thomas L. Brewer, organizer of earth-resources sessions at the computing machinery conference.

Brewer says: "The amount of real-time data that must be generated in the operation of an earth-resources management system defies the imagination. And this is where the computer industry faces a major challenge."

The sessions organized by Brewer, who is manager of systems engineering, Re-entry and Environmental System Div., General Electric, will present the system requirements for the exploration and management of earth resources and environmental control.

British computer gets the sack

In Birmingham it was pay checks that came out wrong too often that caused 4000 workers to strike unless the computer was fired. The factory promised a return to a manual payroll "as soon as possible."

Seems the electronic age is on the spot in the old country.

Artery disease study to use doppler method

With a new utltrasonic pulsed-doppler instrument developed at the University of Washington, researchers hope to detect the first signs of deterioration in the artery walls due to atherosclerosis and to monitor the course of the disease.

Operating on the same principle as radar, the instrument emits ultrasonic pulses into the body, and, from the doppler shift in reflected pulses, determines the velocity of the blood particles. When atherosclerosis attacks the cardio-vascular system, calcium forms in the artery linings. This makes the passage narrower and causes the blood to flow faster at the center of the artery. The instrument pinpoints the damaged areas by plotting blood flow vs. artery diameter.

According to Dr. Curtis Johnson, assistant director of the Center for Bioengineering at the university, even a slight deterioration of the artery walls alters the velocity profile. Thus it will be possible, he says, to study the development of atherosclerosis and to evaluate the effect of treatment. This has never been possible before.

The instrument will be manufactured by Parks Electronics, Beaverton, Ore. A similar device is under study at Guy's Hospital in London, England.

New system fights credit-card fraud

A new weapon against credit-card fraud instantly checks whether a card is valid, lost, stolen or canceled. The computer terminal that does the job reads both standard credit cards or new magnetically coded ones. It is being tested at a number of locations selected by the American Express Company.

Developed by Penril Data Communications, Inc., Rockville, Md., for American Express, the new terminal is linked—via a national telephone network—to a newly developed credit authorization and financial data system using twin IBM 360 computers at American Express headquarters in New York City. The system remembers details on over three million credit card-member accounts.

The new terminal accommodates up to six different charge-card plans. Inserting the card in a tray and pushing a button automatically dials the computer and gives the identification number of the creditor (hotel, airline, etc.).

With the magnetically encoded cards, the user simply enters the amount of the purchase on the keyboard and presses a key. The terminal then reads and verifies the account number and transmits this to the central computer.

On an approved transaction, it then imprints on a record-of-charge form the card member name, account number, service-establishment identification, and the dollar amount and approval code. If the charge is denied, the terminal ejects both the card and the form without printing.

Cannons accelerate high-shock tests

The latest example of turning swords into plowshares is the use of artillery to perform high-shock testing by Sandia Laboratories, Albuquerque, N. M.

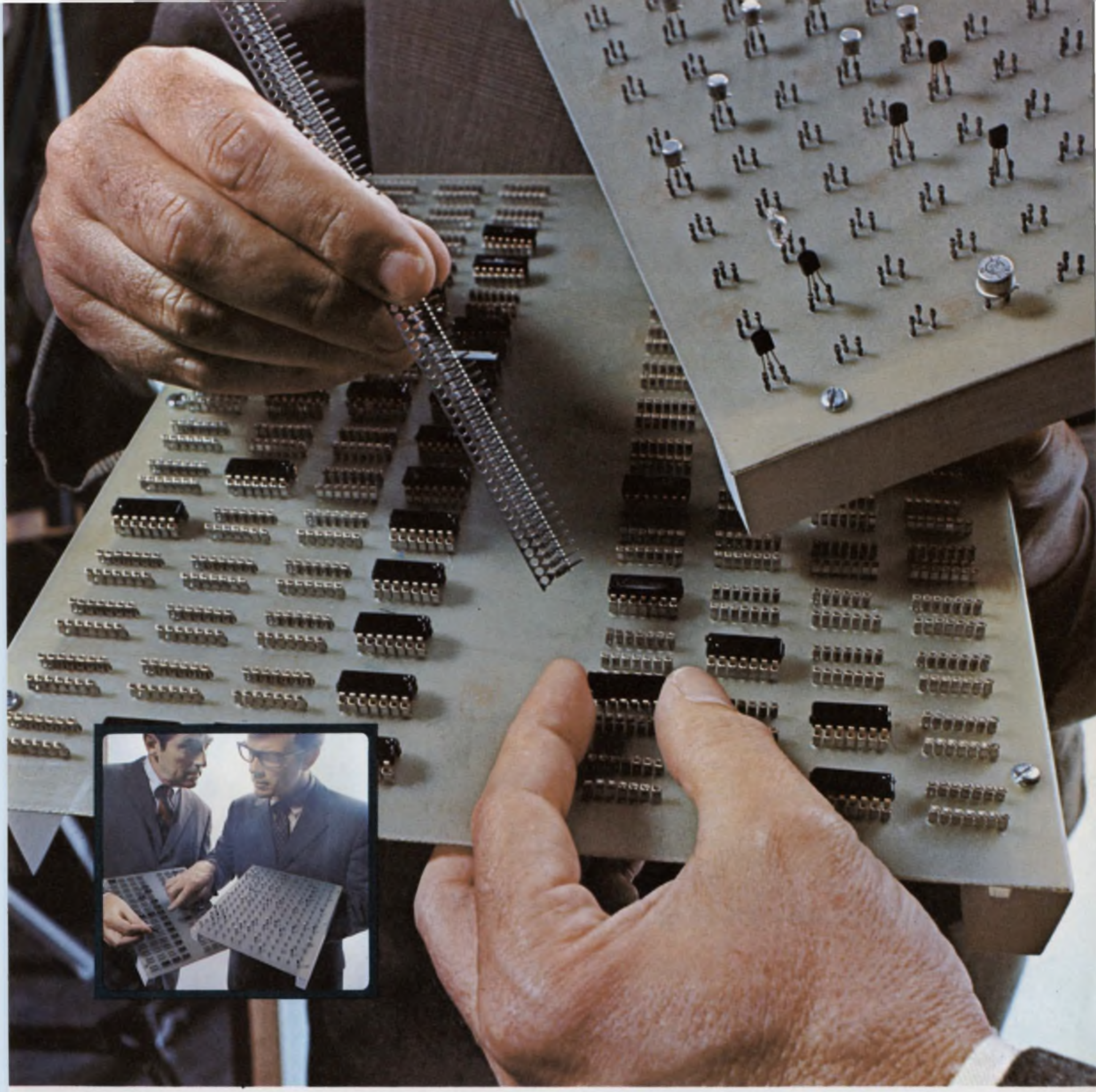
The advantage of the technique is the ease of accelerating a shell containing electronic test components to 16,500g. In addition, if the field piece is rifled, angular spin velocities of 240 rps can also be obtained.

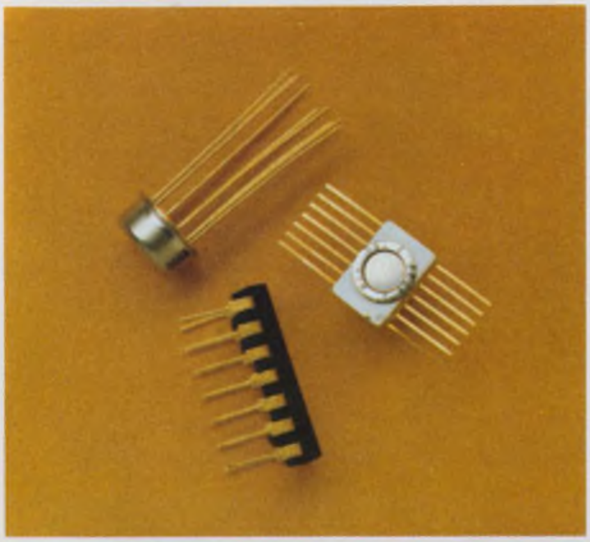
Sandia's location in the desert southwest has one big advantage: there is no nearby population to complain of the noise. Other problems, such as recovering the test vehicle (shell) without allowing deceleration to obscure the effects of acceleration, and obtaining telemetering from the inside of the cannon barrel were solved by thoughtful design: Firing the shell at 85 degrees and then lowering it to the ground by parachute solved the first problem. The latter was solved by loosely attaching a wire to the nose of the shell. This furnished a link to the telemetry receiver.

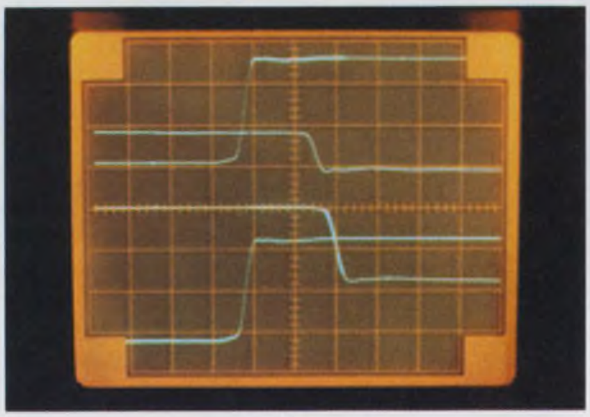
Sandia spokesmen disclaim any originality in the idea. "After all," they said, "Jules Verne used a cannon to launch his spaceship to the moon in 1865."

IEEE seeks panelists on computer testing

A new IEEE subcommittee on computer logic testing is being set up. Interested? If you can "contribute to and stimulate development" of the group, the IEEE requests that you write to P. J. Scola, LSD-C-78, General Electric Co., 13430 North Black Canyon Highway, Phoenix, Ariz. 85029.







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INFORMATION RETRIEVAL NUMBER 19

Air Force to test EL for cockpit lighting

Study of night-vision problems may lead to replacement of bulbs by electroluminescent devices

John N. Kessler
News Editor

An Air Force pilot in Vietnam flying low on a night mission, nears his target. The cockpit lights of his jet are blacked out to preserve his night vision and to prevent "canopy glow"—a dead give-away of the plane's position to the enemy on the ground. But occasional instrument checks are essential, and for these the pilot beams a small flashlight on the cockpit panel. It isn't the best arrangement—because it reduces night vision momentarily and the fleeting light might just be spotted—but it's the best available in combat today.

This is the basic reason why the Air Force is investigating the use of light-emitting phosphors to replace incandescent bulbs in aircraft cockpits: Electroluminescent phosphor displays can be dimmed so as not to impair night vision and not be visible from the ground, yet still provide a readable display for the pilot. An experimental program has been set up at Wright-Patterson Air Force Base, Ohio, to determine the best phosphor lighting and to evaluate EL solid-state instrument displays.

If the results justify it, present incandescent lights for aircraft instruments will give way to EL phosphor panel displays.

An EL lamp consists of a light-emitting phosphor sandwiched between two electrodes. The green EL light—emitted when the proper voltage is placed across the electrodes—is filtered to make it white.

According to Lt. David L. Turney, project engineer at Wright-Patterson, EL phosphors have these advantages over incandescent lights:

- Greater uniformity—rather than having a pinpoint source, the light is spread equally over an area.
- No color shift—with present incandescent bulbs, the color of the source changes with filament temperature (which varies as light intensity is adjusted).
- Low current—which results in a cold light source.

Although EL displays are not new—Cessna Aircraft Co. has been using EL phosphors in its heavier civilian aircraft for nearly three years—the benefits of redesigning cockpit displays have not been clearly established, Turney says.

The EL panel being evaluated by the Air Force was built by the Instrument Div. of Lear Seigler, Inc., Grand Rapids, Mich. Three techniques of lighting are under study:

- Light-reflection—where EL lamps mounted on a light wedge reflect light on the instrument panel.
- Light-transmission—where light through plastic panels illuminates each legend or scale.
- Light-emission—where the light itself is the display element as it shines, for example, through a stencil.

Four tests next year

Four series of tests are planned in the next year by the Air Force Flight Dynamics Laboratory.

According to the Air Force, the pilot will be able to adjust each instrument to the lighting brightness required by him for day or night conditions. An experimenter seated at a console in the passenger cabin will monitor and record all lighting voltages, which will be correlated with display brightness by periodic checks with a photometer.

Outside brightness, says the Air Force, will be "recorded by receptors which pick up the light and channel it through fiber-optic bundles to a photometer, where the light energy is converted to electrical energy and amplified." ■■

How electroluminescent phosphors respond under day and night background conditions is being studied by the Air Force. They seek instrument displays that do not degrade night vision or create a glow in the canopy of a plane. Tests will be completed at Wright-Patterson Air Force Base in July, 1971.

New computer keeps 747 jet engines cool

Jumbo-jet pilots save engines by throttling at a 'red-line' value calculated by on-board system

Jim McDermott
East Coast Editor

When jetliners fly, engine thrust must be held below a maximum "red-line" value to prevent overstressing the turbine blades and shortening engine life. Thrust is usually displayed to the pilot as an "engine-pressure ratio"—the difference in pressures between the inlet air and outlet jet blast. And maximum values are in the order of 2.00 engine-pressure-ratio units.

To set the throttles properly, the pilot determines this red-line value—engine-pressure-ratio limit (EPRL)—and adjusts the throttles to bring the displayed actual value into agreement.

With the older and slower jets, the crew determined the limit by in-flight consultation of charts or tables, using panel readings of altitude and air temperature. But with the new, high-powered jumbo jets—the Boeing 747s, the Lockheed L-1011, and the Douglas DC-10—EPRL is a complicated function of air speed (Mach No.), altitude, temperature, flight mode (takeoff, climb, cruise, etc.) and other factors. As a result, the tables and charts are more complicated, and excessive time can be consumed in using them.

To supply this need for continuous, updated values of engine-pressure-ratio limit, Hamilton Standard, Windsor Locks, Conn., has developed a new digital EPRL computer and display. It will be placed aboard 747s owned by TWA, according to William Blake, supervisor, aircraft instrumentation and avionics development, TWA, Kansas City. Thirty-one systems have been ordered, but TWA is currently performing flight-acceptance tests of the first two systems for the Federal Aviation Agency.

System is nonconventional

Choice of a 16-bit serial computer for the system, instead of conventional parallel configuration, provided significant advantages, according to Robert Donner, preliminary-design engineer at Hamilton Standard. Initial study of use of a 16-bit parallel computer showed that development and prototyping would exceed TWA's deadline in time as well as cost.

But required system speeds were slow—calculations were to be performed and displayed once each half second, and system self-tests performed every other half-second. This permitted the use of a 16-bit, modified serial computer, comprised of two 8-bit strings.

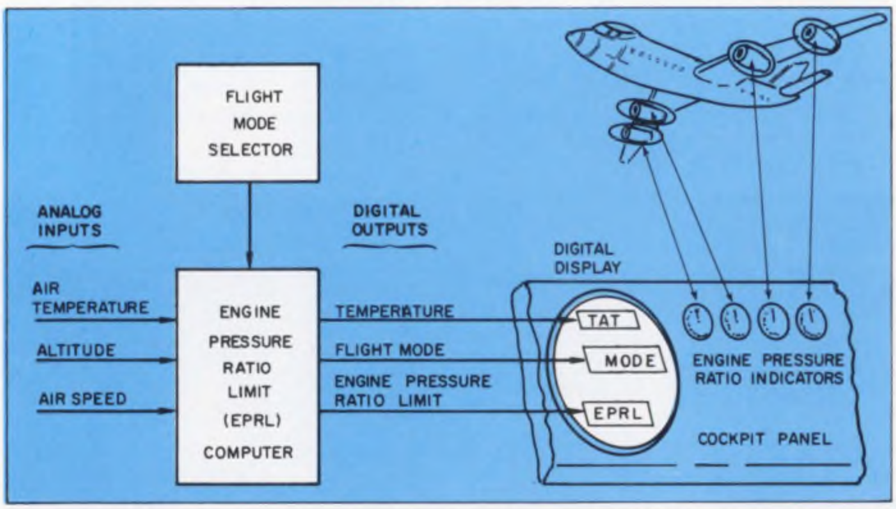
This not only made time and cost goals feasible but other advantages were gained as well. Less hardware was required, reliability was improved through use of fewer parts and bit lines, maintenance was simplified, and self-test features were easily implemented.

"The machine is designed as a 16-bit serial computer that works as two 8-bit machines in parallel," Hamilton's Donner told ELECTRONIC DESIGN. "For computation and other operations, the 16-bit words are split into 8 bits of odd and 8 bits of even serial data. After computation, they are recombined into a 16-bit serial string.

"This gives us the speed of an 8-bit computer with the accuracy of a 16-bit machine."

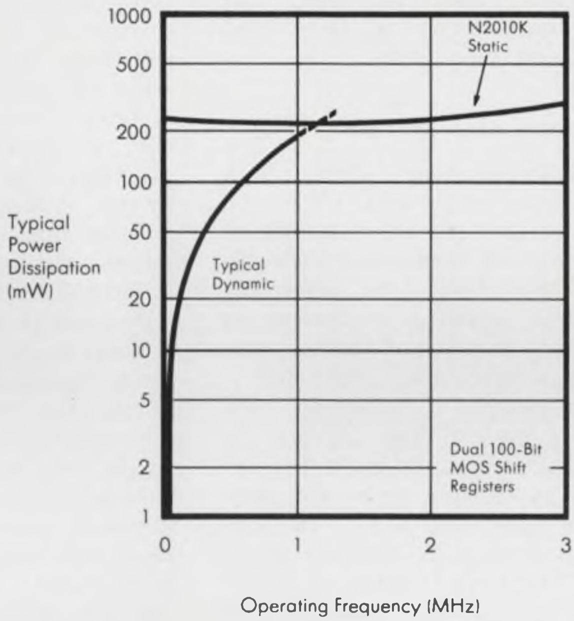
The new system, designed and prototyped for delivery within 4-1/2 months, consists of three replaceable units: (1) a flight-mode selector panel; (2) an indicator unit with digital displays of EPRL, total air temperature, and any one of six flight modes; and (3) a computer with a read-only memory (ROM) storing the various values of EPRL for any of the various flight modes. The ROM also contains programmed instructions for computer and system self-testing.

A complete system self-test is performed every half second. If two consecutive test cycles contain one or more out-of-limit conditions, failure warnings are activated. The test system includes protection against false EPRL values due to noise or to data. ■■



To prevent overloading TWA's 747 jet engines, a new serial computer by Hamilton Standard gives a "red-line" value—engine-pressure-ratio limit (EPRL)—to which throttles may be advanced. EPRL varies with the analog inputs, with air bled off for deicing, as well as the flight mode—climb, cruise, etc. It is calculated and digital displays are updated every half second, while the system is completely self-tested every other half-second.

Some MOS static from Signetics.



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INFORMATION RETRIEVAL NUMBER 20

Laser heat -- not light -- makes holograms

RCA method produces optical read-only memories with potential for storing 300 million bits on a card

A new technique for making holograms uses a high-powered laser as an optical branding iron that burns the image into the surface of a film 30 to 40 atoms thick —all in a few nanoseconds.

The method eliminates conventional film exposure and development, as well as the use of massive, costly vibration-damped tables.

Developed by RCA as a method of making high-capacity read-only memories, it may also find use in nondestructive testing and scientific measurement, according to Dr. William Webster, vice president of RCA Laboratories, Princeton, N.J. He says about 300 million bits of data could be stored on a single holographic card, in contrast with about 2 million bits for a magnetic memory card of the same size.

The new technique records the holograph structure on the surface of a thin film by vaporization. In developing the method, Dr. Juan A. Amodei and Dr. Reuben S. Mezrich at RCA made holograms on a variety of thin films—bismuth, tellurium, selenium, gold and aluminum—using a Q-switched ruby laser (see photo).

An evaporation process

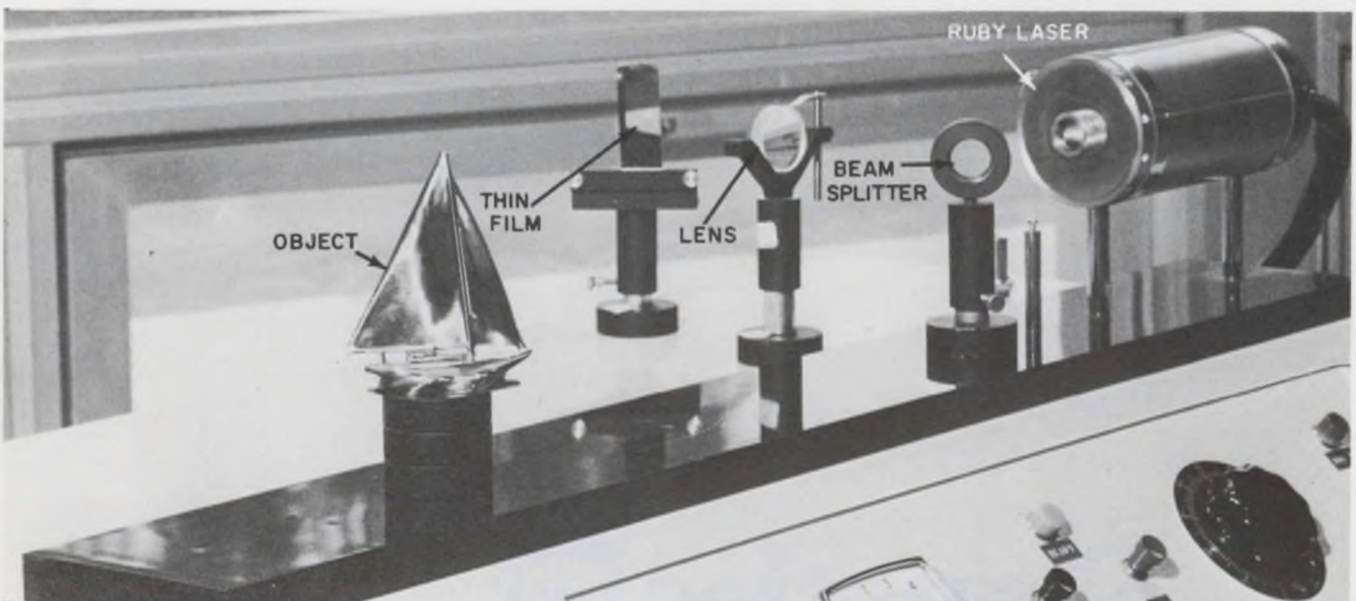
The laser pulses, which are a few nanoseconds long, strike the film surface, and the intensity of the combined beams—one reflected from the object, the other the reference beam—is sufficient to evaporate portions of the film, producing a holographic engraving.

The material is evaporated from each point of the surface in amounts that are closely proportional to the integrated intensity of the light absorbed by the film at that point. In this manner a profile of the film's thickness is generated that closely resembles the spatial intensity variations of the recording light.

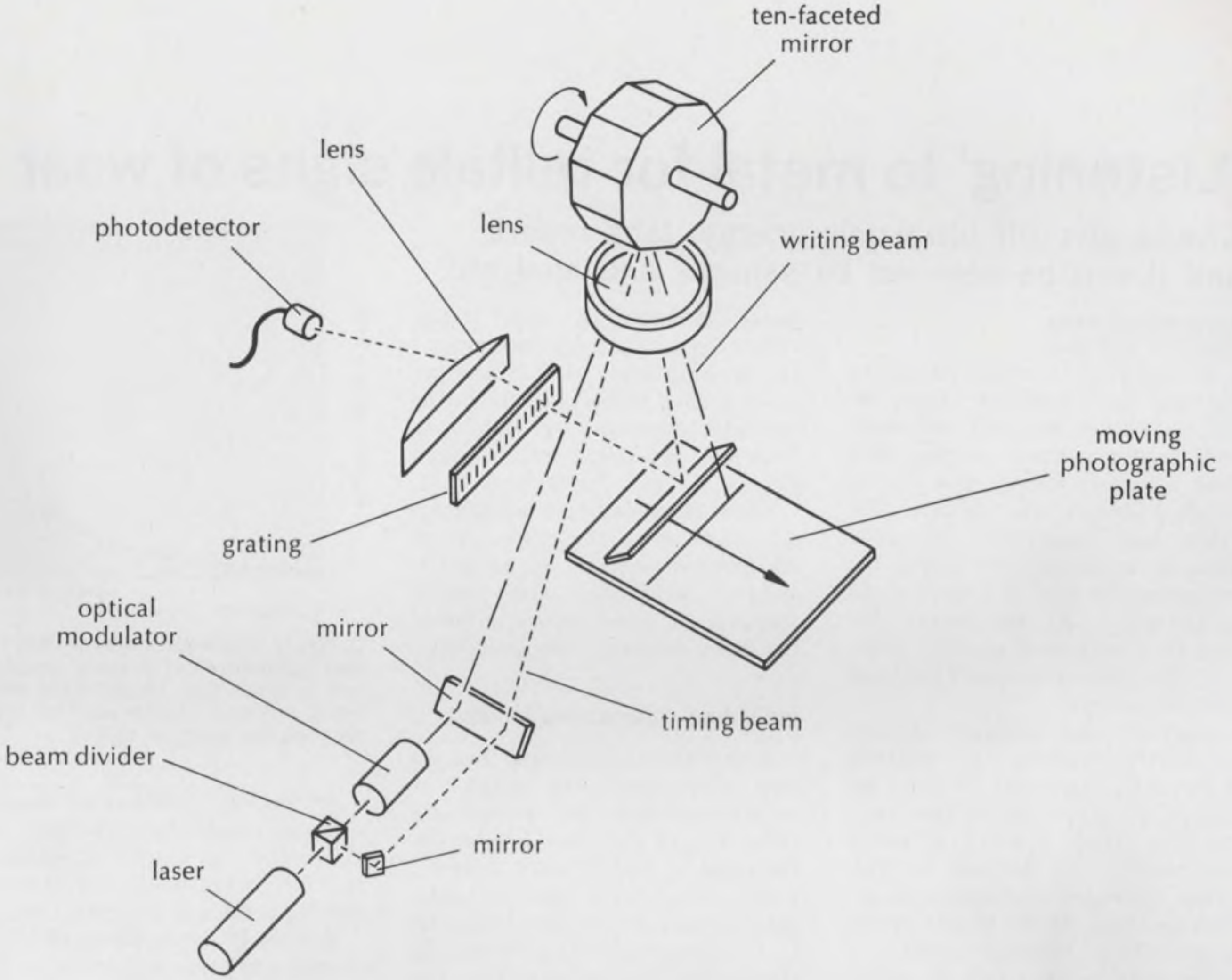
Such a pattern is essentially an amplitude hologram, because while the absorption is considerable, the film is not thick enough to significantly affect the phase of the light passing through it. As a result, the holograms made in this manner can be read out by either reflection or transmission with about equal efficiencies.

Actual readout has been done with a 20-mW, helium-neon cw gas laser. The resolution obtained by Dr. Amodei and Dr. Mezrich is more than 1000 lines per millimeter—equivalent to the best resolution obtainable with conventional light-sensitive holographic film.

Because the new technique depends on heat rather than the light of the laser beam, it can be used with lasers of essentially any wavelength, making the system panchromatic. As a result, the more efficient infrared lasers can be used—wavelengths not suitable for photographic work. The metallic film holographs are free of "grain noise" that normally limits the storage capacity of photographic holograms. ■■



RCA's method of making holograms by heat rather than by light converts the Q-switched laser beam into a reference and a direct beam, which is reflected from the object. These combine to burn the thin film.



Better circuit masks exposed

Making integrated semiconductor and thin-film circuits requires a set of photographic masks to outline the application or removal of materials during processing. The demand for these masks has increased as integrated electronics has come of age and it will continue to grow with the technology.

Mask-making has long been automated. The engineer feeds a geometric description into a standard program and a computer generates a tape. The tape controls a machine which moves a light beam or a knife along coordinate axes to draw the mask. This takes many hours.

Now, Bell Labs has developed a machine which can produce complex masks in under 10 minutes. The machine contains an argon-ion laser. The laser beam is scanned across an 8 by 10 inch photographic plate and switched on and off to expose the emulsion on the plate according to the mask pattern. As each scan is completed, the plate is shifted one linewidth. Scanning time—20 milliseconds per line—is independent of the number of times the beam is switched on and off.

Each facet of a ten-faceted rotating mirror (above) sweeps the beam once across the plate. At the same time, each facet sweeps an auxiliary laser beam across a grating, generating 26,000 timing pulses for each scan. A digital computer processes the pulses to determine the position of the scanning beam and to generate control signals for an acousto-optic modulator which switches the beam on and off.

The laser beam can be directed with an accuracy better than 2 arc-seconds, the equivalent of a mile-long straight line with less than 5/8 inch deviation. For such precision, the machine is operated in a special controlled-environment chamber where temperature is maintained within 1/7°C and a cubic meter of air contains fewer than 3500 dust particles larger than one micron.

These high-speed, precise machines will supply the Bell System's mask needs for several years. As integrated circuits gain wider telephone use, this will keep costs down.

From the Research and Development Unit of the Bell System:

Bell Labs

'Listening' to metal for telltale signs of wear

Cracks give off ultrasonic energy, labs report, and it can be detected by sensors and analyzed

Elizabeth de Atley
West Coast Editor

A crack in a metal structure such as an airplane, a bridge, or even a skyscraper, can withstand just so much stress at the rated load before it bursts open. Yet a moment before the failure, the crack may have been invisible. How is it possible to detect the presence of a flaw in time to avoid catastrophe? By monitoring the structure with new acoustic emission equipment now emerging from the laboratory.

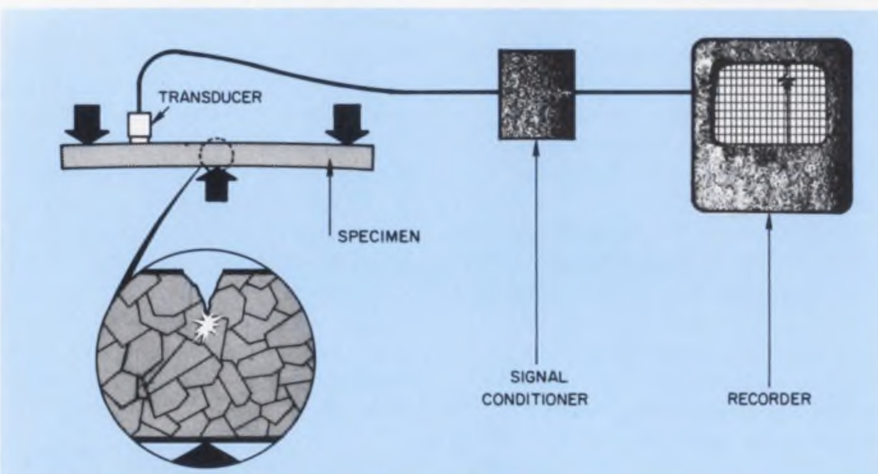
Gary J. Dau, manager of nondestructive testing at Battelle Northwest, Richland, Wash., explains acoustic emission this way: "If you stress a piece of metal by bending or hitting it, you cause microdeformations and actual breaking of the metallurgical bonds. This releases energy, a large portion of which is ultrasonic. We attach a sensor to the surface of the material and detect the energy (Fig. 1)."

A "perfect" material—one that contains no cracks or other flaws—must undergo considerable stress before it will emit any appreciable ultrasonic energy. But cracked materials emit such energy when subjected to relatively little stress. Why? Because the stresses around the growing edges of the crack are much higher than elsewhere in the material, according to Harold L. Dunegan, president of Dunegan Research Corp., Livermore, Calif.

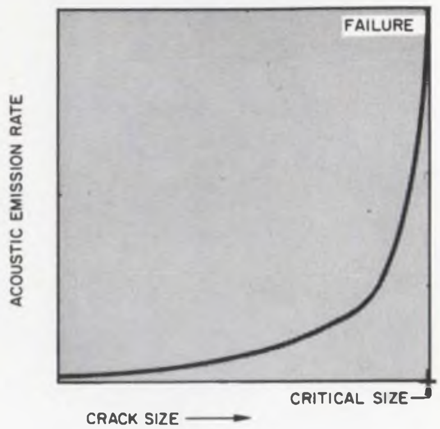
These stresses break metallurgical bonds along the crack, giving off ultrasonic energy. By using triangular techniques with several transducers, investigators can locate the crack precisely, Dunegan says.

Individual "signatures" noted

Every type of material has its own "signature," or graph, of acoustic emission rate vs crack size (Fig. 2). As the crack approaches the point of "catastrophic failure," where the material will rip apart, the emission rate increases rapidly. If a cracked material is repeatedly stressed beyond its rated load and the ultrasonic pulses that are emitted by the growing edge of the crack during each stress cycle are summed, it is possible to estimate the size of the crack from the signature of the material and to predict the number of cycles the material can withstand before ripping open.



1. **The growing edge of a crack breaks metallurgical bonds** and releases ultrasonic energy that can be detected by electronic equipment.



2. **Every cracked material has its own "signature"** of acoustic emission rate vs crack size. The acoustic emissions increase rapidly as the crack reaches the point of failure.

At Battelle Northwest, acoustic emission has been successfully used to monitor the quality of welds as they are being made and to measure flight fatigue in aircraft wings.

Besides Dunegan Research Corp., acoustic-emission equipment is also being manufactured by Nortec Corp., Richland, Wash. The equipment consists of transducers that convert the ultrasonic bursts into analog electrical signals. These are amplified and filtered, then put into a digital counter that sums the pulses and produces a dc output that is proportional to the number summed. This output can be displayed on an X-Y plot.

Probably the biggest problem in designing the equipment, says Mike King, applications engineer at Nortec, is background noise. That's why most acoustic emission systems operate at ultrasonic frequencies, where background noise is attenuated.

Even the noise in the semiconductor amplifier can be a problem, King says, because it is of the same magnitude as that of the breaking metallurgical bonds, which give rise to the acoustic emissions. One way to get rid of background noise, he says, is to use two transducers and to subtract the noise in one from the noise in the other. ■■

INFORMATION RETRIEVAL NUMBER 22

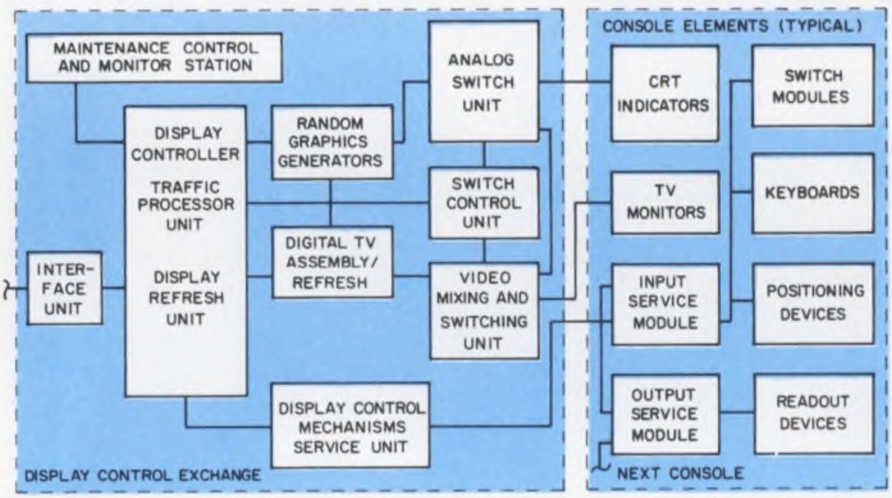
Quick-change simulator is easy to build

A "cheap and dirty" way of simulating a system—whether it's an airplane cockpit, a police dispatch network or a new computer terminal—has been developed by the Boeing Co.'s Aerospace Group in Seattle. It's called the Man-Machine Interface (MMI). Minor changes in the arrangement of switches and displays on the console can be made in half an hour, and the system being simulated can be changed overnight. The console is built out of inexpensive plywood or foam core that is easy to cut and patch.

Most of the electronics that control the input/output devices at the console are in a display control exchange that is physically and electrically separated from both the console and the central processor (see block diagram). So all that is needed to change the system being simulated is a new program in the central processor and a change in hardware at the console.

The MMI looks like a programmable peripheral to the central processor, says Richard C. Landgref, research engineer at Boeing. Because the central processor can talk to it in general terms, it is very flexible, he explains. "For example, the processor just says, 'Put Image A on Indicator B using Generator C,' and the system takes care of the details itself."

This takes the burden of many housekeeping chores off the central processor. For example, says Landgref, the mechanism that keeps track of the position indicator (such as a joystick) and updates the cursor image on the screen is contained in the MMI. In earlier systems these functions took 80 to 90% of the processor's time. ■■



The heart of Boeing's Man-Machine Interface is the display control exchange, which contains most of the electronics that control the input/output console elements.

Typical console in the unusual Man-Machine Interface can be built in less than a week.

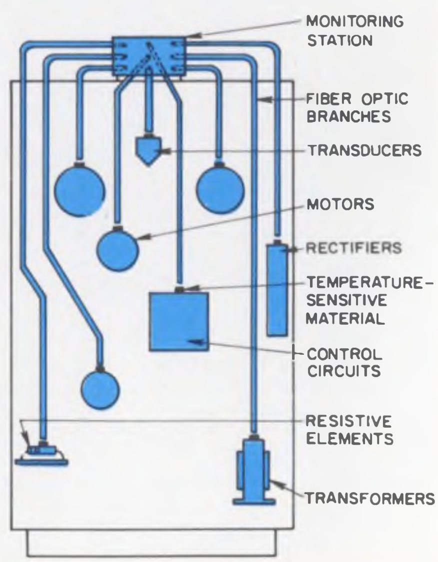
Telling component heat failures by color

Packets of fiber optics attached to electromechanical components have been used experimentally by IBM to predict temperature-related failure.

Engineers at the company's Systems Development Div. in Boulder, Colo., say that if such components as servomotors, rectifiers, transformers and transducers are coated with a temperature-sensitive material, fiber optic bundles could be used to transmit probable failure conditions to a display station.

The use of a paint, wax or decal that would change, for example, from a clear color to black in the presence of excessive heat could alert operators or engineers and permit them to change the temperature conditions or replace the component.

IBM suggests that a photoelectric detector could provide a means of monitoring several units from a central station. The company says that fiber optic light monitoring is an engineering concept only and that IBM is not using it in its current product line. ■■



Fiber optic branches from a typical group of electromechanical components would transmit color changes caused by excessive temperature to a monitoring station.

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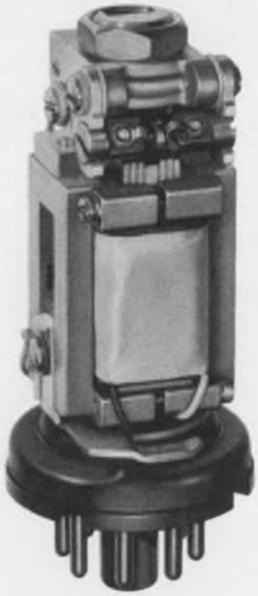

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INFORMATION RETRIEVAL NUMBER 24

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Devices with leakage resistance in excess of 10^{12} ohms are available for circuits requiring this property. Such applications would include sample and hold for A to D conversion, and capacitor memory systems. See Signalite Application News for typical applications.

voltage regulators better than 1% accuracy

These subminiature voltage regulators are used in regulated power supplies, as reference sources, photomultiplier regulators, oscilloscopes, calibrators, etc. They are available in voltages from 82 to 143 V. They are used in multiples as regulators in KV ranges. See Signalite Application News for typical applications.

photo-cell applications

The A074 and A083 have been designed for use with Cadmium Sulfide or Cadmium Selenide photocells. Applications include photo choppers, modulators, demodulators, low noise switching devices, isolated overload protector circuits, etc. Speed of operation is limited only by the photo-cells. See Signalite Application News for typical applications.

neon timers

The bi-stable characteristics and high leakage resistance of Signalite's special glow lamps make them ideal as a component for timing circuits. The basic circuit resembles a relaxation oscillator network. See Signalite Application News for typical applications.

INFORMATION RETRIEVAL NUMBER 26

Signalite glow lamps have solved problems in these areas:

- Voltage Regulation & References
- Photo-Cell Drivers
- SCR Triggering
- Timing
- Photo Choppers
- Oscillators
- Indicator Lights
- Counters
- Voltage Dividers
- Surge Protectors
- Logic Circuits
- Flip-Flops
- Memory
- Switching
- Digital Readouts

Signalite glow lamps combine long life, close tolerance and economy, and are manufactured with a broad range of characteristics to meet individual application requirements. For a creative approach to your design problem . . . contact Signalite's Application Engineering Department.

SIGNALITE APPLICATION NEWS —

is used to communicate new and proven techniques and applications of Signalite's neon lamps and gas discharge tubes. Signalite Application News provides a forum for an exchange of ideas to keep the design engineer aware of the versatility of neon lamps and their many applications. Copies are available from your Signalite representative or contact Signalite.

INFORMATION RETRIEVAL NUMBER 123

Signalite A DIVISION OF GENERAL INSTRUMENT

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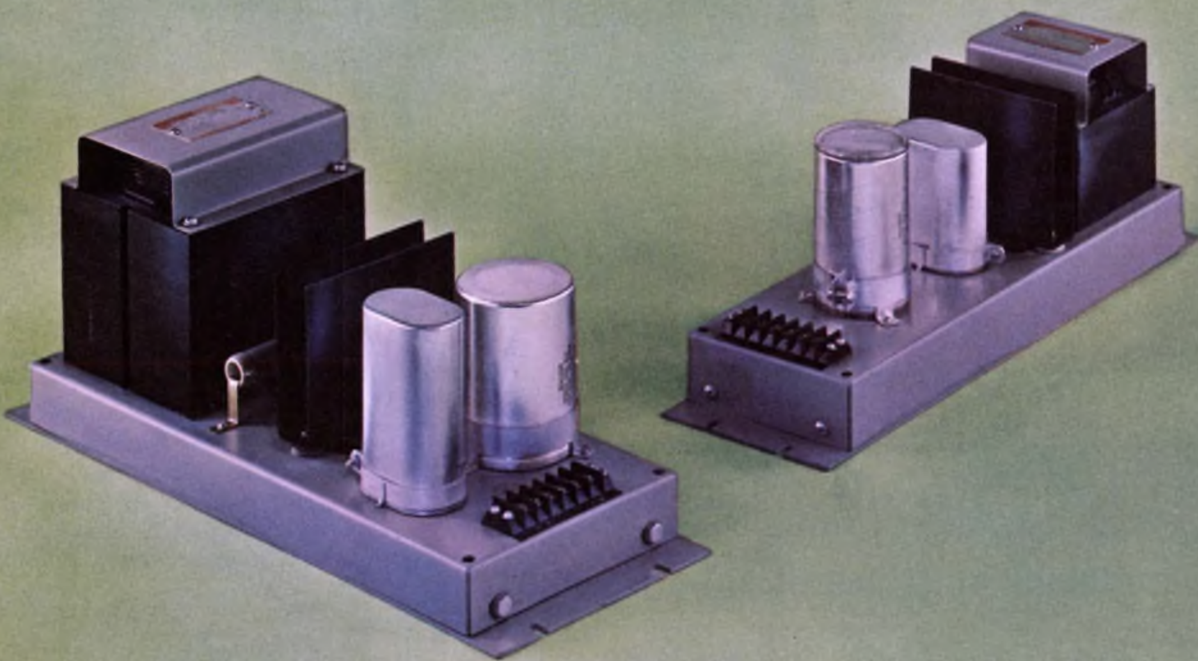
INFORMATION RETRIEVAL NUMBER 27 ►

did you know?



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Technology Abroad

A LOW-COST SYSTEM FOR HOME TV PROGRAMMING has been announced by Teldec, an organization jointly owned by AEG Telefunken of Germany and Decca of Britain. Known as **Videodisc,** the development makes program selection much like choosing what record to play on the living-room phonograph. An eight-inch TV record made of 0.10-mm, flexible polyvinyl chloride is placed on a specially designed turntable. **The system is attached to a standard TV set.** The turntable revolves at 1500 rpm, using a specially shaped diamond stylus that drives a small piezoelectric ceramic element. The record grooves are packed at a density of between 120 and 140 per millimeter, providing about five minutes of TV time. **Teldec expects the discs to be on the market in about two years,** with black-and-white program costs comparable to those for ordinary phonograph records and color program costs about double that. The TV playback portion will cost around $120.

BRITAIN'S ROYAL AIRCRAFT ESTABLISHMENT IS EVALUATING A NEW BINOCULAR HEADS UP DISPLAY developed by Elliott Flight Automation of Rochester. Two matching groups of signals, positioned to form a single image, are projected from parallel cathode-ray tubes to a see-through reflector placed close to the pilot's eyes. **The system is compact and features a foldaway screen.** The dual-CRT arrangement offers redundancy in case of failure.

BRAZIL PLANS TO PUT A SATELLITE INTO SYNCHRONOUS ORBIT IN 1976. The space vehicle would be used to relay radio and TV educational programs to remote parts of the country, working in conjunction with American ATS satellites.

A NEW INFRARED SYSTEM

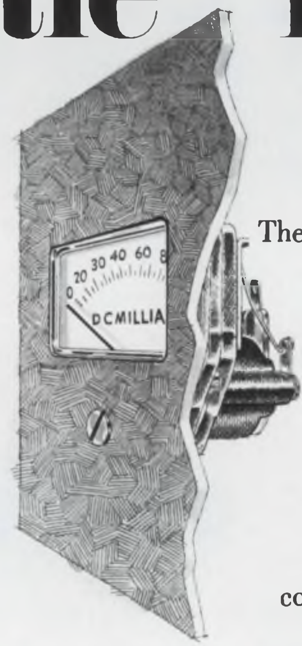
THAT SENSES HEAT RADIATED FROM THE GROUND AND TRANSFORMS IT INTO A CONTINUOUS PICTURE on photographic film will be developed by Britain's Hawker Siddely Dynamics Ltd. for the Royal Air Force. Called **Linescan,** this night-vision equipment follows successful development of a Type 201 infrared Linescan for the AN/USD Airborne Surveillance Drone, developed by Canadair for the Canadian, West German and British forces. **The new system is said to be superior in terms of price, performance and weight.**

A STUDY OF MICROWAVE TRANSMISSION IN THE 7.5-TO-5-CM BAND will be performed by the British Post Office with a new 6-meter dish radar antenna at the University of Birmingham. The $96,000 university antenna will transmit and receive from 3 cm to 7 mm for atmospheric studies. **The Post Office is interested in the communications possibilities of very-short wavelengths**—the range in which the Birmingham antenna works, for instance, theoretically could hold around 5000 TV channels or 7 million telephone channels. The Post Office is building its own antenna at Marlesham, Essex.

OVER A QUARTER OF A MILLION COMPONENTS AND 14 MILES OF WIRING ARE USED in a new solid-state electronic scoreboard now in operation at Scotland's $5.5 million Meadowbank Sports Center in Edinburgh. **The scoreboard—claimed to be one of the most advanced of its type anywhere—has 208 alphanumeric display boxes, each 15-3/4 inches high and 11-1/4 inches wide.** Each box contains a 7x5 matrix of individual lights. Control is by a typewriter-style keyboard, and a memory bank is incorporated so that information can be stored for later use.

JEWELL'S SPACE-SAVING

little meters



The Jewell Series 80T panel meters combine maximum readability with minimum panel space. That big plastic barrel has been eliminated making the Series 80T a little meter on both sides of the panel.

Don't let the size fool you! You'll see the large easy to read scale on an uncluttered dial. Behind the dial, Jewell's efficient taut-band mechanism is completely frictionless and self-shielded. Since Series 80 meters cost no more than conventional meters you don't have to pay a lot to get a little.

actual size

Want more facts about the "Space saving little meters"? Write for our new catalog . . . or get in touch with your nearest Jewell representative, distributor, or modification center.

Jewell

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INFORMATION RETRIEVAL NUMBER 30

Washington Report

DON BYRNE, WASHINGTON BUREAU

A new communication system for TV envisioned

A report prepared at the request of the three major television networks concludes that ABC, CBS and NBC could save $15-million to $20-million a year by putting up their own satellite system or microwave system. Page Communications Engineers, a Washington-based subsidiary of the Northrop Corp., in a $100,000 study, concludes that the three networks now pay AT&T about $70-million a year in interconnection fees. Page estimates the AT&T facilities could be replaced by a microwave system at an initial cost of $160-million to $215-million—or by a satellite system costing $145-million to $160-million initially but with higher annual maintenance costs. The annual cost of operating either system, Page says, would run about $50-million to $55-million.

The satellite system envisioned would include three satellites in fixed orbit, each with a capacity of 12 color channels plus radio and other communications facilities. Approximately 160 ground stations, costing $600,000 to $800,000 each, would be required. The alternative microwave system would have about 18,000 "system miles" and would require 600 microwave towers.

Page, since 1962, has been the prime contractor for the communications network in Vietnam but in recent months has been moving toward civilian communications areas. It specializes in building systems such as it recommended to the television networks.

Defense contractors endorse fly-before-buy policy

The National Security Industrial Association, a group of more than 400 defense contractors, has endorsed the announced Defense Dept. switch back to a fly-before-buy procurement policy and has recommended additional changes in the procurement practices. In a 103-page report, the association recommended, among other things, more consultation between the military and industry when a weapons systems is in the concept stage, a reduction in Defense Dept. "management" personnel and a corresponding reduction in industry of like personnel. The report also asked that Government managers of weapons programs be given greater authority and a clearer definition from Congress of the information the lawmakers need on weapons systems.

Off-the-shelf avionics slated for new attack aircraft

Six major aerospace concerns have submitted bids for development of the Air Force's new A-X close-support aircraft, intended to be the service's low-cost, but highly effective, daylight attack aircraft from the mid-1970s until the end of the 1980s. Major cost-cutting decisions of the program called for the elimination of all-weather and night-vision capability, the use of a fixed noncomputing gunsight and the use of only off-the-shelf avionics and communications systems. The Air Force estimates R&D costs for the airplane at $194-million. A production run of 600 aircraft is expected to cost slightly more than $1.12-billion. Two of the competing bidders will be chosen around Nov. 1 to develop and test aircraft for a fly-before-buy evaluation. Bidders are The Boeing Co.'s Vertol Div., General Dynamics Corp.'s Convair Div., Lockheed Aircraft Corp., Cessna Aircraft, Fairchild Hiller Corp.'s Republic Div. and the Northrop Corp.

Japan seeking U.S. rockets for satellite launching

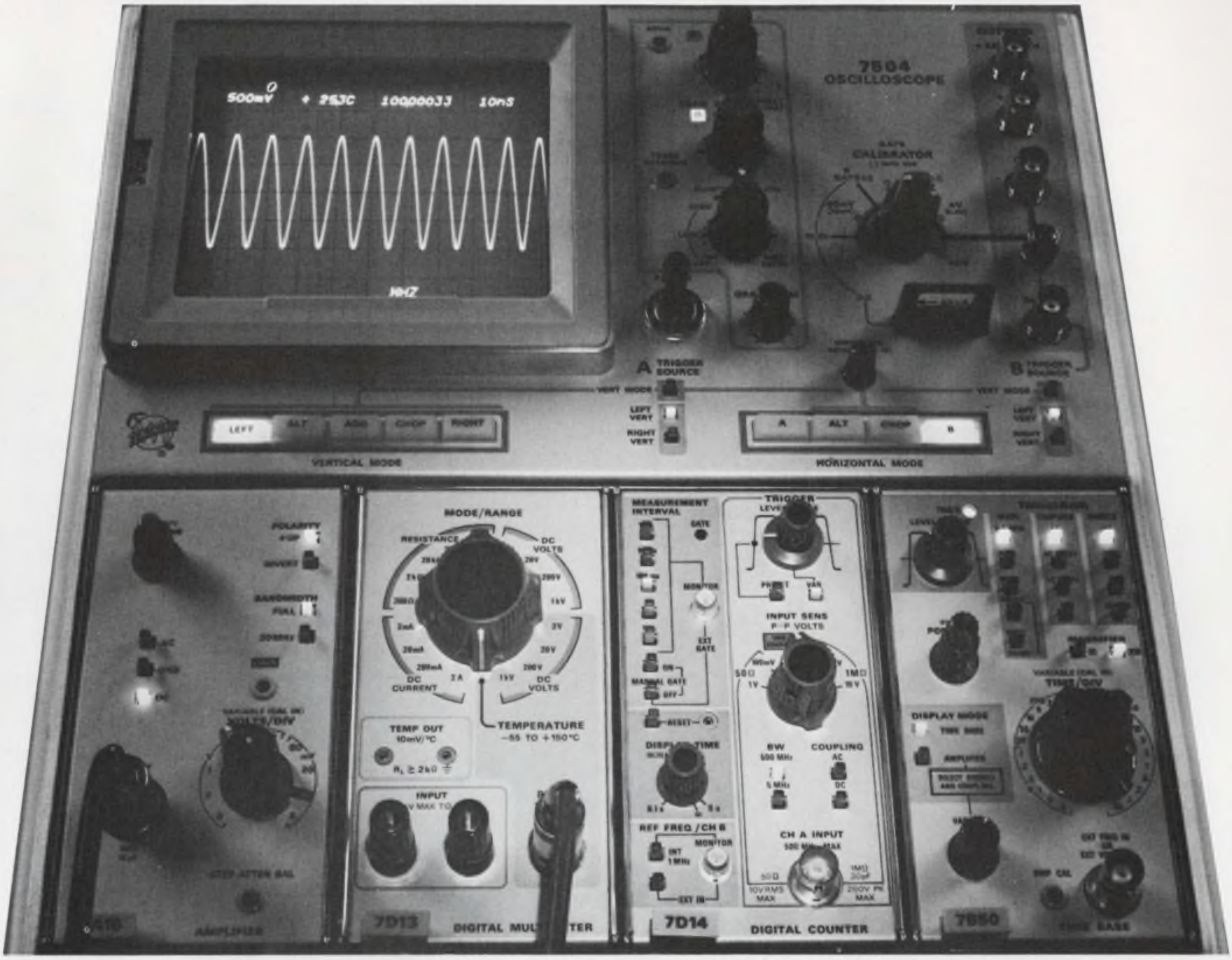
Japanese Government officials are talking with NASA and the U. S. State Department about the purchase of Titan III rockets to launch broadcast satellites. The Japanese plan to use the satellites for a direct exchange of programs between countries in East Asia and Oceania. One of the proposed satellites reportedly would relay television signals to 11 countries simultaneously. Japan plans to submit her proposals for the system at a meeting of the Asia Broadcasting Union, to be held later this month in Istanbul.

Hughes wins major Navy radar contract

The Hughes Aircraft Co., of Fullerton, Calif., will conduct the engineering development phase of the target acquisition system for the Navy's improved point defense surface missile system. This radar is also intended for universal use aboard Navy surface ships in the next decade and will be compatible with all types of air defense weapons. The development work will be performed under a $24.3-million, fixed-price, incentive-fee contract.

Capital Capsules:

Competitive flight tests of the Hughes and Westinghouse radar systems for the F-15 fighter **are expected to be finished this month and a contractor selected for the development by Nov. 1.** McDonnell Douglas, the prime contractor, has been conducting the tests in two RB-66 aircraft.... Before the end of the year communications common carriers with more than 16 employees **must file with the Federal Communications Commission a statement specifying hiring practices to be followed,** to prevent discrimination because of sex, race, color, religion or nationality. Forms must be filed annually under the new FCC ruling.... Watch for an announcement that Great Britain and Belgium will undertake a joint project to develop **a low-cost anti-tank weapon in which laser reflections from the target will be used to guide the warhead.** The system is expected to be adaptable to artillery as well as missiles.... The president's Advisory Council of Executive Organization **has recommended that the Interstate Commerce Commission, Civil Aeronautics Board and Federal Maritime Commission be unified in one new agency.** The council also expressed concern over the ability of regulatory agencies to represent the public interest adquately.



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With the introduction of two new digital plug-ins, a 500-MHz Direct Counter (no prescaling) and a versatile Digital Multimeter, it is even more apparent that the Tektronix 7000 Series was intended to be more than just another oscilloscope . . . ITS much more!

There are already 5 mainframes and 17 plug-ins in the 7000 Series . . . with more to come.

Consult your August Catalog Supplement for complete information. If you do not have a Supplement, check the inquiry card, we will send you one promptly.

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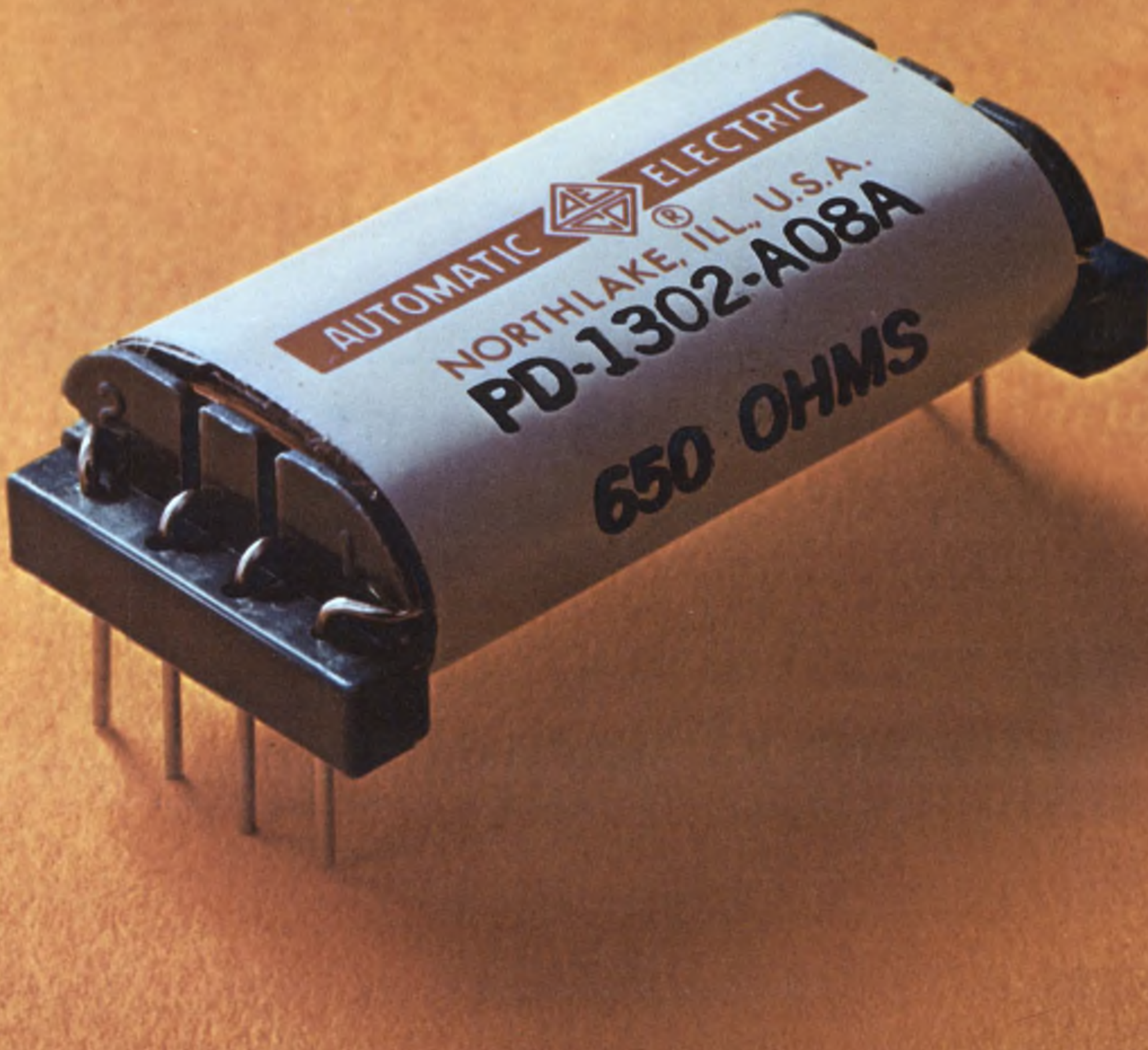
INFORMATION RETRIEVAL NUMBER 31

Everyone talks correed reliability,



here's the way it looks.

Switches under glass.

The heart of every AE correed is a reed switch consisting of two overlapping blades. For protection, we seal them inside a glass capsule. But only after we pull out all the dirty air and pump in a special, pure atmosphere. That way there's no chance of contact contamination or oxidation. Ever.

Notice our terminals are one piece. A special machine delicately forms them to precision tolerances. It's a lot of work, but one-piece terminals have distinct advantages over the two- and three-piece kind.

For one thing, there's no extra joint so you're always assured of a positive contact. Also, one piece terminals are more reliable when the correed is used to switch low-level analog signals. That's because thermal EMF is reduced to practically zero.

A different kind of bobbin.

Since we go through so much trouble with our correed capsules, we designed a special bobbin to protect them.

It's molded of glass-filled nylon. (You know how plastic chips and cracks.) Moisture and humidity have no effect on this stubborn material. No effect means no malfunctions for you to worry about. No current leakage, either.

Running the full length of the bobbin are a series of slots. They pamper the capsules and keep them from getting damaged or jarred.

And to help you remember which terminal is which, we mold the terminal numbers into the end of the bobbin. You can read them at a glance.

Little things mean a lot.

Reliability means that we pay attention to the little things. Like the tiny pressure rods we use in every miniature correed. They're placed at each end of the bobbin, across the one-piece terminals. What they do is prevent stresses from being transmitted from the terminals to the reed blades. This keeps the contact gap right on the button. All the time.

The contacts are normally open. To provide them normally closed, we employ another little device—a tiny magnet. It's permanently tucked into a slot next to the reedcapsule. The magnetic action keeps the contacts normally closed.

Coiled by computer.

Once all the parts are secure in the bobbin, we cover them with protective insulation. Around this, we wind the coil. You can be sure the coil winding is correct. It was all figured out for us by computer.

Our next step is to protect the coil. We do that with more protective insulation.

A coat of iron.

On top of the insulation goes a layer of annealed iron. It acts as a magnetic shield and minimizes interaction between coils. Also, it improves the sensitivity of the entire unit. A coat of iron is standard on all AE correeds.

Finally comes super wrap.

To wrap it all up, we use some very special stuff. A layer of mylar laminated material. It's so tough we guarantee it to withstand all cleaning solvents known to man.

It's attention to detail that helps us keep our miniature relays miniature. Now we're just waiting to show you how perfectly it measures up to your specifications. Automatic Electric Company, Northlake, Illinois 60164.

AUTOMATIC ELECTRIC

SUBSIDIARY OF GENERAL TELEPHONE & ELECTRONICS

The world of electronics is shrinking

"Japan will be the strongest threat to the U. S. electronics industry in the next few years," says Graham Miller, left, project engineer for Teradyne, Boston. On a recent trip to Boston and Washington, Managing Editor Raymond Speer found company managers very much aware that fast, economical transportation and communications are bringing foreign markets ever closer. Marketing managers are keenly eying Japanese competition and sales opportunities in Europe.

Progress can be an editor's headache

The electronics field is moving ahead fast—almost too fast, according to Mike Riezenman, technical editor, who handled the op-amp article featured on the cover of this issue. Three times the article was complete—and three times author Bob Demrow called to tell him of changes in the state of the art that had recently taken place. Lower prices, improved specs and increased versatility kept Mike revising and re-revising—right up to deadline date.

"Our final product," says Mike, "is as up-to-date as we could make it. The picture will change, again and again, because of the rapid growth of advances in the op-amp field. But in spite of price and performance data revisions the relative differences between op-amp types will remain reasonably stable, and this article should prove to be a reliable selection guide for some time. It's not easy," Mike added, "to keep up with the electronics field, but it's a challenge."

The article begins on p. 54.

Oops, sorry! Our memory slipped

We forgot to credit the manufacturer of the semiconductor memory (shown with superimposed cores) on the July 19, 1970, cover of Electronic Design. It's a 1024-bit MOS random-access memory made by Advanced Memory Systems, Sunnyvale, Calif,. and its dimensions are 120 by 150 mils. The cores superimposed on it are 18 mils in diameter, which is the standard size for high-speed production cores today.

How the Wizard of Barnes helped the ugly bug.

ONCE UPON A TIME there was a homely little electronic bug. He was so ugly that he hid himself under a large hat so that just his long skinny legs stuck out at the bottom. People laughed and called him T.O. (meaning Terribly Objectionable). With complete disregard for his feelings, they brutally stuffed him into P/C boards and other electronic things. Sometimes his legs got so bent and twisted he couldn't function at all. "Because I'm so ugly, people really push me around," whimpered the bug. "While I don't do plastic surgery," said the kindly old Wizard, "I can protect your fragile little frame from damage." Waving his magic wand, the Wizard produced a row of little plastic carriers to protect the electronic bug on his trips around the country, and a series of magic sockets and contactors for protection during burn-in and testing. "Marvelous," exclaimed the ugly bug, "but what about on the job protection?" "No problem, bug," replied the Wizard, again waving his magic wand. There appeared before the bug, a series of magic sockets. "Now bug, the socket can be dip soldered to a P/C board or mounted in the equipment and you can do your electronic thing in complete safety." "Gee, Mr. Wizard, you're the greatest," cried the ugly little bug, "what can I ever do to repay you for the kindness?" "Just tell all the folks out there in electronics land about me bug, and everything will be really beautiful."

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Our new line of amplifiers and oscillators are as small as, or smaller than the competition's. But they're a big thing to us because this is the first time we've ever offered them to you. After years of making them for our own use, we decided to make them generally available. And we've formed a new Microwave Products Division just to handle them.

What does this mean to you? It means that you can now buy sub-assemblies from the people who are famous for high quality transistors and diodes. And it means that you're assured of the same high quality, because KMC transistors and diodes are used throughout.

For example. Our RF, IF and wide band amplifiers are ultra-low-noise and cover a frequency range from 2 to 1200 MHz. And our oscillators cover a frequency range from 100 MHz to 18 GHz.

The selection, as you can see, is quite complete, and KMC will further assemble these components into sub-systems (such as receiver front ends).

Of course, there are some of you who'd rather buy our transistors and diodes for in-house assembly. Fine. We have Applications Notes that tell you, in detail, how to fabricate these components.

If you'd like more information – on either the sub-assemblies or the Application Notes – write:

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Parker Rd., Long Valley, N.J. 07853.
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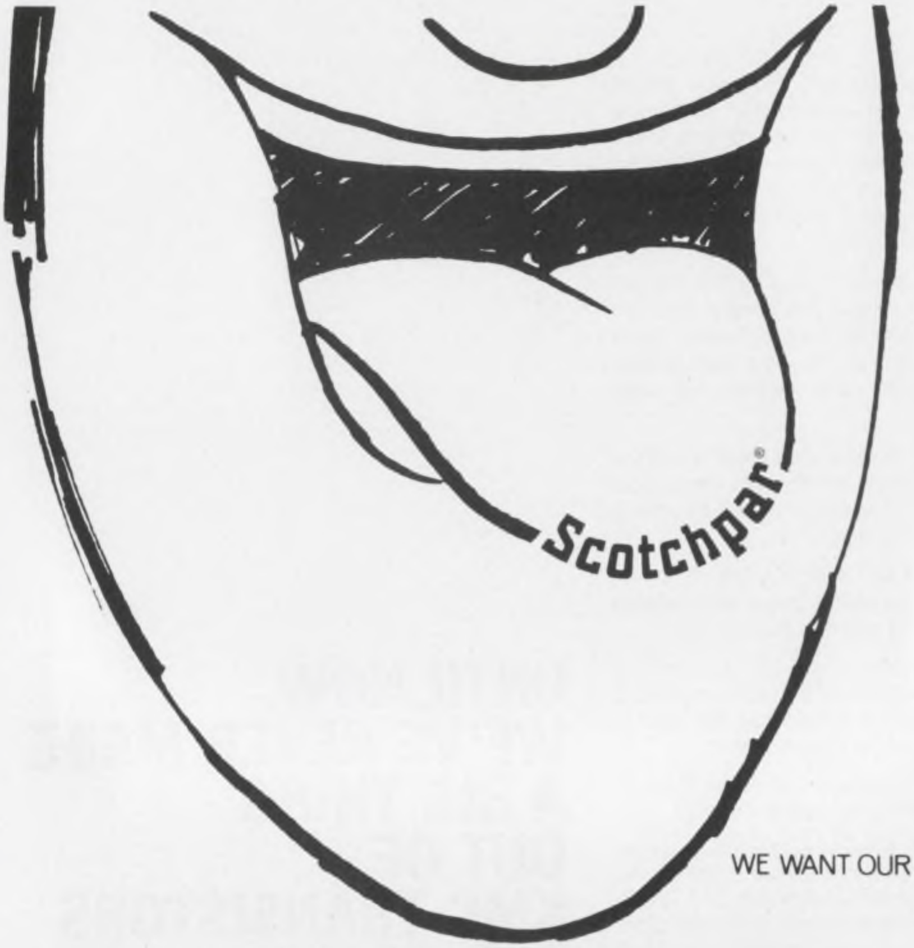

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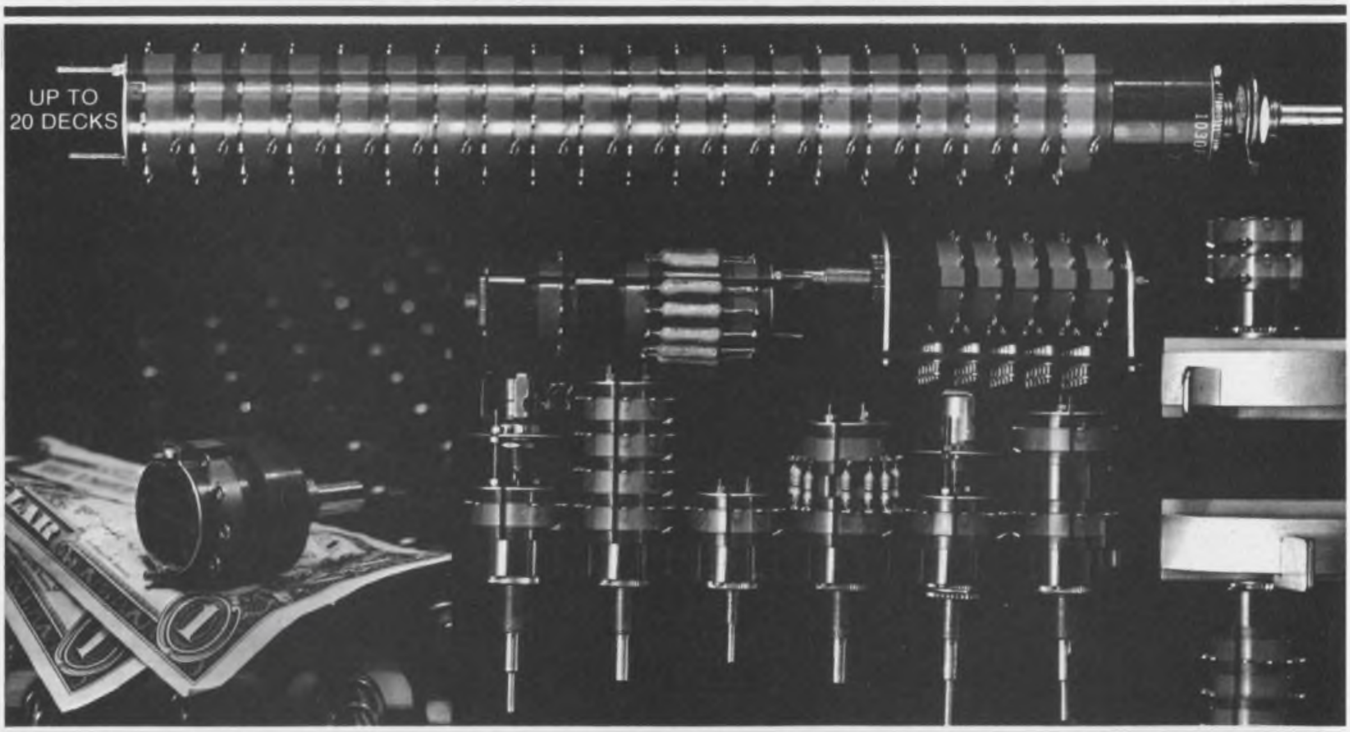

INFORMATION RETRIEVAL NUMBER 37

Guess the price of HP's new counter

Clues:

it averages time intervals to 10 picoseconds
it has a built-in 0.05% integrating DVM
it's dc to 50 MHz, CW or burst
its counter and DVM are easily programmable

Surprise: $1550. That modest amount buys a Hewlett-Packard timer/counter that does things universal counters never did before. For example, it averages time intervals as short as 0.15 nanoseconds. So you can resolve to 10 picoseconds on repetitive signals.

That modest sum also buys a counter with a built-in integrating digital voltmeter. So it's the only counter that can measure internal trigger level settings or other inputs with DVM precision. Now you can measure 10 to 90% rise times, half power points and other voltage-dependent time intervals. That means unprecedented simplicity, for example, in propagation delay measurements. The counter also features four integration times. As a DVM, it provides three voltage ranges, 60 dB noise rejection and 0.05% accuracy.

Even without these exclusive features, the 5326's are real bargains. They count to 50 MHz direct with seven-digit resolution (eight digits optional), measure period and multiple period average and scale input frequencies by any power of 10 up to 10^8. They measure ratio and they totalize.

With programming and BCD output options, the 5326's fit easily into systems applications. Counter and DVM are DTL programmable through a common connector.

You can get all of these benefits in the 5326B for $1550, or buy the same counter, less the DVM, in the 5326A for $1195. Any way you look at the 5326 A or B—either is a great counter value. Your local field engineer has all the facts about HP's new IC counter line. Give him a call or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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ELECTRONIC COUNTERS

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INFORMATION RETRIEVAL NUMBER 38

Which 5-digit multimeter is your best buy?

The new S-D 7005 offers five-digit resolution and accuracy. Designed for top performance in actual laboratory use.

Price: $1,295.

S-D just introduced it.

Prove it to yourself. Ask these questions in evaluating any competitive DVM:

Does the basic DVM include **four dc ranges** from 1 V full scale to 1,000 V full scale?

Can all **optional functions** be added by means of individual cards at any time? (Auto-ranging, AC volts, DC millivolts, ohms, DC current and digital outputs?)

Is the **input impedance** greater than 10,000 megohms on 1 V and 10 V ranges? Is **feedback noise** at the input terminals less than 1 mV? Is full scale **response time** less than 400 millisecs?

Does the unit use **dual slope integration** for max noise immunity at line frequencies? Are **plug-in cards** used for easy maintainability of all measurement circuitry?

Does it have an **annunciator** to remind you what measurement you're making? Are its **digital outputs** compatible with both IC logic and discrete component logic?

The S-D 7005 offers all these features and more for just $1,295. Request technical data or a demonstration from your local Scientific Devices office or contact: Concord Instruments Division, 888 Galindo St., Concord, California 94520. Phone: (415) 682-6161. TWX: 910-481-9478.

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EDITORIAL

Take time out to quiz engineers in Congress

- What could the U. S. Government do to help stabilize employment in the electronics industry?
- Does the present Administration have a feeling for technology and where it's taking us?
- Which government-sponsored engineering projects are under the most attack in Congress, and why?

These are just a few of the questions that are going through the minds of today's aware engineer. Answers to many of them can be obtained by writing to one's Congressman.

Or you can write to ELECTRONIC DESIGN, instead.

We'll select the questions asked most often and send them to the seven engineer-Congressmen we interviewed recently (see "Seven Engineers Help Design Our Laws," ED 14, July 5, 1970, p. 60.) Worthwhile exchanges between you and the Congressmen will appear in a future Management article.

We think that communication between our readers and Congress is important. Our Government works only as long as we allow it to. If we're too busy to stay informed and get involved, we deserve to lose the right to govern ourselves.

Most of the legislators we talked to when we wrote the article said that they rarely hear from the engineers in their constituencies. Sen. Symington of Missouri, for instance, says that he hears from engineers only when the most publicized projects, like the Safeguard antiballistic missile system, are being discussed. Sen. Mansfield says that engineers have a responsibility to write their representative to let him know whether an engineering project before Congress is good or bad. Engineers' should share their expertise, other Congressmen say, by speaking with authority, at local hearings on technical issues.

So get involved and write to us at:

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Take time out to talk it over with the engineer/Congressmen.

RICHARD L. TURMAIL

Pick the right op amp to make your precision dc measurement. Many factors can complicate the decision when truly high performance is desired.

Part one of a two-part article

To measure a dc voltage to within 0.1% when it's across a fairly low impedance is no great feat. The cheapest reasonable monolithic IC operational amplifier can do the job. But when an accuracy of 0.001% is needed and the source impedance is on the order of hundreds of kilohms, some very interesting and subtle problems can arise. If the optimum choice of op amp and op-amp circuit is not made, the required performance may be impossible to obtain.

An analogous situation comes up in selecting an op amp to make highly accurate current measurements on fairly low-impedance sources. In both cases the biggest problem is temperature drift, although supply-voltage variations and component aging also play roles.

In addition to drift, there are initial imbalances in the various op-amp components that lead to a substantial zero offset. Most discrete-component op amps have provision for adjusting this initial offset to zero; monolithic IC units tend to be not so easily adjustable.

To make the optimum choice of an amplifier for a given precision measurement, the drift characteristics of the various types of op amps should be considered, along with the nature of the source. Only when both factors are taken into account can a wise decision be made.

For example, the low voltage drift of a chopper-stabilized operational amplifier makes it the preferred choice for extremely accurate voltage measurements across low impedances.

However, when the voltage source has an impedance on the order of hundreds of megohms (or higher) the varactor-bridge type of op amp is better. The extremely low current drift of the varactor-bridge amplifier gives it the edge, even though its voltage drift is about 100 times worse than that of the chopper-stabilized variety.

Written by: **Robert I. Demrow,** Manager of Applications Engineering, Analog Devices, Inc., 221 Fifth Street, Cambridge, Mass. 02142.

Edited by: **Michael J. Riezenman,** Technical Editor

Two ways to fight drift

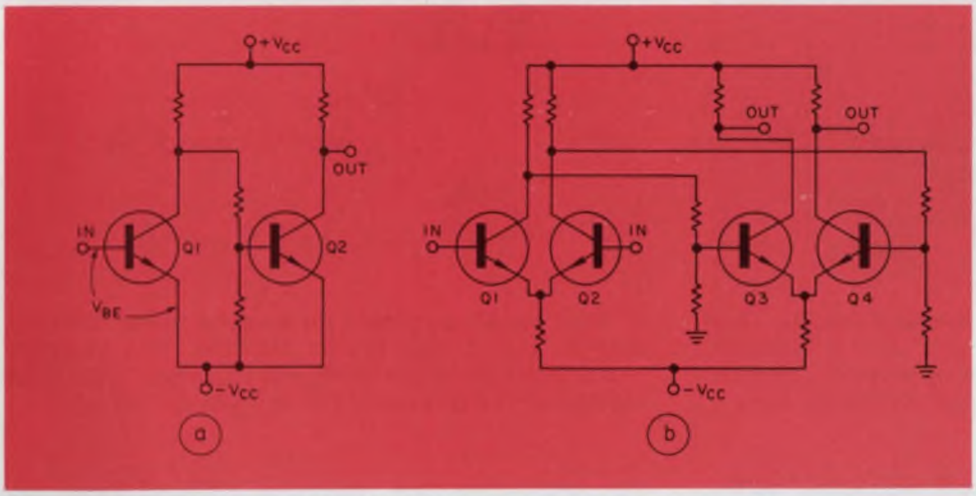
To gain insight into the characteristics of various types of op amps let's consider the two most common types of circuits used to reduce drift:

- Balanced differential circuits.
- Chopper-stabilized circuits.

A simple single-ended dc amplifier stage (Fig. 1a) is highly vulnerable to supply voltage variations. Any change in supply voltage changes the collector current, producing a variation in base-emitter voltage. By contrast, an equivalent differential amplifier stage (Fig. 1b) resists the effects of supply voltage variation because both transistors in each stage tend to be influenced equally, resulting in only minor net output variations. In fact, the very high levels of stability and regulation available in op-amp power supplies (0.01% to 0.1%) coupled with the excellent power-supply rejection of modern op amps make

Editor's Note:

Because of the rapid rate at which advances are continually being made in the op-amp field, much of the numerical price and performance data in this article will probably change before very long. However, the relative differences between op amp types will be reasonably stable and should provide a reliable guide to the selection of op amps for some time to come.



1. **Supply-voltage variations cause collector-current changes** in Q_1 of the single-ended amplifier (a). This, in turn causes changes in V_{BE}. The differential circuit (b) overcomes this problem since its errors depend upon differences between matched components.

this source of error a relatively minor worry to circuit designers.

The use of transistors in matched pairs also minimizes the errors caused by component variation. If the collector resistor of one transistor changes by 1% during the course of a year it is highly likely that the other transistor's collector resistor will change by a similar amount.

This leaves the effects of temperature upon amplifier stability. And temperature is usually the design engineer's main concern. It is instructive to consider the degree of matching that must be maintained for a differential amplifier to achieve a drift specification of 0.5 μV/°C. This consideration will also reveal how precarious a 0.5 μV/°C drift specification actually is—it is really a statement of the amplifier's steady-state stability rather than its maximum drift specification throughout normal operation.

Let's consider voltage offset and drift first, because this parameter depends upon component matching. Current drift, by contrast, is a function of the bias-current stability for each individual transistor. The base-emitter voltage vs temperature relationship for an ordinary transistor is approximately 2400 μV/°C. When two matched transistors are connected as a differential pair, both base-emitter voltages must vary in unison to leave a negligible differential voltage offset.

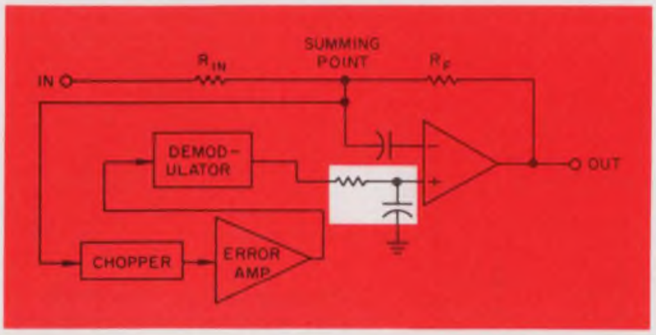
When one considers the degree of matching and temperature tracking required for a voltage drift specification of 0.5 μV/°C, the magnitude of the differential amplifier designer's task can be appreciated. The specification requires the two junctions to track within 0.5 parts in 2400, which is almost 0.02%. Yet amplifiers with this specification are available.

However, the user should be alerted to some of the pitfalls in a differential amplifier's voltage-drift specification. While it is true that an amplifier with 0.5 μV/°C maximum drift specification will produce only 10 μV offset for a 20°C temperature change, it would very likely produce considerably greater offsets while arriving at this steady-state condition. The reason is that the input transistors would probably be at slightly different temperatures during the change. The tight drift specifications do not refer to dynamic temperature conditions, but instead define the offsets that can be expected after circuit components have attained temperature equilibrium.

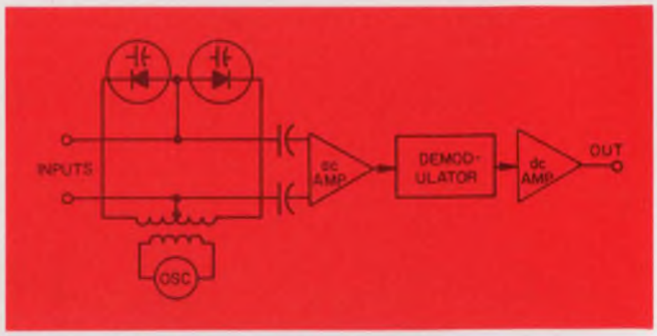
An important difference between low-cost discrete op amps and the more sophisticated variety is that the economy types usually use separate matched transistors for the differential gain stages while the more expensive units use dual transistors. The intimate physical spacing of the two junctions, along with the high temperature conductivity of the common substrate, provides excellent base-emitter voltage tracking between the two junctions of the dual transistor over wide temperature ranges. They are also responsible for the speed with which the junction reaches a steady-state condition after subjection to a temperature transient.

Unlike the voltage-drift specifications just discussed, good current-drift specifications do not result from careful tracking between two different sets of transistor-current values. Rather, the current drift of the simplest bipolar transistor op amp refers to the variations in base current drawn by each input-stage transistor.

Since there are two transistors in each gain stage, it is possible to utilize the tracking tendency of the two base currents (called bias currents) to minimize the effects of current drifts by properly designing the external circuit. Hence op-amp manufacturers frequently list the difference current and its temperature coefficient, along with the bias current and bias-current



2. **Chopper stabilization uses a feedback loop** to keep the summing-point voltage near zero. The RC network between the demodulator and the noninverting input is a low-pass filter. A potential problem is chopper noise.



3. **Input signals unbalance the varactor bridge** and produce an output from the ac amplifier. This approach is characterized by low noise and extremely high input resistance. The bias current is only about 0.01 pA.

drift specs. Typically, for well matched pairs over wide temperature ranges, difference current varies at about one-fifth the rate of bias current.

The chopper-stabilized amplifier

The chopper-stabilized op amp (Fig. 2) uses a built-in error-correcting loop that monitors dc offsets regardless of their source (initial offsets, steady-state offsets and transient offsets), then injects an error-correcting bias voltage into the amplifier to bring the summing-point error to the correct dc level (zero).

The advantages of the chopper-stabilized amplifier are numerous and include considerably better steady-state voltage drift specifications than differential types (0.1 μV/°C vs 0.5 μV/°C), as well as rapid automatic correction for offsets caused by temperature transients, load changes, localized heating, temperature gradients, long-term component variations and so forth. Then, too, the chopper-stabilizing circuit holds initial voltage, and current offsets orders-of-magnitude lower than the comparable initial conditions for even the best bipolar differential amplifiers.

Also, because the chopper amplifier's stability does not depend so crucially upon matching between input transistors, resistors, and so forth but instead depends upon the error-correcting feedback, it is possible for the unit to be assembled from relatively economical components. Thus, for example, Analog Devices can offer a chopper-stabilized op amp using monolithic IC circuitry but featuring 0.25 μV/°C maximum drift for $62, while a comparable bipolar unit with 0.5 μV/°C maximum drift costs $75.

The stabilizing circuit of Fig. 2 illustrates the automatic drift-correction process, and at the same time reveals one of the most serious drawbacks of many chopper amplifiers: Only one input terminal is available for the application of input signals; the other is "used up" in receiving the drift-correcting voltages. (Note: Very recently, several manufacturers have introduced chopper-stabilized noninverting and differential op amps, but most available chopper units are of the single-ended inverting variety.)

The single-ended types of amplifiers are pretty much confined to circuits that operate with one input terminal grounded, as will be discussed subsequently.

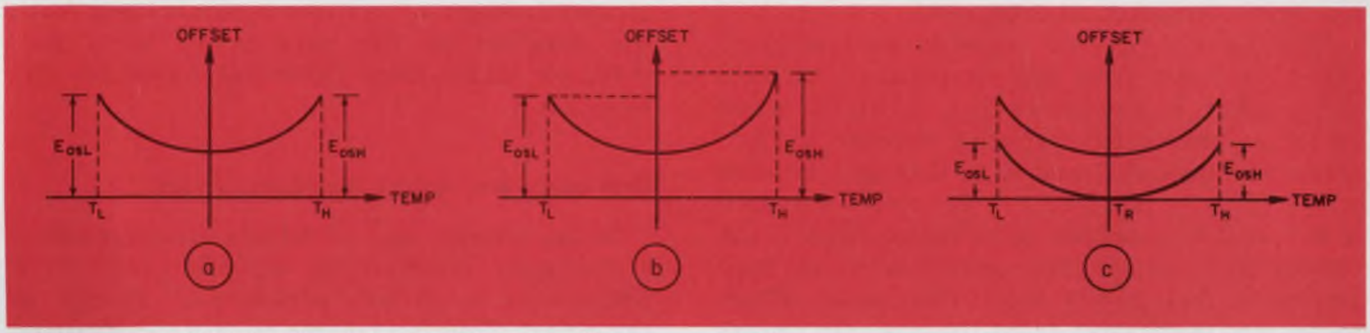
Another limitation of the single-ended units is input impedance. Since the device is confined primarily to inverting circuits, the over-all circuit impedance is set by the value of input resistance, R_{in}, chosen. The differential and noninverting types can be operated in noninverting circuits, where the input impedance is not limited to the resistance levels of available high-stability resistors. Also, the relatively low input resistance of the single-ended type can wipe out the advantages of chopper stabilization in applications that need high resistance levels for their external circuitry.

Another important chopper amplifier limitation is noise induced by the modulation-demodulation process. Sometimes the chopper process will create intermodulation problems when low-frequency signals are being measured. In such cases, it is possible for the chopper frequency to beat with the input signal resulting in low-frequency output perturbations at the difference frequency. This effect can be cured by filtering, but it can create surprises for the unwary user.

Two newer types

In addition to the differential-input and chopper-stabilized types discussed above, two newer op-amp varieties that should be considered are the FET input differential type and the varactor-bridge op amp.

FET op amps provide very high input impedance, excellent bias current and difference current stabilities, but relatively poor voltage-drift



4. **"Specsmanship" is the name of this game.** If the offset difference between the two temperature extremes is zero (a) a drift spec of zero could be cited as the average offset variation. Even if the offsets at the temperature extremes are not equal (b) an enormously understated drift spec can result. Zeroing the offset at room temperature (c) and quoting the worst-case average drift is a much more meaningful approach.

and common-mode characteristics. Since FET amplifiers are intended for high-impedance circuits in which the current of bipolar types is by far the predominant source of error, modest voltage drift performance is less of a drawback than it might appear.

It is worth noting that the FET amplifier's bias current varies nonlinearly with temperature, and in fact doubles with approximately every 10°C temperature rise. This nonlinearity makes it difficult for the op-amp manufacturer to give a hard and fast picoamps-per-degree specification for current drift. (The drift rate also doubles with every +10°.) Instead, most FET op-amps manufacturers list initial bias current and difference current values and then point out that both values rise exponentially.

An approximate figure for the FET amplifier's current drift in the vicinity of a given temperature can be obtained quite simply. For example, if the unit has a 20-pA initial bias current at 25°C, then the bias current will have doubled to 40 pA at 35°C. This is a 20-pA change. The average current drift over this 10°C interval is thus 20 pA/10°C = 2 pA/°C. For the next 10°C temperature rise, the drift will average 4 pA/°C, thence to 8 pA/°C, and so on. At 85°C the bias current will have increased from 20 pA to 1280 pA, and the current drift in the 75°C-85°C interval will have risen to 64 pA/°C.

Varactor-bridge op amps harness the parametric amplification principle and apply it to low-noise dc measurements. The physical embodiment of the varactor-bridge amplifier (Fig. 3) also provides excellent voltage stability, because of the use of a pair of matched varactor diodes, while the ultra-low current drift and noise permit fractional picoamp resolution.

The device is operated by applying input signals to alter the capacitance values of the two voltage-sensitive varactor diodes. In turn, this unbalances the bridge configuration, which then feeds a fraction of the auxiliary carrier voltage to the ac amplification stage, thence via the demodulator to the output dc amplifier. Ideally, the bridge section of this amplifier is devoid of ohmic resistance, so the Johnson noise is totally eliminated.

In other words, the bridge consists only of capacitive and inductive (transformer secondary) components, which do not generate noise. In practice, of course, the two halves of the transformer secondary have finite resistance, while the varactor diodes have leakage resistance and nonlinearities. Despite these deficiencies, however, the varactor-bridge op amp is on the way to displacing electrometer tubes—one of the last holdouts from the vacuum-tube era.

The varactor-bridge amplifier differs from previous types in that it does not have a difference current. This comes about because bias current flows in series through the bridge configuration, entering at one terminal and emerging from the other.

The varactor-bridge amplifier's bias current is nonlinear, somewhat like the FET's, leading to doubled bias current for every 7°C temperature increment. Nevertheless, with a bias current of 0.01 pA at room temperature, the amplifier has a wide lead over any existing semiconductor device for accurate measurement of fractional picoamp current signals, and resolving fractional millivolt signals developed by multi-megohm sources.

The many ways to specify drift

There are a number of ways for an op-amp manufacturer to measure and present the drift specifications for a particular op-amp type. He can use a seemingly rigorous maximum drift level (averaged over the permissible temperature range). But even the apparently straightforward maximum drift spec leaves some potential pitfalls. For a start, consider the least effective method for drift determination, based simply upon the measurement of offsets at upper and lower temperature extremes.

The curve (Fig. 4a) presents an imaginary offset variation from one temperature extreme to the other. It also shows that, if drift is based on the average offset variation between the two offset readings, E_{osL} and E_{osH}, then this average offset $(E_{osH} - E_{osL})/(T_H - T_L)$ reduces to zero if E_{osL} and E_{osH} happen to be equal. Even if the offsets at the temperature extremes do not happen to be fortuitously equal, their small differences can easily lead to an enormously understated actual drift performance as Fig. 4b shows.

The next step toward better drift specification is to take the same two offset readings but with the amplifier previously zeroed at room temperature (Fig. 4c). This more critical method for drift determination specifies drift as the sum of the absolute values of the two offset readings, divided by the total temperature excursion. Voltage drift is then expressed as the average value: $(|E_{soH}| + |E_{osL}|)/(T_H - T_L)$, while current drift would be defined similarly. However, even this improved method for averaging drift over the whole temperature interval can give overoptimistic results. For example, if the offsets for a 50°C temperature excursion on either side of room temperature are -100 μV and $+150$ μV, the average drift will work out to 2.5 μV/°C. In reality, the offset varies at an average rate of 150 μV/50°C = 3 μV/°C for positive temperature excursions.

Another method for drift presentation specifies amplifier performance in terms of the worst-case (average) drift for either positive or negative temperature excursion. This method, called the "True Butterfly" technique, states that the average drift anywhere within the amplifier's working range will be less than either $E_{osH}/[T_H - T_R]$ or $E_{osL}/[T_R - T_L]$, whichever is worse. (T_R is room temperature). This method for drift presentation would show that the amplifier cited previously had a maximum drift figure of 3 μV/°C for the full ±50°C range, even though the drift remained within 2.5 μV/°C for temperature decreases.

Even then, of course, the drift performance remains an average value, albeit a maximum average, for the ±50°C temperature environment. In reality, the offset curve could exhibit steep slopes betwen zero and either offset extreme. As a general rule, the offset curve is shallowest around room temperature, so that stability for small temperature excursions is usually better than specified for a wider temperature range. On the other hand, if an amplifier is to operate in an elevated temperature environment, the offset slope, or true incremental drift can actually be worse than the figure listed as maximum average. Consequently, users intending to make sensitive measurements with the amplifier located in warm or cold rooms should check with the manufacturer for more details about performance under their particular operating circumstances.

Drift specs and voltage measuring errors

In the simplest case of voltage measurement—a unity-gain noninverting amplifier used as a buffer—the amplifier's offsets add directly to the output. Thus, an op amp with 3 μV/°C drift, used in a unity-gain noninverting voltmeter input stage operating over a ±10°C range, would add 30 μV of offset voltage to the output signal. If the circuit happened to be measuring a 10-mV dc level, the 30 μV would create an error of 0.3%.

If the noninverting configuration were set for a gain of 50, the output error caused by voltage drift would be increased 50-fold, but the signal would also be amplified 50-fold so the proportion of error would remain constant.

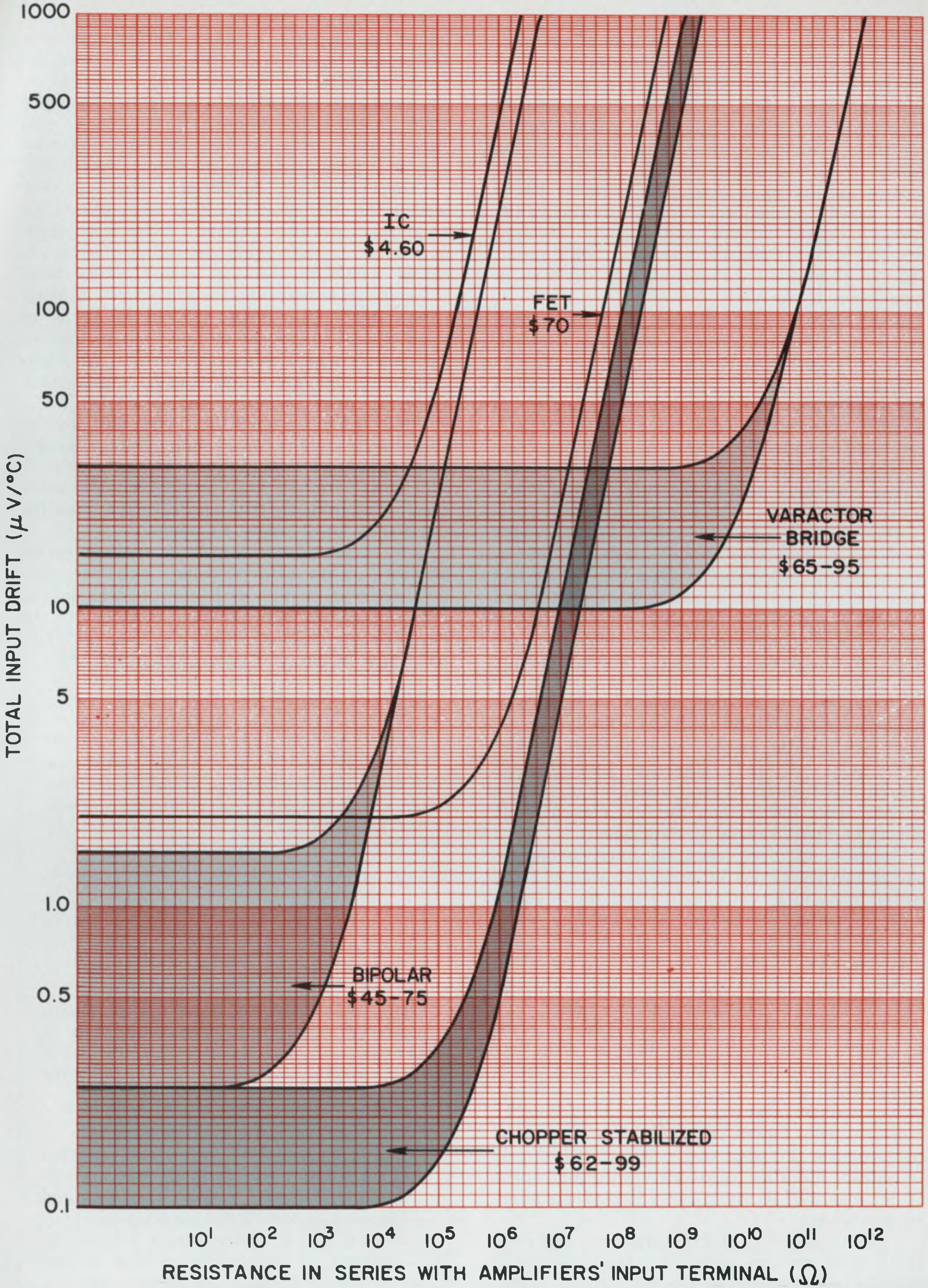
However, if the noninverting circuit is used to measure the same 10-mV signal from a high-impedance source, a new set of errors will get into the act. Base currents (bias currents) drawn by the amplifier's input transistors would be sucked through whatever external impedance was inserted in series with the amplifier's input terminals. If the signal source had resistance R_s, the bias current I_b flowing through this resistance would produce a voltage of I_bR_s across it, which in turn would be applied to the amplifier's input terminal, adding to the error produced by voltage offsets.

It is, of course, a simple matter to zero the amplifier for any specific level of the combined $E_{os} \pm I_bR_s$ offsets, but neither offset voltage nor bias current remains constant in an operating equipment. Hence, the amplifier's measuring accuracy will vary with both voltage and bias current drift.

If the amplifier cited previously exhibited a 1-nA/°C bias current drift, as well as the 3 μV/°C voltage drift, and was used to measure a 10-mV signal from a 10-kΩ source, the bias current variation would apply a voltage signal to the amplifier that drifted at the rate of 10 μV/°C. This bias-current error would considerably outweigh the 3 μV/°C voltage drift of the same circuit, creating a total error for the specified ±10°C range of ±130 μV, or ±1.3% total error.

Composite drift curves

There is a method of graphical presentation for the total drift performance of a given amplifier that combines voltage and current drift errors for any value of resistance in series with



5. **Compare op amps at a glance** with this total-drift chart for five basic types. (The IC unit, which is not suitable for most precision measurements, is included for comparison.) All of the ampifiers shown here are by Analog Devices, but the reader can easily generate similar curves for other units. Note: All of these curves are based on bias-current drift, not on difference-current drift which can be five times smaller.

the amplifier's terminal. Although every individual amplifier has its own characteristic curve for the combined drift effects, it is possible to span the whole range of today's drift performance with curves for merely half a dozen representative amplifiers of various types. If the curves for these representative amplifiers are plotted on the same sheet, the engineer has a very speedy method for comparing widely different amplifier types and quickly deciding whether to use a bipolar transistor, FET input, chopper-stabilized, varactor-bridge, or even a monolithic IC op amp.

The composite drift curves (Fig. 5) display series input resistance on the horizontal axis and total drift (referred to the input) along the ordinate. As one might expect, the curves remain flat at a value of $\Delta E_{os}/\Delta T$ for low values of resistance. They don't begin to rise until the current drift component, $R_s \Delta I_b/\Delta T$, becomes comparable to the voltage-drift component. Then, for larger resistance values, the current component predominates.

This graph provides the circuit designer, who proposes to measure voltage signals from a known source resistance, with a convenient tool that will tell him at a glance whether a given op amp is suitable for his purposes, or not. Any specific op amp not included on the chart can be added by the designer by using the manufacturer's voltage and current drift specs.

Note that in some applications it is possible to use measuring circuits that make the errors dependent upon the amplifier's difference current drift, $\Delta(I_{b1} - I_{b2})/\Delta T$, rather than upon the bias current drift itself. In such cases, the difference current drift rather than the bias current drift should be used to make up the graph.

Actually, in most cases, the current-compensating method cannot be used. For example, the introduction of a compensating resistor in series with the amplifier's noninverting terminal raises the whole amplifier off the ground and adds common-mode problems to the existing drift errors. The compensating resistor also multiplies the noise voltage caused by current noise.

Furthermore, the compensating resistor must be exactly equal to R_s. And this isn't an easy condition to meet if R_s varies, as source resistances often do.

It is evident from Fig. 5 that the high-stability dual-transistor input amplifiers provide good performance at modest cost, provided that circuit impedance levels are relatively low. Beyond about 10 kΩ, the designer must begin to consider alternative types.

FET amplifier drift characteristics are close to those of the less costly dual-transistor input bipolar transistor types for low circuit resistances. However, the FET's ultra-low bias current allows this amplifier to gain a distinct edge over the bipolar types beyond 100 kΩ. Still, with bipolar transistor amplifiers listing from $45 or so, compared with $70 for a high-performance FET amplifier, the designer should use all possible tricks, including bias-current compensation, to get the most from the bipolar amplifiers.

Chopper-stabilized amplifiers show up very well on the drift chart. They are unsurpassed for measuring low-level voltages from low-impedance sources, while their low initial offsets, excellent long-term stability, and freedom from warmup errors make them a wise choice in many other circuits. Of course, it must be borne in mind that most chopper units cannot be used in the noninverting configuration needed for high-impedance voltage measurements unless they employ a costly isolated power supply.

Varactor-bridge amplifiers are the obvious choice when it comes to handling voltage signals from impedance levels beyond approximately 10 MΩ. Their relatively low cost may actually make them a better choice than an FET type, even for impedance levels below 10^7 ohms.

Low current noise, which is another major attribute of the varactor-bridge amplifier, cannot be shown on this drift curve; nevertheless, low noise and excellent current stability are the key characteristics in resolving microvolt signals from sources of 10 MΩ and upward. ■■

This first part of the two-part article concentrates mainly on voltage measurements. Part two will discuss the basics of current measurements and will go into some detail about inverting and noninverting circuits.

Test Your Retention

Here are questions based on the main points of this article. Their purpose is to help you make sure you have not overlooked any important ideas. You'll find the answers in the article.

1. *How does input-current drift affect the accuracy of voltage measurements?*
2. *In what two respects does the varactor-bridge op amp outperform all other types?*
3. *What are the major strengths and weaknesses of the FET-input op amp?*
4. *How can a compensating resistor in series with the noninverting input reduce the effects of bias-current drift?*

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IMPEDANCE INSTRUMENTS

18002

Shift phase independent of frequency.

Nonminimum-phase networks exhibit constant phase difference and all-pass characteristics.

A pair of nonminimum-phase networks with the same input can provide a 90-degree phase difference between their outputs. This difference is maintained over a wide band of frequencies and is very useful in single sideband and other signal-processing applications where quadrature signals are needed.

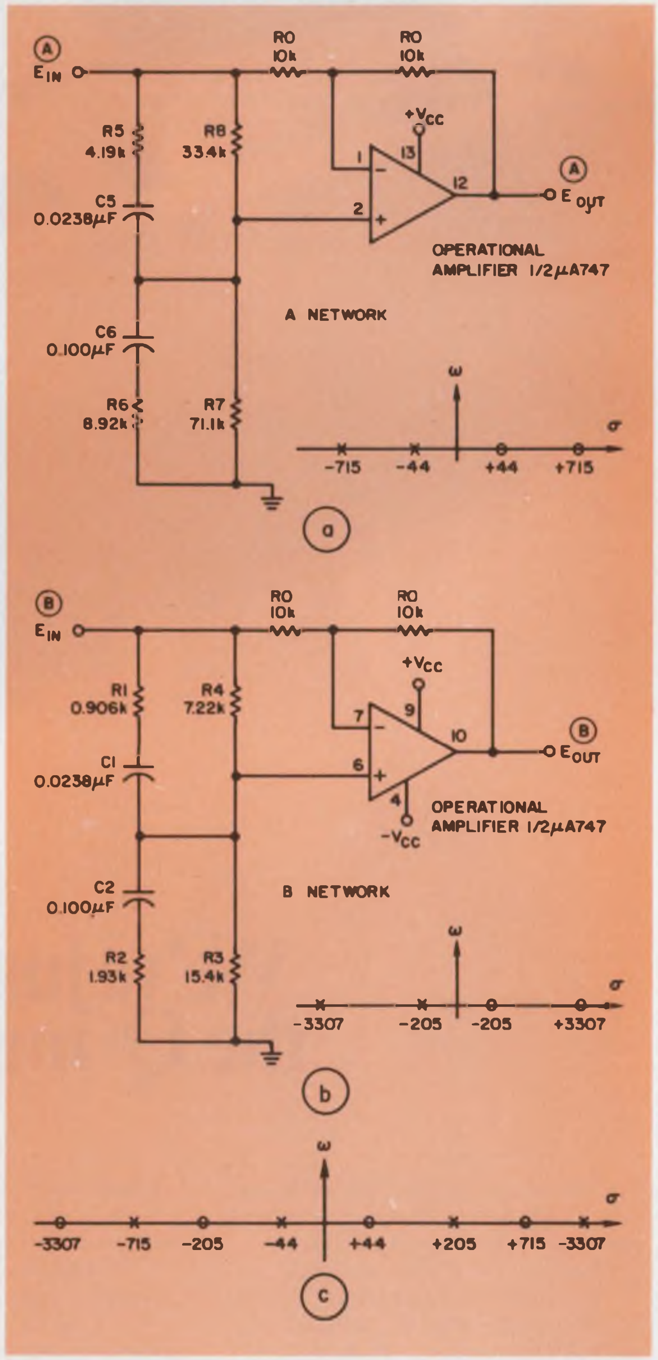
The principle that underlies the design is the placing of a zero in the right half of the complex frequency plane for each pole in the left half-plane.[1] The tedious mathematics involved in performing this calculation is avoided by programming the problem in BASIC and using a computer to perform the routine arithmetic.

Each of the two networks is all-pass with constant insertion loss, but the phase shift varies over the pass band. However, they are so designed that one of the networks always lags the other by the desired 90 degrees, with a small error, through five octaves.

Choose the poles for optimum phase

Typical networks and their pole-zero locations are shown in Fig. 1. The A network is two-pole all-pass, with poles at −44 Hz and −715 Hz on the real axis. The B network is all-pass with poles at −205 Hz and −3307 Hz. With a common input signal, the phase difference between the outputs of the two networks is also an all-pass function, with poles at −44 Hz, +205 Hz, −715 Hz and +3307 Hz (Fig. 1c). The right half-plane poles imply that the one network has more phase delay than the other (not that either output anticipates the input signal).

The phase characteristic of each network decreases monotonically with frequency. Figure 2 is a plot of phase vs frequency for the two networks. Note that because of lower frequency poles, the phase of the A network is always greater in magnitude than that of the B network. The A-minus-B phase shift can be read from Fig. 2 by finding the difference between the two



1. **Two all-pass networks** with the same input signal have the pole-zero locations in "a" and "b." Their outputs are 90 degrees apart through five octaves. The pole-zero locations of the difference is shown in "c."

Frederick R. Shirley, Technical Staff, Sanders Associates, Inc., 95 Canal St., Nashua, N.H. 03060.

curves. This theoretical difference characteristic is computer-plotted[2] in Fig. 3 and is within ±3.8 degrees of 90 degrees from 70 to 2100 Hz.

For narrower frequency ranges the phase tolerance is reduced, and for wider ranges it is increased. The relationship between phase tolerance and frequency range is given in the curve of Fig. 4. For applications where the four-pole phase tolerance is too wide, a six or eight-pole[1] phase shifter can be used instead.

Frequency is key variable

The variables in the phase-shifter design are frequency band and circuit impedance level. Its frequency band is specified by the upper (F_2) and the lower (F_1) frequency limits, while impedance level is specified by the maximum capacitance value, C_o. Frequency range R and mean frequency W in radians/second are defined as

$$R = F_2/F_1$$

and

$$W = 2\pi\sqrt{F_2F_1}\ .$$

The frequency range of a two-pole 90-degree phase shifter with the same desired phase accuracy but a narrower frequency range is used to help locate the poles and zeros of the four-pole circuit. This two-pole frequency range, R_2, is

$$R_2 = (R^{1/2} + R^{-1/2})/2\ .$$

The two-pole phase shifter is further reduced to a one-pole phase shifter with a frequency range[1] of

$$R_1 = (R_2^{1/2} + R_2^{-1/2})/2\ .$$

In order to locate the poles, we define

$$K_2 = -R_2^{1/2}\ [R_1^{1/2} + (R_1+1)^{1/2}]$$

and

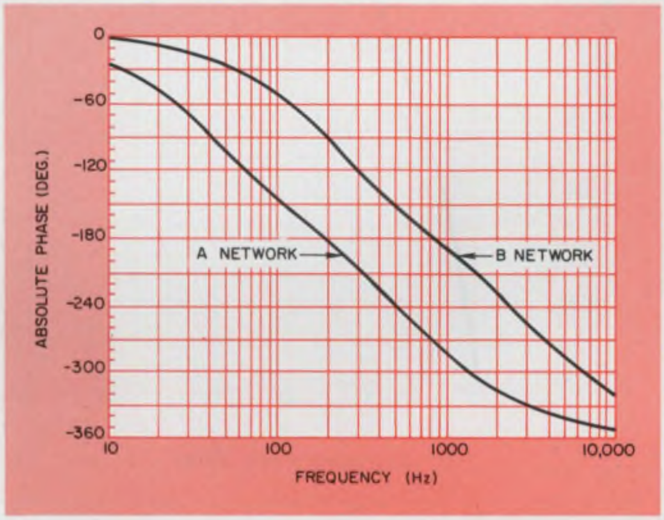
$$K_1 = -R_2/K_2\ .$$

The pole and zero locations[1], L_i, in hertz are given by

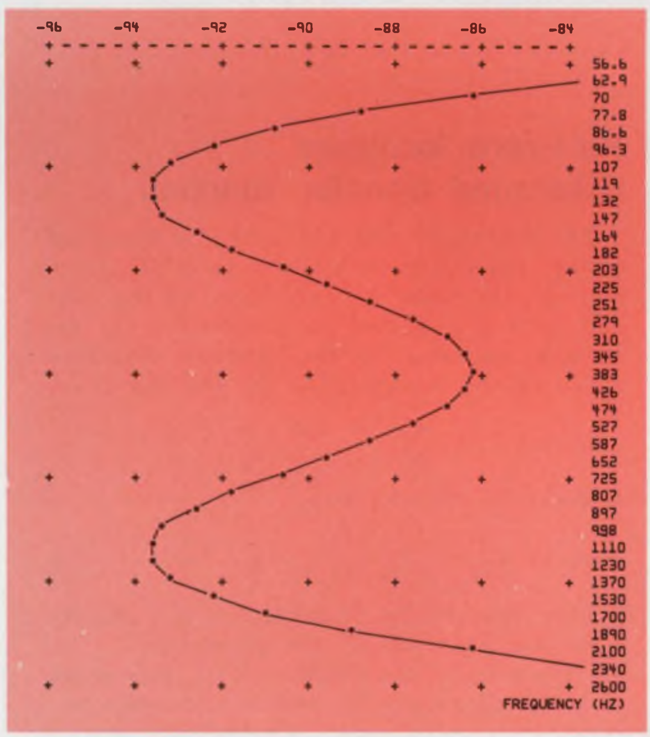
$$L_1 = \frac{W}{2\pi}\left[\frac{1}{\sqrt{1+K_2^2} - K_2}\right],$$

$$L_2 = \frac{W}{2\pi}\left[\frac{1}{\sqrt{1+K_1^2} + K_1}\right],$$

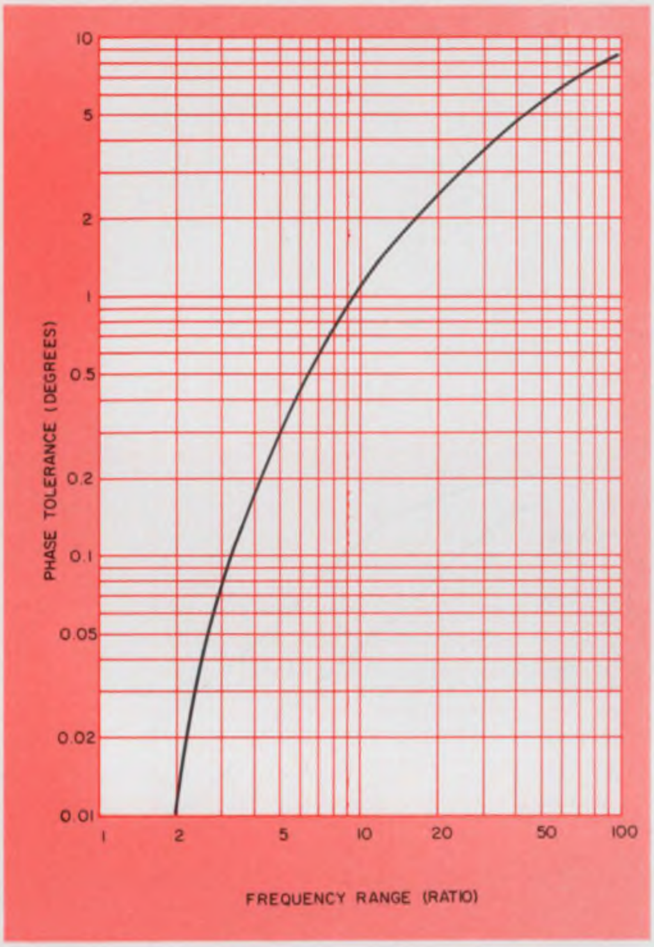
$$L_3 = \frac{W}{2\pi}\left[\frac{1}{\sqrt{1+K_1^2} - K_1}\right],$$



2. **A plot of the calculated phase response** of the A and B networks of Fig. 1 illustrates the 90-degree differential phase shift from 70 Hz to 2.1 kHz.



3. **A computer plot** of the A and B network differential phase demonstrates that the tolerance on the desired 90 degrees does not exceed 3.8 degrees over the frequency band of interest.



4. **A four-pole phase shifter** exhibits this theoretical relationship between frequency range and phase tolerance. If a tighter tolerance is required, more poles must be incorporated into the circuit.

Pole-zero locations determine transfer function

The location of poles and zeros of a dynamical system establishes its transfer function. Alternatively, the transfer function locates the poles and zeros. The system in question and the designer's approach to the problem determine which of the statements is the starting point.

$$\text{If } H(s) = K\frac{a_0 s^n + a_1 s^{n-1} + \ldots a_{n-1}s + a_n}{b_0 s^m + b_1 s^{m-1} + \ldots b_{m-1}s + b_m}$$

this can be factored into

$$H(s) = K\frac{(s+z_1)(s+z_2)\ldots(s+z_i)\ldots(s+z_n)}{(s+p_1)(s+p_2)\ldots(s+p_j)\ldots(s+p_m)}$$

The roots of the numerator, $-z_i$, are the zeros and the roots of the denominator, $-p_j$, are the poles of the function. Real roots result in poles and zeros on the real axis; complex conjugate root pairs result in poles and zeros in the complex plane and, if the real part is zero, on the imaginary axis.

and

$$L_1 = \frac{W}{2\pi}\left[\frac{1}{\sqrt{1+K_2^2}+K_2}\right].$$

The L_i are all positive numbers, and $L_1 > L_3 > L_2 > L_4$. Each L_i represents a pole-zero pair on the real axis of the complex-frequency plane, with the pole located at a distance $-L_i$ in the left half-plane and the zero at $+L_i$ in the right half-plane. The odd L_i, L_1 and L_3, are realized in the A network of Fig. 1 and the even L_i, L_2 and L_4, are realized in the B network.

The phase difference between the A and B networks is within a tolerance of $\pm E_2$ degrees of -90 degrees over the frequency range. The precise phase at any given frequency can be found by summing the phase contributions of the four poles and four zeros in the network pair. In particular, the value of E_2 can be found by evaluating the phase at the frequency-range limit F_1.

$$E_2 = 2\sum_{i=1}^{4}(-1)^i \tan^{-1}\left(\frac{F_1}{L_i}\right) + 90^\circ .$$

The arctangent is multiplied by two because each zero in the right half-plane adds as much phase as the corresponding pole in the left half-plane. The negative sign for odd values of i in the summation represents the subtraction of the B network phase from that of the A network. The phase offset of $+90$ degrees is required because E_2 is the tolerance around -90 degrees rather than 0 degrees.

Pole locations determine components

Since the A and B networks are identical in form, the same synthesis procedure can be used for both. The transmission gain of the B network can be expressed in terms of the component values of Fig. 1b.

$$\frac{E_{out}}{E_{in}} = \frac{Q(s)-1}{Q(s)+1},$$

$$Q(s) = \frac{R_3\,[1+(R_1+R_4)C_1 s]\,[1+R_2C_2 s]}{R_4\,[1+(R_2+R_3)C_2 s]\,[1+R_1C_1 s]}, \qquad (1)$$

and $s = \sigma + j\omega$.

The desired transmission gain of the B network can also be expressed in terms of the theoretical pole locations, with a constant scale factor K.

$$\frac{E_{out}}{E_{in}} = K\frac{(s-2\pi L_2)(s-2\pi L_4)}{(s+2\pi L_2)(s+2\pi L_4)}.$$

This equation for E_{out}/E_{in} can be expressed in the same form as Eq. 1 by multiplying out the factors and collecting terms.

Let $K = (H-1)/(H+1)$ where H is also a constant. Then

```
100 PRINT"   ","90-DEG PHASE-DIFFERENCE NETWORKS"
110 PRINT
120 PRINT
130 PRINT
140 PRINT"   FREQ LIMITS (HZ)";
150 INPUT F1,F2
160 PRINT
170 PRINT"   MAX C (NANOFARADS)";
180 INPUT C0
190 PRINT
200 LET R=F2/F1
210 LET W=SQR(F2*F1)*6.2831853
220 LET R2=(R↑.5+1/R↑.5)/2
230 LET R1=(R2↑.5+1/R2↑.5)/2
240 LET K(2)=-(R1↑.5+(R1+1)↑.5)*R2↑.5
250 LET K(1)=-R2/K(2)
260 PRINT"   POLE-ZERO LOCATIONS (HZ):"
270 PRINT
280 LET J1=0
290 LET E2=90
300 FOR I=1 TO 4
310 LET J1=J1+(-1)↑(I+1)*(3-I)
320 LET L(I)=W/6.2831853/(SQR(1+K(J1)↑2)+(-1)↑I*K(J1))
330 PRINT"      ";L(I)
340 LET E2=E2+(-1)↑I*ATN(F1/L(I))*360/3.14159265
350 NEXT I
360 PRINT
370 PRINT"   PHASE TOLERANCE (DEG):  ";INT(E2*100+.5)/100
380 PRINT
390 LET H=(L(4)+L(2))/2/SQR(L(4)*L(2))
400 FOR Z=0 TO 4 STEP 4
410 LET V1=W/6.2831853/SQR(L(4-Z/4)*L(2-Z/4))
420 LET V3=M↑2+SQR(H↑4-1)
430 LET C(2+Z)=C0/1E9
440 LET R(2+Z)=V1/C(2+Z)/W
450 LET R(3+Z)=R(2+Z)*(V3-1)
460 LET R(1+Z)=R(2+Z)/H
470 LET C(1+Z)=V1/V3/R(1+Z)/W
480 LET R(4+Z)=R(3+Z)/H
490 NEXT Z
500 LET K=(H-1)/(H+1)
510 PRINT"   INSERTION LOSS (DB):  ";-INT(2000*LOG(K)/LOG(10)+.5)/100
520 PRINT
530 PRINT"   COMPONENT VALUES (KILOHMS AND NANOFARADS):"
540 PRINT
550 PRINT"      'B' NETWORK","'A' NETWORK"
560 PRINT
570 FOR I=1 TO 4
580 PRINT"      R";I;R(I)/1E3,"R";I+4;R(I+4)/1E3
590 NEXT I
600 PRINT
610 FOR I=1 TO 2
620 PRINT"      C";I;C(I)*1E9;"   ","C";I+4;C(I+4)*1E9
630 NEXT I
640 PRINT
650 PRINT"   ('A' LAGS 'B' BY 90 DEG)"
660 END
```

5. **This BASIC program** can compute the component values for a four-pole phase shifter. The LET statements translate design equations into computer form. The other statements cover control and input/output.

$$\frac{E_{out}}{E_{in}} = \frac{Q'(s) - 1}{Q'(s) + 1}$$

where

$$Q'(s) =$$

$$H\,\frac{1 + \frac{s}{2\pi H}\left(\frac{1}{L_2} + \frac{1}{L_4}\right) + \left(\frac{s}{2\pi}\right)^2\left(\frac{1}{L_2L_4}\right)}{1 + \frac{sH}{2\pi}\left(\frac{1}{L_2} + \frac{1}{L_4}\right) + \left(\frac{s}{2\pi}\right)^2\left(\frac{1}{L_2L_4}\right)}. \quad (2)$$

In order to be able to compare this equation with Eq. 1, it must be factorable into positive real roots. This sets an upper limit on the value of H and hence a minimum insertion loss for the B network of Fig. 1b. The limiting value H_{max} is found by solving the numerator of Eq. 2 for the value of H, which produces a double root:

$H_{max} = (L_2 + L_4)/(2\sqrt{L_2L_4})$.

It is desirable to use H_{max} as the value of H in Eq. 2 because this minimizes the network insertion loss and also minimizes the sensitivity of the network response to component value variations. Using $H = H_{max}$, Eq. 2 may again be rewritten:

$$Q'(s) = H\,\frac{\left[1 + \frac{V_1}{W}s\right]\left[1 + \frac{V_1}{W}s\right]}{\left[1 + \frac{V_1V_3}{W}s\right]\left[1 + \frac{V_1}{V_3W}s\right]}.$$

where the intermediate variables are

$V_1 = W/(2\pi\sqrt{L_2L_4})$.

and $V_3 = H^2 + \sqrt{H^4 - 1}$.

Because Q(s) and Q′(s) are in identical form, these equations can be compared term by term in order to derive the component values in the circuit of Fig. 1 from the L_i pole locations. This comparison yields five equations, but one degree of freedom remains since six component values are to be determined. The sixth constraint scales the network impedance to a convenient level by specifying the value of the largest capacitor as C_0 in nf. Solving the six equations gives the following values for the six components in the B network:

$C_2 = C_0$, $R_2 = V_1/(W C_2)$,
$R_3 = R_2(V_3 - 1)$, $R_1 = R_2/H$,
$C_1 = V_1/(WV_3R_1)$, $R_4 = R_3/H$

The value of the two R_0 resistors may be chosen independent of the values of the other components as long as they are closely matched for unity gain inversion.

The component values in the A network are found by a similar synthesis. In order to solve the A network, odd pole-zero locations are used rather than the even ones. The value of H_{max} does not have to be recalculated because it is the same as that for the B network due to the symmetry of the L_i pole locations. The same equations may be used to find the A network components if each component subscript is increased by four (R_1 becomes R_5, etc.) and each pole location subscript is decreased by one (L_2 becomes L_1, etc.).

BASIC program automates the design

A computer program to automate the phase-shifter design is given in the listing of Fig. 5.

```
FREQ LIMITS (HZ) ? 70, 2100

MAX C (NANOFARADS) ? 100

POLE-ZERO LOCATIONS (HZ):

    44.4505
    205.458
    715.475
    3307.05

PHASE TOLERANCE (DEG):   3.71

INSERTION LOSS (DB):   8.85

COMPONENT VALUES (KILOHMS AND NANOFARADS):

   'B' NETWORK                 'A' NETWORK

   R 1  0.906219               R 5  4.1887
   R 2  1.9308                 R 6  8.92451
   R 3  15.3838                R 7  71.1065
   R 4  7.22034                R 8  33.3737

   C 1  23.7592                C 5  23.7592
   C 2  100                    C 6  100

('A' LAGS 'B' BY 90 DEG)
```

6. **A printout of the solution** of a phase-shifter design problem requires the user to enter frequency limits and impedance level after the question marks. The rest of the printout gives circuit values.

This program is written in BASIC.[3,4] LET statements implement the design solution derived above. Most of the remaining statements in the program are input/output control to enter parameters and printout the final design solution (Fig. 6). The parameter input is accomplished in lines 100-190. The INPUT statement in line 150 causes a question mark to be printed, after which the computer pauses until two numbers corresponding to the values of F_1 and F_2 are typed by the user. Similarly, lines 170-180 allow the user to input the third design variable, the maximum capacitance value C_0.

The printout of the design solution begins in lines 260 and 330 where the four pole-zero locations are listed. Lines 300-350 contain an iteration loop, with I varying from 1 to 4. Each time the computer passes through this loop the value of I is increased by one, and the value of another pole location is printed. The dummy variable J1 defined in lines 280 and 310 is used to properly select either K_1 or K_2 in line 320. The next portion of the solution printout is the phase tolerance E_2 and insertion loss K; and the final portion of the solution printout is the component values. A Z iteration loop from line 400 to 490 uses the same statements to calculate the component values for both the B network and the A network. These 12 component values are then printed out in lines 580 and 620.

Values are calculated for example

The printout in line 650 gives the direction of the differential phase shift between the outputs of the two networks. Because the poles of the A network are closer to the origin in the complex frequency plane, the A network experiences more phase delay than the B network at any given frequency. Therefore, the A-minus-B phase difference is approximately −90 degrees rather than +90 degrees.

The circuit values for the pole-zero configuration of the design example are shown in Fig. 1. Here, R_0 was chosen to be 10k for optimum biasing of the op amps. A single integrated circuit, μA747, is used for both active elements in the phase shifter design. The component values have been rounded to three significant figures, thus causing a slight variation from the ideal phase and gain response. Care must be taken that tolerance and temperature variations are kept within acceptable limits. Computer programs, such as ECAP, can be used to determine response sensitivity and to minimize the effects of component variation. ■■

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4. *BASIC Language Reference Manual,* General Electric Information Service Department Publication 202026A, January, 1967.

Test Your Retention

Here are questions based on the main points of this article. Their purpose is to help you make sure you have not overlooked any important ideas. You'll find the answers in the article.

1. What are the gain vs frequency characteristics of the phase-shifter networks?

2. What effect does the number of poles have on phase-shifter performance?

3. Which component determines circuit impedance level?

4. How are the pole-zero pairs determined and realized?

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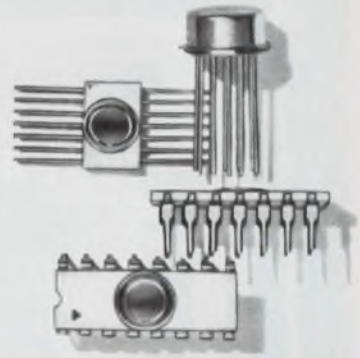

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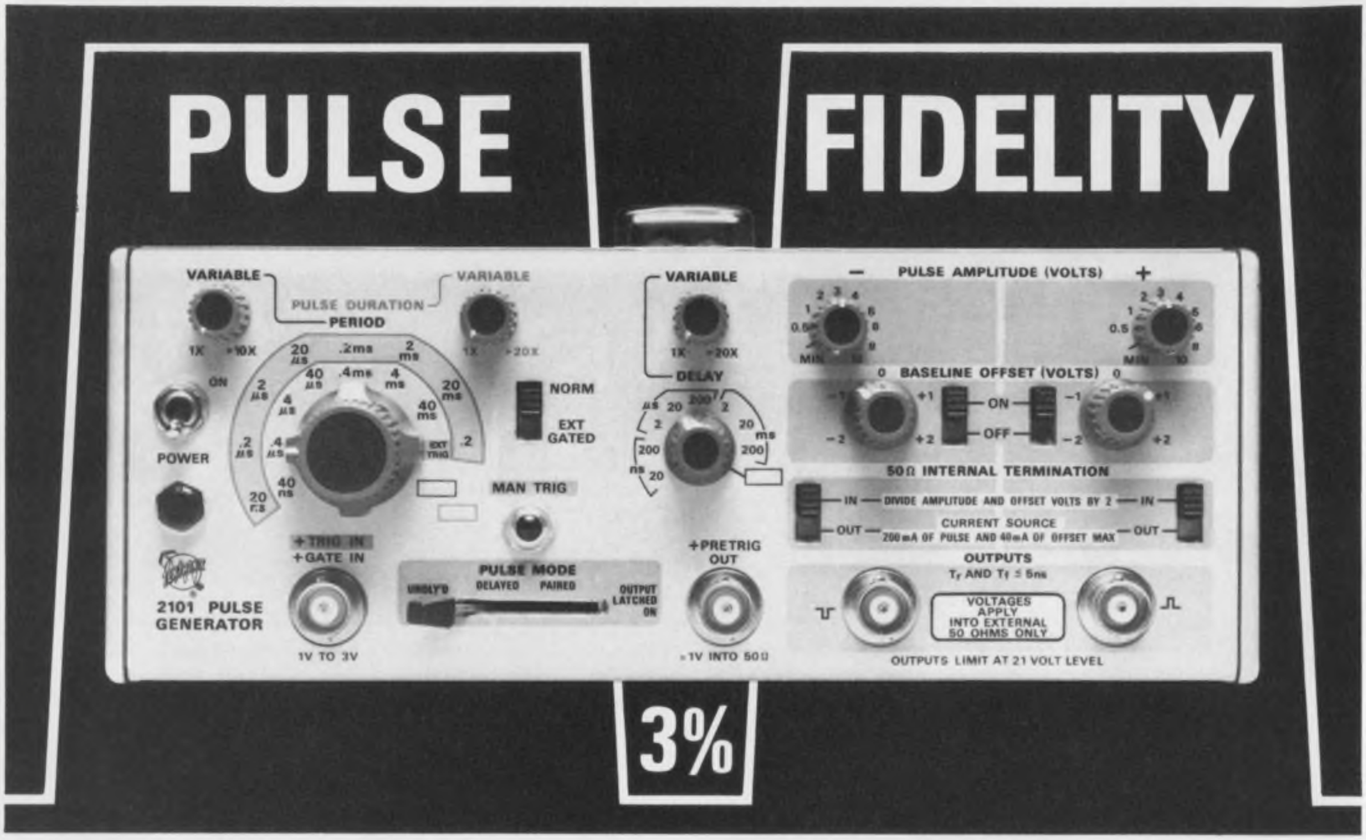

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This 25-MHz, 10-volt, general-purpose generator produces exceptionally clean pulses with aberrations not exceeding 3%. Positive and negative-going pulse outputs are simultaneously available and independently variable from 0.5 V to 10 V. (See photo at right.) Each output is provided with a continuously variable baseline offset of +2 V to −2 V.

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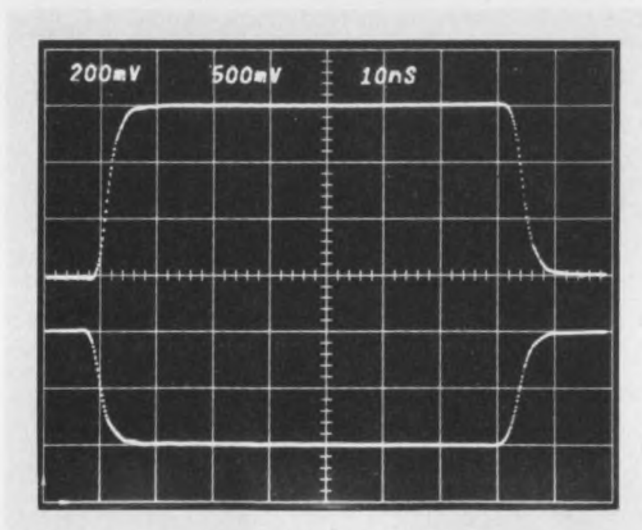

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Compare reliability at a glance.

Computer-generated, direct-reading curves show the effect of redundant units.

System reliability can be improved by using redundant components, and its numerical value can be calculated by using the binomial expansion. However, the analytic approach can be tedious. Here is a set of computer-generated curves that makes system reliability comparisons possible at a glance.

The curves can be applied to two types of redundancy calculation: back-up and back-off. Back-up redundancy means that incremental or fractional spares are available to replace failed units in order to maintain a given capability. Back-off redundancy refers to the probability of meeting a degraded requirement—something less than a desired goal.

A trivial example of back-up redundancy is the availability of two 10-W power supplies to supply a 10W load. More involved is the fractional back-up redundancy involved in having three 5-W supplies for a 10-W load. In the first case there are incremental spares. In the second case, there is reserve power, but it is a fraction of the requirement rather than an increment.

A case of back-off redundancy exists if there are three 5-W supplies for a 15-W load, but it is later decided that only 10 of the 15 W are critical. The interpretation of the needs is different, but the calculation is carried out in the same way as the back-up case.

Derivation of reliability curves

R_u = single-unit reliability
$1-R_u$ = single-unit unreliability
n = number of redundant paths
j = number of unit failures

Then: $(1-R_u) + R_u = 1$

$[(1-R_u) + R_u]^n = 1$ and can be expanded into:

$$R_u^n + n R_u^{n-1}(1-R_u) + \ldots + \binom{n}{j} R_u^{n-j}(1-R_u)^j + \ldots + (1-R_u)^n = 1$$

The left side of the final equation represents all possible combinations of success and failure. By subtracting all cases of failure from both sides of the equation, the left-hand side then represents all chances for success and the right-hand side all chances of failure subtracted from unity.

Each solution of the expanded equation gives one point on one curve. If, for example, n=3;

$R_u^3 + 3R_u^2(1-R_u) + 3R_u(1-R_u)^2 + (1-R_u)^3 = 1.$

Now, if at least two successes are required to make the system successful, the first two terms on the left are equated to R_s, the probability of system success is

$R_s = R_u^3 + 3R_u^2(1-R_u)$ or

$R_s = 1-[3R_u(1-R_u)^2 + (1-R_u)^3]$

If $R_u = 0.95$, $R_s = 0.993$ and one point has been calculated. The only way to expedite this tedious procedure is to program the calculation on a computer.

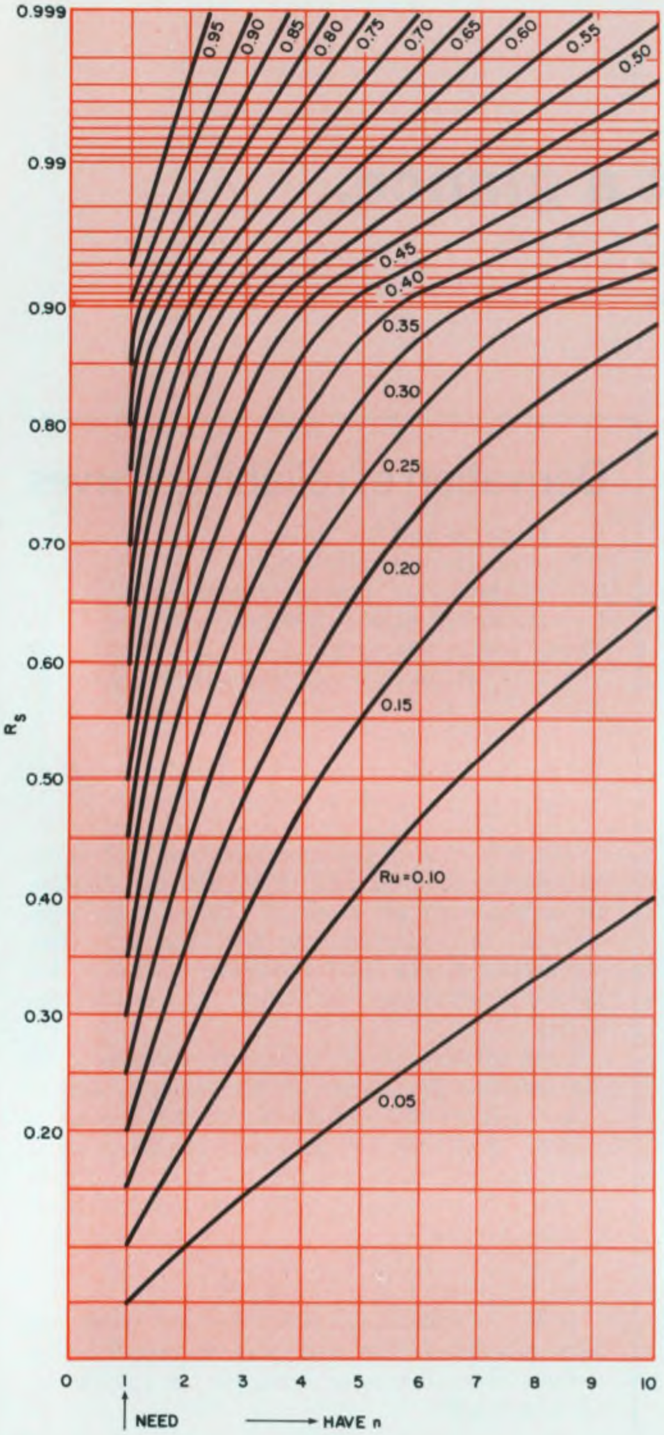
Use redundancy curves

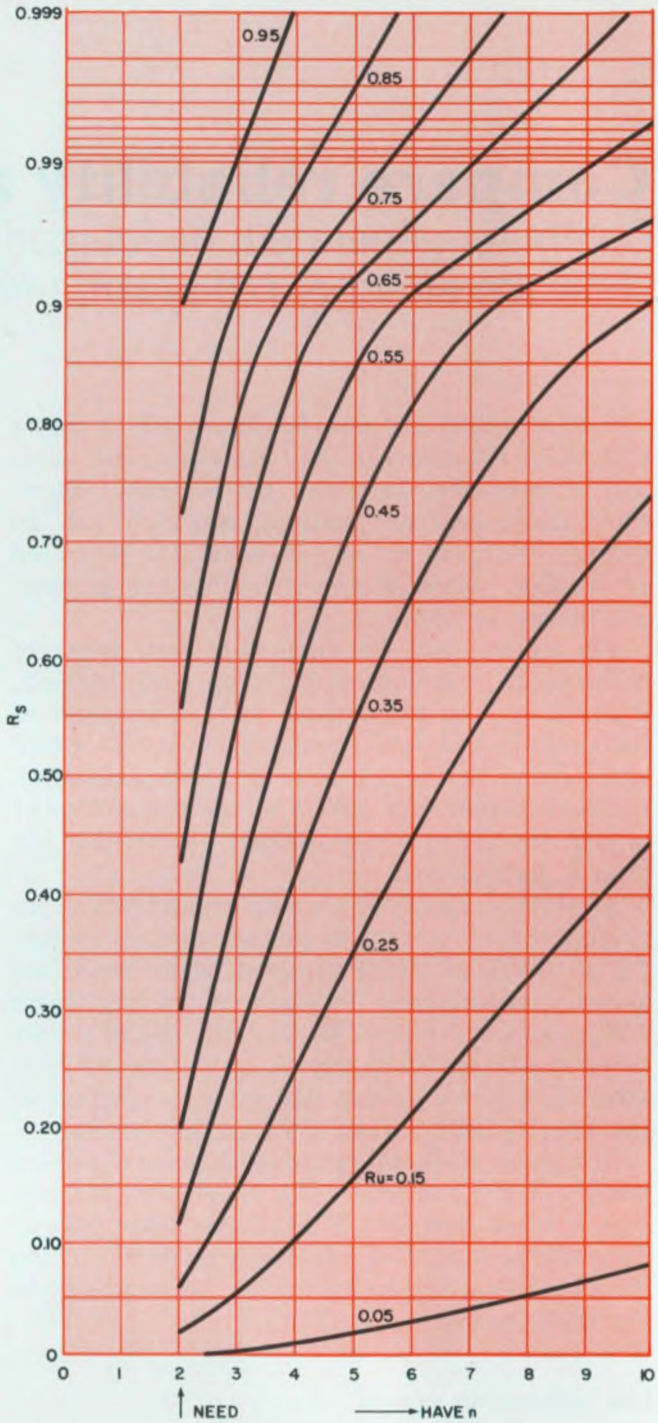
For instance, the redundancy curves in Figs. 1-4 relate three variables. The units above the minimum required are plotted along the abscissa. The ordinate represents probability of system success, R_s. The parameter for each individual curve is the reliability of a unit of equipment, R_u. Note that the lowest value plotted on the abscissa is the number of units required as a back-up minimum or a back-off limit. Therefore, a separate set of curves is needed for each minimum value. Four such curve families are given here. If additional ones are necessary, the equations in the box can be used to construct them.

Suppose a mission reliability requirement for a power-supply system is $R_s = 0.85$ to deliver at least 18 W. How many back-up units are needed if each can deliver 6 W with a unit reliability of 0.65? Refer to Fig. 3, because at least three units must be used. Follow the 0.85 ordinate until it intersects the 0.65 unit reliability curve. The corresponding abscissa is 5.7. Therefore, six units are required to meet the specified reliability.

As a second example, consider a requirement

Charles H. Karr, Senior Engineer, Reliability Engineering, Aerospace & Electronic System Div., Westinghouse Electric Corp., PO Box 746, Baltimore, Md.



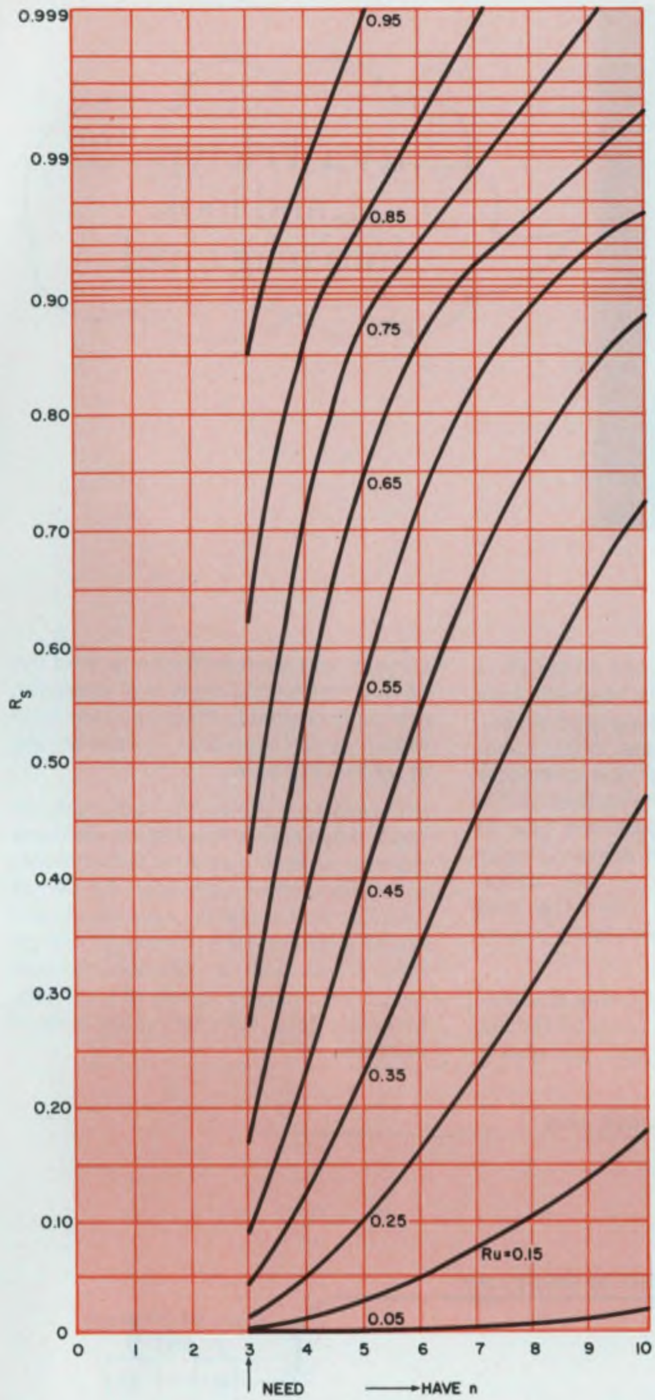


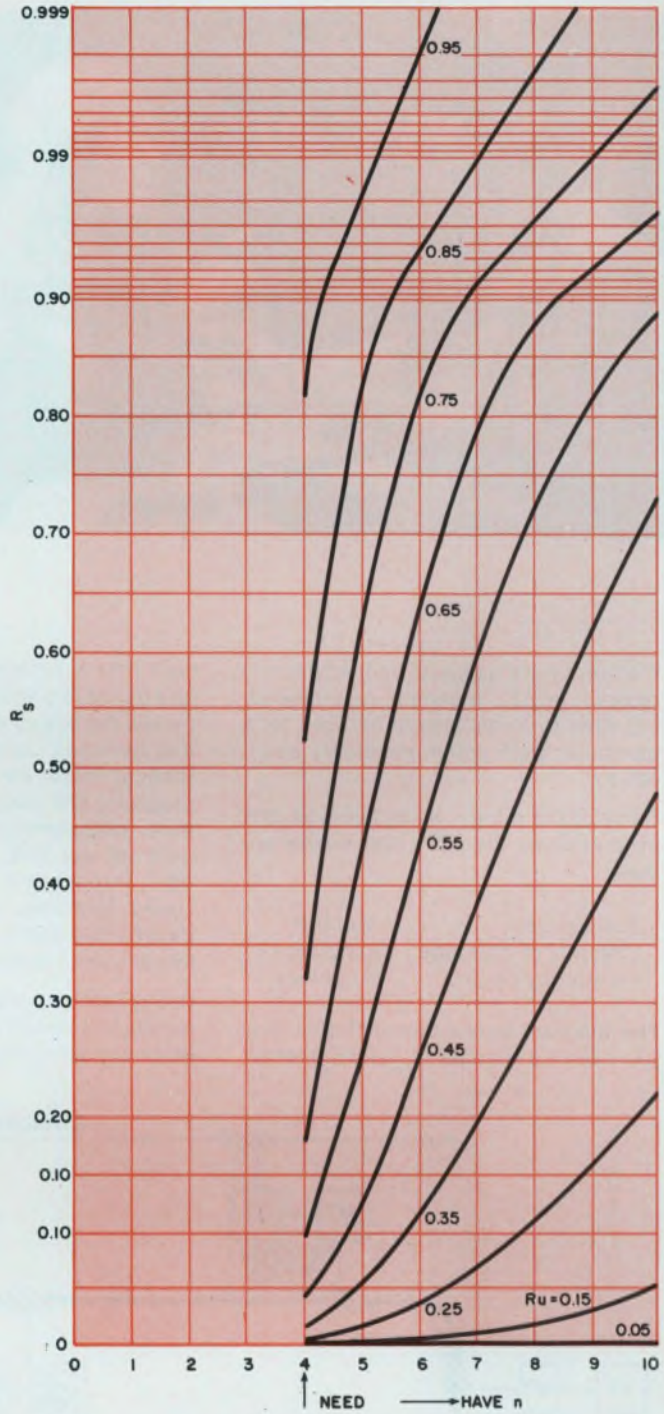
1-4. This set of curves relates system reliability (R_s) to unit reliability (R_u) based on the number of spare units available. In Fig. 1, one unit is needed and one to ten are available. In Figs. 2, 3, and 4, the number of required units are two, three, or four, respectively, and up to 10 are on hand.

for 90 W with $R_s = 0.86$. If three 30-W units are chosen, each must have a reliability of at least 0.95 in order to meet the system requirement. Now, if only 60 W are needed to supply critical loads, what is the back-off reliability of the system?

Since two units can meet the reduced specification, refer to Fig. 2. Follow the abscissa for three units until it intersects $R_u = 0.95$. The corresponding ordinate, 0.993, is system reliability for the reduced backed-off power level.

If an orbiting satellite is to perform five experiments (n=5), each with an equal probability of success of 0.55, the over-all probability of





success is $0.55^5 = 0.05$. What is the probability of completing at least two experiments?

For the solution, again refer to Fig. 2 and follow abscissa 5 to the $R_u = 0.55$ curve, at which point the ordinate is 0.87. Thus, backing off the requirement has increased the probability of success from 5 per cent to 87 per cent. ■■

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Test your retention

Here are questions based on the main points of this article. Their purpose is to help you make sure you have not overlooked any important ideas. You'll find the answers in the article.

1. What is back-up redundancy?

2. What is back-off redundancy?

3. On what mathematical function is the calculation of redundant reliability based?

4. What are incremental spares?

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We don't have a crystal ball. And rarely resort to mystic means in recommending what terminal should be used for a particular data communications application.

Some of the things, we at Teletype look at, that make the job a little easier are these:

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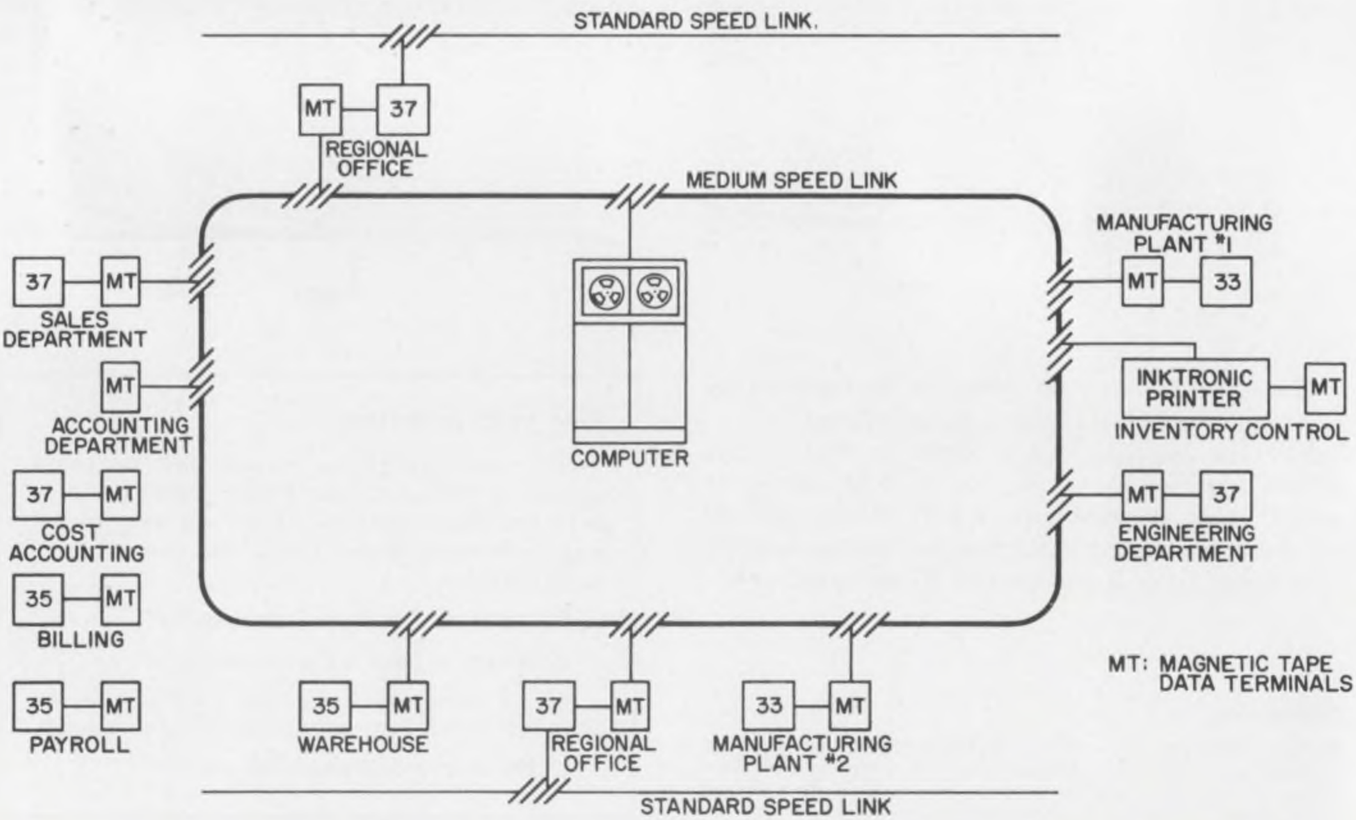

DATA COMMUNICATIONS

equipment for on-line, real-time processing

Routine aspects of the system are maintained in standard speed links. Branch offices are tied into the regional office terminals on standard speed networks. Regional offices batch routine branch office data on one magnetic tape. Transmit the data to the central office processor at one time. Saving a number of additional computer port requirements.

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INFORMATION RETRIEVAL NUMBER 43

Contraction puts a squeeze on managers.

A slowdown of company pace and growth rate is the most troublesome management problem of the 'slump,' says this president.

Richard L. Turmail, Management Editor

Because technology in the electronics industry is constantly and rapidly changing, the job of managing an electronics firm is difficult, even during business weather that's fair. During a business drought the problems change and multiply.

An example of how management problems can increase during such a dry spell is found at Analog Devices, a highly successful and expanding producer of analog-function modules and digital-computer interface equipment for the scientific, industrial and Government markets.

The company, with net sales of nearly $10.4 million last year, has grown out of its random cluster of century-old buildings on Fifth Street in Cambridge, Mass., and is constructing a new plant in Westwood, Mass. Yet its president, Emil B. Rechsteiner, says that one of his most troublesome management headaches is trying to maintain the pace and growth the company had before the present general business slump. And he believes that these headaches could have been avoided if the stock market was not the object of so much misunderstanding.

According to Rechsteiner, the present slump is the result of what happens when people equate the economy with the stock market. He pointed out that, while the market has dipped 30 or so per cent, the Gross National Product (GNP), "the only reliable picture of the economy," is just leveling out. But Rechsteiner sees decreases in sales in the third quarter, and blames the contraction on a "market" psychology. And the combination is discouraging to employees.

Slump slows company growth

"Most electronics companies that were founded in the last ten years have never experienced a serious business contraction," Rechsteiner said. "Never before had there been such an expansion of the GNP as from 1959 to 1969." Founded in 1965, Analog Devices is experiencing its first contraction—and finding it frustrating.

The obvious pace problem common to most electronics companies now is that they have cash tied up in inventory that doesn't move.

To counter this problem, Rechsteiner said that his company has been forecasting more frequently by taking a closer look at its past product models and more thoroughly scrutinizing the competition. The company has also promoted the product lines it believes will sell best during the business slump by writing a brochure listing new applications that make the product more economical.

Another problem that hampers a company's pace is the problem of mounting account receivables. With business slowed down, the company needs more cash on hand to operate.

One way to shrink the pile of receivables, according to Rechsteiner, is doing a bit of research to eliminate those new customers who would be most prone to become debtors.

"When we dug beneath the surface," he said, "we found that, of the customers who don't pay their bills, a large number are small companies that are undercapitalized."

Growth depends on capable employees

Part of the management problem of pace is a leveling off of the company's growth rate.

Rechsteiner said that, although for the first half of this fiscal year the company is 42% ahead of last year, the third quarter won't match the level of the second quarter.

"For the first time," he said, "we're not expanding as we previously have." And he explained that a slowdown in expansion can have a negative effect on the employees.

"Employees get used to expansion, and they become discouraged when it doesn't happen. Ironically, they become more discouraged than employees of a company that hasn't had a history of continual expansion." The employees' main worry, Rechsteiner says, is whether they'll be laid off, or not promoted.

Management tries to dissuade employees from leaving. It highlights the company's good points and compares it with similar companies. Analog's future growth rate depends on its ability to attract, train and develop capable employees. At the end of 1969, the company had a staff of 380 full-time employees, compared with around 255 at the end of 1968.

Problem as old as the industry

Rechsteiner's other major management problem is shifting prices. It's a chronic problem of the electronics industry—one that is not necessarily brought on by the slump, but isn't helped by it, either.

"There aren't many industrial markets," Rechsteiner said, "in which the price is constantly changing as rapidly as it does in the electronics industry."

He indicated that consumer products are less prone to fluctuate in price, but that the price of components, functional circuits and, to a lesser degree, instruments, changes frequently.

One example of changing prices is the computer field in which the cost to the user has gone down tremendously in a short time. Rechsteiner said that four to five years ago computers were confined to business and industrial usage, but with the introduction of minicomputers with applications for home use, the costs have come down. Why? As the computer industry matures, the cost of materials is subject to the same sort of competitive action as products are. And there's a lot of competition because it's still fairly easy to enter the computer market with very little capital.

Production—a must capability

"Our company has recognized," Rechsteiner continued, "that although it was possible to operate inefficiently initially and still survive, we must now maintain a strong manufacturing operation to match our marketing and engineering capability."

President Emil B. Rechsteiner (standing) is shown with other members of the Analog Devices, Inc., corporate staff group, including (left to right) James Hackbush, director of industrial relations; Ray Stata, senior vice president and company co-founder; and Richard I. Krieger, treasurer.

Intrinsic to all manufacturing operations is the problem of trying to stretch the design specs of the product, although the parts may not be improved enough to do so. Rechsteiner says that, when Analog makes a product composed of other companies' components, it has found the following decisions were necessary for success in production:

- Building a new plant in Westwood, Mass., that will give them much-needed space for production work.
- Hiring an experienced production manager and giving him full authority to operate.
- Formalizing meetings and forecasts for the sake of efficiency.

This last decision, according to Rechsteiner, has resulted in weeding out unprofitable custom-made devices and concentrating on standard products and the introduction of new ones.

"We have found," Rechsteiner said, "that by putting restraints on custom product expansion we can benefit from purchasing large volumes of parts for standard products. We found it necessary to curtail production of custom-made products because even when we got the cost down on a custom product, the customer would often either change his specs or find a manufacturer that would produce the item for less."

Rechsteiner believes half his management problems would clear up if employee stockholders, industry-wide, would wait out the stock market and realize that it's subject to cycles.

"Because of the erroneous equation people form between the market and the Gross National Product," he said, "events in the market are going to be acutely felt in our industry, because a large number of electronics companies are either employee-owned or the employees have equity at stake due to the stock options they hold."

"Unfortunately," Rechsteiner continued, "employees forget that the current stock quotation for our company, for instance, does not reflect its true worth. Because the stock is down, they feel that the company is less strong—which is not true—and if they need the money, they sell out, causing the stock to fall further.

Rx for half a headache

"Many branches of the electronics industry did so well in terms of expansion during the past ten years," said Analog's president, "that they find it difficult to cope with the changed conditions at this time. Perhaps the unwarranted optimism that accompanied the rapid growth of the recent past is now matched by an equally unwarranted pessimism at a time when the economy is leveling out." ■■

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INFORMATION RETRIEVAL NUMBER 44

Standby power source uses diodes and battery

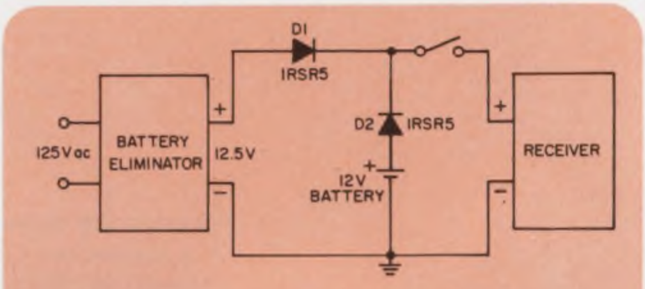
Here's an easy way to provide an instantaneous emergency power supply for small electronic devices—say a transistor radio—normally operated from a battery eliminator.

Two diodes, D_1 and D_2, are connected as shown in the diagram. When the receiver is operated from the power supply, D_2 is reverse-biased. The battery will not be drained, since the power supply output voltage, 12.5 V, is kept slightly higher than the nominal battery voltage, 12 V.

Should the ac power fail, the D_2 reverse-bias voltage is removed. This forward-biases D_2, and the 12-V battery then powers the receiver.

Diode D_1 prevents battery drain through the power supply when the receiver is off.

Thus a simple combination of two diodes, properly rated for the maximum current drain, provides automatic changeover from ac mains to a battery supply. This principle can be extended to cover other types of electronic equipment and instruments.



Emergency supply instantly provides battery power to the receiver when the ac fails. Diodes prevent battery drain under normal operating conditions.

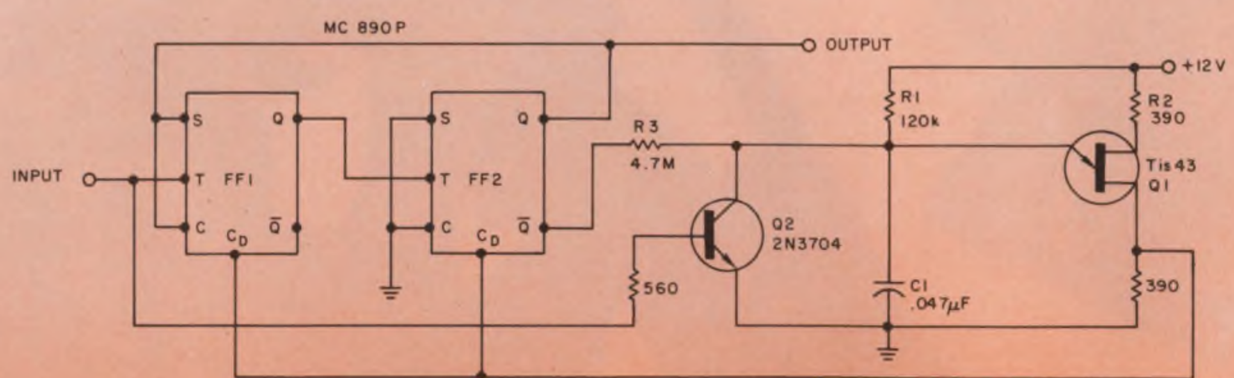
G. N. Sharma and G. N. Acharya, Design Engineers, Central Electronic Engineering Research Institute, Pilani, India.

VOTE FOR 311

Frequency discriminator generates logical output

This circuit, consisting of one dual flip-flop, a unijunction transistor (UJT), Q_1, and a bipolar transistor, Q_2, decides within a single period of the input if this signal's repetition frequency is above or below a desired threshold. According to the decision, it generates a logical ONE or ZERO output.

Q_1 together with R_1 and C_2, forms a free-running oscillator, but the beginning of Q_1's charging period is synchronized through Q_2 by the in-



The output is logical ZERO if the input signal period is greater than the threshold t_0. A logical ONE output results if the input signal period is smaller than t_0.

put signal. The input signal should consist of short pulses that, if not directly available, can be generated by using a Schmitt trigger and differentiating capacitor for input wave shaping.

If the period of the input signal is greater than period t_0, where:

$t_0 = R_1C_1\ln [1/(1-\eta)]$

(η = intrinsic standoff ratio of UJT Q_1), then Q_1 has time to fire and set both flip-flops simultaneously to ZERO. This will happen at least once over every period of the input signal; therefore flip-flop FF2 will never be able to switch to a logical ONE.

If the period of the input signal is smaller than t_0, then the second input pulse will switch FF1 off, causing a negative-going voltage on FF1's Q output, which triggers FF2 to the logical ONE state. A logical ONE on output Q of FF2, which appears exactly one period after signal is supplied to the input, denotes that the input signal has a repetition frequency larger than the threshold frequency $1/t_0$. After this decision has been made, the feedback loop from FF2 to FF1 keeps FF1 from switching. This forces a continuous logical ONE on FF2.

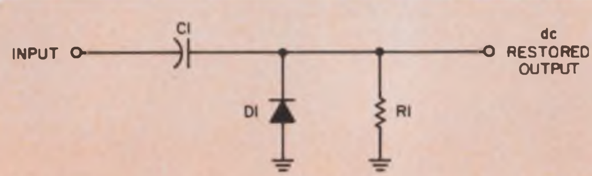
As long as the input signal's period remains shorter than t_0, Q_1 will never fire. C_1 cannot acquire charge since it is constantly shunted by Q_2. If at any time the input period exceeds t_0, Q_1 fires and sets both flip-flops back to ZERO.

Hysteresis is introduced by means of resistor R_3 to provide reliable switching even when there is jitter on the input frequency. When R_2 is chosen for proper UJT firing-period temperature compensation, a threshold stability of better than 1% over 0°C to 70°C is obtained.

J. Diggelmann, Design Engineer, Institut fur Technische Physik an der ETH, Zurich, Switzerland. VOTE FOR 312

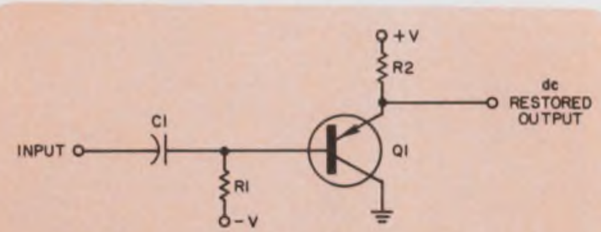
Stable, low-cost dc restorer uses a single transistor

A simple, economical improvement can be made over the standard dc restorer (Fig. 1) by using a transistor as a combination diode and emitter follower (Fig. 2). The base/collector junction of Q_1 serves as the rectifier (similar to D_1 of Fig. 1). C_1 and R_1 form the circuit time constant. R_1 also provides base drive for Q_1, holding it in saturation under static conditions.



1. **A typical dc restorer** suffers from diode temperature sensitivity and moderately high output impedance.

Under signal conditions, negative input forward-biases the Q_1 collector/base junction, clamping the most negative peaks below ground by the base/collector voltage drop. Positive signals drive Q_1 out of saturation into the active region where normal emitter follower action takes place.



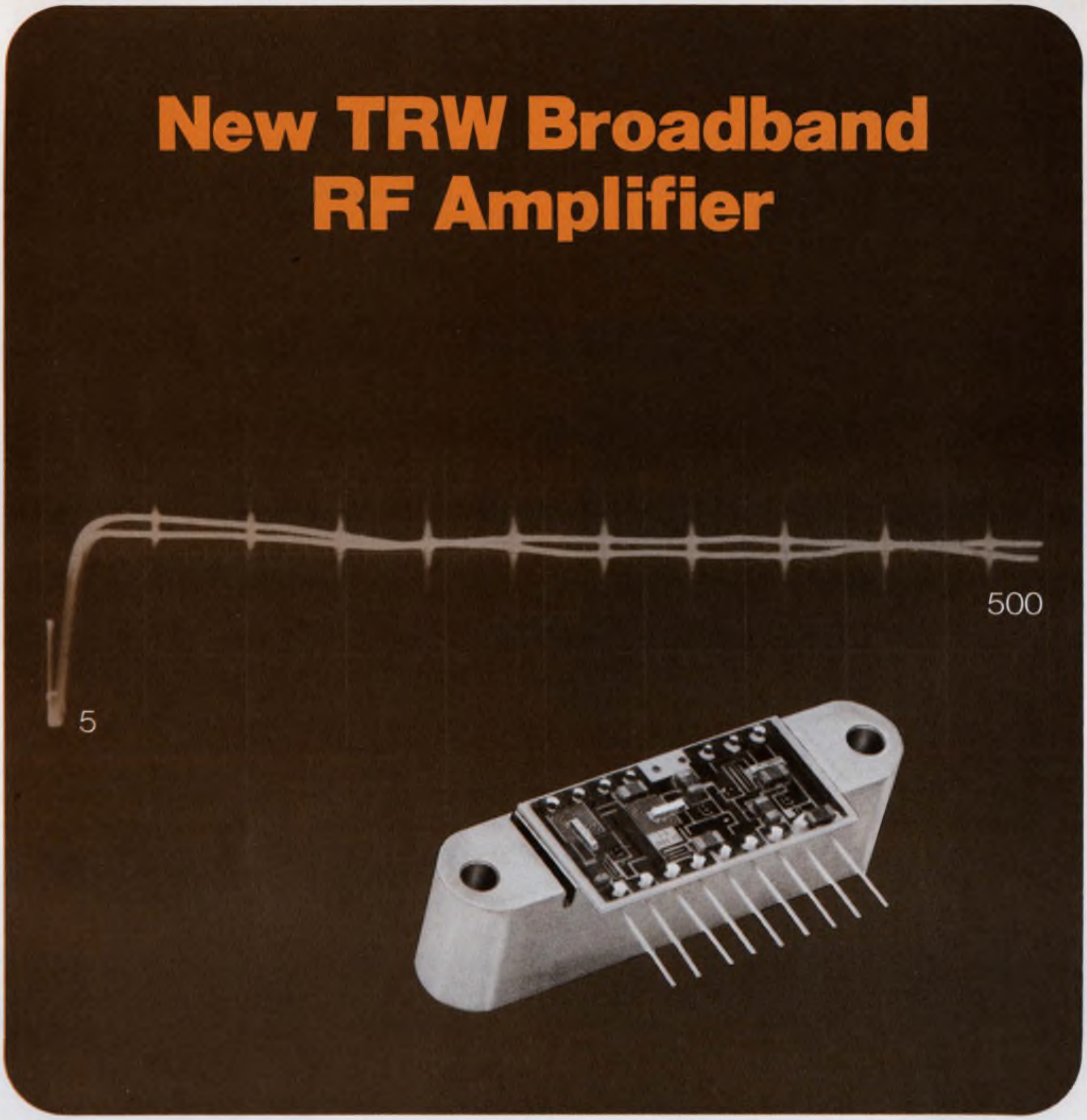
2. **This improved dc restorer** uses Q_1 as both a diode and emitter follower. The low impedance output can drive a wide variety of loads.

There are three main advantages to this circuit:

- The two voltage drops across the transistor junctions effectively cancel each other (both statically and driftwise), and the output is a low-temperature coefficient signal with negative peaks referenced to ground.
- The buffering action of the emitter follower configuration provides a low impedance output that does not affect the input time constant and can drive a wide variety of loads.
- The circuit is simple and inexpensive.

Although the connection shown in Fig. 2 is a pnp negative clamp, positive signals can be easily accommodated by reversing supply polarity and substituting an npn transistor. Best performance is realized by using low $V_{ce\ sat}$ devices such as germanium-alloy switching transistors.

Walter G. Jung, Engineering Consultant, Forest Hill, Md. VOTE FOR 313



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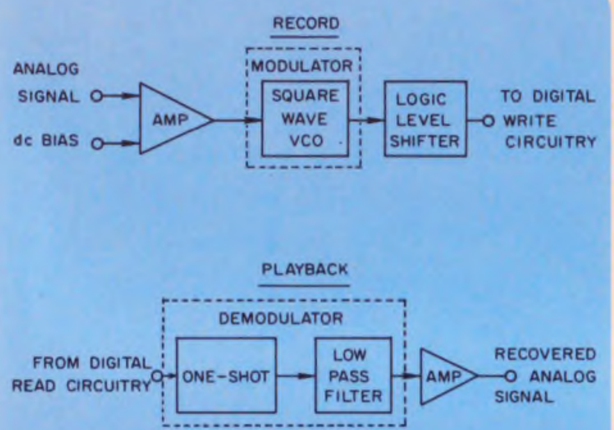
INFORMATION RETRIEVAL NUMBER 46

Digital tape channel converted for analog record/playback

Standard digital tape recorders are designed to accept pulses and are useless for recording analog data unless a/d conversion is employed. Special units, which have separate analog channels, can be purchased at considerable expense. But here is a simple technique for recording analog signals (such as voice) that contain frequency components several times below the digital record head's maximum writing rate. Since the digital recorder cannot respond to amplitude information, a novel frequency modulator is used as the source encoder.



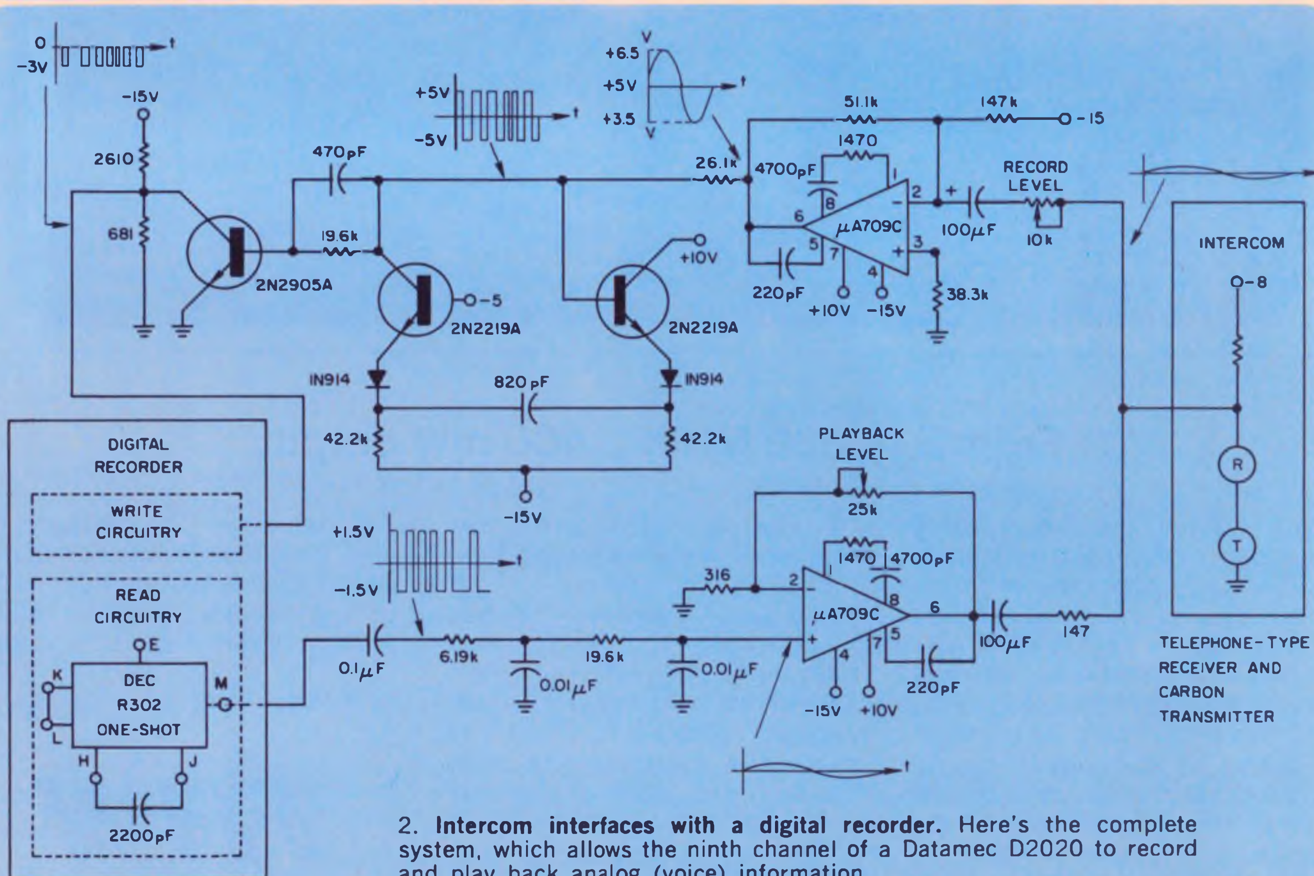
1. **During recording the VCO center frequency is set by dc bias,** and analog input is converted to square-wave FM. Playback recovers the analog signal by responding to the filtered dc level of the one-shot's output.

The heart of the record channel is the voltage-controlled squarewave oscillator (VCO) which is used as the frequency modulator (Fig. 1).[1] As the control voltage from the input amplifier increases, the repetition rate of the oscillator decreases, and vice versa.[2]

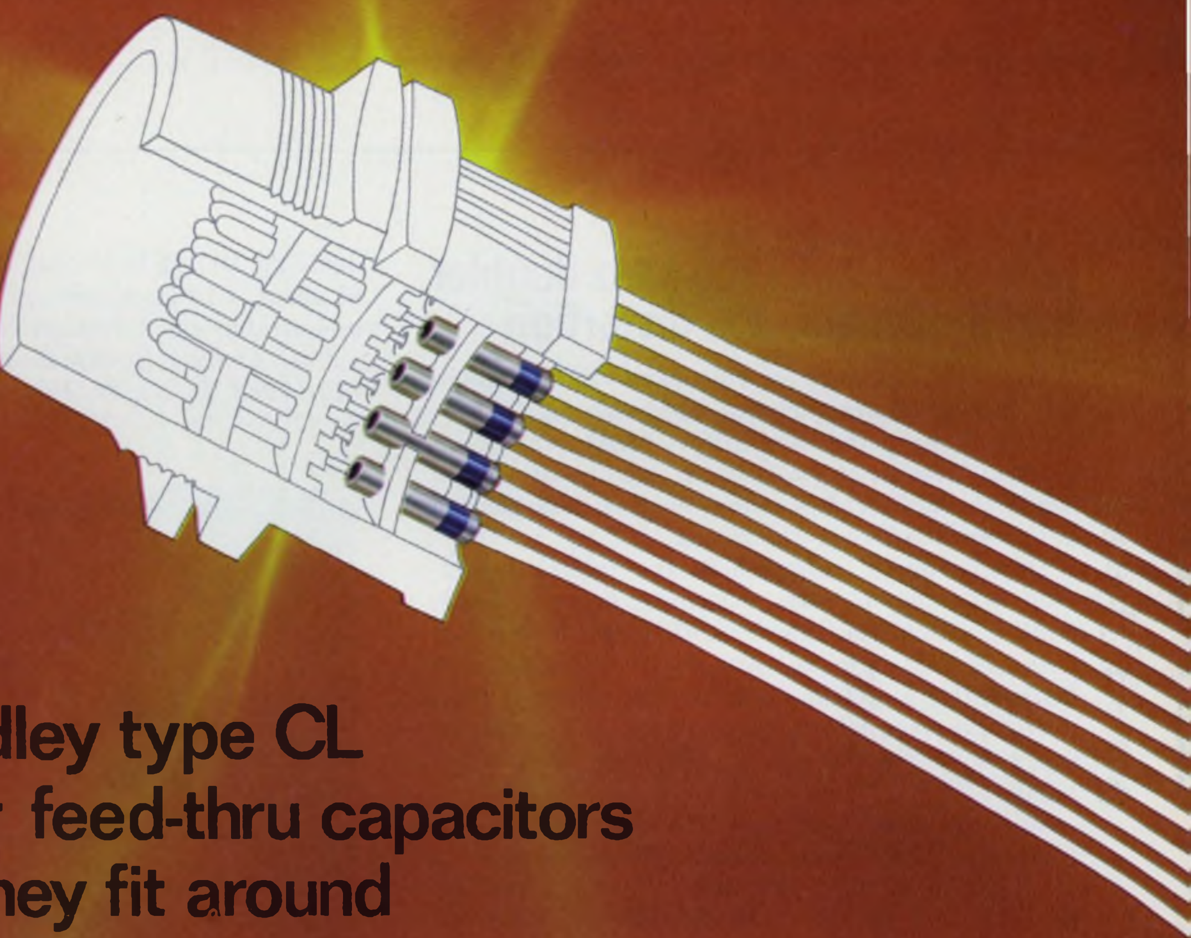
The logic level shifter serves two purposes. It adjusts the output levels to be compatible with the particular digital recorder employed, and it also removes the amplitude modulation inherent in the oscillator output. The dc bias input to the amplifier sets the VCO center frequency.

During playback, the one-shot multivibrator lengthens the narrow pulses received from the read circuits in the digital recorder. The machine for which this system was designed already has a one-shot in the read channel. Thus, only an additional capacitor is necessary to increase the pulse width.

The one-shot output is a frequency-modulated wave of constant pulse width. Hence, the information is contained in the instantaneous dc level.



2. **Intercom interfaces with a digital recorder.** Here's the complete system, which allows the ninth channel of a Datamec D2020 to record and play back analog (voice) information.



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The low-pass filter extracts this dc level, completing the demodulation process.

The system shown in Fig. 2 was designed to record voice from a simple intercom onto the ninth channel of a Datamec D2020 digital tape unit used as part of a PDP-9 computer system. Recorded data can also be played back through the intercom. The center frequency of the modulator is approximately 18 kHz. The frequency deviation is about ±3 kHz.

This method yields results far superior to the zero-crossing technique that symmetrically clips the voice signal. While symmetrical clipping theoretically removes amplitude information only, in practice frequency distortion results from slight imbalances in the zero-crossing detector.

Louis A. Campolo, Electronics Engineer, RCA Defense Electronic Products, Missile and Surface Radar Div., Moorestown, N.J. 08057.

References

1. Zangrillo, S., "Get Wide-Range or VCO Capability From the Basic Astable Multi." *Electronic Design*, March 15, 1969, pp. 272-274.

2. Beneteau, P. J., and Evangelisti, A., "An Improved Emitter-Coupled Multivibrator," *Fairchild Application Data, APP-59*, February, 1963, pp. 1-4.

VOTE FOR 314

Low-cost 100-to-200-MHz doubler has 5-dB gain, 1% distortion

A simple, inexpensive full wave vhf/uhf doubler, having characteristics approaching that of an ideal squaring amplifier—$f(\omega t) = (1 - \cos 2\omega t)/2$—can be made from any one of several readily available ICs, some costing less than a dollar each in large quantities.

Odd harmonic rejection in the full-wave doubler depends on close matching between base-emitter transistor junctions that can be cheaply obtained only in an IC. Any of several integrated differential amplifiers will do, providing the appropriate circuit terminals are available and the units have the necessary high-frequency capability.

For example, the RCA CA3026 has enough transistors for two doublers. These transistors are to be used as a push-push class B amplifier so that it is necessary to saturate or short out the current source transistor normally found in this IC.

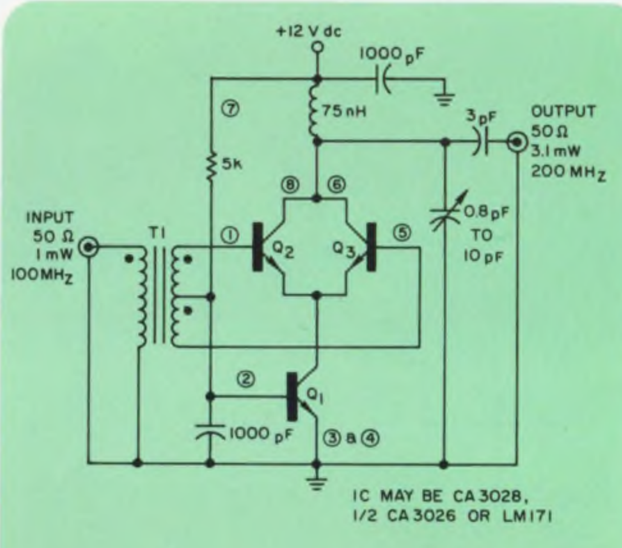
To achieve class B operation, a stable, temperature-compensated bias source is necessary for the common emitter transistors. The CA-3026's current-source transistor (when saturated) makes an ideal bias supply. This biasing produces a small quiescent current that has a slight negative temperature coefficient.

The balanced doubler shown is designed with a broadband input transformer (Balun) and a tuned, narrowband output. An additional 25 dB of fourth harmonic and fundamental attenuation is provided by the output tank circuit. The output waveform of this doubler has less than 1% distortion when driven at about 0 dBm. The third and fourth harmonics are 45 dB down, and the sixth harmonic is 50 dB down. All other harmonics, including the fundamental, are greater than 50 dB down.

The circuit has about 5-dB net gain when doubling 100 MHz to 200 MHz. Limiting begins at about +10 dBm, but operation at this level is undesirable since distortion here is about 10%.

Carl Andren, Electronic Communications, Inc., 1501 72nd St. N., St. Petersburg, Fla. 33733.

VOTE FOR 315



This doubler can be built from any of several suggested ICs. With a broadband Balun input and a tuned narrowband output it provides low distortion, gain and economy at 100 MHz. The Balun has 6 turns of trifilar no. 32 transmission line on a Micrometals T-25-22 core.

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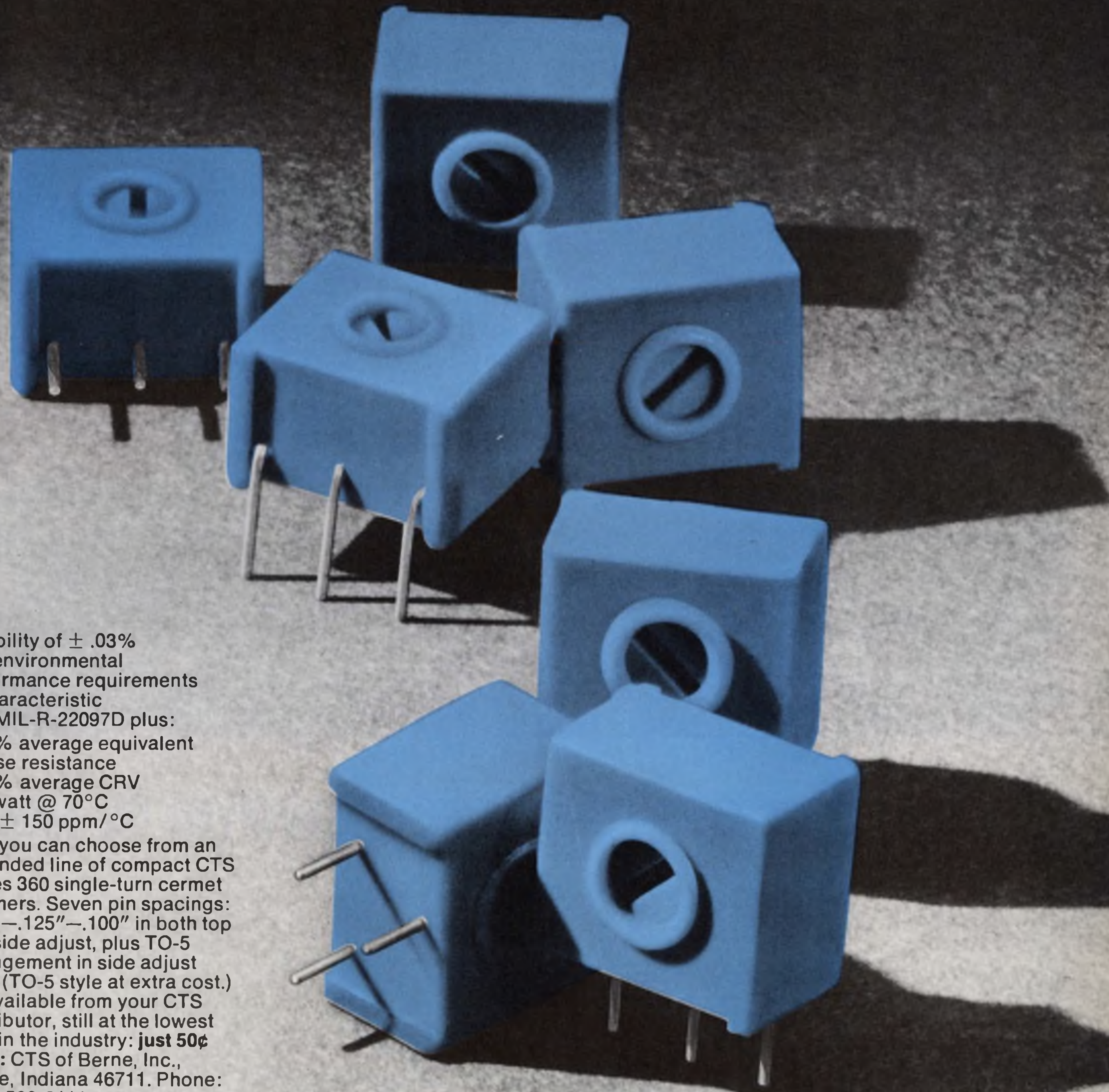

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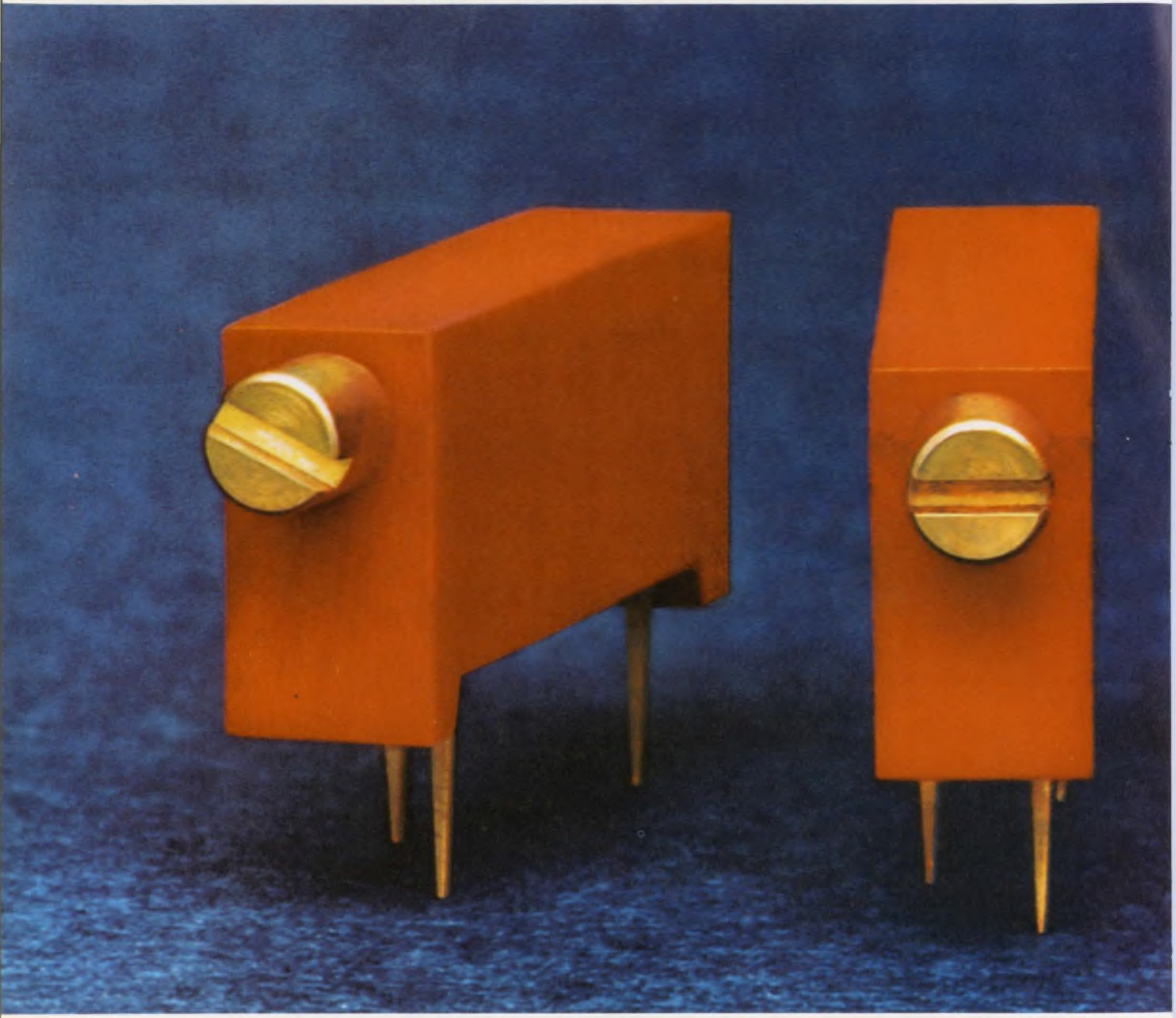

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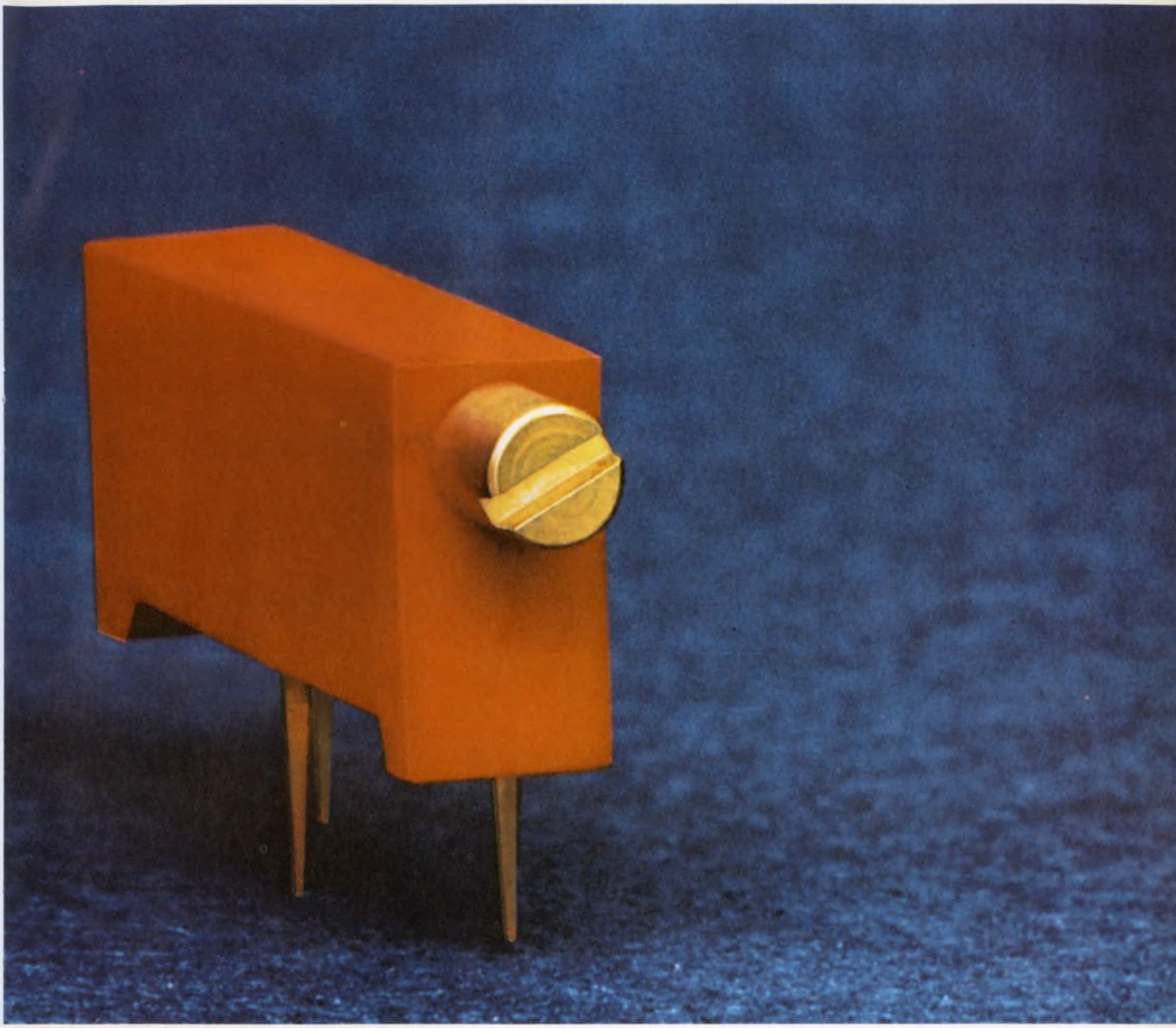

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INFORMATION RETRIEVAL NUMBER 49

Product Source Directory

Trimmer Potentiometers

This Product Source Directory covers trimmer potentiometers.

Units are listed in ascending order according to their maximum resistance value. Each maximum-resistance group is then arranged alphabetically according to manufacturer, and further subdivided numerically per the manufacturer's model number.

All popular trimmer types are included: wirewound, conductive plastic, cermet, and metal and carbon film. The price figures shown represent the cost of a single unit when buying in quantities of 1000.

Manufacturers are identified by the abbreviations shown in the Master Cross Index below. The abbreviation "req" means request.

Abbrev.	Company	Information Retrieval No.
Ace	Ace Electronic Assoc., Inc. 99 Dover St. Somerville, Mass. 02143 (617) 623-3800	448
AB	Allen-Bradley Co. 1201 S. Second St. Milwaukee, Wis. 53204 (416) 671-2000	449
Amphenol	Amphenol Corp. Controls Div. 120 S. Main St. Janesville, Wis. 53545 (608) 754-2211	450
Beckman	Beckman Instruments Inc. Helipot Div. 2500 Harbor Blvd. Fullerton, Calif. 92633 (714) 871-4848	451
Bourns	Bourns, Inc. Trimpot Div. 1200 Columbia Ave. Riverside, Calif. 92506 (714) 684-1700	452
Centralab	Centralab Electronics Div. of Globe-Union Inc. 5757 N. Green Bay Ave. Milwaukee, Wis. 53209 (414) 228-1200	453
Clarostat	Clarostat Manufacturing Co., Inc. Washington St. Dover, N.H. 03820 (603) 742-1120	454

Abbrev.	Company	Information Retrieval No.
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Dale	Dale Electronics Inc. Box 609 Columbus, Neb. 68601 (402) 564-3131	457
Diploh	Diplohmatic Div. Harry Levinson Co. 1211 E. Denny Way Seattle, Wash. 98122 (206) 323-5100	458
Electra	Electra/Midland Corp. Cermetrik Div. 3347 Industrial Ct. San Diego, Calif. 92121 (714) 453-0353	459
Fairchild	Fairchild/Controls 225 Park Ave. Hicksville, N.Y. 11802 (516) 938-5600	460
Fluke	John Fluke Manufacturing Co., Inc. Box 7428 Seattle, Wash. 98133 (206) 774-2211	461

Abbrev.	Company	Information Retrieval No.
Mark	Mark Micro-Electronics Mfg. Co. Potentiometer Products Div. 21 Cottage St. Bayonne, N.J. 07002 (201) 339-2121	**462**
Maurey	Maurey Instrument Corp. 4555 W. 60th St. Chicago, Ill. 60629 (312) 581-4555	**463**
Minelco	Minelco 600 South St. Holbrook, Mass. 02343 (617) 963-7717	**464**
NEI	New England Instrument Co. 14 Kendall Lane Natick, Mass. 01760 (617) 873-9711	**465**
Ohmite	Ohmite Manufacturing Co. 3635 Howard St. Skokie, Ill. 60076 (212) 675-2600	**466**
PEC	Precision Electronic Components, Ltd. 19 Hafis Rd. Toronto, Ontario, Canada (416) 249-7103	**467**
Spectrol	Spectrol Electronics Corp. 17070 E. Gale Ave. City of Industry, Calif. 91745 (213) 964-6565	**468**
Stackpole	Stackpole Components Corp. P.O. Box 14466 Raleigh, N.C. 27610 (919) 828-6201	**469**
Techno	Techno-Components Corp. 7803 Lemona Ave. Van Nuys, Calif. 91405 (213) 781-1642	**470**
TRW	TRW Inc. IRC Div. 1100 Glendon Ave. Los Angeles, Calif. 90024 (213) 477-6061	**471**
Vishay	Vishay Instruments Resistor Products Div. 64 Lincoln Hwy. Malvern, Pa. 19355 (215) 644-1300	**472**
Waters	Waters Manufacturing 533 Boston Post Rd. Wayland, Mass. 01778 (617) 358-2777	**473**
Weston	Weston Instruments Archbald Div. Archbald, Pa. 18403 (717) 876-1500	**474**

Trimmer Potentiometers

Manufacturer	Model	Type	Resistance Range (Min-Max, kΩ)	Tolerance %	Power Rating (Watts at °C)	Number of Turns	Operating Range °C	Notes	Price $/1000
Clarostat	39	wirewound	0.004-5	±20	2 at 40	1	105 max		0.165
Techno	RT27	wirewound	0.01-5	±5	0.5 at 85	25	-50 to +175	h (19)	req
Amphenol	2301	metal film	0.01-10	±10	0.5 at 85	26	-55 to +150	f (28) (29)	4.81
CTS	110	wirewound	0.0005-10	±20	2 at 55	1	105 max	(8)	0.14
Maurey	25-M11	wirewound	0.025-10	±10	0.3 at 85	1	-55 to +150		2
Maurey	37-M13	wirewound	0.05-10	±5	0.5 at 85	1	-55 to +135		5
NEI	C	plastic	1-10	±20	1 at 70	1	-65 to +125	(10)	4.99
Techno	117S, 126S, 133S, 151S, 176S, RT24	wirewound	0.01-10	±5	0.5 at 85	25	-65 to +175	h (11)	req
Techno	RTR24	wirewound	0.01-10	±5	0.5 at 85	25	-65 to +175	(20)	req
Vishay	1202	metal film	0.002-10	±5	0.5 at 85	25	-55 to +150	adhi (30)	4.55
Waters	JP/2C	wirewound	0.02-10	±10	2 at 40	1	-55 to +105	g	req
Minelco	MP2, 5	wirewound	0.02-15	±10	0.25 W	1	-55 to +125	(16)	5.50
Minelco	MS1, 2, 4, 5, 7	wirewound	0.02-15	±10	0.25 W	1	-55 to +150		8
Amphenol	2300	wirewound	0.01-20	±5	0.75 at 85	26	-55 to +150	fh	4.10
Amphenol	2600	wirewound	0.01-20	±10	1 at 40	22	-55 to +125	b (28)	1.06
Amphenol	2610	wirewound	0.01-20	±10	1 at 40	22	-55 to +125	b (28)	1.43
Amphenol	2851	metal film	0.02-20	±10	0.75 at 85	22	-55 to +150	d (28) (29)	4.28
Amphenol	2901	metal film	0.01-20	±10	0.75 at 85	25	-55 to +150	e (28) (29)	4.70
Amphenol	3600	wirewound	0.1-20	±10	0.5 at 40	23	-55 to +125	f (28)	1.77
Amphenol	3610	wirewound	0.01-20	±10	0.5 at 40	23	-55 to +125	f (28)	2.13
Amphenol	3800	wirewound	0.01-20	±10	1 at 40	23	-55 to +125	b (28)	1.06
Amphenol	3810	wirewound	0.01-20	±10	1 at 40	23	-55 to +125	b (28)	1.29
Amphenol	3811	metal film	0.01-20	±10	0.75 at 40	15	-55 to +125	b (28)	1.77
Bourns	3065	wirewound	0.05-20	±10	0.5 at 25	15	-55 to +85	c	1.23
Bourns	3067	wirewound	0.05-20	±10	0.5 at 25	15	-55 to +85	c	1.14
CTS	P115	wirewound	0.0005-20	±10	2 at 55	1	105 max	(8)	0.21
CTS	117	wirewound	0.0005-20	±10	2 at 55	1	105 max	(8)	0.22
Clarostat	76	wirewound	0.1-20	±5	0.75 at 85	11.5	150 max		4.75
Minelco	MP32	wirewound	0.01-20	±10	0.5 W	1	-55 to +150		4.50
Spectral	51	wirewound	0.01-20	±5	0.75 at 85	23	-65 to +150	f (28) (29)	3.31
Spectral	94	wirewound	0.05-20	±10	0.5 at 70	22	-65 to +105	(28)	1.85
Techno	75S-CT	wirewound	0.1-20	±5	0.5 at 85	25	-65 to +175		req
TRW	300	wirewound	0.05-20	±5	0.6 at 60	1	-55 to +150	e	2.60
TRW	650	cermet	0.01-20	±5	0.75 at 85	22	-65 to +150	du	3.43
TRW	800	wirewound	0.01-20	±5	0.6 at 70	15	-65 to +150	(13)	2.22
TRW	900	wirewound	0.01-20	±10	1 at 40	20	-65 to +125	b	1.23
TRW	940	wirewound	0.01-20	±10	1 at 40	18	-65 to +125	(15)	2.25
Vishay	1201	metal film	0.002-20	±5	0.75 at 85	25	-55 to +150	adi (30)	6.40
Waters	APD 1/2	wirewound	0.01-20	±5	1 at 60	1	-65 to +125	g (16)	req
Waters	JP/2	wirewound	0.02-20	±5	2 at 85	1	-65 to +150	g	req
Waters	JPD/2	wirewound	0.02-20	±5	1 at 85	1	-65 to +150	g (22) (28)	req
Waters	PT 3/4C	wirewound	0.025-20	±10	2 at 85	1	-65 to +150	(8) (28)	req
Weston	313, 318	wirewound	0.2-20	±5	0.75 at 85	45	-55 to +150	e (29)	7.05
Weston	501, 502	wirewound	0.01-20	±5	0.6 at 70	15	-55 to +150	(13)	1.96
Weston	504, 505	wirewound	0.01-20	±5	0.6 at 70	1	-55 to +150	(13)	1.89
Weston	561, 562	wirewound	0.01-20	+5	0.25 at 85	13	-55 to +150	(3) (29)	4.14
Ace	CP05	plastic	1-25	±10	0.3 at 70	1	-65 to +125	g	req
Bourns	3005	wirewound	0.01-25	±10	1 at 40	20	-55 to +125	b	1.30
Bourns	3260	wirewound	0.01-25	±5	0.2 at 70	11	-65 to +175	(3)	4.63
Bourns	3300	wirewound	0.01-25	±5	0.5 at 70	1	-65 to +175	(4)	3.96
Bourns	3305	wirewound	0.01-25	±5	0.5 at 70	1	-55 to +125	(4)	1.17
Diploh	301	wirewound	0.01-25	±10	0.5 at 40	(12)	-50 to +125		0.40
Maurey	50-M124	wirewound	0.05-25	±5	1.5 at 125	1	-55 to +175		11
Minelco	MS37	wirewound	0.02-25	±10	0.75 W	1	-55 to +150		7.95
Techno	12S, 14S, 15S	wirewound	0.01-25	±5	0.5 at 85	25	-50 to +175	h	req
Techno	17S, 18S	wirewound	0.01-25	±5	0.5 at 85	25	-65 to +175	h	req
Weston	561, 562	wirewound	0.01-25	±5	0.25 at 70	13	-55 to +175	(3)	4.14
Weston	510	wirewound	0.01-30	±5	1 at 50	1	-55 to +175	(27)	3.77-5.29
Ace	CP08	plastic	1-50	±10	0.5 at 70	1	-65 to +125	(8)	req
Amphenol	992	wirewound	0.01-50	±5 or ±10	1 at 40	22	-55 to +125	d (28)	1.82
Amphenol	994	wirewound	0.01-50	±10	1 at 40	22	-55 to +125	d (28)	1.85
Amphenol	2700	wirewound	0.01-50	±5	0.75 at 85	15	-55 to +150	chp	3.64
Amphenol	2750	wirewound	0.01-50	±5	0.75 at 85	22	-55 to +150	chr	3.05
Amphenol	2850	wirewound	0.01-50	±5	0.75 at 85	22	-55 to +150	dhq	3.05
Amphenol	2860	wirewound	0.01-50	±5	0.75 at 85	22	-55 to +150	d (28)	2.90
Amphenol	2900	wirewound	0.01-50	±5	0.75 at 85	25	-55 to +150	ehs	2.65
Amphenol	6900	wirewound	0.01-50	±10	1 at 40	1	-55 to +125	g (28)	1.94
Bourns	271, 3, 5	wirewound	0.01-50	±10	0.5 at 20	25	-55 to +105	d	1.96
Bourns	3250	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	e	4.14
Bourns	3255	wirewound	0.01-50	±5	1 at 50	25	-65 to +150	e	1.96
Bourns	3280	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	f	4.66
Bourns	3290	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	f	4.52
Bourns	3365	wirewound	0.01-50	±5	1 at 25	1	-55 to +125	g	2.05
Bourns	3367	wirewound	0.01-50	±5	0.5 at 70	1	-55 to +105	g	3
Dale	2300	wirewound	0.01-50	±10	0.5 at 25	15	-55 to +105	c	req
Dale	2400	wirewound	0.01-50	±10	1 at 40	20	-55 to +125	b	req
Dale	5000	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	s	req
Dale	5800	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	(11)	req
Maurey	50-M7	wirewound	0.05-50	±5	1.5 at 85	1	-55 to +135		5

a. infinite resolution
b. 3/4-in. rectangular
c. 1-in. rectangular
d. 1-1/4-in. rectangular
e. 1/2-in. square
f. 3/8-in. square
g. 1/2-in. round
h. meets MIL-R-27208
i. meets MIL-R-22097
j. front-panel mounting
k. rear-panel mounting
m. top adjust
n. side adjust
p. style RT10
q. style RT11
r. style RT12
s. style RT22
t. style RJ24
u. style RJ11
v. style RJ22
w. style RJ50
x. thumbwheel adjust
y. leads
z. pins
1) solder lugs
2) style RJ12
3) 1/4-in. square
4) 5/16-in. round
5) 1/2-in. rectangular
6) 1/4-in. round
7) 11/32-in. round
8) 3/4-in. round
9) 19/32-in. round
10) bushing mounting
11) style RT24
12) linear slider
13) 5/16-in. square
14) 1.5-in. round
15) 3/4-in. dual-in-line
16) PC-board mounting
17) 7/8-in. round
18) TO-9 transistor can
19) style RT27
20) meets MIL-R-39015
21) dual unit
22) meets MIL-R-39002
23) meets MIL-E-5272
24) concentric shafts
25) 1-1/8-in. round
26) 1-1/16-in. round
27) TO-5 transistor can
28) industrial/commercial grade
29) military grade
30) temperature coefficient of ±10 ppm/°C
31) temperature coefficient of ±150 ppm/°C
32) temperature coefficient of ±100 ppm/°C
33) 1-7/16-in. round
34) 1-3/4-in. round
35) 2-in. round
36) 3-in. round
37) 3/8-in. round
38) 0.516 by 0.68 by 0.25 in.
39) 0.406 by 0.438 by 0.12 in.
40) 0.923 by 1.91 by 0.506 in.
41) 0.702 by 0.75 by 0.6 in.
42) triple unit
43) 0.6-in. round

Trimmer Potentiometers

Manufacturer	Model	Type	Resistance Range (Min-Max, kΩ)	Tolerance %	Power Rating (Watts at °C)	Number of Turns	Operating Range °C	Notes	Price $/1000
Maurey	50-M34	wirewound	0.05-50	±5	1.5 at 85	1	-55 to +135		8
Maurey	50-M128	wirewound	0.05-50	±5	1.5 at 85	1	-55 to +135		8
Maurey	50-M149	wirewound	0.05-50	±5	1.5 at 135	1	-55 to +135		8
Spectrol	55	wirewound	0.01-50	±5	1.5 at 70	23	-65 to +150	s (28) (29)	3.63
Spectrol	74	wirewound	0.01-50	±10	1 at 70	22	-65 to +125	(28)	2.90
Spectrol	80	wirewound	0.01-50	±5	1 at 50	1	-65 to +150	(18)	2.20
Spectrol	84	wirewound	0.01-50	±5	1.5 at 70	1	-65 to +125	x (10)	1.95
Techno	101S, 104S	wirewound	0.01-50	±5	0.5 at 85	25	-65 to +175	y	req
Techno	191S, 192S, 193S	wirewound	0.01-50	±5	1 at 50	25	-65 to +175	(21)	req
Techno	105S, 160S	wirewound	0.01-50	±5	0.5 at 85	25	-65 to +175	jy (1)	req
TRW	60	wirewound	0.01-50	±10	1 at 70	22	-55 to +125	dq	2.12
TRW	100	wirewound	0.01-50	±5	1 at 70	1	-55 to +150	g	2.05
TRW	205	wirewound	0.01-50	±5	1 at 70	25	-65 to +175	es	3.16
TRW	500	wirewound	0.01-50	±10	0.5 at 70	1	-55 to +105	g	1.30
TRW	700	wirewound	0.01-50	±5	0.75 at 85	21	-65 to +175	f (11)	4.55
TRW	5001	wirewound	0.01-50	±5	2 at 40	1	-55 to +150	g	7
TRW	7501	wirewound	0.05-50	±5	2.25 at 40	1	-55 to +150	(8)	7
Weston	517	wirewound	0.01-50	±5	1 at 55	1	-55 to +125	g	1.19-1.51
Weston	530, 531	wirewound	0.01-50	±10	1 at 40	15	-55 to +125	b	0.97-1.07
Weston	543, 544, 545	wirewound	0.01-50	±5	1 at 70	25	-55 to +175	f	3.57
Weston	543, 544, 545	wirewound	0.01-50	±5	0.75 at 85	25	-55 to +150	f (29)	3.95
Weston	550, 551, 552	wirewound	0.01-50	±5	1 at 70	35	-55 to +150	e	1.86
Weston	553, 554, 555	wirewound	0.01-50	±5	1 at 70	35	-55 to +175	e	2.99
Weston	553, 554, 555	wirewound	0.01-50	±5	0.75 at 85	35	-55 to +150	e (29)	3.16
Weston	701	wirewound	0.01-50	±5	1 at 70	37	-55 to +175	e	1.79
Weston	701	wirewound	0.01-50	±5	0.75 at 85	35	-55 to +150	e (29)	2.29
Weston	534, 535, 539	wirewound	0.01-50	±5	1 at 70	24	-55 to +175	d (28)	3.41
Weston	534, 535, 539	wirewound	0.01-50	±5	0.75 at 85	24	-55 to +150	d (29)	3.41
Fairchild	6010	wirewound	0.01-75	±5	0.75 at 85	22	-55 to +175	d	2.41
Fairchild	6020	wirewound	0.01-75	±5	0.75 at 85	22	-55 to +175	d	2.56
Ace	CP09	plastic	0.5-100	±10	0.5 at 70	1	-65 to +125	(17)	req
Bourns	200	wirewound	0.01-100	±10	0.5 at 70	25	-65 to +125	d	3
Bourns	224	wirewound	0.01-100	±20	1 at 70	22	-65 to +175	d	4.33
Bourns	260	wirewound	0.01-100	±10	1 at 70	25	-65 to +175	d	3.66
Bourns	3010	wirewound	0.01-100	±5	1 at 70	25	-65 to +175	d	4.33
Dale	100	wirewound	0.01-100	±5	0.8 at 70	25	-65 to +135	d	req
Dale	200	wirewound	0.01-100	±10	0.5 at 70	25	-65 to +105	d	req
Dale	300	wirewound	0.01-100	±15	0.25 at 70	25	-65 to +85	d	req
Dale	600	wirewound	0.01-100	±5	1 at 70	15	-65 to +175	p	req
Dale	1100	wirewound	0.01-100	±10	1 at 70	25	-65 to +175	d	req
Dale	1200	wirewound	0.01-100	±5	1 at 70	15	-65 to +175	q	req
Dale	1600	wirewound	0.01-100	±5	1 at 70	22	-65 to +175	r	req
Dale	2100	wirewound	0.01-100	±10	1 at 70	25	-65 to +125	q (28)	req
Dale	2200	wirewound	0.01-100	±10	1 at 70	15	-65 to +125	p (28)	req
Fluke	23A, 24A	wirewound	0.1-100	±3	3 at 25	1.5	100 max		7
Fluke	30A	wirewound	1-100	±5	5 at 20	2.5	100 max		20
Maurey	50-M123	wirewound	0.05-100	±5	1.5 at 88	1	-55 to +135		5
Minelco	MF2	metal film	0.01-100	±10	0.25 W	1	-55 to +125		6.75
Ohmite	ANP	wirewound	0.1-100	±20	0.33 at 50	25	-55 to +100		req
Spectrol	42	wirewound	0.01-100	±5	1 at 70	22	-65 to +175	r (28) (29)	3.27
Spectrol	44	wirewound	0.01-100	±5	1 at 70	22	-65 to +175	q (28) (29)	3.27
TRW	151	wirewound	0.1-100	±5	3.5 at 40	1	-55 to +125	(14)	7
TRW	400	wirewound	0.01-100	±5	1 at 70	22	-65 to +150	dr	3.25
TRW	600	wirewound	0.01-100	±5	1 at 70	22	-65 to +150	dq	3.25
Waters	AP 1/2	wirewound	0.01-100	±5	2 at 60	1	-65 to +125	g (29)	req
Waters	APH 1/2	wirewound	0.01-100	±5	2 at 60	1	-55 to +125	g (23)	req
Waters	APR 1/2	wirewound	0.01-100	±5	2 at 60	1	-65 to +125	g	req
Waters	APW 1/2	wirewound	0.01-100	±5	2 at 60	1	-65 to +125	g (23)	req
Weston	534, 535, 539	wirewound	0.01-100	±5	1 at 70	24	-55 to +175	q	3.41
Weston	534, 535, 539	wirewound	0.01-100	±5	0.75 at 85	24	-55 to +150	d (29)	3.41
Ace	CP11	plastic	0.5-200	±10	0.75 at 70	1	-65 to +125	(26)	req
Ace	CP15	plastic	0.5-200	±10	1 at 70	1	-65 to +125	(33)	req
Ace	CP18	plastic	0.5-200	±10	1.5 at 70	1	-65 to +125	(34)	req
Waters	APC 7/8	wirewound	0.01-250	±5	3 at 60	1	-65 to +150	(17) (24)	req
Waters	MAP 1/2	plastic	0.5-250	±10	1 at 65	1	-65 to +125	g	req
Waters	MAPW 1/2	plastic	0.5-250	±10	1 at 65	1	-55 to +125	g	req
Waters	PT 112-M	plastic	0.01-250	±10	2 at 40	1	-55 to +125	(25)	req
Waters	PT 112W	wirewound	0.05-250	±10	2 at 40	1	-55 to +125	(25) (28)	req
Waters	RT 7/8	wirewound	0.01-250	±5	2 at 85	1	-65 to +150	(17) (29)	req
Waters	RT 7/8M	plastic	0.5-250	±10	1 at 60	1	-65 to +125	(17)	req
Ace	CP20	plastic	0.5-300	±10	2 at 70	1	-65 to +125	(35)	req
Waters	AP 1 1/16	wirewound	0.025-300	±5	4 at 60	1	-65 to +125	(26) (27)	req
Waters	AP 1 1/8	wirewound	0.025-300	±5	4 at 60	1	-65 to +125	(25) (29)	req
Waters	APC 1 1/8	wirewound	0.025-300	±5	4 at 60	1	-65 to +150	(24) (25)	req
Ace	APO5	wirewound	0.01-500	±5	2 at 85	1	-65 to +125	g	req
Ace	APO8	wirewound	0.02-500	±5	2 at 85	1	-65 to +125	(8)	req
Ace	APO9	wirewound	0.02-500	±5	2.5 at 85	1	-65 to +125	(17)	req
Ace	AP11	wirewound	0.025-500	±5	3 at 85	1	-65 to +125	(26)	req
Ace	AP15	wirewound	0.025-500	±5	3 at 85	1	-65 to +125	(33)	req
Ace	AP18	wirewound	0.025-500	±5	3.5 at 85	1	-65 to +125	(34)	req

Trimmer Potentiometers

Manufacturer	Model	Type	Resistance Range (Min-Max, KΩ)	Tolerance %	Power Rating (Watts at °C)	Number of Turns	Operating Range °C	Notes	Price $/1000
Ace	CP30	plastic	1-500	±10	3 at 70	1	-65 to +125	(36)	req
CTS	385	cermet	0.02-500	±10	0.125 at 125	1	175 max	(7)	3.35
CTSB	190	cermet	0.05-500	±20	0.5 at 85	20	-55 to +150	b	1.20
CTSB	195	cermet	0.05-500	±20	0.75 at 85	23	-55 to +150	d	2.71
CTSB	340	cermet	0.05-500	±20	0.75 at 25	1	-55 to +150	m (3)	1.25
CTSB	385	cermet	0.02-500	±20	0.125 at 125	1	-55 to +150	(7)	3.10
Ace	AP20	wirewound	0.025-750	±5	4 at 85	1	-65 to +125	(35)	req
AB	S	cermet	0.05-1000	±10	0.5 at 85	1	-65 to +150	(37)	1.15
AB	Z	cermet	0.05-1000	±10 or ±20	0.5 at 70	1	-55 to +125	(3)	1.20-1.40
Ace	AP30	wirewound	0.025-1000	±5	6 at 85	1	-65 to +125	(36)	req
Amperex	EC86	carbon film	0.1-1000	±20	0.1 at 40	1	-10 to +70		8
Amphenol	2305	cermet	0.02-1000	±10	0.5 to 85	26	-55 to +150	fit	4.34
Amphenol	2855	cermet	0.1-1000	±10	0.75 at 85	22	-55 to +150	diu	3.32
Beckman	61	cermet	0.01-1000	±10	0.5 at 85	1	-65 to +150	aijkmnw	4.13-4.88
Beckman	62	cermet	0.01-1000	±10	0.5 at 70	1	-25 to +125	amnx	1.31-1.88
Bourns	3012	cermet	0.01-1000	±10	1 at 70	22	-65 to +175	d	3.96
Bourns	3052	cermet	0.01-1000	±10	1 at 70	22	-65 to +175	d	3.96
Bourns	3068	plastic	20-1000	±20	0.2 at 25	15	-55 to +85	c	1.14
Bourns	3251	plastic	20-1000	±20	0.5 at 50	25	-65 to +150	e	4.83
Bourns	3262	cermet	0.01-1000	±10	0.25 at 85	12	-65 to +175	(3)	4.08
Bourns	3281	plastic	20-1000	±20	0.5 at 50	25	-65 to +150	f	4.66
Bourns	3282	cermet	0.01-1000	±10	0.5 at 85	25	-65 to +175	f	4.34
Bourns	3292	cermet	0.01-1000	±10	0.5 at 85	22	-65 to +175	f	4.34
Bourns	3329	cermet	0.01-1000	±20	0.5 at 85	1	-55 to +150	(6)	1.22
Bourns	3339	cermet	0.01-1000	±20	0.5 at 85	4	-55 to +150	(6)	1.46
CTS	175	cermet	0.05-1000	±10	0.5 at 85	35	150 max		3.25-3.45
CTS	185	cermet	0.025-1000	±10	1 at 85	25	175 max		2.28-2.58
CTS	195	cermet	0.02-1000	±10	0.75 at 85	23	150 max		2.86
CTS	340	cermet	0.01-1000	±20	0.5 at 85	1	150 max	(3)	1.25
CTS	360	cermet	0.05-1000	±20	0.5 at 70	1	125 max	mn	0.66
CTS	RJ22	cermet	0.05-1000	±10	0.5 at 85	35	150 max		3.60-3.70
CTS	RJ24	cermet	0.05-1000	±10	0.5 at 85	25	150 max		3.70-3.75
CTS	RVC6	cermet	0.1-1000	±10	0.75 at 85	1	175 max	(10)	2.94
CTSB	165	cermet	0.05-1000	±20	0.5 at 85	25	-55 to +150	f	3
CTSB	170	cermet	0.05-1000	±20	0.75 at 85	42	-65 to +150	e	4.05
CTSB	175	cermet	0.05-1000	±20	0.5 at 85	35	-55 to +150	iv	2.95
CTSB	185	cermet	0.025-1000	±20	1 at 85	25	-55 to +150	(10)	2.18
CTSB	360	cermet	0.05-1000	±20	1 at 25	1	-55 to +125	mn	0.65
Clarostat	371	carbon film	0.1-1000	±20	0.375 at 70	1	120 max		0.65
Centralab	Centrim	carbon film	0.1-1000	±20	0.5 at 70	1	-55 to +150	(38)	0.30
Diploh	311	cermet	0.1-1000	±10	1 at 25	(12)	-55 to +125		0.75
Fairchild	6011, 21, 22	metal film	0.01-1000	±10	0.75 at 85	22	-55 to +175	d	3.60
Fairchild	6023	metal film	0.01-1000	±20	0 at 125	22	-25 to +125	d	2.15
Fairchild	6031	metal film	0.01-1000	±10	0.5 at 85	15	-55 to +125	b	1.55
Fairchild	6033	metal film	0.01-1000	±20	0.5 at 85	15	-55 to +125	b	1.20
Fairchild	6035	metal film	0.01-1000	±30	0.5 at 85	15	-55 to +125	b	1.20
Fairchild	6121	metal film	0.01-1000	±5	0.5 at 85	27	-55 to +150	f	2.60
Fairchild	6123	metal film	0.01-1000	±10	0.5 at 85	27	-55 to +150	f	2.20
Fairchild	6125	metal film	0.01-1000	±20	0.5 at 85	27	-55 to +150	f	2.20
Mark	B	cermet	0.01-1000	±1 to ±20	0.5 at 85	1	-55 to +150	h	0.47
PEC	AC	cermet	0.1-1000	±10 or ±20	1 W	22	-50 to +125	(28)	1.25
PEC	RJ11	cermet	0.1-1000	±10	1 W	22	-65 to +150	i (29)	2.05
Spectrol	41	cermet	0.1-1000	±10 or ±20	0.75 at 25	15	-65 to +125	uz (16)	1.25
Spectrol	53	cermet	0.1-1000	±10 or ±20	0.5 at 85	1	-65 to +125	mn	1.10
Spectrol	62	cermet	0.1-1000	±10 or ±20	0.75 at 25	1	-65 to +125	mnw (16)	1.15
Spectrol	78	cermet	0.1-1000	±20	0.75 at 70	22	-25 to +125	(2)	2.01
Spectrol	949	cermet	0.1-1000	±20	0.75 at 70	22	-25 to +105	(28)	1.78
Techno	226, 251, 276	cermet	0.2-1000	±10	0.5 at 85	25	-65 to +175	i	req
TRW	450	cermet	0.01-1000	±10	0.75 at 85	22	-55 to +150	d (2)	3.43
TRW	750	cermet	0.01-1000	±10	0.5 at 70	19	-65 to +150	ft	4.86
TRW	850	cermet	0.01-1000	±10	0.3 at 70	13	-65 to +150	(13)	3.42
TRW	950	cermet	0.01-1000	±10	0.75 at 25	20	-65 to +150	b	1.14
TRW	990	cermet	0.01-1000	±10	0.75 at 40	18	-65 to +150	(15)	2.25
Waters	AP 1 1/16-M	plastic	1-1000	±10	2 at 60	1	-65 to +125	(26)	req
Waters	AP 1 1/8-M	plastic	1-1000	±10	2 at 60	1	-65 to +125	(25)	req
Weston	532, 533	cermet	0.01-1000	±10	0.75 at 25	15	-55 to +125	b	1.07
Weston	546, 547, 548	cermet	0.01-1000	±10	0.5 at 85	25	-55 to +150	f (29)	3.49
Weston	566, 567, 568, 569	cermet	0.01-1000	±10	0.5 at 70	1	-55 to +150	(6) (28)	1.04-1.60
Beckman	50	cermet	0.01-2000	±10	1.5 at 125	32	-65 to +200	ay	6.00
Beckman	53	cermet	0.01-2000	±10	1.5 at 125	32	-65 to +200	az	5.62
Beckman	54	cermet	0.01-2000	±10	1.5 at 125	32	-65 to +200	a (1)	5.62
Beckman	55	cermet	0.01-2000	±10	1 at 85	22	-65 to +175	aiuyz (1)	4.13
Beckman	56	cermet	0.01-2000	±10	1 at 85	22	-65 to +175	aiyz (2)	4.13
Beckman	58	cermet	0.01-2000	±10	1 at 85	22	-65 to +175	aiz (1) (2)	4.13
Beckman	63	cermet	0.01-2000	±10	0.5 at 85	20	-65 to +150	ait	4.88
Beckman	66	cermet	0.01-2000	±10	0.5 at 25	20	-25 to +105	at	2.62
Beckman	76	cermet	0.01-2000	±10	0.75 at 25	15	-55 to +105	auz	1.46
Beckman	77	cermet	0.01-2000	±10	0.75 at 25	15	-55 to +105	az	1.46
Beckman	78	cermet	0.01-2000	±10	0.75 at 70	22	-25 to +125	a (2)	2.25
Beckman	79	cermet	0.01-2000	±10	0.75 at 25	15	-55 to +105	az	1.46
Beckman	89	cermet	0.01-2000	±10	0.75 at 25	15	-55 to +105	a	1.01

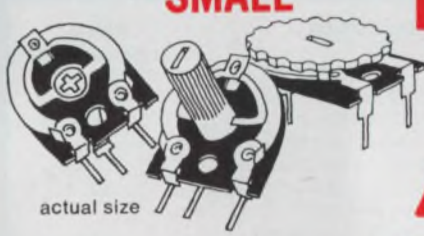
Trimmer Potentiometers

Manufacturer	Model	Type	Resistance Range (Min-Max, kΩ)	Tolerance %	Power Rating (Watts at °C)	Number of Turns	Operating Range °C	Notes	Price $/1000
Bourns	3009	cermet	0.01-2000	±10	0.75 at 25	20	-55 to +125	b	1.29
Bourns	3059	cermet	0.01-2000	±10	1 at 70	22	-55 to +150	d	1.99
Bourns	3069	cermet	0.01-2000	±10	0.75 at 25	20	-55 to +125	b	1.29
Bourns	3082	cermet	0.01-2000	±10	0.3 at 85	10	-65 to +150	(5)	4.75
Bourns	3099	cermet	0.01-2000	±10	0.75 at 25	20	-55 to +125	(15)	2.25
Bourns	3252	cermet	0.01-2000	±10	1 at 70	25	-65 to +150	e	3.45
CTS	170	cermet	0.02-2000	±20	0.75 at 85	42	150 max		4.05-4.40
CTS	190	cermet	0.02-2000	±10	0.5 at 85	20	150 max		1.31
CTS	191, 2	cermet	0.02-2000	±10	0.5 at 85	20	150 max		1.35
Dale	8100	cermet	0.01-2000	±10 or ±20	0.75 at 70	25	-65 to +125	d	req
Dale	8300	cermet	0.01-2000	±10 or ±20	0.75 at 25	15	-55 to +105	c	req
Dale	8400	cermet	0.01-2000	±10 or ±20	0.75 at 25	20	-55 to +125	b	req
Electra	ET12	cermet	0.01-2000	±20	1 at 85	22	-55 to +150	(31)	1.99
Electra	ET24	cermet	0.01-2000	±20	0.5 at 85	25	-55 to +150	(31)	3.10
Electra	ET34	cermet	0.01-2000	±20	0.5 at 85	15	-55 to +150	(31)	1.20
Electra	ET50	cermet	0.01-2000	±20	0.5 at 85	1	-55 to +150	(31)	1.20
Electra	RJ12	cermet	0.01-2000	±10	1 at 85	22	-55 to +150	(32)	3.84
Electra	RJ24	cermet	0.01-2000	±10	0.5 at 85	25	-55 to +150	i	4.55
Electra	RJ26	cermet	0.01-2000	±10	0.25 at 85	15	-55 to +150	(32)	5.25
Fairchild	6201	metal film	0.01-2000	±30	0.25 at 85	1	-25 to +125	(6)	0.88
Fairchild	6203	metal film	0.01-2000	±20	0.25 at 85	1	-25 to +125	(6)	0.98
Fairchild	6205	metal film	0.01-2000	±10	0.25 at 85	1	-25 to +125	(6)	1.15
TRW	150	cermet	0.01-2000	±10	0.75 at 70	1	-55 to +150	g	3.08
TRW	255	cermet	0.01-2000	±10	0.75 at 70	24	-55 to +150	ev	3.78
TRW	550	cermet	0.01-2000	±30	0.5 at 70	1	-25 to +105	g	1.31
Weston	518	cermet	0.05-2000	±10	0.5 at 70	1	-55 to +125	g (28)	1.19-1.51
Weston	546, 547, 548	cermet	0.01-2000	±10	0.5 at 85	1	-55 to +150	f	3.39
Weston	556, 557, 558	cermet	0.05-2000	±10	0.5 at 85	35	-55 to +150	e	2.99
Amperex	2322-412	carbon film	0.1-2200	±20	0.125 at 70	20	-30 to +70		0.45
AB	N	carbon	0.1-2500	±10 or ±20	0.33 at 50	25	-55 to +100	d (12)	1.20-1.35
AB	R	carbon	0.1-2500	±10 or ±20	0.25 at 70	25	-55 to +125	d (12)	2.50-2.65
CTS	165	cermet	0.02-2500	±10	0.5 at 85	25	150 max		3.10-3.20
CTS	630P	cermet	0.02-2500	±10	0.5 at 85	1	150 max	g	1.85
CTS	220	carbon film	0.1-2500	±20	0.125 at 55	1	85 max		1.09
CTS	330P	carbon film	0.1-2500	±10	0.375 at 85	1	150 max	g	0.95
Clarostat	63M	carbon film	0.1-3000	±10	0.25 at 70	1	120 max		1
Amperex	E097	carbon film	0.1-4700	±20	0.25 at 40	1	-10 to +70		8
AB	F	carbon	0.1-5000	±10 or ±20	0.25 at 70	1	-55 to +120	g	1-1.15
AB	O	carbon	0.1-5000	±10 or ±20	0.4 at 70	1	-55 to +150	g	1.20-1.40
AB	Y	carbon	0.1-5000	±10 or ±20	0.25 at 70	1	-55 to +120	g	0.90-1.05
Amphenol	2905	cermet	0.02-5000	±10	0.5 at 85	25	-55 to +150	eiv	3.82
Amphenol	3805	cermet	0.02-5000	±10	0.75 at 40	22	-55 to +125	b (28)	1.13
Amphenol	3815	cermet	0.02-5000	±10	0.75 at 40	22	-55 to +125	b (28)	1.32
Amphenol	6905	cermet	0.02-5000	±10	0.5 at 40	1	-55 to +125	g (28)	2.40
Bourns	215	plastic	5-5000	±20	0.25 at 50	22	-65 to +135	d	3
Bourns	272, 4, 6	plastic	5-5000	±20	0.2 at 20	25	-55 to +105	d	2.33
Bourns	3051	plastic	5-5000	±20	0.25 at 50	22	-65 to +150	d	4.33
CTS	201	carbon film	0.1-5000	±20	0.25 at 40	1	85 max	(9)	0.16
Ohmite	AFR	wirewound	0.1-5000	±20	0.25 at 70	1	-55 to +120		req
Centralab	3TR	carbon film	0.1-10,000	±30	0.5 at 70	1	-55 to +150	(3)	0.15
Centralab	4TR	carbon film	0.1-10,000	±30	0.1 at 70	1	-55 to +150	(39)	0.15
Centralab	5ATR	carbon film	0.125-10,000	±30	0.25 at 70	1	-55 to +150	(40) (42)	0.12
Centralab	5TR	carbon film	0.125-10,000	±30	0.25 at 70	1	-55 to +150	(41)	0.12
Centralab	Slim-Trim	carbon film	0.1-10,000	±30	0.4 at 70	1	-55 to +150	(38)	0.085
Stackpole	Minipot	carbon film	0.1-10,000	±30	0.25 at 50	1	-30 to +100	(43)	0.11

Amperex high quality trimmer pots priced to help you beat inflation.

When you buy trimmer pots from a volume producer you have a right to expect volume prices. And here are three groups of carbon film preset trimmer pots that meet your expectations. They are all top quality in design and manufacture, available off-the-shelf in production quantities . . . and they sell at prices lower than anything the competition has to offer.

SMALL



actual size

7½¢ TO 9¢ each

IN PRODUCTION LOTS

Resistance range: 100Ω to 4.7megΩ;
Tolerance: ±20%; **Dissipation:** 0.25 watt.

Available for horizontal or vertical mounting on printed circuit boards with pitch of 0.200 inch. The slider is equipped with a central screwdriver slot or plastic knob to facilitate adjustments. Designed for radio and television receivers and industrial applications.

MINIATURE

actual size

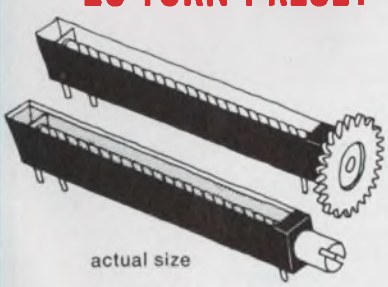
7½¢ TO 9¢ each

IN PRODUCTION LOTS

Resistance range: 100Ω to 1megΩ;
Tolerance: ±20%; **Dissipation:** 0.1 watt.

Completely new design. No price penalty for miniaturization of our standard trimmer. Height: 0.4", Width: 0.4". Available for horizontal or vertical mounting on printed circuit boards with pitch of 0.100 inch. Adjustment by a central screwdriver slot or a plastic knurled wheel. Designed for new products in which small size is a necessity . . . transceivers, portable TV's, etc.

20-TURN PRESET



actual size

33¢ TO 41¢ each

IN PRODUCTION LOTS

Resistance range: 100Ω to 2.2megΩ;
Tolerance: ±20%; **Dissipation:** 0.125 watt.
Adjustment range: 20 turns full-scale; linear or non-linear resistance curve.

Brand new in concept. They break the "dollar apiece" barrier without yielding an inch in performance.

Available with knurled thumbwheel or with screwdriver slot in shaft. (Thumbwheel is actually a spur gear to allow indirect drive where desired.) Dust cover of unique design can also be supplied; seals carbon track and slider against contamination. These 20-turn pots are suitable for use in TV and radio fine tuning, precision instruments, tape recorders, servomechanisms, etc.

Write for detailed data sheets on these three examples of Amperex quality and pricing and for our catalog on the complete Amperex line of components . . . carbon film resistors, non-linear resistors, electrolytic capacitors, film dielectric capacitors . . . and much more. Amperex Electronic Corporation, Component Division, Hauppauge, New York 11787.

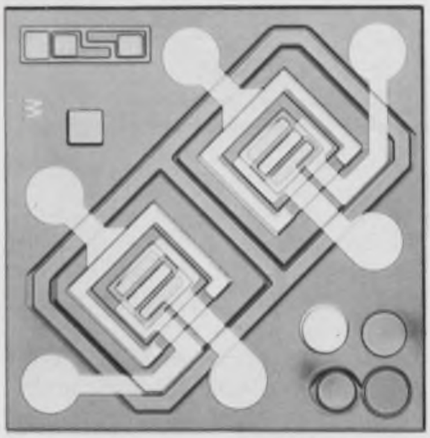
Amperex®

TOMORROW'S THINKING IN TODAY'S PRODUCTS

A NORTH AMERICAN PHILIPS COMPANY

New Products

Low-cost IC transistors increase performances



Amelco Semiconductor, 1300 Terra Bella Ave., Mountain View, Calif. Phone: (415) 968-9241. P&A: $2 to $8; stock.

Consisting of npn and pnp bipolar and field-effect types, two new series of monolithic dual transistors offer superior temperature tracking and high current gain at low costs.

SA2913 through SA2920, SA2453 and SA2453A bipolar dual transistors exhibit typical tracking (base-voltage differential drift) of 3 μV/°C and a typical base voltage differential of 2 mV.

Dc current gains range from 150 to 600 while collector-to-base breakdown voltage is rated at 60 V.

Prices range from $2 to $4.50 in quantities of 100 units. Packaging is in six-lead TO-18 cans.

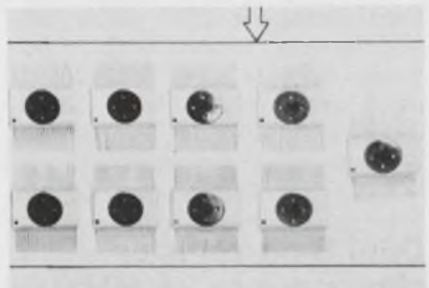
SU2365 through SU2369 dual FETs exhibit tracking of 1 μV/°C over the temperature range of −55 to +125°C, a gate-to-source breakdown voltage of 30 V, source transconductance of 2 μmhos and gate-to-gate breakdown voltage of over 60 V.

Other characteristics include a common-mode rejection ratio of 100 dB and output impedance of 1 MΩ.

Prices range from $2 to $8 in quantities of 100 units. Packaging is also in six-lead TO-18 cans.

CIRCLE NO. 250

LSIs for calculators cut size to 1-1/2-in²

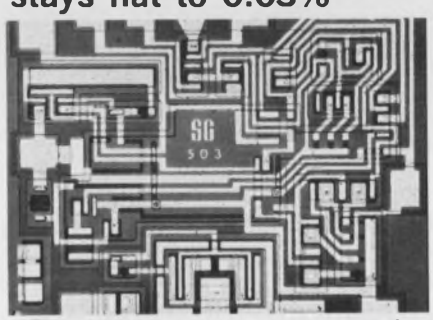


Hitachi America, Ltd., 437 Madison Ave., New York, N. Y. Phone: (212) 758-5255.

Nine LSI circuits, each only 1-1/2-in. square, mount on a single base to form all the electronic circuitry for a 16-digit desk-top calculator that measures 9-1/2 by 12 by 4-1/4 in. The new LSI circuits are available in 8 types: 2 memory, 5 calculation control, and 1 display control unit. They can be used for various mathematical calculations.

CIRCLE NO. 251

Adjustable regulator stays flat to 0.03%

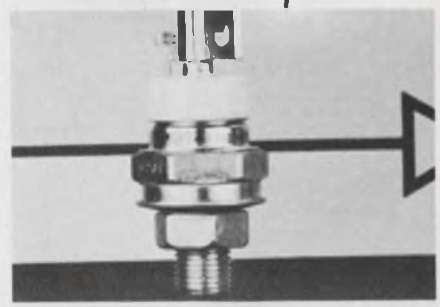


Silicon General Inc., 7382 Bolsa Ave., Westminster, Calif. Phone: (714) 839-6200. P&A: $3.05; stock.

With either positive or negative supply operation, a new linear IC voltage regulator offers 0.03% line and load regulation and an output that is adjustable from 2 to 37 V. The SG723/723C may be used as a series, shunt, switching or floating regulator with currents up to 150 mA. External power transistors can boost output current.

CIRCLE NO. 252

High-power SCR turns on in 3.5 μs



Westinghouse Electric Corp., Semiconductor Div., P.O. Box 868, Pittsburgh, Pa. Phone: (412) 391-2800. P&A: $43.50; 2 wks.

Handling frequencies up to 10 kHz for half sine-wave operation and up to 7 kHz for rectangular-wave operation, the T507 SCR turns on in 3.5 μs. Its dynamic forward voltage drop is 4.5 V maximum and it can handle a forward current of up to 100 A. Di/dt is 800 A/μs, turn-off time is 30 μs, and gate current is 150 mA.

CIRCLE NO. 253

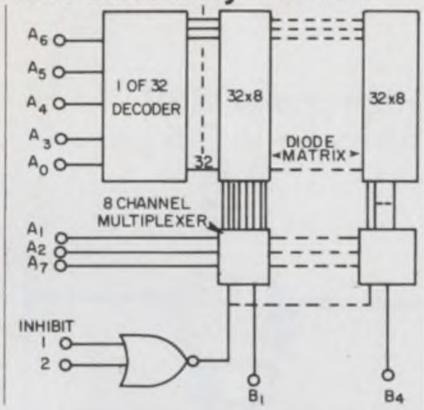
Phase-locked ICs multiply frequency

Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. Phone: (408) 739-7700. P&A: $6.35 or $18; stock.

Going from subaudio frequencies to vhf, two phase-locked-loop linear integrated circuits can accurately multiply, divide or even fractionalize frequencies—virtually in any ratio. Operating range of the model 562 is 0.1 Hz to 50 MHz, while the model 565 performs from 0.1 Hz to 500 kHz.

CIRCLE NO. 254

TTL read-only memories access in only 40 ns



Computer Microtechnology, 610 Pastoria, Sunnyvale, Calif. Phone: (408) 736-0300. Price: $36 to $76.

Three new high-speed TTL read-only memories, the CM2900 1120-bit character generator and the CM2850 and CM2800 1024-bit code converters, offer fast access times of typically 40 ns.

The CM2900 1120-bit memory can directly drive light-emitting-diode displays without a driver for each output and contains logic circuitry on the chip.

The logic circuitry, which is normally built by the user, senses the memory input to determine whether or not an incoming signal represents a character for display or a non-display control signal.

Other features include power dissipation of only 500 mW, a fan out of 10, an organiaztion of 224 by 5-bit words, and the availability of custom font for 5 by 7 or 7 by 10 characters .

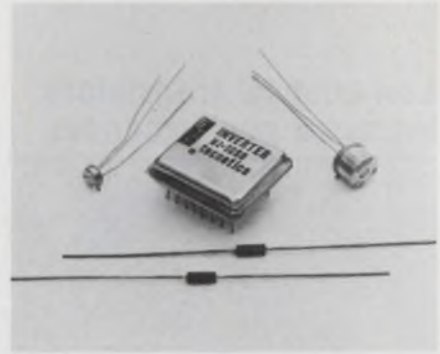
The CM2850 1024-bit code converter is organized as 256 by 4-bit words, and is easily expandable to two chip select inputs or tie outputs. Other features include a power dissipation of 460 mW, and a fan out of 10.

The CM2800 1024-bit code converter is organized as 128 by 8-bit words and except for its organization, is similar to the CM2850 in its characteristics.

Prices for the CM2900 are $76 each for 1 to 9 and $43 each for 25 to 99. The CM2850 costs $65 each for 1 to 9 and $36 each for 25 to 99. The CM2800 costs $69 each for 1 to 9 and $39 each for 25 to 99.

CIRCLE NO. 255

Hybrid dc/ac inverter dissipates 3 watts

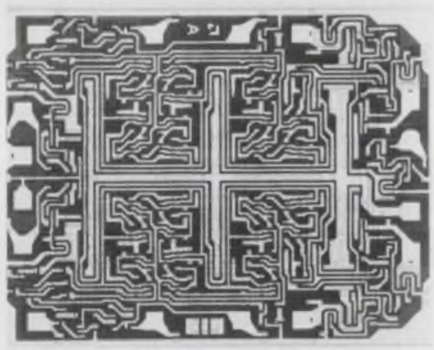


Tecnetics, Inc., Boulder Industrial Park, Boulder, Colo. Phone: (303) 442-3837. Price: $79.

Featuring 80% full-load efficiency, a new hermetically sealed, hybrid microelectronic dc/ac square wave inverter for on-card mounting dissipates 3 W. Specifications include a 20-V input. Sixteen different models with center-tapped outputs from 5 to 300 V pk-pk are available. With the addition of filters, the inverter can generate other functions.

CIRCLE NO. 256

Dual 8-bit register clocks out to 25 MHz



Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, Calif. Phone: (408) 732-2400. P&A: $15.40; stock.

The 9328 high-speed dual 8-bit shift register with a 2-input multiplexer in front of each data input offers a 25-MHz clock rate as well as active pullup outputs. This bipolar serial storage element has an asynchronous master reset with a low logic level that allows clearing of its 16 stages independently of any other signal.

CIRCLE NO. 257

Thick-film converters offer ±0.05% accuracy

Beckman Instruments, Inc., Helipot Div., 2500 Harbor Blvd., Fullerton, Calif. Phone: (714) 871-4848. Price: $225; $175.

Models 871 a/d and 847 d/a cermet thick-film converters offer accuracies of ±0.05%. The 871 consists of an MOS/LSI circuit, a ladder, a translator, and a flip-flop. Its resolution is up to 12 bits. The 847 consists of an MOS/LSI circuit, a ladder, an output amplifier, and output resistors. Its resolution is 10 bits.

CIRCLE NO. 258

Replacement transistor improves construction

Texas Instruments, Inc., 13500 N. Central Expwy., Dallas, Tex. Phone: (214) 238-2011. P&A: $1; stock.

A new plastic-encapsulated replacement for the popular 2N3055 metal-can power transistor features better construction to reduce costs. The TIP3055 has a glass-passivated chip for lower leakage, improved moisture resistance and stability, soldered contacts, and copper heat sinks. These combine to reduce costs to $1 (100-999 quantities).

CIRCLE NO. 259

Bench or System — the HP 3450A gives you maximum performance in a minimum space.

A quick look at the unfolding dodecahedron shows each of the 12 functions the Incredible Dodecameter performs. What it doesn't show is just how well this 5-digit multifunction meter performs each function.

For instance, you not only get true rms capability—you also get value-plus features like true 4-terminal ac ratio testing and 4-terminal ohms measurements.

And, accurate, fast measurements in each of these twelve categories is only the start. You can add digital output and directly control external equipment like a printer. Or, add remote control and get full programmability for system use.

No matter what the application, you get more for your money with the HP 3450A.

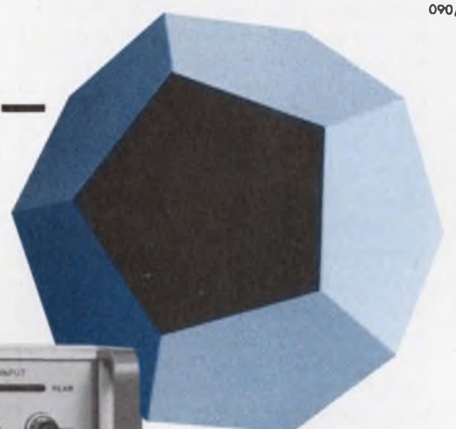
This Incredible Dodecameter lets you start with the basic dc meter and add the capability that best fits your requirements. If your needs change, any of the options (except the rear input terminals) can be easily installed in the field.

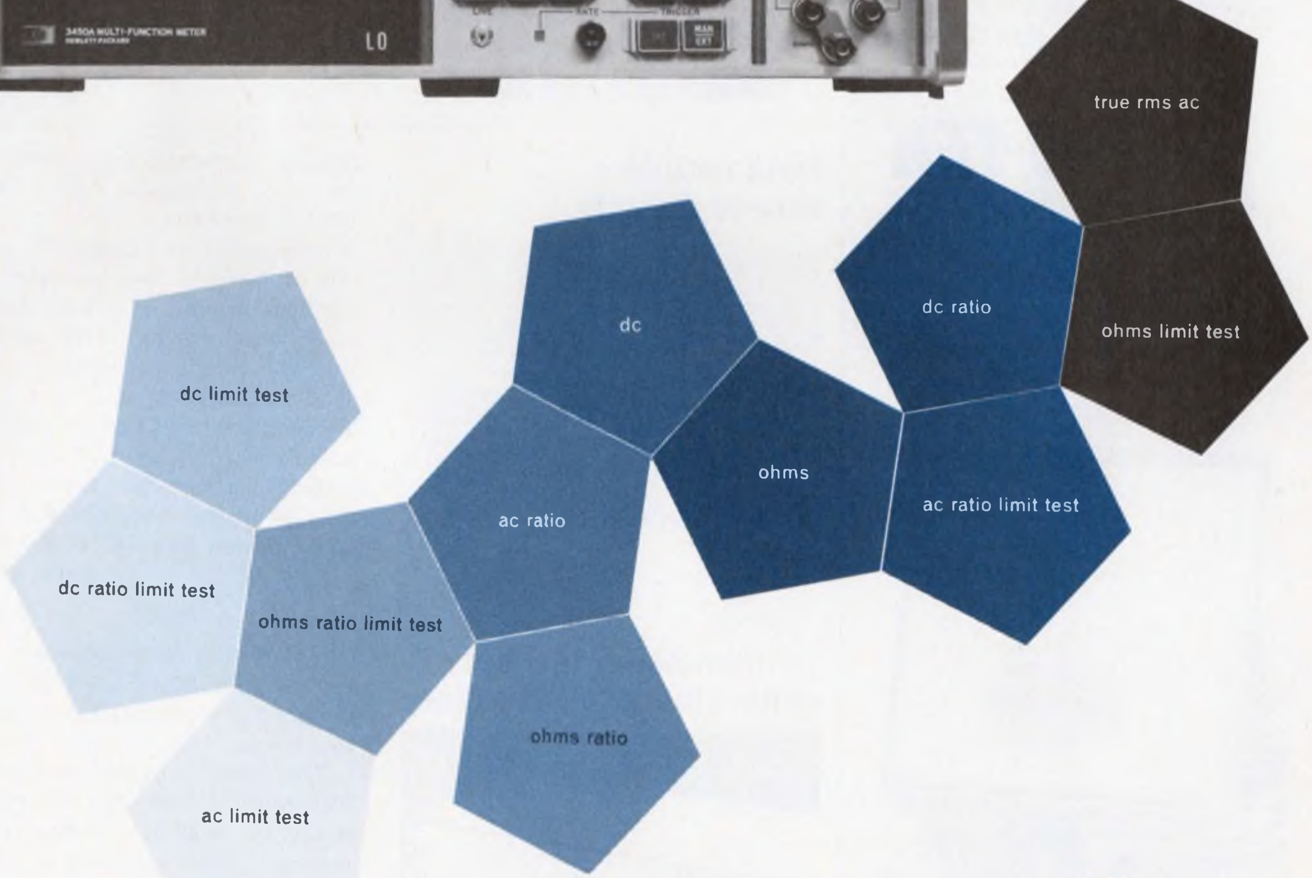
For more information on this outstanding 12 in 1 bargain, just call your local HP field engineer. Or, write Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.

Price Basic HP 3450A, $3300; AC Option 001, $1250; Ohms Option 002, $425; Limit Test Option 003 $375; Digital Output Option 004, $190; Remote Control Option 005, $245; Rear Input Terminal Option 006, $70.

090/8A

The Incredible Dodecameter— A 12-in-1 way to better measurements!



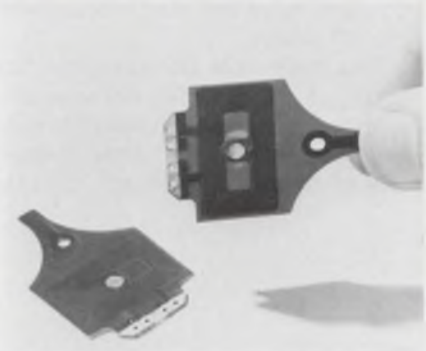


HEWLETT hp PACKARD

DIGITAL VOLTMETERS

INFORMATION RETRIEVAL NUMBER 56

Flat 2-layer coil card types out phone pulses

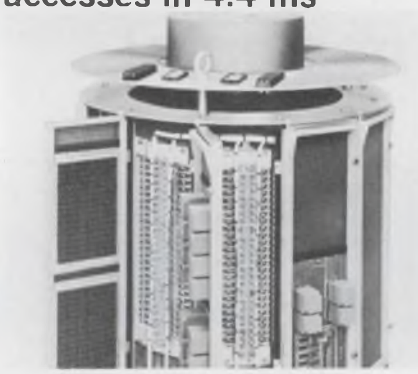


Rogers Corp., Rogers, Conn. Phone: (203) 774-9605.

A new flat two-layer coil card translates electrical pulses received by telephone into duplicate copies of typed or printed documents or photographs. Direct current entering the card creates a magnetic field and causes the card tip to strike a stylus. The stylus, moving axially on a rotating drum of sensitized paper, proceeds a line at a time to impart as many as 1200 tiny dots/s on the paper.

CIRCLE NO. 260

Fast drum memory accesses in 4.4 ms



General Instrument Corp., 13040 S. Cerise Ave., Hawthorne, Calif.

Operating at 7200 rpm, the SA 8000 series high-speed drum memory provides average access time of 4.4 ms. Its storage capacity is 5 to 20 megabits with densities up to 1800 bits/in. It is available with 256, 512, or 1024 tracks, each with its own read/write flying head. The drum features 360-degree access to all circuits. Controller logic for interfacing with a central processor is optionally available.

CIRCLE NO. 261

Data couplers access directly

Design Elements, Inc., 1356 Norton Ave., Columbus, Ohio. Phone: (614) 294-2694.

Designated as Design 80, a new line of direct-access hardwire data couplers provide a reliable method of communicating with a time-shared computer or with a remote data terminal via an ordinary telephone line. Units are available in originate-only, answer-only, and originate/automatic-answer models. Features include FM data transmission and LC filtering.

CIRCLE NO. 262

Transmission test set generates pseudo noise

International Data Sciences, Inc., 100 Nashua St., Providence, R. I. Phone: (401) 274-5100. Availability: stock.

The Range Rider model 1100 transmission test set generates a repeating 2047-bit pseudo-random sequence. For synchronous operation, it operates over the range of dc to 0.5 MHz. For asynchronous operation, data rates can be selected up to 9600 bits/s.

CIRCLE NO. 263

Need a hybrid op amp with 2 watts power output? DICKSON has it!

That's right!
A hybrid op amp with up to 2 watts power output in a 12-lead TO-8 package.

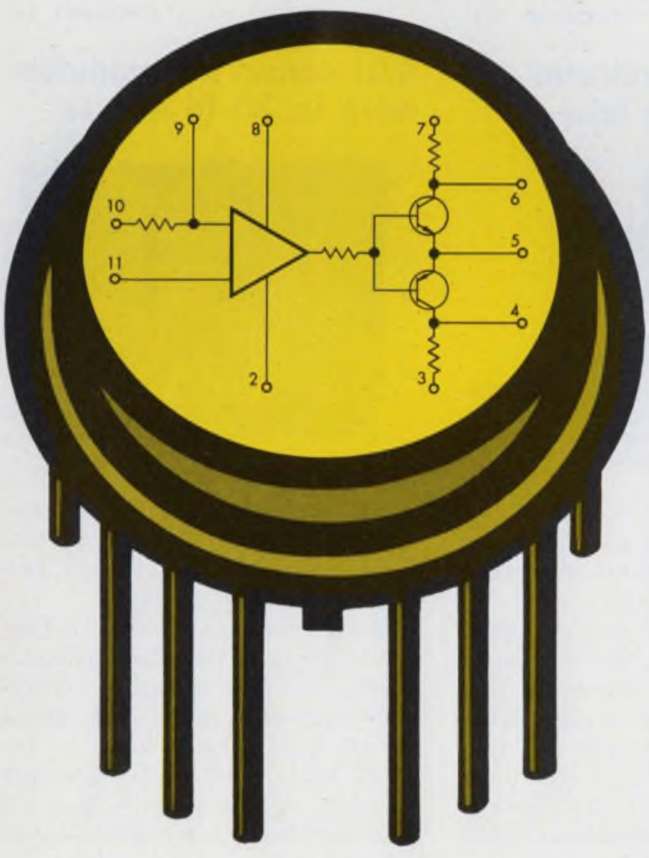
This new Dickson unit, the DPA 500, *combines* a standard monolithic operational amplifier with a complementary current amplifier. It has internal frequency compensation, a large input voltage range, and there's no danger of latch-up.

The price is just $14.50 (in 100 unit quantity) and it's in stock for immediate delivery.

EASILY CUSTOMIZED IN OEM QUANTITIES
The DPA 500's unique design also enables Dickson to supply customized units in OEM quantities at reasonable prices.

To meet your special requirements, a wide selection of resistors, voltage regulator diodes and voltage reference devices can be easily mounted inside the can without extensive engineering changes.

FOR COMPLETE DETAILS
on the DPA 500 including application information, use this publication's reader service card or phone Dickson Electronics Corporation.



DPA 500 POWER OPERATIONAL AMPLIFIER

- INTERNAL FREQUENCY COMPENSATION
- NO LATCH-UP
- LARGE INPUT VOLTAGE RANGE
- CAPABLE OF DRIVING EXTERNAL HIGH-POWER TRANSISTORS

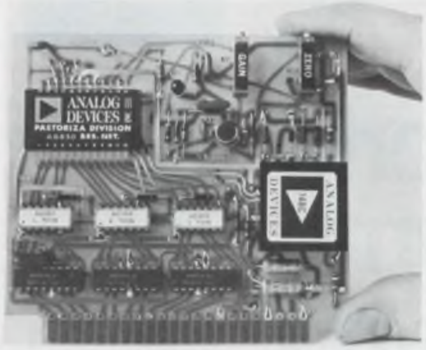
ELECTRICAL CHARACTERISTICS
(Closed Loop, $1 \leq A_V \leq 10$) (Power Supplies = ± 15 Volts)

Input Voltage		± 15 Volts
Power Dissipation	@ $T_A = 25°C$	1.25 Watts
	@ $T_C = 25°C$	2.0 Watts
Harmonic Distortion		.2%
Output Voltage		26 Volts (P-P)
Output Current	DC	200 mA
	AC	500 mA pk
Offset Voltage		5 mV
Output Impedance		4.0 ohms

DICKSON
ELECTRONICS CORPORATION
PHONE (602) 947-2231 TWX 910-950-1292 TELEX 667-406
P. O. BOX 1390 • SCOTTSDALE, ARIZONA 85252

INFORMATION RETRIEVAL NUMBER 58

Complete d/a converter comes on a $275 PC card

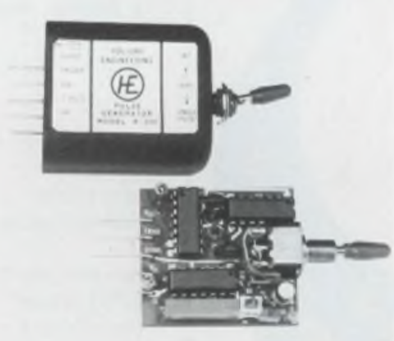


Analog Devices, Inc., Pastoriza Div., 221 5th St., Cambridge, Mass. Phone: (617) 492-6000. P&A: $185 to $275; stock.

Based on earlier announced μDac monolithic packages, the model DAC-12Q 12-bit d/a converter on a single PC card retails for only $275. Accuracy is 1/2 the least significant bit, settling time is 2.5 μs and temperature coefficient is ±7 ppm/°C. The $275 price includes a reference source, a ladder network, an input register and an output amplifier.

CIRCLE NO. 264

Tiny pulse generator has 10-ns rise time



Holiday Engineering, 2540 Teresina Drive, Hacienda Heights, Calif. Phone: (213) 336-0821. P&A: $79.95; 10 days.

The series 300 panel-mounted pulse generator provides an adaptable compact clock source for ICs with an undelayed output pulse duration of 50 ns at rise and fall times of 10 ns. Pulse repetition rates are available in 16 discrete steps within the frequency range of 100 Hz to 10 MHz. Frequency stability is ±1%.

CIRCLE NO. 265

Voltage-standard module stabilizes to ±50 ppm

CODI Semiconductor, Pollitt Dr., Fairlawn, N. J. Phone: (201) 797-3900. P&A: $99.50; stock.

Called the Certavolt, a new voltage-standard module has a guaranteed output voltage of 10.000 V ±50 ppm (0.005%) for an input variation of ±5% and a load variation of from 0 to 10 mA. Operating temperature range is 15 to 55°C and noise is 10 μV rms and 100 μV pk-to-pk from dc to 1 MHz. Applications include calibration of voltmeters and digital panel meters.

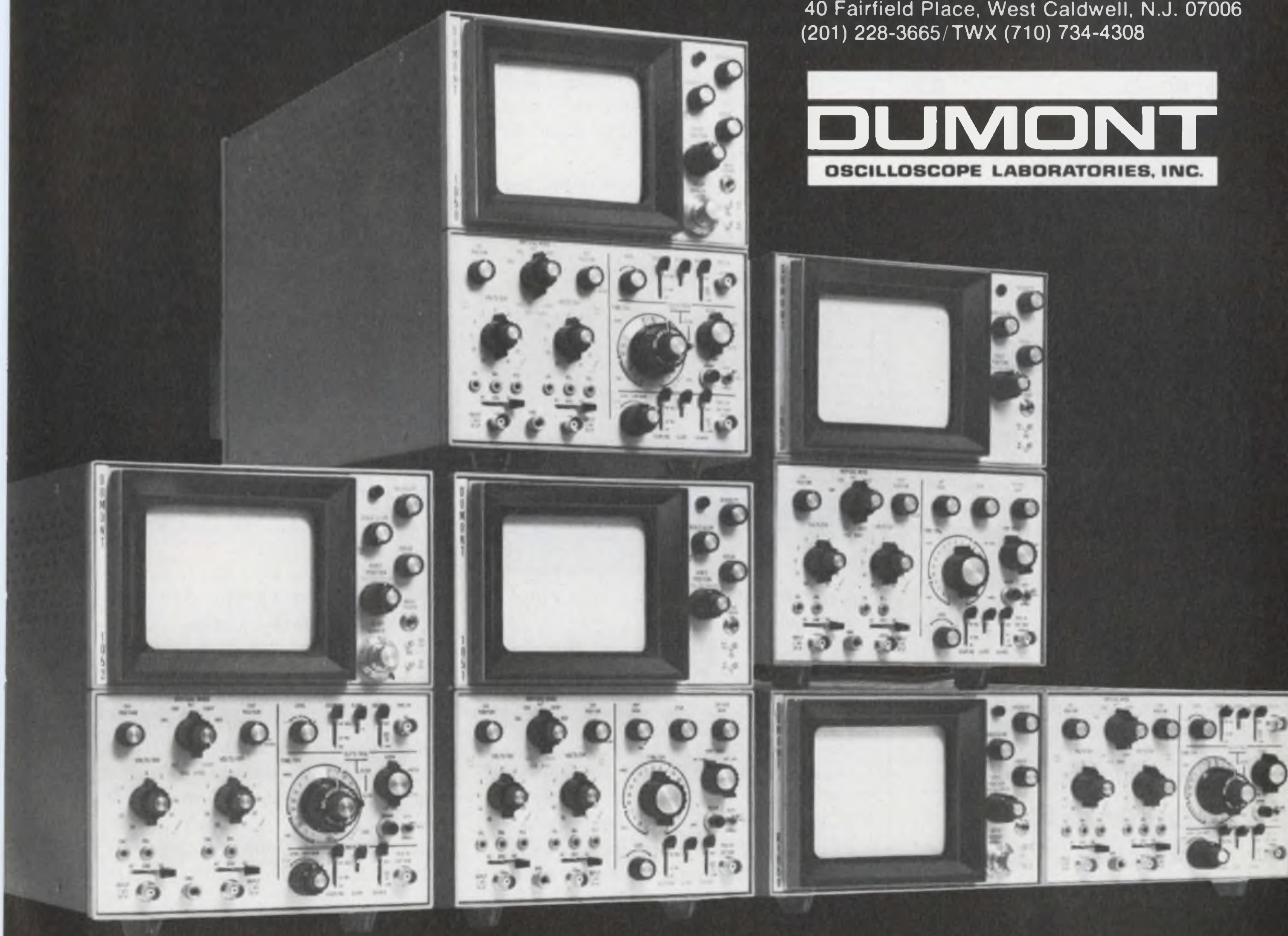
CIRCLE NO. 266

A/d converter modules work in 20 to 40 μs

Burr-Brown Research Corp., International Airport Industrial Park Tucson, Ariz. Phone: (602) 294-1431. Price: $195 to $345.

Using successive-approximation, a new series of modular analog-to-digital converters feature conversion times that range from 20 μs for the 8-bit units to 40 μs for the 12-bit units. The relative accuracy of series ADC30 modules is ±1/2 least-significant bit, while over-all relative accuracy is ±1 least-significant bit.

CIRCLE NO. 267



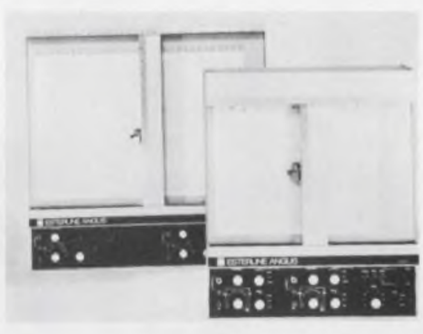
Single-sweep generator scans 1 to 125 MHz

Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, Ind. Phone: (317) 357-8781. P&A: $3000; 6 wks.

The SS-25 high-power sweep generator covers the entire frequency range of 1 to 125 MHz with only one sweep. Center frequency dial adjustments aren't necessary as the sweep width is adjusted because the sweep is symmeterical about the center frequency. Isolation between the oscillator and the output load is more than 40 dB. Power output is 5 W.

CIRCLE NO. 268

0.1-mV/in. recorders increase slewing speed

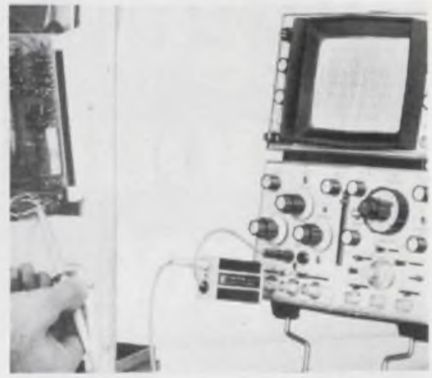


Esterline Angus, P.O. Box 24000, Indianapolis, Ind.

With a 0.1-mV/in. sensitivity, two new X-Y recorders have slewing speeds of 35 in./s in the X axis and 50 in./s in the Y axis One accepts 8-1/2 by 11-in. paper (model X-Y 8511) and another accepts 11 by 17-in. paper (model X-Y 1117). Paper is held in place by a vacuum. Source impedance is 25 kΩ on the most sensitive range (0.1 mV/in.). Zero offsets can be set to 0.1% accuracies.

CIRCLE NO. 269

$95 scope-input probe converts impedances



Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $95; stock.

A new low-cost active probe converts a high-frequency oscilloscope's 50-Ω input to a 10-MΩ-10 pF impedance at the probe tip for $95. The model 1124A probe has two switch-selected voltage ranges: ±10 V with an attenuation factor of 10, and ±100 V with an attenuation factor of 100. Maximum steady-state input is ±350 V (10-V range) and ±500 V (100 V range).

CIRCLE NO. 270

Precision HV supplies are accurate to 0.25%

Velonex, sub. of Varian, 560 Robert Ave., Santa Clara, Calif. Phone: (408) 244-7370. P&A: $1895, $2295; stock to 90 days.

Two new precision high-voltage power supplies have output voltage accuracies within 0.25% of their selector switch settings. Output voltage is continuously adjustable from 1 to 20 kV at 3 mA on the model 180, and from 10 to 30 kV at 1 mA on the model 190. Voltage line and load regulations are 20 ppm, and 25 ppm, respectively.

CIRCLE NO. 271

10 microvolt sensitivity with a lot of numbers.

40,000 to be precise.

Our latest bi-polar Model 1294 packs more numbers than any other into industry's smallest package! And it reads them with a sensitivity of *10 microvolts!* The 1294 is a true bi-polar 4½-digit instrument with a display capability of 19999 and out-of-range indication. Its state-of-the-art electronics utilizes T²L logic and unique time-sharing circuitry that cuts power consumption to less than six watts. BCD output is optional.

Input impedance is high: 10 megohms on the 100 millivolt range. Reading rate is 5 per second. Response time is well under one second. Accuracy is .05% of reading, ±1 digit.

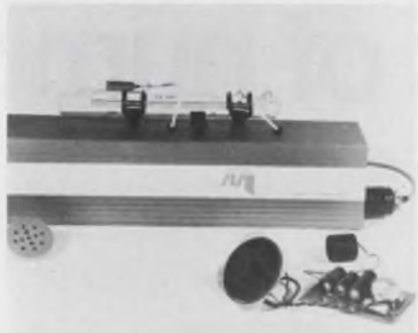
Housed in the same 7 sq. in. front-panel-mountable case as our five other DPM's, the 1294 offers all the features that have distinguished this line . . . Weston's patented dual slope* integration, plug-in Nixie** tubes, repairable (non-potted) circuit boards, and ten standard voltage and current ranges.

If you're sensitive about your numbers, Weston Model 1294 provides the ultimate at a reasonable price. See how the 1294 complements industry's broadest DPM line. Write for details from the DPM originators.

WESTON INSTRUMENTS DIVISION,
Weston Instruments, Inc., Newark, N.J. 07114
a Schlumberger company
WESTON®

*U.S. Pat. #3,051,939
**Registered trademark, Burroughs Corp.

Communications laser costs $150 in kit form



Metrologic Instruments, Inc., 143 Harding Ave., Bellmawr, N. J. Price: $150 (kit) $200 (assembled).

A practical, low-cost laser system provides two-way communication over laser beams at less than $150 in kit form and less than $200 assembled. The system modulates a laser beam with voice, video, or data signals and transmits the beam for distances of several miles. A 0.75-MHz bandwidth makes the system applicable for multichannel telemetry.

CIRCLE NO. 272

IR photodiode array detects 2 to 5 microns

Spectronics Inc., 541 Sterling Dr., Richardson, Tex. Phone: (214) 231-9381.

Featuring a choice of three different types of packages, a new IR detector array using InSb and InAs photodiodes exhibits a response ranging from 2 to 5 microns. Packaging choices include flatpack, glass dewar or metal dewar cases. The new array also features such optional features as cold shielding, cold filters, and adapters for mechanical coolers.

CIRCLE NO. 273

470-MHz transistors provide 5-W outputs

Kertron, Inc., 7516 Central Industrial Dr., Riviera Beach, Fla. Phone: (305) 848-9606. P&A: $10.80, $12.55, $21; stock.

Operating from 28 V and at 470 MHz, 3TX transistors feature output power of up to 5 W. Power gain is specified at 8 dB for the 3TX630, 7 dB for the 3TX631, and 6 dB for the 3TX632. They are packaged in molded 1/4-in. stripline packages with the leads isolated from the cases. They are also available in ceramic 1/4-in. stripline cases.

CIRCLE NO. 274

Rf power transistors cross-over at 50 MHz

General Semiconductor Industries, 230 W. Fifth St., Tempe, Ariz. Phone: (602) 966-7263. P&A: $11.95; stock.

Rated at 30 W, a new line of rf power transistors offer a unity-gain cross-over frequency as high as 50 MHz with collector-emitter voltages up to 80 V. Types 2N2877, 2N2878, 2N2879 and 2N2880 are housed in a standard hermetically sealed TO-111 package. Applications include high-frequency inverters and converters.

CIRCLE NO. 275

INFORMATION RETRIEVAL NUMBER 64 ►

The new PDP-8/e: Its own mother wouldn't know it.

The PDP-8/e is a radical departure in computer design. There's no back panel wiring—everything plugs into the OMNIBUS,™ even the CPU. In any order. It's completely flexible; you buy only what you need. And if you need more later, just buy it and plug it in. And the PDP-8/e is easier to interface and easier to maintain than old-style computers.

We've made a few other changes. Easier programming. 1.2 μ sec memory cycle time. 15 added instructions. 256 words of read-only memory. 256 words of read/write memory.

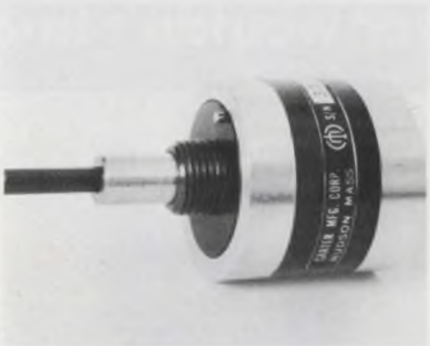
Yet there's no generation gap between the PDP-8/e and the rest of the PDP-8 family computers in 7500 world-wide installations. They all use the same peripherals (over 60 of them). They're all program and interface compatible, they all have extensive applications and documentation. PDP-8/e was born with a silver software package in its mouth.

The basic 4K machine sells for less than $5000. With teletype, less than $6500. Quantity discounts available.

digital
COMPUTERS · MODULES

Digital Equipment Corporation
Maynard, Mass. 01754 (617) 897-5111

Plastic potentiometer has vernier control



Carter Manufacturing Corp., 23 Washington St., Hudson, Mass. Phone: (617) 562-6987.

A new conductive plastic instrument potentiometer consists of a direct drive on its outer shaft and a 10:1 or 5:1 vernier ratio on an inner shaft to provide for smooth control adjustments. Standard total resistances are 1000, 2500 and 5000 Ω with special values available. Linearity is ±1% and linearities of ±0.5 or ±0.25% are available. The electrical angle is 300 degrees.

CIRCLE NO. 276

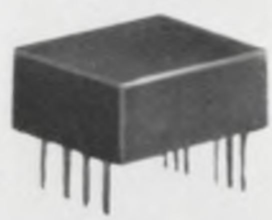
Eight-decade totalizer has electronic decades

Veeder-Root, 70 Sargeant St., Hartford, Conn. Phone: (203) 527-7201. Price: $150 (1 decade), $185 (2 decade).

The new series 7124 Mini-Flex counter combines two electronic counting decades with a six-figure electromechanical totalizer for high-speed counting. It operates from switch closures or pulse inputs. When a pulse input is used, speed is 400 counts/s with one electronic decade and 4000 counts/s with two electronic decades.

CIRCLE NO. 277

Latching 2-pole relays come in flatpack cases

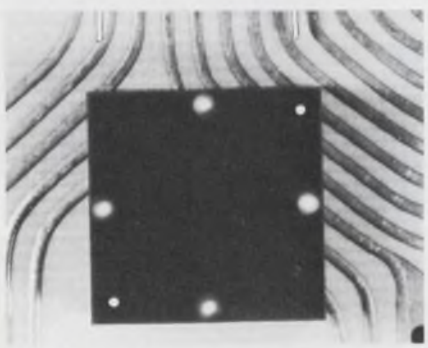


Deutsch Relay Div., 65 Daly Rd., East Northport, N. Y. Phone: (516) 266-1600.

The MLL series two-pole double-throw latching relays are available in flatpack cases and are designed to meet MIL-R-5757. Life expectancy is 150,000 operations with a 1-A contact load. Contact resistance is 100 mΩ maximum. Each relay is less than 0.1 cubic in. in size and lays flat on a 0.1-in.-grid PC board. Each requires a 2.5 ms pulse at 145 mW for actuation.

CIRCLE NO. 278

Low-outline inductors span 0.1 μH to 10 mH



Engineered Components Co., 2134 W. Rosecrans Ave., Gardena, Calif. Phone: (213) 321-6565.

A new line of low-silhouette torodial inductors features 89 models covering the range of 0.1 μH to 10 mH. SPL units are designed to provide minimum distributed capacitance, maximum Q, and high self-resonant frequency commensurate with minimum size. Standard tolerance is ±5%. Sizes range from 0.2 by 0.2 by 0.125 in. to 0.55 by 0.55 by 0.3 in.

CIRCLE NO. 279

Plastic capacitors withstand 12.5 kV

Film Capacitors, Inc., 100 Eighth St., Passaic, N. J.

Housed in specially treated plastic tubes and end-filled with epoxy resin, type KM9 high-voltage capacitors are available in voltage ratings from 1 to 12.5 kV. They are designed to operate over a temperature range of −55 to +85°C without derating. Standard tolerance is ±20%, with closer tolerance available upon request. Dissipation factor is a maximum 0.8% at 1000 Hz.

CIRCLE NO. 280

Power thick films supply to 10 MΩ/square

TRW Inc., IRC Div., 401 N. Broad St., Philadelphia, Pa. Phone: (215) 922-8900. Availability: 3 wks for prototypes.

Metal-glaze cermet thick-film power resistors are available in a resistance range of 0.1 Ω/square to 10 MΩ/square with tolerance to ±1% (±5% for beryllia). Power loading to 100 W/square in. with suitable heat sinking is possible. Temperature coefficient is ±200 ppm/°C. A variety of configurations can be supplied.

CIRCLE NO. 281

Electrolyte batteries operate at 350°F

Gould Ionics Inc., P.O. Box 1377, Canoga Park, Calif. Phone: (213) 341-1040.

Month-long battery power at 350°F is now possible with the HTB series of prototype solid-electrolyte batteries. Shelf life is projected for more than 10 years. For lower temperature operation, lower available energy can be increased by merely heating the batteries. They can be custom-packaged in a wide range of voltages (multiples of 5/8 V), capacities (from a few milliampere-hours) and sizes. 1/2 and 1-in. dia versions will be offered initially.

CIRCLE NO. 282

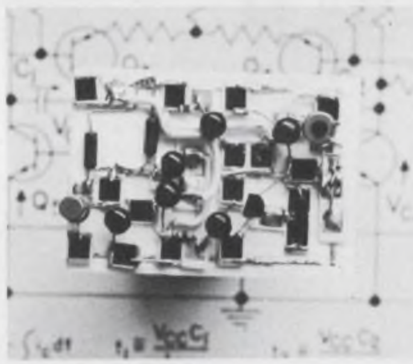
Cordless soldering unit uses Ni-Cd batteries

Vapo-kleen Products Co., 824 N. Hollywood Way, Burbank, Calif. Phone: (213) 849-1471. Price: $78.50.

Completely self-contained, the model 43A portable cordless soldering unit operates on high-energy nickel-cadmium batteries. Controlled heat is achieved instantly by means of a hermetically sealed miniature coaxial heater in the tip assembly. The heater permits operation at very high temperatures within 3 to 5 s.

CIRCLE NO. 283

IC breadboarding kit is assembled in 1 hour



Epitek Electronics Ltd., 19 Grenfell Crescent, Ottawa, Ontario, Canada. Phone: (613) 825-3911.

With the Epichip breadboarding kit, microelectronic circuits can be laid out, assembled and tested in one hour using standard bench tools. The microcircuit kit contains a wide selection of thick-film chip resistors, ceramic substrates and metallized mounting pads offering experimenters and designers a new fast and economical way to build their circuits.

CIRCLE NO. 284

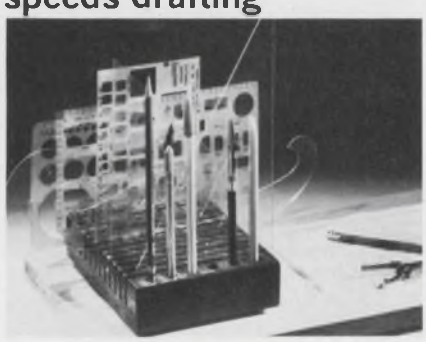
Manual plotter makes 3-D graphs

Dimension, Inc., 95 Madison Ave., Hempstead, N. Y. Phone: (516) 483-3636.

Dimen-Plot manual plotter makes true three-dimensional graphs through the insertion of long headed-pins, with the aid of a guide, into graph paper mounted on a plastic base. The X and Y coordinates are determined by the graph paper; the Z coordinate is determined by the height of the pins above the paper. Resolution in all three directions is infinite.

CIRCLE NO. 285

Template holder speeds drafting

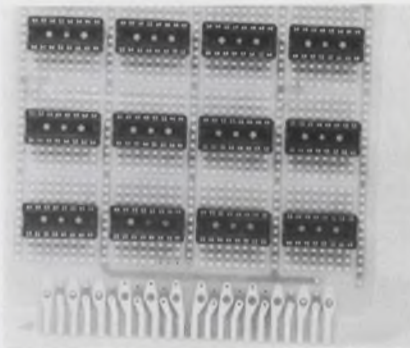


Tempate, 562 N. Madison Ave., Pasadena, Calif. Phone: (213) 254-9203. Price: $4.95.

The new model 410 template holder is specifically created for use by designers, engineers, draftsmen and architects whose work requires quick and easy access to drafting tools. It eliminates drafting-table clutter and keeps tools clearly visible. It is fabricated of high-quality hardwood and features a hand-rubbed natural-oil finish.

CIRCLE NO. 286

Breadboarding PC card accepts 12 DIP sockets

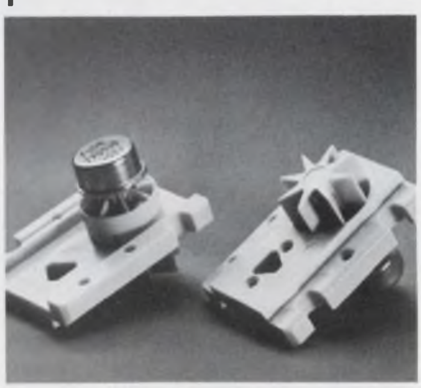


Douglas Electronics, Inc., 718 Marina Blvd., San Leandro, Calif. P&A: $19.50; stock.

Model 11-DE-1-S is a new PC card that accepts 12 DIP sockets and associated components. Its circuit layout includes two power supply lines which are not connected to DIP pins and are adjacent to each package location. It has three additional 0.038-in.-dia holes on each DIP pad. It is made of FR-4 glass epoxy and is laminated on both sides with copper.

CIRCLE NO. 287

Plastic carrier protects TO-5 ICs



Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. Phone: (415) 962-3563.

The Stoppenfloppen is a new plastic carrier that protects the leads of TO-5 linear ICs against damage during shipping, testing and handling. It holds a TO-5 package snugly in place and allows inspection and testing of the circuit in the carrier. Measuring 1-in. long and 3/4-in. wide, it is designed to engage guide pins in automated insertion equipment.

CIRCLE NO. 288

Conductive coating grips surfaces

Dynalog, Inc., 7 Great Meadow Lane, Hanover, N.J. Phone: (201) 887-9270. Price: $9.50 for 3 oz.

Dynaloy 479 is an electrically conductive silver-alloy polymer coating that readily adheres to metals, plastics, glass, rubber and ceramic surfaces. The material gives good environmental protection and can easily be soldered with conventional solders. It is easily applied by dip, brush, roller coating or spraying. Applications include printed circuit repair.

CIRCLE NO. 289

New kind of Teflon enhances insulation

Chapman Industries, Avondale, Pa. Phone: (215) 268-2252.

A new Teflon product, tradenamed Fepline, is said to offer excellent release and protective surface properties for all types of electronic equipment. One use is as a boot which has no seams or welds, and which withstands dielectrical testing at 10,000 V. The interior surface of the equipment or device to which the boot is applied can be etched so that the boot can be permanently bonded to the element it protects.

CIRCLE NO. 290

MIC substrates offer variety

Surface Technology Inc., Mountain View, Calif.

Thin-film metallized substrates for hybrid microwave integrated circuits are now available. These chrome/gold metallized 99.5%-pure aluminum-ozide substrates measure 1 by 1, 1 by 2, or 2 by 2 in. The intermediate resistor film which is sputtered directly onto the substrate surface provides a resistivity of 50 ohms per square. High-purity gold is then sputtered directly over the chrome to a minimum thickness of 250 micro-inches.

CIRCLE NO. 291

small wonders: big news

Denser PC packaging at low cost is now possible . . . thanks to CAMBION's low-profile standard variable inductors. They're wound on new, thin wall coil forms that allow higher Q's and inductance values.

Ultra-reliable as well as miniature, these high performance inductors are built for longer life . . . longer by a factor of ten in tuning torque. They have an operating temperature range of —55° to 125°C and a tuning range of ±20% from the mean inductance.

For total circuit reliability – at a small price – it pays to choose CAMBION inductors. They're available in a wide choice of values, sizes, styles and finishes for immediate delivery.

Cambridge Thermionic Corporation, 445 Concord Ave., Cambridge, Mass. 02138. Phone: (617) 491-5400. CAMBION Electronic Products, Ltd., Castleton, Near Sheffield, England. Phone: Hope 406/407.

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The Guaranteed Electronic Components

INFORMATION RETRIEVAL NUMBER 70

The newest volume in the Wiley-Interscience Series on Systems Engineering and Analysis...

FROM IDEA TO WORKING MODEL

By IRA G. WILSON
and MARTHANN E. WILSON

A volume in the *Wiley Series on Systems Engineering and Analysis*, edited by Harold Chestnut

From Idea to Working Model is a practical, non-mathematical guide to assist the innovator or designer systemize his work, and to help the supervisor/manager evaluate progress and avoid stumbling blocks. The authors discuss design problems, the steps in system design, the end results of design, system organization, design theory concepts, information handling, system design procedure, techniques of design, and human factors. Recommendations are given to managers on what characteristics they should look for in selecting prospective innovators.

1970 — 320 pages — $12.95

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405 Essex Road, Neptune, New Jersey 07753

INFORMATION RETRIEVAL NUMBER 72

Evaluation Samples

Pushbutton switches

Free samples of lighted pushbutton switches are available in personalized colors to match any equipment. The switches, designated the 1820 series, are available in any color or combination of colors for the individual buttons, nylon bezels and housings. Metal bezels are available in chrome, black-oxide or brass-plated steel styles. Ratings include 2 to 9 A at 125 or 250 V ac. Molex, Inc.

CIRCLE NO. 292

Mounting clips

To speed up the anchoring of cable, tubing, pipe or rod up to 1-in. in dia, Self-Stik mounting clips have an adhesive backing that gives permanent holding on any smooth surface without any special surface treatment or tools. They are available in three styles—top clips, side clips and pressure-lock clips. There are 13 holding sizes from 1/8 to 1-in. in dia. Free samples are available. Lorain Tool & Mfg. Co.

CIRCLE NO. 293

Conductor tape

A universal conductor line tape for PC artwork preparation is available as a free sample. The LA550 tape replaces individual requirements for separate crepe and matte-finish tapes by combining the best characteristics of both into a single opaque black tape. The completely opaque LA550 tape returns a clean and sharp reproduction image. Backing is of a transparent adhesive that permits repositioning during application and provides a permanency that will not lift after final positioning. Widths from 1/64 to 4 in. in 20-yard rolls are available. By-Buk Co.

CIRCLE NO. 294

Design Aids

Wire and cable chart

Measuring 15 by 22 in., a new four-color wire and cable reference chart lists the electrical, physical and chemical properties of over 21 commonly available wire insulation materials. Graphs and sketches included in the chart show common conductor materials, coatings and configurations, bare copper wire characteristics, current carrying capacities and correction factors. Other characteristics shown include stranding, color coding, shielding and jacketing. Judd Wire Div. of Electronized Chemicals Corp.

CIRCLE NO. 295

Headline lettering

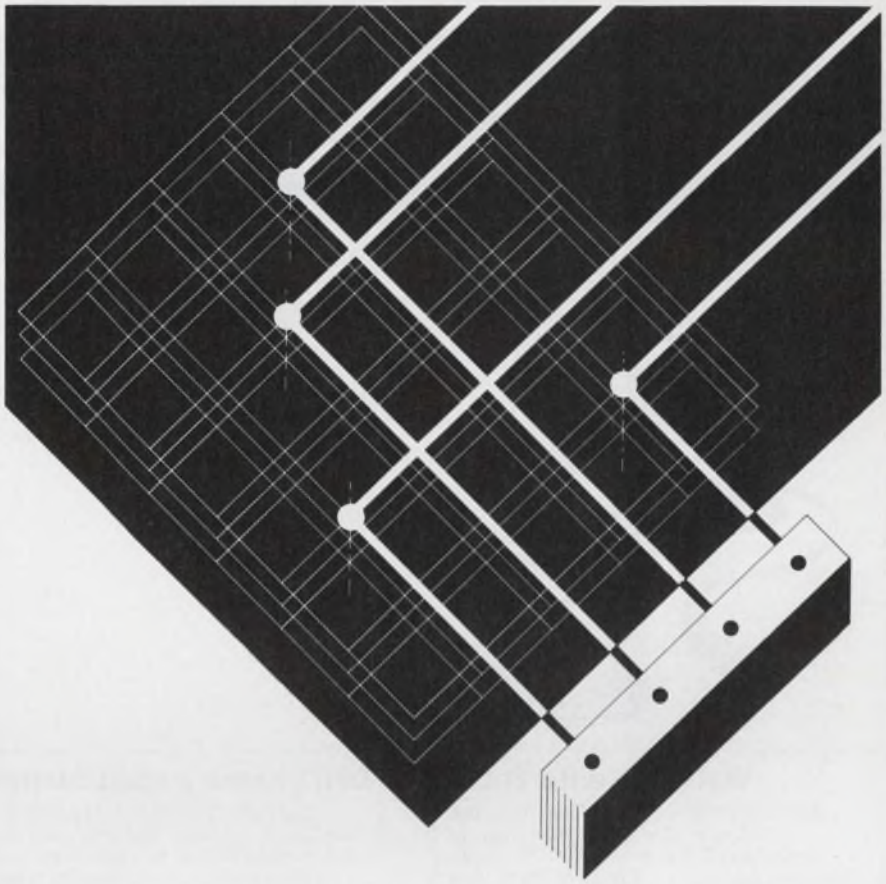
The Formatt Headline-Setter is a new device for simplifying and speeding up the setting of headline lettering. Guide lines are printed along its leading edges and it is made of rigid vinyl. With its use, letters are easily applied to its guide lines. The complete headline can then be moved in its entirety and positioned precisely onto reproduction art and drawings. After the headline is rubbed down, the Headline-Setter is cut away from the letters and is ready for reuse. Graphic Products Corp.

CIRCLE NO. 296

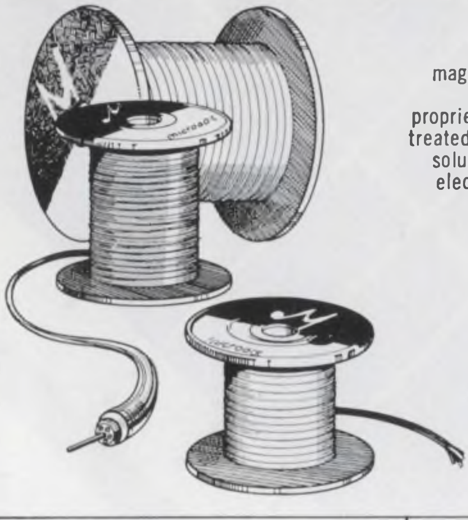
Waveguides & switches

Featuring listings of waveguides and coaxial switches, a new wall chart measuring 16 by 22 in. simplifies the selection of microwave components. It features the electrical and mechanical specifications of various waveguides and coaxial switches. It also includes numerous photographs of the listed products. In addition to these listings, a brief outline of the manufacturing company's facilities and capabilities is included. Waveline, Inc.

CIRCLE NO. 297



Very, Very Microdot.



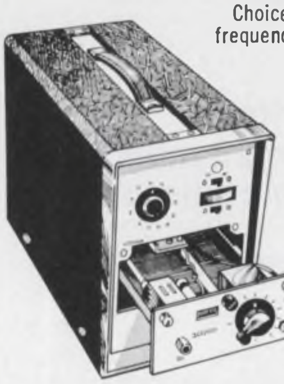
Able cable.

"Mini-Noise" coaxial reduces noise voltage magnitude by a factor of 100 to 1 compared with other cables. Reason: Our Cable Division's proprietary process of coating cable with specially treated Teflon* or polyethylene dielectrics. A great solution to audio noise problems encountered by electronic component manufacturers and users.
*Du Pont Trademark

We present, for your pleasure and profit, a sampling of the superb in electronics and aerospace products. Engineered by divisions and companies of Microdot Inc. Designed to solve specific problems. For lack of space, your particular problem may not be discussed here. Don't fret. Call us. For some very, very interesting solutions.

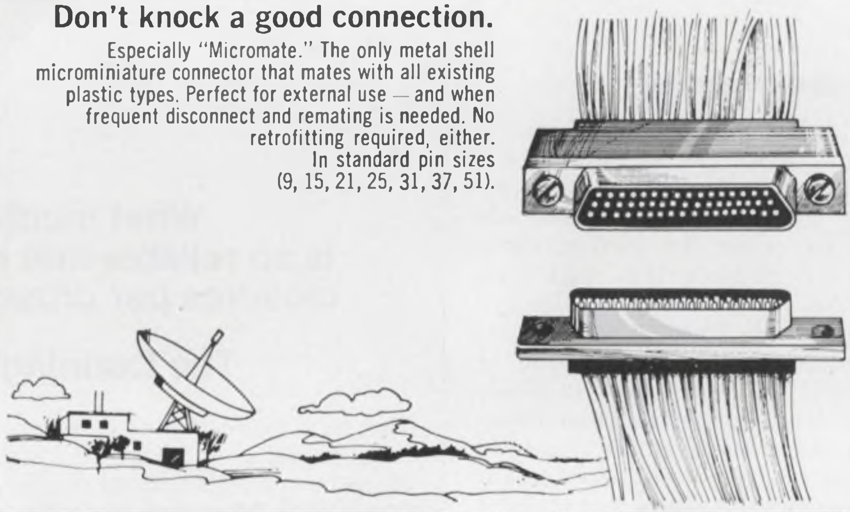
Watts the difference?

Microdot's Model 445 oscillator, of course. A 50-watt plug-in performer from our Instrument Division. With VHF-UHF power. Choice of heads for 6 frequency ranges. From 2-2500 MHz. Has positive no-load protection. Must equipment for everything from power meter calibration to antenna pattern measurements.



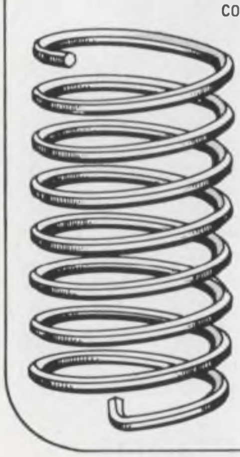
Don't knock a good connection.

Especially "Micromate." The only metal shell microminiature connector that mates with all existing plastic types. Perfect for external use — and when frequent disconnect and remating is needed. No retrofitting required, either. In standard pin sizes (9, 15, 21, 25, 31, 37, 51).



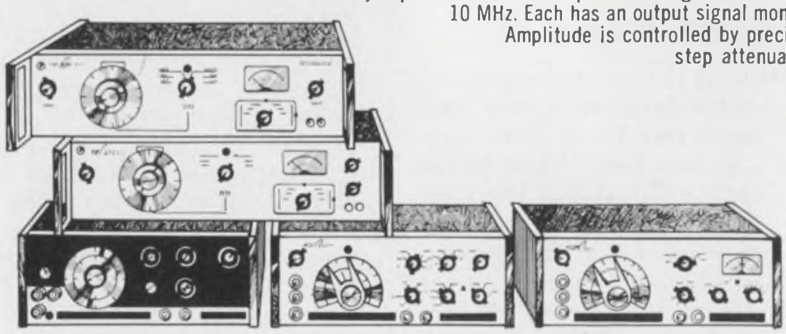
Decisions. Decisions.

You now have a choice in helically coiled threading inserts. Plus good reasons for deciding on Perma-Thread from our Kaynar Manufacturing Division. Available in Std. 208 Free-running and Pitch-Lok 209 Locking series. Inserts increase assembly reliability, eliminate thread failures, stay securely in place. They're the lightest, smallest inserts on the market. Interchangeable with all other coiled inserts.



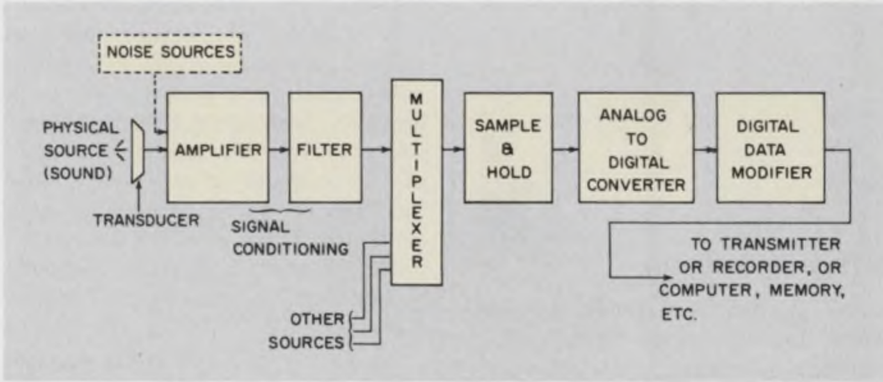
Testing: 1-2-3-4-5.

Microdot's Instrument Division is offering a new line of general test oscillators and waveform generators. Five in each series. Waveforms cover frequency spectrum of .005 Hz to 3 MHz. Output signals: sine, square, triangle, ramp and sync pulse. Oscillator frequencies range from 10 Hz to 10 MHz. Each has an output signal monitor. Amplitude is controlled by precision step attenuation.



MICRODOT INC.
220 Pasadena Ave., South Pasadena, Calif. 91030

Application Notes



A/d converters

Three publications give a thorough treatment of the subject of signal conditioning. One discusses what's wrong with a/d converter specifications. It explains analog errors, problems encountered in designing precision a/d converters, whether one should build or buy a converter and what a/d converter specifications really mean to the user. The second publication discusses techniques of digital sampling and recovery of analog signals, and includes a glossary of terms. The third publication talks about signal conditioning for a/d conversion in instrumentation systems, and shows various conversion methods used—such as successive-approximation and integrating converters and sample-and-hold circuits. All discussions are fully illustrated with block diagrams, operating curves and pertinent circuits. Analogic Corp.

CIRCLE NO. 298

Impedance measurements

Detailed methods of ratio-type measurements of swept-impedance are given in a new application note. Where traditional techniques, such as those employing Smith charts, usually restrict measurement to the vicinity of 50 or 60 Ω, the swept technique provides wide dynamic range around virtually any impedance level between 10 and 1000 Ω. Hewlett-Packard.

CIRCLE NO. 299

Wideband op amps

The practical and theoretical considerations necessary in applying wideband amplifiers to high-speed analog circuitry are outlined in a new 12-page brochure. It details basic theory and key parameters such as closed-loop bandwidth, damping ratio, delay and rise and fall times. Intronics.

CIRCLE NO. 300

Noise data

Entitled "Noise Engineering Data," a six-page brochure describes desirable noise in terms which permit the engineer to analyze his needs and make best use of the data presented. It indicates several applications in which noise is desirable—as the carrier for secure communications and as a jamming signal. In addition, the brochure explains how to purchase noise as in raw diodes, in modules or in systems. Solitron/Microwave, Microwave Semiconductor Div.

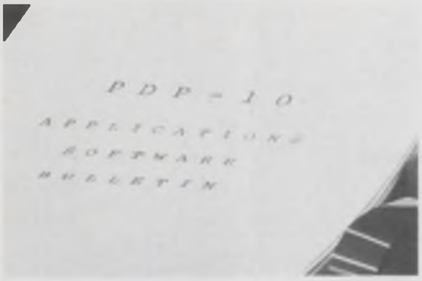
CIRCLE NO. 301

IC notes

Two sets of application notes show 11 different uses for various types of integrated circuits. Each application is presented on a separate sheet with supporting schematics and logic drawings. Sylvania.

CIRCLE NO. 302

New Literature



Software bulletin

700 applications programs are listed in the new "Application Software Bulletin." Included is software available either through the Digital Equipment Computer Users Society, (DECUS), or through sale or trade, and programs presently under development. Revisions of the bulletin are planned quarterly. Digital Equipment Corp.

CIRCLE NO. 320

Timers

A 40-page illustrated catalog offers fundamental timer information and a glossary of industrial timer terminology. Raymond Controls Corp.

CIRCLE NO. 321

Rotary switches

An eight-page rotary switch bulletin includes 32 standard circuit configuration examples, available options, clip information and printed circuit clip patterns. Oak Manufacturing Co.

CIRCLE NO. 322

Power semiconductors

A four-page selection guide features high-power and high-speed semiconductors with current and voltage spectrums of 5 to 50 A and 70 to 300 V. Detailed specifications are given for 140 silicon devices. TRW Semiconductors Inc.

CIRCLE NO. 323

IC notes

Six integrated-circuit application notes describe logic gates, adders, decade counters, shift registers and binary counters. Sprague Electric Co.

CIRCLE NO. 324

Lectures

A catalog of lecture surveys and courses to be given in Los Angeles, Calif., and Washington, D.C. between September 1970 and February 1971 is now available. A few of the subjects offered are fundamentals of radar, modeling and control of large systems, and computer-oriented methods in pattern recognition. Technology Service Corp.

CIRCLE NO. 325

Software packages

New data sheets on software packages discuss both basic and application software. Included is an engineering drafting package designed to produce detailed drawings on a digital plotter with input easily coded by a draftsman or an engineer using English statements. Milgo Electronic Corp.

CIRCLE NO. 326

Connectors and sockets

A 28-page catalog, listing 2000 interconnection devices, contains technical data and specifications on stock printed-circuit edge and rack-and-panel connectors, integrated-circuit sockets and a wide variety of other sockets for tubes and transistors. Cinch Manufacturing Company.

CIRCLE NO. 327

Roadway safety handbook

A pictorial catalog of highway conditions which might cause an accident or contribute to its severity, published by the Highway Users Federation for Safety and Mobility, is available. Entitled "Maintenance and Highway Safety Handbook," it is intended to help point out road hazards so that they can be corrected before they become a factor in a crash. It includes nearly 100 photographs of typically poor road conditions. Highway Users Federation for Safety and Mobility.

CIRCLE NO. 328

Interface IC

Multiple uses of the SN75450 peripheral interface IC are discussed in a six-page application report. In 23 separate applications, it shows how designers can use this IC advantageously. Circuit schematics, a package configuration and a functional block diagram are illustrated. Texas Instruments Inc.

CIRCLE NO. 329

Components and tools

A cross-referenced catalog gives a complete selection of electronic components, test leads, chemicals, TV hardware, and research in new products. GC Electronics.

CIRCLE NO. 330

Flexible wire

A 16-page brochure describes all types of flexible wire assemblies for computer, commercial electronics, aerospace and military applications. Ansley Div. of Thomas & Betts Corp.

CIRCLE NO 331

Tunnel diodes

Tunnel diodes are described in a four page brochure. It features performance curves, typical circuit configurations and general engineering data on amplifier, switching, oscillator, mixer and detector diodes. KMC Semiconductor Corp.

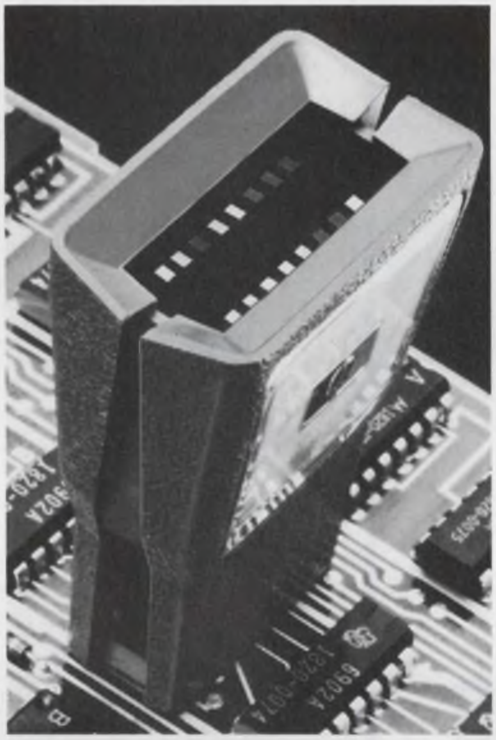
CIRCLE NO. 332

Relays and switches

An eight-page catalog features PC relays and switches. It also includes magnetic-counter and standard relays and PC track switches. ITT Corp.

CIRCLE NO. 333

The IC troubleshooters.



For $125, it lets you see logic states at a glance.

Engineers testing the logic states of DTL or TTL IC packages no longer have to go the troublesome voltmeter route. The new HP 10528A Logic Clip shows you the state of all 16 (or 14) pins. This simple tool clips over the IC package, uses the circuit's power, is auto-seeking of Vcc and ground.

Bright LED's light up, indicating a high logic state. All this for just $125. Or less in quantity.

For $95, it lets you see pulse activity at a glance.

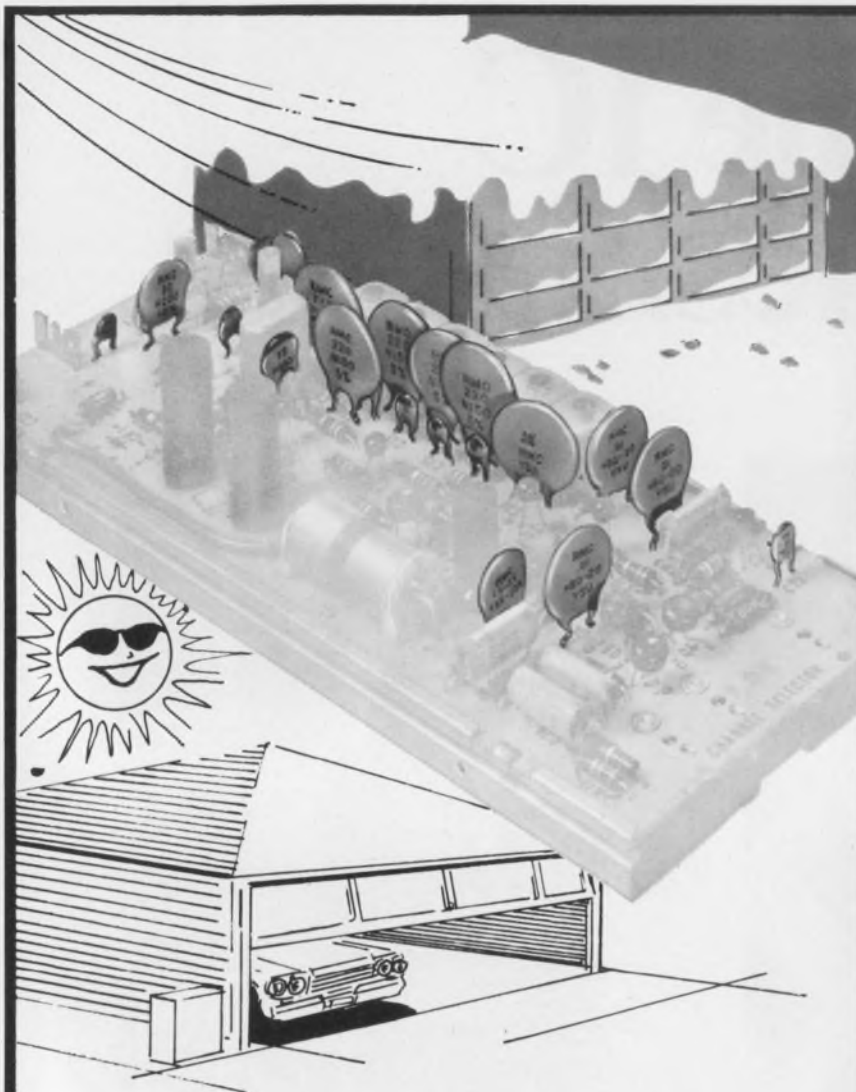
The HP 10525A Logic Probe makes tracing pulses through integrated circuits a painless task. Just touch the DTL or TTL circuit with the probe, and the tip flashes a signal for pulses as narrow as 25 nsec. A light in the tip indicates pulse, polarity, pulse trains, logic state.

It's almost like having an oscilloscope squeezed into a ball-point pen. And it only needs 5 volts and $95 to start troubleshooting your circuits.

Your local HP field engineer is your source for the clips and probes to speed up your IC testing. So give him a hurry-up phone order. Or you can write for full information from Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

HEWLETT hp PACKARD

INFORMATION RETRIEVAL NUMBER 86



Microwave devices

A new 43-page microwave components catalog describes and illustrates microwave devices. Featured are engineering data and diagrams showing dimensions for each component. Bendix Microwave Devices Division.

CIRCLE NO. 334

Coaxial shunts

Coaxial shunts for surge and high-frequency current measurements are described in a catalog. They provide an inductance-free output voltage directly proportional to circuit current. T&M Research Products, Inc.

CIRCLE NO. 335

Silicones

"Silicones for the Electronic Equipment Industry" is a 20-page bulletin detailing a variety of silicone products for improving the performance, reliability, safety and service life for electronic products. Dow Corning Corp.

CIRCLE NO. 336

Instrument rental

A 4-page brochure provides economic justifications for renting electronic equipment such as DVMs, oscilloscopes, counters, power supplies, recorders and generators. Electro Rents, Inc.

CIRCLE NO. 337

Transistor tester

A brochure outlines means to test and sort all ranges of transistors and diodes on a go/no-go basis according to predetermined sets of specifications. Also included are techniques used to measure transistors and diodes with 1% accuracy. Lorlin Industries.

CIRCLE NO. 338

Stereo accessories

A catalog contains a wide variety of accessories and equipment for the care and maintenance of audio tape recorders and phonographs. Audiotex, GC Electronics.

CIRCLE NO. 339

Bulletin board

of product news
and developments

When connected to the speaker of any audio equipment (stereo, TV or tape recorder) a new wireless speaker adapter broadcasts the sound to any regular or portable radio within 100 feet. The unit includes automatic volume control to prevent distortion for overmodulation, resulting in a good clear sound. It needs only two wires, clipped to either the speaker terminals or to the earphone jack. This battery-powered speaker adapter from Herbert Salch & Co., Marketing Div. of Tompkins Radio Products, Woodsboro, Tex., costs $19.95. An optional power supply is available for $3.95.

CIRCLE NO. 340

A price reduction on its premium-grade operational amplifiers has been announced by Precision Monolithics, Inc., Santa Clara, Calif. Prices for the SSS101A amplifier have dropped from $45 to $36 for quantities of 10 to 24, and from $30 to $18 for quantities of 500 to 999. The SSS107 amplifier has dropped in price from $50 to $40 for quantities of 10 to 24, and from $33 to $19 for quantities of 500 to 999.

CIRCLE NO. 341

Printout speeds of IBM 360 and 370 computer systems can now be increased with **the Compuspeed software package** of Computing Efficiency Inc., Bohemia, N. Y. The package maximizes I/O processing overlap when using the IBM 1403, 1443, and 3211 printers.

CIRCLE NO. 342

The IVC-870 is a new color videotape recorder with both insert and assemble editing features. The 1-in.-format recorder of International Video Corp., sells for $8000 (color version) and $7500 (monochrome version).

CIRCLE NO. 343

Electronic Design

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Design Data from

How To "Design-Your-Own" Precision Power Supply In Minutes.

Super/reg® miniature, pre-packaged, precision power regulators (series and shunt types) make possible design/fabrication of **custom** power supplies with virtually no engineering time or effort. Data Sheets S201A, S202A, S204 show how just a front end of raw DC or a transformer with rectifying diodes and filter capacitor — and a heat sink mounting area — are all that are needed. Single or multiple outputs easily accommodated. 104 models provide wide range of voltage levels, maximum layout flexibility, low output Z(0.01% regulation), temperature compensation 0.01%/°C, 125°C operation, output adjustability ±10%, short circuit protection.

CIRCLE NO. 171

Trio Laboratories, Inc.
80 Dupont Street
Plainview, N.Y. 11803

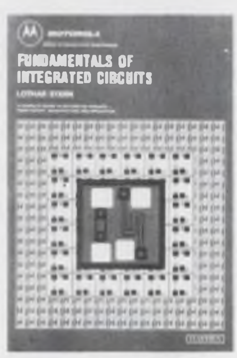
IC Controlled, Field-Serviceable Power Modules Featured in Comprehensive New Catalog/Designer's Handbook

Technipower's Catalog No. 701 gives complete data, electrical and mechanical, on more than 3000 power modules and accessories, including: **New PK Series,** 0-32 VDC, to 80 watts, designed to meet MIL specs (vibration, shock, moisture, RFI), have IC control circuitry, are field serviceable, multi-surface mounting, ideal computer supply; **New OP Series** low cost overvoltage protective devices for above; **New Logic Card Supply** provides regulated 5VDC/1ADC, with overvoltage protection, at very low cost; **Plus** many fully-described options, expanded thermal applications data, and glossary.

CIRCLE NO. 172

Technipower, Inc.
a subsidiary of Benrus Corporation
Benrus Center, Ridgefield, Conn. 06877

FUNDAMENTALS OF INTEGRATED CIRCUITS



A practical guide to integrated circuits, their theory, manufacture, and applications. This new guide by Lothar Stern offers compete, highly readable coverage of the various techniques of circuit fabrication, and their effect on circuit design and performance. As to marketing considerations, it compares the characteristics of the numerous IC structures devised to date in terms of economics and logistics. A volume in the **Motorola Series in Solid-State Electronics.** 198 pages, 7 x 10, illustrated. $8.95, clothbound. Circle the reader-service number below for 15-day examination copies.

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Hayden Book Company, Inc.
116 West 14th Street
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Manufacturers

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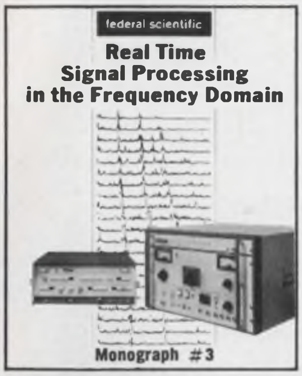
New Monograph on Real-Time Data Processing Techniques



A new publication by Federal Scientific, originators of the Ubiquitous® Spectrum Analyzer, covers general and specific signal processing techniques and theoretical constraints.

- Random data processing and statistical certainty of Power Spectral Density Estimates
- Constraints in frequency analysis due to bandwidth, sampling and signal length
- Time domain weighting, with charts of theoretical performance using different weighting functions
- Theory of operation of time-compression analyzers
- Cross-property analysis and application in determing transmission and transfer functions by correlation and cross-power spectral density
- Processing of Transient data

CIRCLE NO. 174

Federal Scientific Corporation
a subsidiary of Elgin National Industries, Inc.
615 West 131st Street, New York, N. Y. 10027

Clamp or Tie Wire Bundles In Seconds!

Six-page catalog contains complete ordering information for CAB-L-TITE® clamps and BUND-L-TITE® straps, devices which provide a fast and reliable means of securing wires and wire bundles. Units withstand loadings greater than 50 G's, are removable in seconds for re-routing wires, and are self-locking—no tying, no knots, no hitches to come loose. Lightweight Du Pont Zytel meets MIL-P-17091 and MIL-P-20693. Proved in aircraft and missiles. Photos, dimensional drawings, tables, physical properties, specifications, price list. Request catalog A.

CIRCLE NO. 175

Dakota Engineering, Inc.
4315 Sepulveda Blvd.
Culver City, California 90230

How To Write Technical Articles

A guide for the engineer-author, "How to Write Articles for Electronic Design" shows how easy it is to write for publication—once the engineer knows what to write and how to write it. The Author's Guide includes a complete run-down of the types of articles published by Electronic Design—plus detailed instructions on how to prepare technical articles and short special features. A MUST for every "would-be-writer" in the electronics industry. Send for your complimentary copy by circling the number to the right.

CIRCLE NO. 176

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