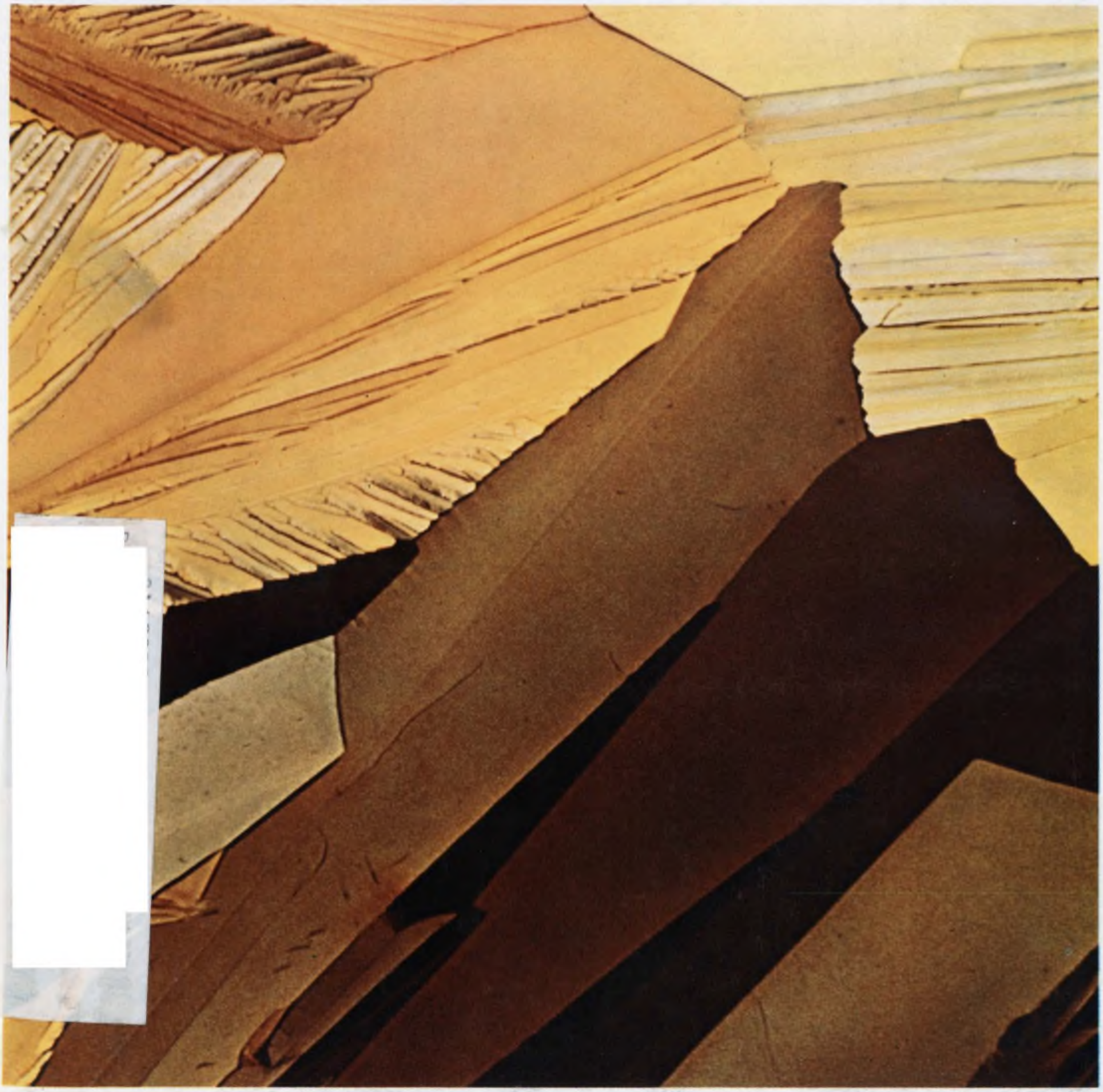
VOL. 17 NO.

Electronic Design 12

FOR ENGINEERS AND ENGINEERING MANAGERS

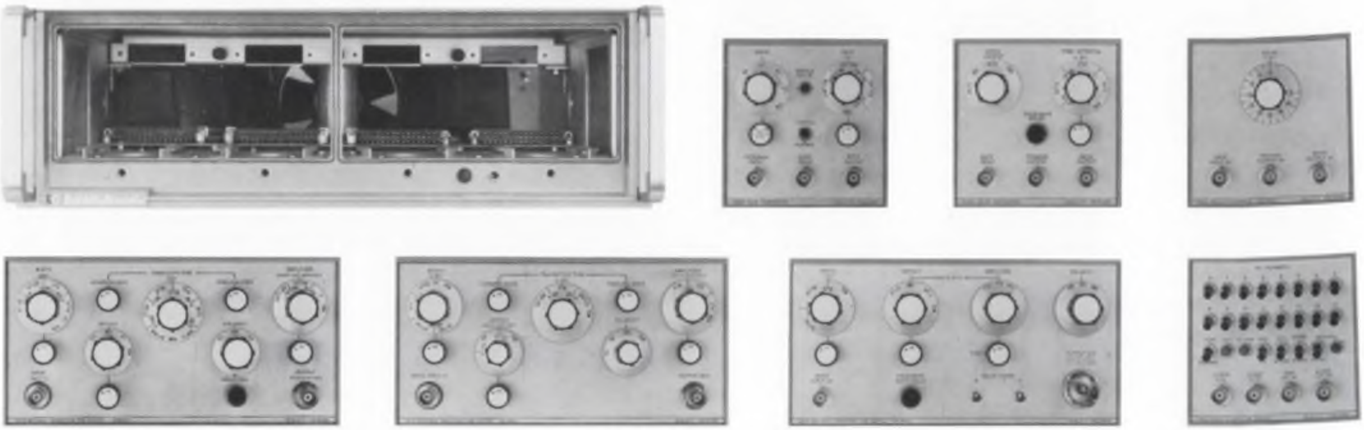
JUNE 7, 1969

Don't take insulation for granted. Choose it carefully, or you may doom an otherwise sound design. This holds true whether you are specifying connectors, buying PC boards or designing radomes. But what are the differences between insulating materials? And how do you select the best type for an application? It's easy. See p. 65.



Pulse problems change and change and change and change..............and

so does the 1900 pulse system



HP's brand new solution for people with pulse problems is a set of multi-purpose building blocks. You put what you want in your pulse generating system. With the HP 1900 Pulse System, you start with a standard mainframe that contains only power supplies and optional programming wiring.

Where do you go from there? That's up to you. HP is currently offering seven different functional plug-ins with more to come later. You can start with a relatively simple system and add to it as your needs change. Even complex pulse systems can be formed easily by using several mainframes and appropriate plug-ins.

Just to give you an idea of the capability of the 1900 system, here is a very brief description of the 7 existing plug-ins and some of their capabilities. And, keep in mind that the optional programming wiring allows you to make the 1900 completely automatic!

HP 1905A Rate Generator—provides output triggers variable in frequency from 25 Hz to 25 MHz; it includes a pushbutton for single pulse triggers. ($200)

HP 1908A Delay Generator—delays or advances pulses up to 25 MHz over a range of 15 ns to 10 ms and includes a double pluse mode. ($200)

HP 1910A Delay Generator—pulses up to 125 MHz can be delayed from 5 to 100 ns in 5 ns steps. It has a 3 ns risetime and sufficient output to drive two variable transition time output plug-ins. ($150)

HP 1915A Variable Transition Time Output—varies pulse risetime and falltimes from 7 ns to 1 ms and output currents from 40 mA to 1A, amplifies RZ or NRZ word formats. ($1600)

HP 1917A Variable Transition Time Output—varies pulse risetime and falltimes from 7 ns to 500 μs, amplifies RZ or NRZ word formats, 0.2 to 10 V amplitude at frequencies up to 25 MHz. ($525)

HP 1920A Pulse Output—provides very fast 350 ps fixed risetime and 400 ps falltime with variable width and 0.5 to 5 V amplitude. Reversible polarity and offset capability. ($1750)

HP 1925A Word Generator—provides 2 to 16-bit words, RZ or NRZ format at frequencies to 50 MHz. Has remote programming and pseudo-random noise sequence generation capabilities. ($850)

Two mainframes—are available to let you select the one that best meets your power requirements. Price: HP 1900A Mainframe, $750; HP 1901A Mainframe, $450.

Put together the system that best fits your needs. No other pulse system will do so much, so well—at such an economical cost! For more information, contact your local HP field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.

INFORMATION RETRIEVAL NUMBER 242

HEWLETT hp PACKARD

SIGNAL SOURCES

Electronic Design 12

VOL. 17 NO. 12

FOR ENGINEERS AND ENGINEERING MANAGERS

JUNE 7, 1969

NEWS

TECHNOLOGY

PRODUCTS

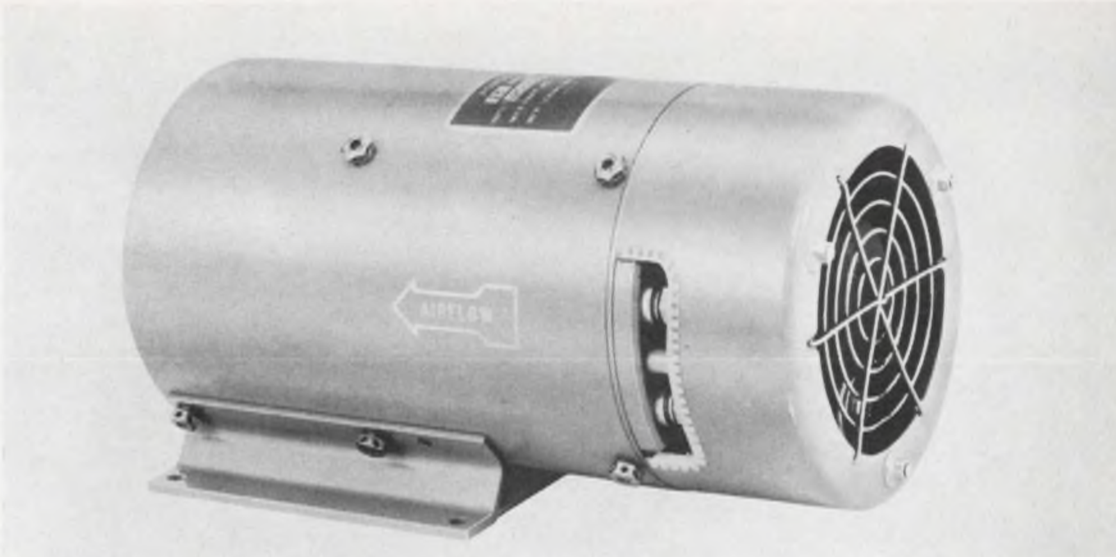
Departments

COVER PHOTO: a micrograph of bismuth A, courtesy of Union Carbide Corp.

ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N.Y. 10022. James S. Mulholland, Jr., President. Printed at Brown Printing Co., Inc., Waseca, Minn. Controlled circulation postage paid at Waseca, Minn., and New York, N.Y. Copyright © 1969, Hayden Publishing Company, Inc. 77,523 copies this issue.

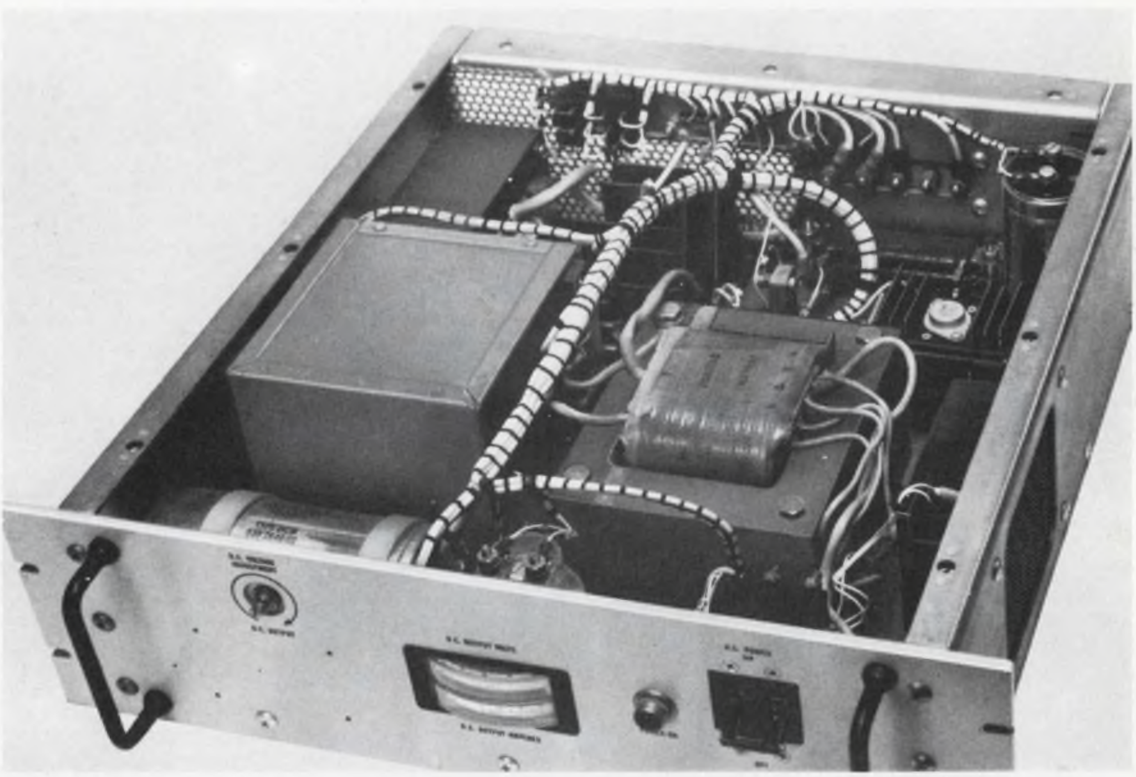
The deepest source for answers to ceramic magnet questions.

PRE-ENGINEERED POWER!



28G5P 47-65 Hz input (also style 28GP for 400 Hz), high-efficiency 28 V D.C. output; lightest, most compact static unit.

Here are two readily available ways to get dependable 28 V. D. C. high-current power



CR27.5 High-current, adjustable, 1% regulation, 28 V.D.C. output, 50-60 Hz unit. Withstands substantial overloads.

Tung-Sol pre-engineered standard power supplies meet lots of special requirements. You'll find they offer many cost/efficiency/size-weight/availability advantages. No more shoehorning in at the last minute with a make-do power unit. No more high-cost custom or do-it-yourself designs. In all likelihood, Tung-Sol's done it before ...and can meet the specific requirements of your circuitry.

Tung-Sol pre-engineered power supplies reflect unique production abilities and in-house capabilities in solid-state components, transformers and electromagnetics which contribute added performance-value to your equipment. Units meet EMI and MIL Specs.

Talk to one of our experienced factory engineers. He's backed by a versatile line of pre-engineered, readily available, standard power supplies. Tung-Sol Division, Wagner Electric Corporation, 630 West Mt. Pleasant Ave., Livingston, N.J. 07039. Telephone (201) 992-1100.

TUNG-SOL*

Helps you do more
...with less

*Registered trademark Wagner Electric Corporation

INFORMATION RETRIEVAL NUMBER 5

INFORMATION RETRIEVAL NUMBER 6 ▶

Small, compact size, yet large capacity; long life.

HP RELAYS – Here is a new series of high power, high reliability relays designed with the user in mind. Complete standardization and design simplification have made it possible to deliver this high performance line in all quantities at prices that will demand the attention of the experienced relay buyer.
HC RELAYS, HM RELAYS – HC relays are new, extra long life, AC or DC miniatures. The HM relays are DC types, and are offered in a wide range of voltages. Both types are interestingly priced, especially when performance is considered.

HP RELAYS

HP2-S

S-series – for direct solder tab connection or used with AMP-connectors.

HP2-R

R-series – for plug-in to standard sockets.

FEATURES: □ UL Approval □ Long life, high reliability, superior contact performance. □ DPDT, 3PDT & 4PDT types available at all voltage levels. □ Both solder and plug-in types available for AC and DC HP applications at 6, 12, 24, 48, & 120 volts. □ Complete standardization & simplification allow minimized sizes and lowest prices. □ Totally interchangeable with U.S. components, including pin configurations.

SPECIFICATIONS:

Max. switch-off current	10A AC
Max. switch-on current	20A AC
Max. contact current	10A
Max. contact voltage	250V AC
Max. contact power	120W (at DC 24V), 2.5 KVA
Max. pull-in/drop-out time	15 ms
Shock resistance	10G
Mech. life	Over 10,000,000

HP 3 RELAYS

Brand new series – 3-pole versions of HP relays, for both AC & DC high power applications.

HC RELAYS

HC 4
4C contact arrangement

HC 2
2C contact arrangement

Especially designed to meet market demand for EDP, computer, process control and many other applications.

FEATURES: □ UL Approval □ Extra-long life: Mechanical – 10^8 / Electrical – 10^5 □ High reliability – gold flashed silver-cadmium oxide contacts. □ Compact size – 1.2 cu. in. □ AC & DC types □ Large control capacity: 3A for 4C, 5A for 2C.

SPECIFICATIONS:

Shock vibration resistance	10-5G, 55 Hz
Coil voltage	6 to 115 VAC, 6 to 110 VDC
Pull in/Drop out time	13/10 ms
Temperature range	−50° to +50°C

Coil power @ 25°C:
AC=1.20V amps nom.; 0.77V amp min.
DC=0.90 watt nom.; 0.58 watt min.

HM RELAYS

P terminal

S terminal

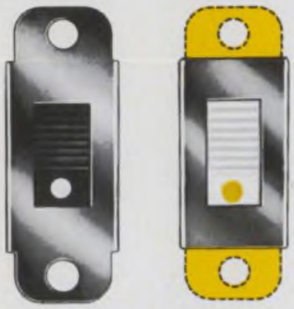
FEATURES: □ Minimum 15g contact pressure □ High life □ Low price □ Contact material: gold flashed silver □ SPDT types available with both P and S terminals at 3V, 6V, 9V, 12V, 18V, 24V, 35V, 42V, and 60V.

SPECIFICATIONS:

Max. switch-off current	3A
Max. switch-on current	10A
Max. contact current	6A
Max. contact voltage	250V
Max. contact power	90W/1 KVA
Mechanical life	20,000,000
Pull-in/Drop-out time	12/8 ms
Vibration resistance	5G, 55 Hz

Call or write for details:
REMVAC COMPONENTS, INC.
37-55 61st Street, Woodside, Long Island, New York 11377 • (212) TW 9-6100
Agents for U.S. sales of components manufactured by Matsushita Electric Works, Ltd.

Got a switching problem? Perhaps an ordinary slide or rocker switch is what you really need. Or a standard switch with merely a slight modification. Stackpole can do more with a simple slide or rocker switch than you ever thought possible. Here are just a few examples. Look them over. Consider how you could be utilizing these versatile, yet economical and rugged devices. Stackpole makes more slide and rocker switches than anybody in the world. And makes them better!



CASE MODIFICATION SAVES COSTLY PRINTED CIRCUIT BOARD SPACE

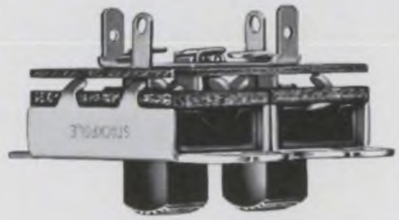
Space savings of up to 35% are possible by this simple case modification. Printed circuit terminals on the switch permit fast, simple insertion into the circuit board either manually or automatically. Also note that a hot stamped yellow dot was included to indicate ON position.

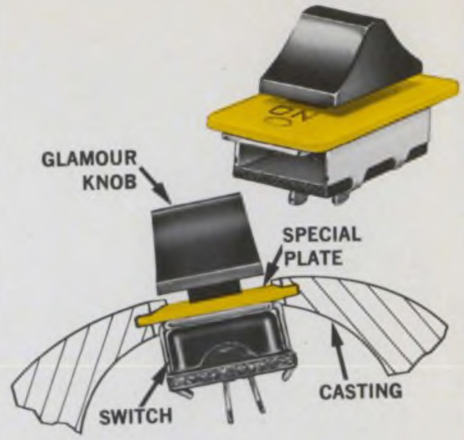
PLUG-IN CAPABILITY REDUCES ASSEMBLY TIME

The addition of wire leads with quick connectors provides a package that can literally be plugged into the unit. Any of the currently popular quick connection devices can be used. Leads can be specified to any length.

DOUBLING THE SWITCHES CAN HALVE THE COST

By ganging two slide switches, Stackpole saves this customer the time required to make two additional solder connections in the unit. Ganging can also solve complex switching function problems efficiently. This single operating knob controls the "on/off" of two separate functions in a floor polisher.





CASTING CAPTURE SIMPLIFIES APPLIANCE SWITCH MOUNTING ON CAST METAL OR MOLDED FRAMES

Simple attachment of a special metal mounting plate to a slide switch provides an effective, yet economical means of capture mounting the switch between two halves of a housing. The plate is inscribed so that the glamour cap provides visual indication of switch position by hiding one side while exposing the other. This modification is particularly applicable for power tools and appliances utilizing cast metal or molded frames.

MINOR CHANGES CAN MEAN MAJOR SAVINGS

This inexpensive slide switch was "adapted to a customer's individual application" simply by means of a slightly modified case. This particular case was adapted to include elongated mounting centers. Also incorporated into this design was a yellow notation spot to visually indicate whether the switch is in the ON or OFF position.

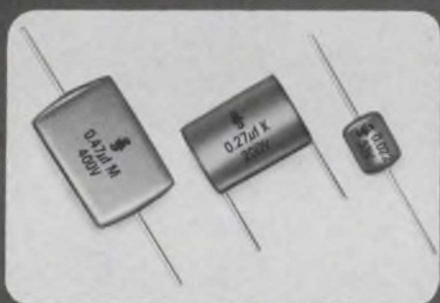
GLAMOUR CAPS... GREAT WAY TO TOP OFF A SWITCH DECORATIVELY, FUNCTIONALLY

Glamour caps for slide switches and custom knobs for rocker switches are two highly versatile means of adding sales appeal to any item. Shapes are almost infinite. So also are the colors. Lettering, "on-off," "high-low," etc., can be hot stamped in various colors.

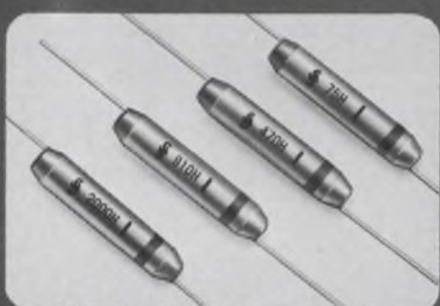
SIEMENS

Capacitors

A Full Range of Capacitance And Voltage Ratings In Four Types -- Designed With Your Application In Mind.



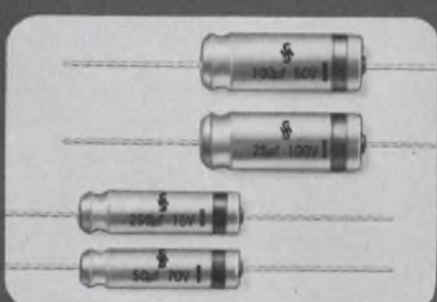
POLYESTER—33-630 V d.c., 1000 pF —0.47 MF



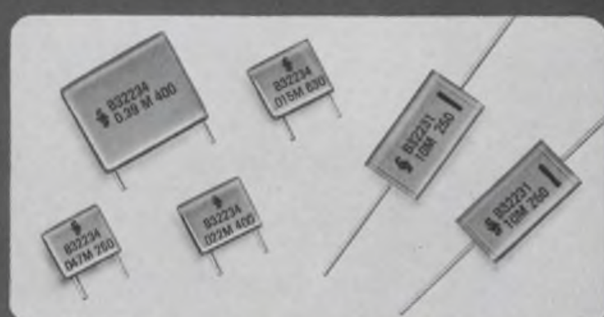
POLYSTYRENE—33-630 V d.c., 1-25,000 pF

You can rely on Siemens to provide a wide range of precision built capacitors. High performance units that are available now in four major types designed to match your circuit requirements.

In addition, you can call on Siemens experienced engineers to assist you with your application problems involving the capacitors shown, as well as: Tantulum and Polycarbonate capacitors, Ferrite materials, Semiconductors, and many other products.



ALUMINUM ELECTROLYTICS
3—100 V d.c., 0.5—10,000 MF



METALLIZED POLYESTER
100-630 V d.c., 0.01—10 MF

For technical information or assistance, contact:

Siemens America Incorporated, **Components Division**
685 Liberty Avenue, Union, New Jersey 07083 (201) 688-5400

"A tradition of craftsmanship and service since 1847"

INFORMATION RETRIEVAL NUMBER 8

INFORMATION RETRIEVAL NUMBER 9 ►

Rogan Control Knobs For Quality Control

From electronic test equipment to appliances . . . from communications equipment to amplifiers . . . to almost every type of electrical application required today. Rogan offers the added advantage of *unlimited color* possibilities—molded material, or decorative inlays. It's the Rogan Knob that is selected when quality is the specification—and pricing the consideration. It's the Rogan name that makes the Rogan knob the designers' No. 1 choice in knobs.

Write today for new full color catalog or see us in Sweets or Thomas Micro catalog. Outline your requirements for quotation and free knob sample.

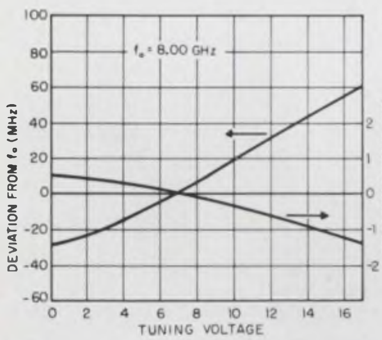
Rogan
BROTHERS, INC.

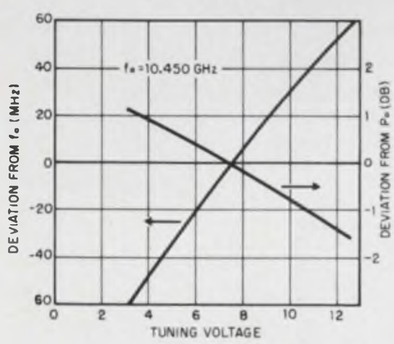
8019 N. Monticello Ave. Skokie, Illinois 60076

Phone: (312) 675-1234

for intradyne SYSTEMS

At **Intradyne**---a new generation of microwave devices and sub-systems with superior performance characteristics is being manufactured in **production quantities** and with **high repeatability** using a Computer Controlled Network Analyzer in design, evaluation and checkout. Printout data can include VSWR, reflection coefficient, attenuation and gain, phase linearity, group delay, coupling and h,y,s and z parameters---**for every unit.** The Intradyne-owned analyzer can complete---with high accuracy---the equivalent of **6 man days in one hour!** The voltage tunable sources and the miniature coupler described are typical **Intradyne** computer-assisted designs.





VOLTAGE TUNED OSCILLATOR

(Actual Size)

Now available---a series of voltage tuned, solid-state oscillators suitable for flight hardware that cover the frequency range from 8 to 12 GHz. The curves to the left show frequency and power output deviations with varying voltage.

FREQUENCY: .... 8.0 to 12.4 GHz.
BANDWIDTH: .... 200 MHz, mechanical.
50 MHz, voltage tuning.
POWER OUTPUT: .... To 50 milliwatts.
TEMPERATURE STABILITY: .. 0.35% max. 0.25% typ.
DELIVERY: .... Stock to 45 days ARO.

To your specifications within short engineering cycles: Miniature, high-rel multi-function assemblies incorporating ferrite devices, couplers, mixers, bandpass filters.

INTRADYNE
SYSTEMS, INC.

470 San Antonio Road,
Palo Alto, Calif. 94306
(415) 328-7840

Computer Analyzer printout of sub-miniature broad-band 10 db coupler

FREQ.	VSWR 1	VSWR 2	VSWR 3	VSWR 4	LOSS DB	ISOLATION DB	COUPLING DB
2000.0	1.05	1.03	1.02	1.05	-.5	-28.0	-11.0
2300.0	1.06	1.05	1.03	1.06	-.5	-27.2	-10.4
2600.0	1.10	1.09	1.07	1.08	-.7	-26.8	-10.1
3000.0	1.14	1.13	1.11	1.10	-.7	-26.4	-10.0
3300.0	1.11	1.10	1.11	1.10	-.7	-26.3	-10.0
3700.0	1.06	1.05	1.10	1.09	-.5	-26.8	-10.3
4000.0	1.00	1.02	1.06	1.05	-.6	-27.8	-10.7

INFORMATION RETRIEVAL NUMBER 11

Designer's Datebook

JULY 1969						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
		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		

AUGUST 1969						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
					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						

For further information on meetings, use Information Retrieval Card.

July 7-11
Nuclear & Space Radiation Effects Conf. (Philadelphia) Sponsor: IEEE, NASA, et al., E. A. Burke, Air Force Cambridge Research Lab., Hanscom Field, Bedford, Mass. 01730

CIRCLE NO. 400

July 20-25
Engineering in Medicine & Biology (Chicago) Sponsor: IEEE, L. Stark, Univ. of Illinois, Chicago. 60612

CIRCLE NO. 401

Aug. 5-7
Joint Automatic Control Conference (Boulder, Colo.) Sponsor: IEEE, G-AC, W. E. Schiesser, Dept. of Chemical Engineering, Lehigh Univ., Bethlehem, Pa. 18015

CIRCLE NO. 402

Aug. 12-15
International Photoconductivity Conference (Palo Alto, Calif.) Sponsor: ONR, American Physical Society, Robert J. Keyes, Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass. 02173

CIRCLE NO. 403

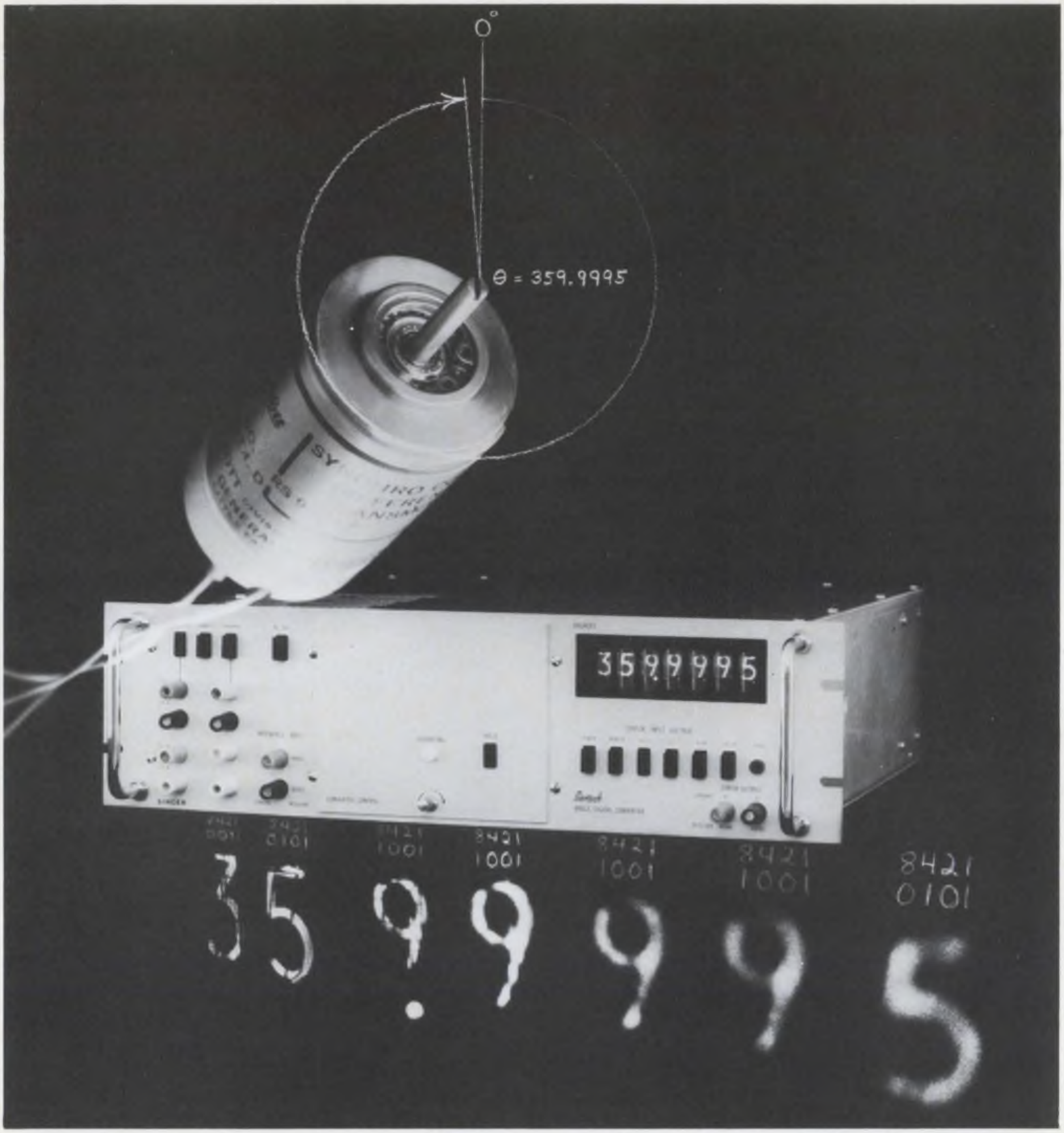
Aug. 19-22
Western Electronic Show & Convention (WESCON) (San Francisco) Sponsor: IEEE, WEMA, T. Shields, WESCON, 3600 Wilshire Blvd., Los Angeles, Calif. 90005

CIRCLE NO. 404

Aug. 24-27
Electronic Materials Technical Conference (Boston) Sponsor: AIME, Edward L. Kern, Metallurgical Society of AIME, 345 E. 47th St., New York, N.Y. 10017

CIRCLE NO. 405

INFORMATION RETRIEVAL NUMBER 13 ►



Instant angles – Instant interface with Gertsch

Whenever you need 0.001° synchro/resolver measurement accuracy in less than 250 milliseconds with computer compatability, look to the versatile converter from Singer. Series ADC Angle/Digital Converters adapt to most all synchros and resolvers.

Protection against application obsolescence is provided by use of front-panel plug-in converter control. For example, when the Model ADC-1 main-frame is equipped with a **Model CC-1** plug-in, the instrument functions as a 0.001° synchro/resolver-to-digital converter. However, when the same main-frame is equipped with a **Model CC-7** plug-in, the unit becomes a digital-to-synchro/resolver converter (digital CT). Several plug-in, main-frame combinations are possible now, with more promised in the future!

Is 0.001° (3.6 seconds-of-arc) too accurate for your application? A 0.01° main-frame (ADC-2) is also available at reduced price.

Regardless of which combination you select, you are assured of:

- Computer compatability, 5V logic levels with current sink inputs and BCD outputs.
- 45° Self-Test from front or rear panel, at any time you want.
- One-Megohm input impedance.
- Isolated inputs and outputs.
- 0 to 50°C operating range
- Immunity to noise, harmonics, and phase shift.

INFORMATION RETRIEVAL NUMBER 14

For a demonstration, or for full technical details, call your local Singer Instrumentation representative or contact us directly at The Singer Company, Instrumentation Division, Gertsch Operation, 3211 S. La Cienega Blvd., Los Angeles, California 90016 (213) 870-2761.

SINGER
INSTRUMENTATION

INFORMATION RETRIEVAL NUMBER 228 ►

Heard the new word in D/A converters? It's MINIDAC ...and it means just what it says.

A miniature, high speed / high performance digital-to-analog converter . . . completely self contained in a tiny encapsulated package.

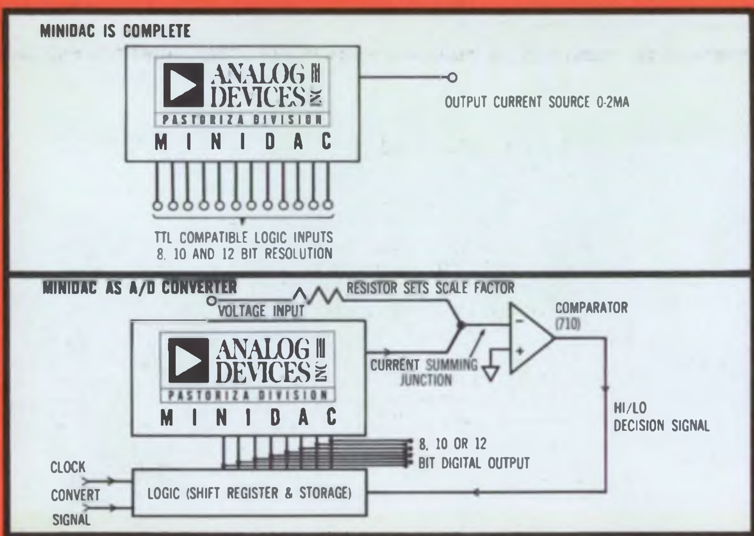
High speed? The fastest! In fact, MINIDAC switching time of just 200 ns means that only your logic or analog circuitry limits system speed. As for precision, you can choose 8, 10, or 12 BIT resolution, (BCD or BINARY), with ½ LSB linearity.

This kind of size and performance is clearly something NEW . . . The secret? An exclusive current switching technique which yields the very ultimate in switching speed, practically eliminates switching transients and supplies a current output for maximum flexibility in driving all kinds of analog circuitry.

Perhaps the most significant feature of this unique design is economy. MINIDAC is priced for the OEM . . . The 12 BIT version just $130.00 (100 lot), 8 BIT models are under $100.00. And remember, MINIDAC is a complete D/A converter!

Where to use it? You name it! High speed flicker-free displays . . . digitally programmed test instrumentation . . . all kinds of computer interface applications. Add a few components (logic and comparator) and your MINIDAC becomes a precision high speed A/D converter. The hard part is done for you . . . switches, reference, resistor networks are all included with performance tested and guaranteed!

Check the specs on the back, then ask for an in-your-plant evaluation. Just use the instant action reply card . . . no obligation, of course.



The MINIDAC module includes all critical components for high speed conversion . . . reference supply, precision resistor network and 8, 10 or 12 high speed solid state switches. Input is compatible with DTL and TTL logic, output is current source for maximum flexibility.

MINIDAC becomes a high speed A/D converter by addition of Op-Amp comparator and shift register logic. Accuracy, linearity and resolution depends on precision components sealed in MINIDAC. Speed is limited only by comparator response and external logic speed. Complete 12 BIT conversion in 8 μsec is possible with 710 Type Comparator.

$130.
12 BIT MINIDAC
(MDA·L,
100 LOT)

BUSINESS REPLY MAIL
NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

FIRST CLASS
Permit No. 39342
Cambridge, Mass.

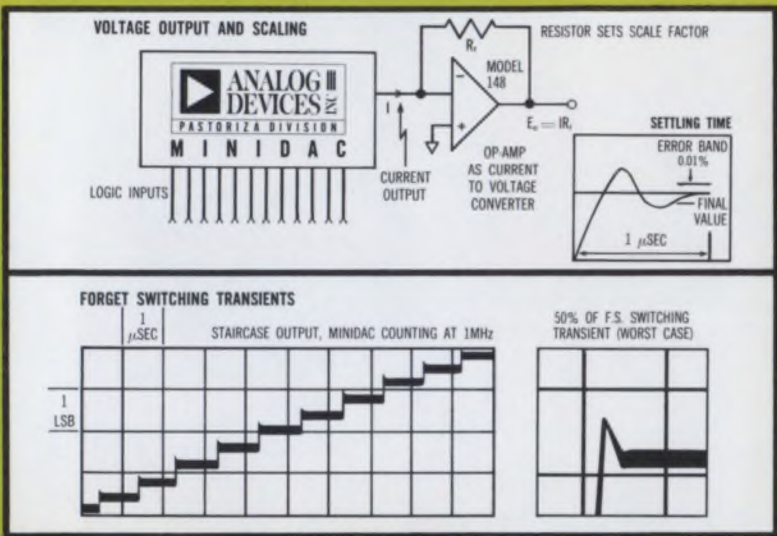
POSTAGE WILL BE PAID BY

ANALOG DEVICES INC

221 FIFTH STREET · CAMBRIDGE · MASSACHUSETTS 02142

S P E C I F I C A T I O N S

INPUT CHARACTERISTICS			**OUTPUT CHARACTERISTICS**	
Input logic levels	DTL, TTL, ETC.		Output current range	Zero to +2mA
MECHANICAL DIMENSIONS			Maximum output voltage	2 Volts
MDA-U	.75" x .75" x 1.5"		Zero offset	20 nA (0°C to 70°C)
MDA-L	2.0" x 2.0" x 0.4"		**ACCURACY / RESOLUTION**	
Power Supply	±15VDC		Digital Resolution	8, 10, or 12 BITS
Price (1-9)	MDA-L	MDA-U	Linearity	½ LSB @ 25°C
8 BIT	$140	$195	Temperature Coefficient	20 PPM /°C
10 BIT	$165	$230	Settling Time to 0.05%	200 ns
12 BIT	$195	$250	Switch Signal Coupling	Less than ½ LSB



Follow MINIDAC with high speed Op-Amp for voltage output or to set scale factor. Analog Devices model 148 settles to 0.01% in less than 1 μsec.

Exclusive current switching technique keeps switch signal coupling well below ½ LSB . . . important for high speed applications where "glitches" (usually generated by conventional voltage switching converters) cause ambiguous data, damage associated circuitry. Besides low amplitude, transient width is less than 40 ns.

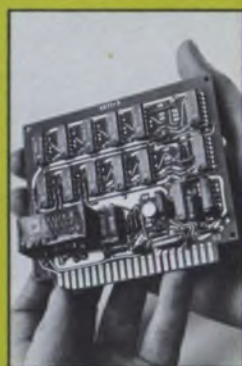
A/D CONVERTERS

FASTEST A/D CONVERTER YET!

Model ADC.F is the fastest A/D Converter commercially available, actually makes a compete 10 BIT conversion in less than 1 μs. High data rates usually require sample and hold units preceding the converter . . . not necessary with the high conversion rate of the ADC.F. Input voltage range is 0-10 Volts and the output supplies 10 parallel binary bits at TTL logic levels. The plug-in module is completely self contained including logic, switches, resistors, comparator and reference. Models are available with either 8 or 10 bit resolution.

LOW COST / HIGH SPEED A/D CONVERTER

The ADC-U is a complete, successive approximation type A/D converter built around the MINIDAC module. This combination of MINIDAC and commercially available components yields a unit which features high speed and low cost. A wide variety of input ranges is available and a choice of 8, 10 or 12 BIT resolution is offered. Conversion time is just 8 μ sec for the 12 BIT model, even faster for 8 and 10 BIT versions. P.C. card packaging is intended for the OEM, and so is the price . . . just $795 for the complete 12 BIT version.



221 FIFTH STREET · CAMBRIDGE · MASSACHUSETTS 02142 · (617) 492-6000 · TWX: (710) 320-0326

INSTANT ACTION REQUEST

☐ Please send Pastoriza Product Catalog

My interest is for:
☐ Information Only
☐ Immediate Application
☐ Anticipated Application

Please send literature on model
☐ ADC-F ☐ ADC-U ☐ MDA-L ☐ MDA-U

Please arrange demonstration of MINIDAC
☐ MDA-L ☐ 8 BIT ☐ BINARY
☐ MDA-U ☐ 10 BIT ☐ BCD
☐ 12 BIT

Special Requirements

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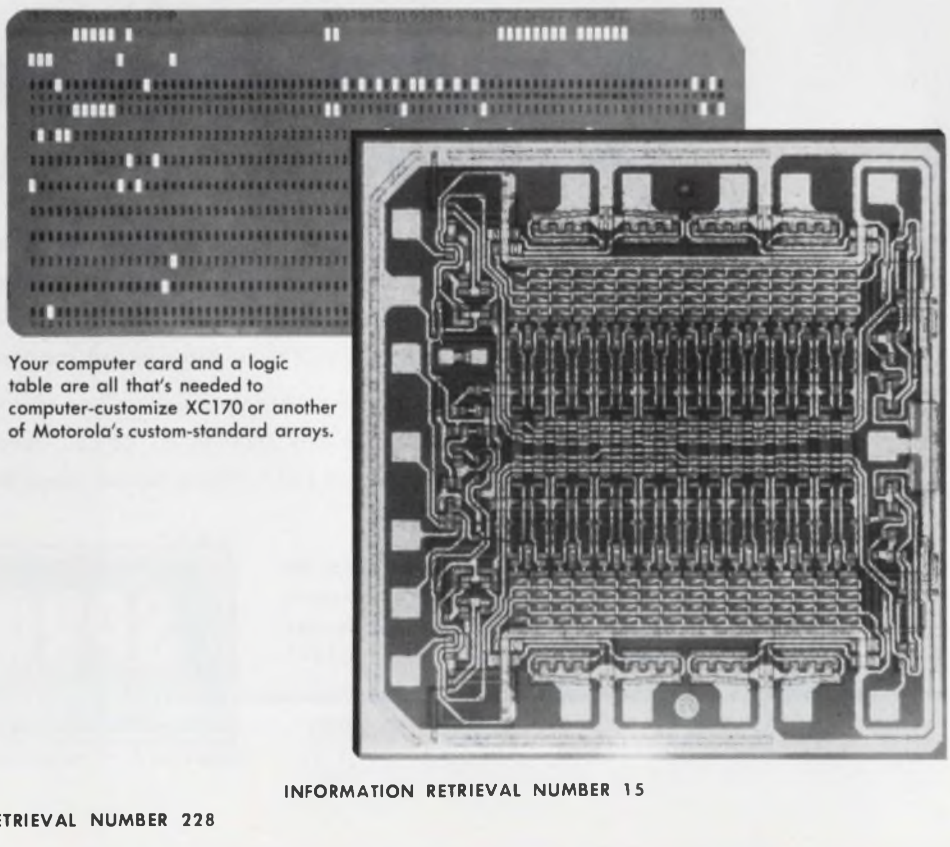

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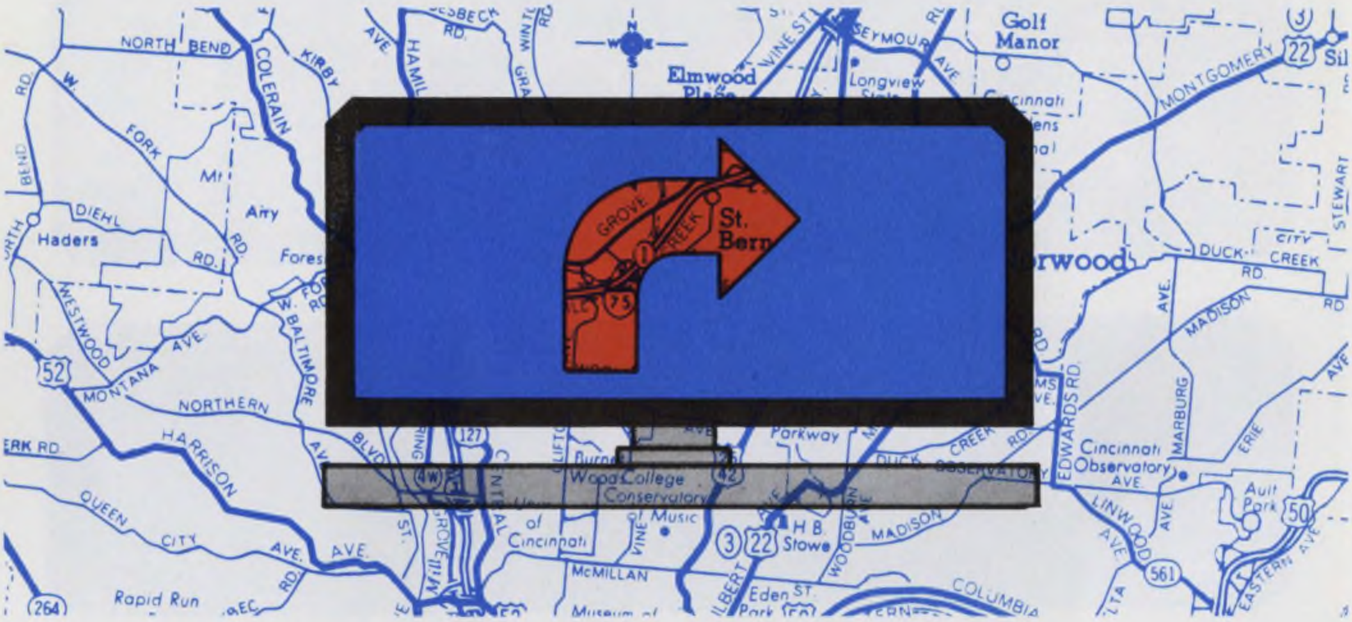
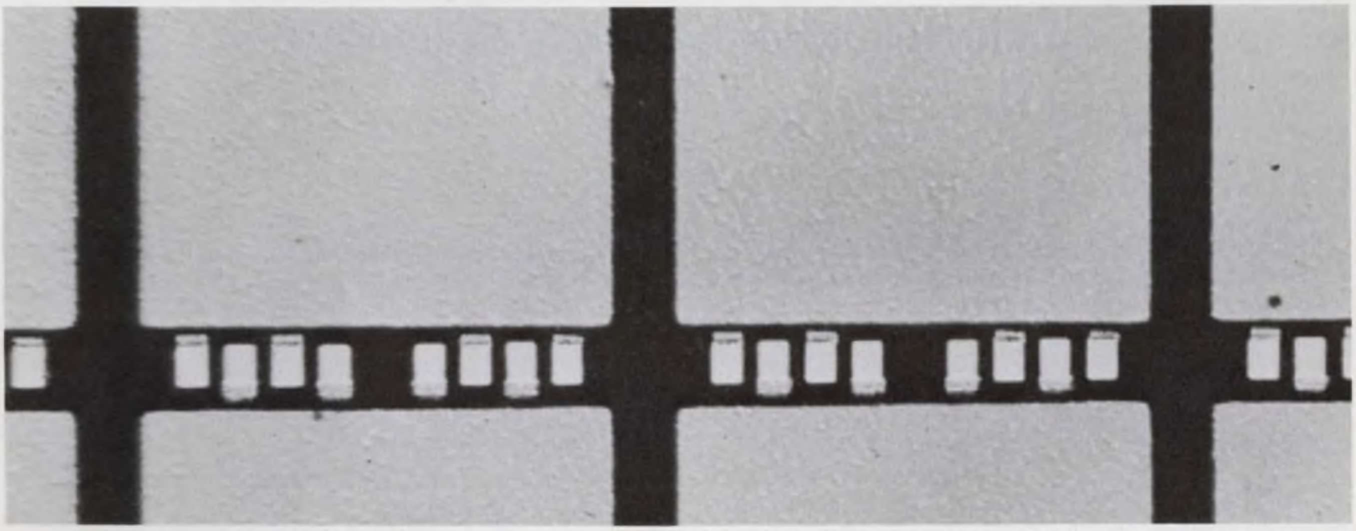
INFORMATION RETRIEVAL NUMBER 15

News



An electronic automobile guidance system now under development may permit drivers to reach any point in the United States fast and without the use of road maps. p. 25.



Capacitor manufacturers are developing new lines of high-temperature-resistant beam-lead devices in chip form for a wide range of semiconductor applications. p. 32.

Also in this section:

News Scope

Airlines seek visual enhancement systems

The nation's airlines are looking for electronic equipment to give pilots a high-fidelity real-world picture of the ground during rain, snow and fog.

This new technology, called "visibility enhancement," was explored in Washington, D. C., recently by experts from government and the aircraft industry.

At the meeting, sponsored by the All Weather Operations Committee of the Air Transport Association, a number of different approaches to the development of visual-enhancement equipment were described:

- Low-light-level television that would convert near infrared radiation to the visible state and intensify visual information. A real-time picture of the landing strip peaked in the visible region would be shown on a direct-view image intensified or the CRT of a TV set.
- Radar systems using frequencies at 16 GHz and 35 GHz for the monitor and 35-GHz band for the antenna that would provide high-resolution mapping of the approaching runway on a radar display.
- Holographic displays that would use the principle of wavefront reconstruction photography to show the pilot a three-dimensional virtual image of a runway.
- Night-vision devices that would operate from light passed through an objective lens and focused on an image intensifier tube or photoelectric cell. These devices require some light and an unobstructed visibility path between aircraft and airport.
- Infrared systems. These have greater resolution capability than radar, but they are subject to transmission losses due to scattering and absorption. Placing IR radiators in the vicinity of the runway is a possibility.
- Lasers, which operate generally in the visible or the IR region. These remain to be evaluated. Clouds, rain, fog and turbulence tend to degrade laser signals, but laser frequency might be varied to obtain best penetration under specific weather conditions.

Which systems are best? Capt. S. G. Granger, Director of Flight Operations-Research and Development, Trans-World Airlines, told ELECTRONIC DESIGN, "It's still too early to say, although the radar approach looks most promising."

Who will use the new system? About 5000 domestic, foreign, and business aircraft, and perhaps as many as 20,000 military aircraft, form a potential market for visual-enhancement equipment.

Such equipment would be a separate system in a plane and is not proposed to replace, or even to be added to, present landing systems.

As to cost, Capt. Francis L. Wallace, Project Director, Reduction and Minima Program, Pan American World Airways, makes a relative comparison: "When we modified our autopilot and instrument panels to meet FAA Category 2 requirements, it cost roughly $65,000 per plane."

(Category 2 refers to conditions where the runway visual range is 1200 feet and the pilot's decision height to land or abort is 100 feet above the landing zone.)

It has been estimated that radar visual-enhancement equipment would cost about $30,000 per plane. Infrared equipment, at the present state of the art, could range from $100,000 to $200,000.

Defense Department pushes satellite communications

The Defense Dept.'s budget request for satellite communications in fiscal 1970 is $149 million—more than twice last year's budget. And its request for detection and defensive techniques and systems in space is $169 million. These are the more significant figures in a total projected military space R&D budget of over $2.2 billion—up $128 million over last year. These figures came out during recent testimony of Dr. John S. Foster, Director of Defense Research and Engineering, before the Senate Committee on Aeronautical and Space Sciences.

Other major outlays requested are as follows: the Manned Orbiting Laboratory program, $528 million; navigation, $25 million; ground-support systems, $263 million; basic and applied research and component development, $147 million; vehicle development, $61 million; and for general support associated with these programs, $868 million.

The Defense Dept., said Foster, will step up development of new ground terminals for the operational Defense Satellite Communications System. It will also update subsystems in existing terminals supporting the network. He noted that TRW, Inc., received nearly $38 million to begin development of a synchronous strategic communications satellite last March.

Foster observed also that the three military services are preparing a joint development plan for the operational version of the Tactical Satellite Communications System. Hughes Aircraft developed the experimental TACSATCOM spacecraft, which was placed into a synchronous orbit last February.

Technology seen as spur to U.S. social progress

Can citizens of cities, states, and nations participate, as individuals in their own homes, in "town hall" meetings via Community Antenna Television? Gen James M. Gavin, chairman of the board of Arthur D. Little, Inc., thinks they can with proper organization—and perhaps a government-subsidized opinion-recording device.

In his keynote address to the Spring Joint Computer Conference in Boston, Gavin told computer engineers that their technology offers real hope for social progress.

"When people are as well informed as they are today," he says, "they want action at a rate comparable to the rate at which they acquire information. And they want to participate in decisions."

The computer and electronics industry can offer such an opportunity, according to Gavin. "It would be a very simple matter to permit people to register their point of view from their own homes—and gather the data at central information gathering stations," he says. "A device, subsidized by government funding, could be provided with each TV set, for instance, which would permit individuals to express their views on an issue."

Gavin doesn't see this as a voting system, but merely as an opportunity for citizens to express their point of view with respect to national problems as they would at a town hall meeting.

"But feedback from citizens is not enough," says Gavin. He also wants a governmental structure specifically designed to deal with social problems—a cabinet post with responsibility for domestic affairs. A critical duty of the structure would be to acquire vast amounts of data that "defines and delineates the problems."

He adds, ". . . the computer industry to date has concentrated on hardware and mathematical languages. It has grown up in isolation from our country's critical social problems.

"Now it is faced with an obligation to make the contribution to social progress that it is capable of—and computer engineers must find the way."

Oceanographic ships need better computers

The USNS John Gilbert Keller, the Navy's newest oceanographic vessel, is 208 feet long and carries about $1 million worth of electronic equipment.

Seaworthy computers are needed for naval oceanographic vessels. The computers built for the new USNS John G. Keller are considered the best in service today, but although they have not even been installed, they are already considered to be inadequate. They are not expected to fully solve the environmental problems a computer has at sea.

These problems involve salt spray, temperature extremes, humidity and general rough handling.

The biggest problem for oceanographic ships, according to Captain T. K. Treadwell, USN, Director of the U.S. Naval Oceanographic Office in Washington, D. C., is data processing. "What we want," he says, "is equipment that is compact, easy to operate, very reliable and extremely environmentally resistant." Capt. Treadwell is very concerned about the amount of downtime, which cuts into data-gathering time. Data quality control is a problem also. As he puts it, "being able to tell when the data that you have is no good—and throwing it out."

Capt. Treadwell feels that "the electronics industry has done a good job so far. The equipment being installed on the Keller is almost fully automated," he says, "and is a tremendous improvement over what we've had in the past."

But designers still have a long way to go to adapt computers for oceanographic work.

On May 22 the Keller received her bronze name plaque and ceramic oceanography plaque. She was sent into service prematurely, due to the present lack of naval oceanographic ships in service. Her function will be primarily to gather information that will aid naval navigation. Such information will include depth of water, position of the shoreline, ocean currents, and type of bottom.

Lockheed loses out—subcontractors suffer

Cuts, by the Army, of Lockheed Aircraft Corp.'s Cheyenne helicopter production contracts means the loss of subcontracts for some 500 firms.

What of the subcontractors? Congressman Barry Goldwater, Jr., who represents part of the San Fernando Valley in Los Angeles, is "extremely concerned over the loss of jobs due to the cut."

The jobs lost at this juncture are almost entirely production personnel. Very few design engineers will be directly affected.

However, the Cheyenne research and development contract is also in danger, and its loss would have a much more profound effect on the engineering community.

Daniel J. Houghton, Lockheed chairman, called the cancellation of the Cheyenne production contract "not justified" and confirmed that the company will "take appropriate legal action to protect our financial position on this contract."

New CRT operates in bright sunlight

A new high-contrast cathode-ray tube using a black phosphor screen, is said to operate in bright light with better resolution than conventional picture tubes. The tube, called the Sigmaconf, is manufactured by Electrovision Industries, Inc., El Segundo, Calif. It has a "multi-persistent" capability that makes it possible to combine TV and radar displays on the same tube. Other applications include computer readout, electro-optical high-speed printing, and video recording.

Telemetry, the road map of the future

Driver-guidance system to be tested by U.S. next year would point the way electronically

Charles D. LaFond, Chief
Washington News Bureau

Drive cross-country without a map and reach your destination on time? Visionaries in the U. S. Bureau of Public Roads say it could happen by the late 1970s.

The proposal, which is under study, is an outgrowth of research that is seeking down-to-earth, civilian uses for telemetry developed by the military and NASA. As envisioned by planners, the mapless drive across the country might work something like this:

You are in San Francisco, driving to Washington, D. C., and are unfamiliar with the route. You get behind the wheel, get out a special route destination booklet and locate "Western Ave.-River Rd." You find the locator letters "DCXSMB" and then rotate five thumb dials on a control box on the dashboard of the car to insert the destination code.

And you are on your way. Once you leave San Francisco, a heads-up display on the windshield, augmented by beeps and visual instructions, automatically give continuous, precise directions to your destination in Washington.

Contracts have been let

The Office of Research and Development in the Bureau of Public Roads has let a number of contracts in the last several years to develop the hardware and prove the feasibility of such a concept. An operational test of the system is planned next year in Washington.

Other applications for telemetry are being explored in such fields as oceanography, law enforcement, the oil and gas industry and earth resources satellite programs.

At the recent National Telemetering Conference and Exposition, held in Washington, only two technical papers dealt with military projects. The rest concentrated on civilian applications. One paper, "Industrial Scientific and Commercial Applications," presented by Erwin S. Teltscher, an engineer with Digicom, Inc., Roslyn, N.Y., described 44 civilian applications in seven major categories:

- Environmental data analysis and control by telemetry.
- Telemetry in the service of urban problems.
- Telemetry for safety, safety testing and warning systems.
- Telemetry for industrial testing.
- Application of telemetry to service industries and industrial processes.
- Industrial and service industry applications of telemetry via a synchronous satellite.
- Remote control and manipulation by telemetry.

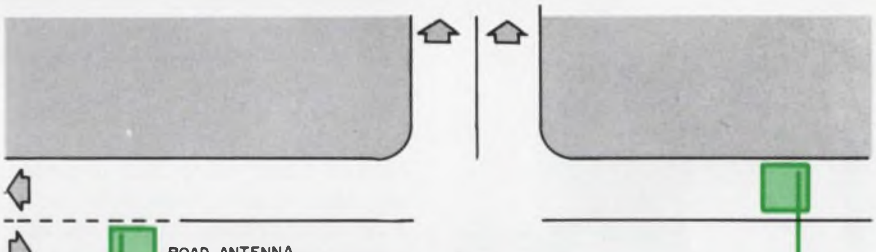
A 3-part road system

Details of the road telemetry network, called Electronic Route Guidance System, were revealed by the Dept. of Transportation in an extensive exhibit at the Washington conference.

The system consists of three major subsystems:

1. For the vehicle, a transceiver and antennas, destination encoder and a visual display with an audible signal.

2. Triggering-communications loop antennas for each lane.



A driver approaching an instrumented intersection transmits a destination code to a roadside unit via a road antenna. The unit interprets the code, compares it with stored data and then transmits appropriate instructions to the driver, either to continue straight ahead or change directions at the next intersection.

(**Telemetry,** *continued*)

3. On the roadside, destination decoders—computers with stored instructions to drivers—and transceivers.

The lane antennas and roadside decoder-transceivers would be spotted at frequent intervals along each controlled route.

In operation, once the driver has selected his destination code from a directory, the rest of the operation is automatic. When the car approaches an instrumented intersection, a loop antenna in the road lane activates the vehicular unit. The equipment in the car transmits the destination code to the roadside unit via the lane communications loop.

The roadside unit interprets the code, compares it with stored data and then transmits appropriate instructions to the driver—either to continue straight ahead or to change direction at the next intersection. The instruction received in the vehicle is accompanied by a beep warning signal and visual directions.

Electronic automobile guidance system now under development will enable drivers to avoid urban traffic congestion.

Millisecond operation cited

The entire sequence, according to Stanley Metalitz, assistant director for R&D in the Bureau of Public Roads, takes but a few milliseconds to complete; a driver need not slow down to receive his instructions. Since the system is "destination oriented," a driver missing an instruction need only continue to the next instrumented intersection to correct any mistake.

The wire-loop antennas in the vehicle and road lanes are essentially the same. Each pair is mounted in mutually perpendicular planes. In a given pair, the larger horizontal loop is for communications; the vertically oriented loop in the road and in the vehicle is for the triggering circuit.

The road trigger loop is always energized, and as a vehicle passes, a voltage is induced in its trigger loop to initiate the transmission of destination data to the communications loop in the lane. The latter relays the signal by cable to the roadside computer. The directions are then transmitted back to the large lane antenna and to the car.

Radio-link circuitry is all-solid-state. Transceivers in the vehicle and on the roadway are nearly identical, operating with a 2-watt output at 170 kHz. Vehicle receiver sensitivity is set at 140 mV, and the road receiver sensitivity at 70 mv. The triggering signal in the lane, from road to vehicle, is at 230 kHz.

Recalibration avoided

To avoid regular maintenance or recalibration, the communications link is asynchronous—that is, timing marks must be included with the signals to establish the framing of the incoming transmission so that the demodulator can sample the received waveform at the correct time.

The PCM transmissions are at a rate of 2000 bits a second. The reference timing mark precedes each data bit and also serves to change the state of the transmitter carrier to either on or off.

Metalitz says that the present system is designed to handle up to 16 vehicles simultaneously. Each lane of a roadway has its own pair of triggering and communication loops. The lane loops are offset by 7 feet each, so that in the worst case (16 vehicles passing simultaneously) the total delay of instruction transmissions for all vehicles is 24.3 ms. This is based on a maximum vehicular speed of 75 mph.

The staggered lane loops prevent the transmission of misinformation to a vehicle, and the low transmitter power prevents local interference. Developers indicate, however, that for the system to work properly, drivers must exercise lane discipline.

The bureau estimates the cost of vehicular equipment as about the same as that for a car's automatic transmission. For highway equipment, the cost is estimated to be comparable to that for an intersection signal system.

Major contractors involved

The Philco Corp. of Philco-Ford, Palo Alto, Calif., one of the early researchers of the system under contracts totaling $225,000, produced a six-character coding scheme last year designed to cover major highways in the entire country.

General Motors Research Laboratory and the Delco Div. of GM in Detroit, developed the prototype hardware for both roadside and vehicular equipment tests. They have worked on the program for the last two and a half years under contracts totaling $500,000.

Serendipity Inc., McLean, Va., under a contract totaling nearly $150,000, has performed studies to determine the human engineering aspects of vehicular displays.

Standard Kollsman Industries, Inc., Philadelphia, is developing a heads-up display for possible use in the system.

The Washington test next year, to be supervised by the Traffic Operation Office of the Bureau of Public Roads, will cover 100 intersections. Each intersection will be instrumented, and easily removable equipment will be provided for temporary installation in 50 vehicles, according to Metalitz. ■■

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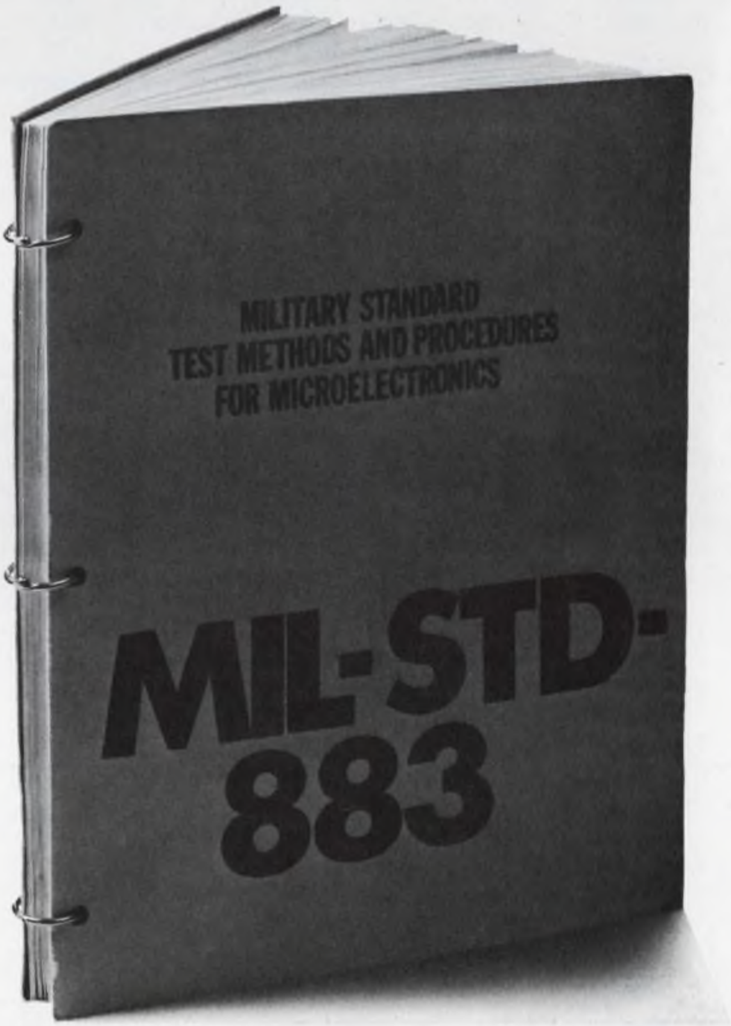

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INFORMATION RETRIEVAL NUMBER 19

Laser-acoustic line reverses time functions

Sweeping a beam along a transparent delay bar can also compress and expand microwave signals

Michael J. Riezenman
Technical Editor

Studies of the interaction between a laser beam and an acoustic wave have led to a device that can reverse a time function in real time. The same device can also expand or compress the time functions and provide the continuously variable delays needed in radar signal processing.

The device, called a laser-acoustic delay line—or LAD line, by most researchers in the field—has been developed by United Aircraft Research Laboratories of East Hartford, Conn.

Speaking at the IEEE Microwave Symposium in Dallas last month, Dr. Michael J. Brienza, chief of applied laser technology for the company reported that the device was the only practical means he knew of for reversing a time function in real time.

Because a LAD line can delay and reverse signals in real time, it can perform auto- and cross-correlations in signal-processing radars and sensitive receivers. For example, the line makes it possible to delay and reverse a transmitted pulse so that it can be correlated with a received signal for good performance in a noisy or jamming environment.

The main component of the LAD line is a transparent acoustic delay bar as shown in Fig. 1. The electrical-to-acoustic transducer at the input launches a sound wave in the transparent bar. As the wave travels along the bar it acts as a moving diffraction grating and scatters the laser beam passing through it. It also frequency-shifts the laser beam by an amount equal to the sound frequency.

Actually, since the optical-acoustic interaction is not 100 per cent efficient, only a part of the beam is frequency-shifted; the rest of it is unchanged. Thus, the scattered light can be combined with some of the unscattered light in the photodetector. Since the optical detector is intensity-dependent, the two light signals are heterodyned together to produce an output signal at the input frequency.

Signal processing with a mirror

In the operation just described, the rotating mirror (Fig. 1) is assumed to be stationary. Its position merely determines the point at which the laser beam crosses the transparent bar and thus determines the delay of the system.

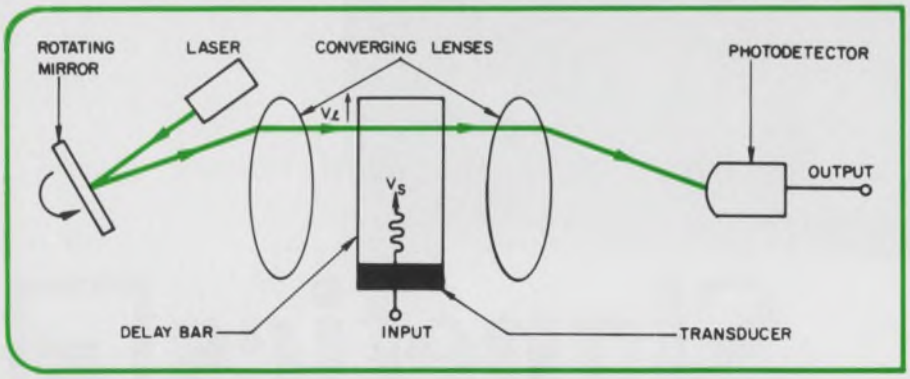
However, to really appreciate some of the tricks that the LAD line can perform, we must consider what happens when the mirror is rotating. When it rotates in the direction of the arrow, the laser beam will move up the delay bar as shown. If the scan velocity of the laser beam is V_l and the acoustic velocity in the delay bar is V_s, then the frequency and time duration of a pulse applied to the input will be shifted as follows:

$$f_o = f_i a$$
$$t_o = t_i / a$$

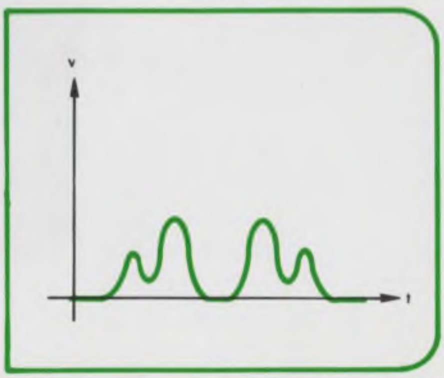
where $a = 1 - V_l/V_s$. The input and output frequencies are f_i and f_o, respectively, and the input and output pulse durations are t_i and t_o, respectively. The scan velocity, V_l, is defined positive in the direction of V_s.

Clearly for $V_l < 0$, the output signal is compressed in time and upshifted in frequency. When V_l is positive, the results will depend upon the relationship between V_l and V_s. For $V_s > V_l$, the output is time expanded and downshifted in frequency. The amount of time expansion and frequency shifting increases as V_l approaches V_s until, when they are equal, the output frequency becomes zero and the time expansion increases to the limit set by the length of the bar.

For $V_l > V_s$, the output signal is reversed in time since the laser beam is actually overtaking the acoustic pulse from the rear. If V_l is chosen so that $2V_s > V_l > V_s$, then the output signal will be exand V_s. For $V_s > V_l$, the output is $2V_s$, the output will be compressed and upshifted. In the interesting case where $V_l = 2V_s$, the output is a perfect time-reversed replica of the input pulse (Fig. 2). It is in this mode of operation that the LAD line will probably have its biggest impact. ■■



1. **Exact time reversal can be obtained** with this LAD line setup if the laser scan velocity, V_l, is exactly twice the sound-propagation velocity, V_s.



2. **Textbook pictures like this** can be achieved in real time with a LAD line.

Ovshinsky displays futuristic thin-film device

But amorphous semiconductors are still a long way from mass production, researcher concedes

John N. Kessler
News Editor

For years, Stanford R. Ovshinsky, president of Energy Conversion Devices, Troy, Mich., has insisted that he could develop commercial devices made of amphorous solids, but his company has been reluctant to sell samples to researchers in industry without an involved contractual agreement. At the Symposium on Semiconductor Effects in Amorphous Solids in New York City, Ovshinsky lifted part of the veil that he has placed over his work. He showed the 300 attending scientists photographs and drawings of thin-film switching and memory devices that his company has developed. Their operation is based on the rapid change in conductance that occurs in amorphous materials with an applied electric field.

Ronald G. Neale, vice president of operations for Energy Conversion Devices, called the new thin-film structures a "material and production evaluation run." But he would not predict when mass production might begin.

If reproducible devices can be mass-produced, a likely first application would be a read-only memory that would require no holding voltage to keep it in the "on" state. It would also be electrically alterable by the customer, thus avoiding rewiring at a factory.

The use of amorphous devices for electroluminescent devices is even more speculative. Potentially there is a large market for CRTs for television, message boards and other displays.

As for using the negative resistance characteristics of these devices to make oscillators and amplifiers, it's too early to make predictions.

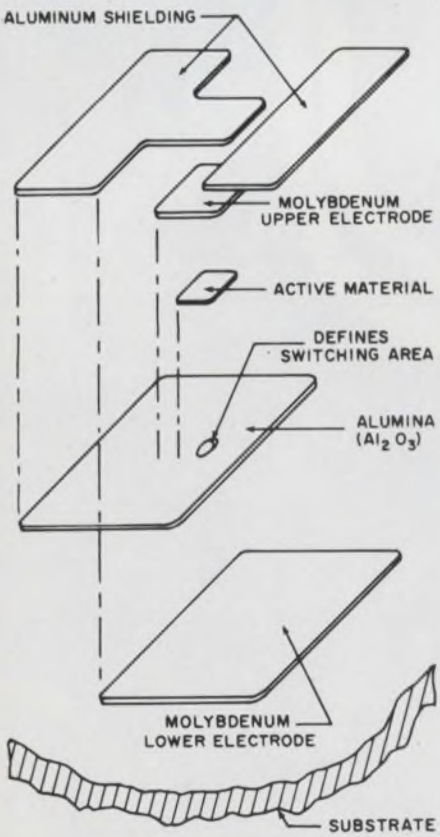
From a commercial standpoint, there are at least four problems to be dealt with so far as Ovshinsky's new devices are concerned:

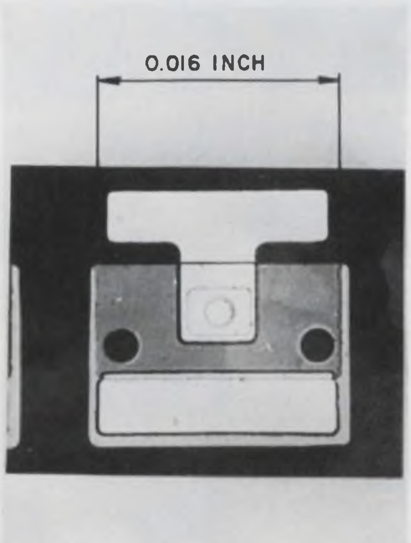
1. Although the switching time is short—150 picoseconds—the delay time before switching varies from about 0.5 to a few microseconds.
2. The devices suffer from lack of reproducibility, although Energy Conversion Devices and its consultants insist this is an interim problem.
3. The phenomenon of switching and memory effect is not peculiar to the glassy materials that Ovshinsky is primarily working with.
4. Any new devices will have to be compatible in electrical characteristics with existing devices.

Ovshinksy himself appeared more cautious than usual at the symposium, sponsored by the Picatinny Arsenal and the Army Research Office. Both he and his vice president of operations made it clear that a number of problems must be solved before mass production of devices can start.

"There is no question in my mind," he told Electronic Design, "that amorphous materials will make an impact, probably in the computer field and the display field. But like any other important development, it's going to take years and not going to be accomplished all at once."

Last November, when Ovshinsky published a paper on amorphous devices in *Physical Review Letters*, the journal of the American Physical Society, a flurry of publicity sent the stock of Energy Conversion Devices flying to dizzy heights. Newspaper stories speculated that Ovshinsky's devices heralded an era in electronics comparable to that of the discovery of the transistor. Flat-screen TV and pocket-sized computers were among the applications predicted. Then, as the facts trickled out—that Ovshinsky's work was still in the laboratory stage and nowhere near mass production—the stock tumbled to more realistic levels. Speculators lost millions, and detractors





At left: An exploded diagramatic view of Energy Conversion Devices' thin-film amorphous switch. It is designed so that 2500 devices can be fabricated on a 1 × 1-inch glass substrate. **Above:** The same switch magnified. The device is for evaluation only and is not commercially available at present, the company's officials emphasize.

began to say that the "Ovshinsky effect" appeared to be more financial than physical.

At last week's symposium, however, Ovshinsky got a respectful hearing. Morrell H. Cohen of the University of Chicago, a consultant to Energy Conversion Devices, said that the reliability of amorphous devices was not entirely dependent on the development of a mathematical model, as some scientists have contended.

"What is needed," said Mr. Cohen," is a mix of empirical information and good experiments.

"What one has to do is get enough of the qualitative understanding to know which way things go when you vary the various device parameters of a device configuration, the electrode materials and so forth. That kind of information is being collected very rapidly, and I think —and now I speak as a theoretical physicist—that adequate commercial reliability is quite likely to beat the theoretical physicists to the punch—in the sense that there will be a reliable device before the mathematical model."

Other scientists report

Nearly a fourth of the papers presented at the Symposium—13 out of 51—came from Energy Conversion Devices. Most of the rest were reports from workers at universities. A scattering of scientists represented some of the larger companies: Bell Telephone Laboratories, General Electric, Lockheed, Corning Glass, Xerox, and IBM.

A. D. Pearson of Bell Laboratories reviewed his early investigations of numerous semiconducting glass systems. In these studies, which were first reported in 1962, Pearson observed memory, switching, and negative resistance effects. Pearson suggested that the change in conductivity involved a thermal effect.

Pearson, Ovshinsky and others have patents covering amorphous materials and devices. But so far as possible patent disputes are concerned, Ovshinsky says there are none. "There are no patent contentions between me and anyone else," he told ELECTRONIC DESIGN, "Scientific work is based on what you do, and patents are a matter of record. ■■

Capacitor designs aim for IC compatibility

High-temperature and beam-lead tantalum devices in chip form developed for wide semiconductor use

Lucinda Mattera
New Products Editor

On the theory that if you can't lick 'em, join 'em, capacitor manufacturers are emphasizing compatibility rather than competition with the snowballing semiconductor industry.

At the 1969 Electronic Components Conference in Washington, D.C., the capacitor industry, with an eye on the blossoming use of hybrid circuit modules, unfolded a new manufacturing program aimed at direct substrate compatibility with integrated circuits. At the same time it disclosed exciting new applications for ceramic capacitors.

Introduced for the first time at the conference were:

- Solid tantalum chip capacitors that can withstand the same high temperatures as ceramic chip capacitors, and offer higher capacitance in less space.
- Beam-lead tantalum chip capacitors that are directly compatible, on the substrate, with silicon integrated circuits and have the extra of improved volumetric efficiency over ceramic devices.
- New alumina ceramic capacitors that can be used in rf transmission applications.

Fail-safe tantalum chip capacitors

Boasting as much immunity to high-temperature exposure as monolithic ceramic capacitors, a new family of solid tantalum chip capacitors was described in a paper by David Maguire, group product manager, Electronics Div., Union Carbide Corp. Previous limitations, caused by the breakdown or outgassing of the silver paint used to contact the counterelectrode, are eliminated by a new solid copper counterelectrode system.

Maguire explains that the solid tantalum chip capacitor consists of a series of layers. Tantalum metal is the positive electrode on which the dielectric layer of tantalum pentoxide is formed. The counterelectrode consists of manganese dioxide impregnated into the pores of the tantalum pentoxide, and a layer of colloidal carbon or graphite making a connection to the manganese dioxide.

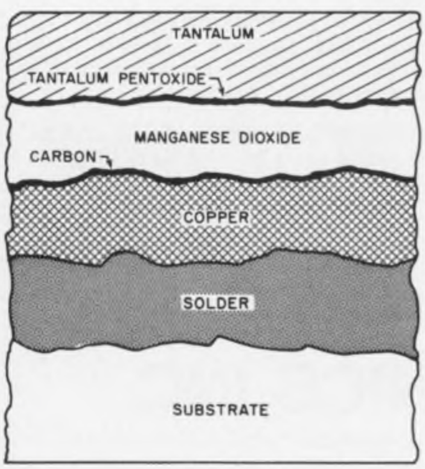
Since carbon cannot be soldered, silver paint is normally used to contact the counterelectrode. But this painted silver layer is destroyed at processing temperatures of about 800°C.

Another temperature problem often occurred in assembling thin-film circuit modules because organics within the sealed package must be prevented from contaminating the semiconductor die. During the baking of these packages for purification, the silver-paint layer could be destroyed if the packages were not sealed; on the other hand, the silver paint tended to outgas if the packages were sealed.

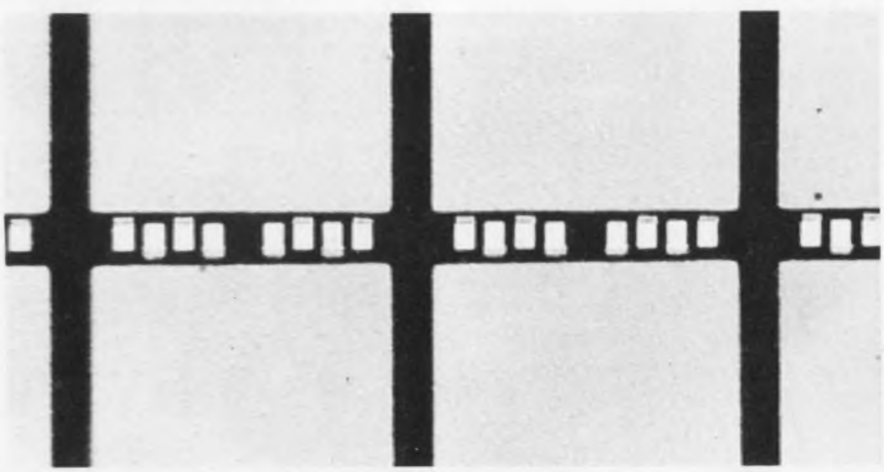
Union Carbide solved both problems by eliminating the silver paint and applying pure copper directly to the counterelectrode.

According to Maguire, the tantalum capacitor is now as easy to use as the monolithic ceramic unit, with the added advantage of increased volumetric efficiency and lower costs.

"Tantalum," he notes, "generally becomes cheaper, over ceramic, once past the 0.1-μF point. At 1 μF, the tantalum chip costs 20% less than an equivalent ceramic unit. With sufficient volume, this



New solid tantalum chip capacitors, shown mounted, replace painted-on silver with pure copper.



Beam-lead thin-film tantalum capacitors offer complete on-the-substrate compatibility with integrated circuits. Only 2 mils thick, these new chips also improve volumetric efficiency over ceramic devices via tantalum.

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SIGNAL SOURCES

099/9

This One Is More Than A Function Generator!

(**New capacitors,** *continued*)

cost difference could be even more pronounced."

Maguire expects a large growth in the tantalum chip capacitor market within the next year because of the removal of temperature limitations. "The market is so small now," he says, "that the growth could involve an order of magnitude increase."

Beam-lead chips go to tantalum

Another paper outlined the advantages, characteristics and processing of beam-lead tantalum thin-film capacitors. Co-authors W. Wesolowski and M. Tierman, of Sprague Electric Co., describe the new devices as combining the ruggedness of beam leads with improved volumetric efficiency through the use of tantalum.

"Up to now," says Wesolowski, development engineer, Thin Film Dept., "the design engineer has not really had anything compatible to put together with silicon integrated circuits in the form of a capacitor. Ceramic monolithics are big fat things, many mils thick. This tantalum chip capacitor is only 2 mils thick, the size of a beam-leaded silicon integrated circuit. The same sort of bonding operations that handle the silicon integrated circuit will handle this."

According to Wesolowski, the use of tantalum means very high capacitance per unit area. He notes that working voltage is the tradeoff for capacitance. For example, at 50 Vdcw, capacitance is about 0.4 pF per square mil, climbing to 1.5 pF per square mil at 12 Vdcw.

Over the working voltage range of 12 to 50 Vdcw, capacitance varies from 100 to 3000 pF for a 60 by 60 mil chip. Other possibilities include a device rated at 2 Vdcw and 10,000 pF, or 15 individual capacitors on a single chip.

The beam-lead configuration, Wesolowski indicates, allows the user to array the chips "very close to the original precision dimensions on the wafer." He expects the ultimate cost per chip to be under $1 for 150 pF at 50 Vdcw or for 600 pF at 12 Vdcw.

When questioned about the possibility of going to a solid tantalum approach, Wesolowski commented, "We feel that our approach, for its capacitance range, yields comparable volumetric efficiencies. Even the layering or sputtering of tantalum would just complicate a process that is complicated to begin with. It is only because ours is a real batch process that you wind up with a relatively inexpensive chip."

Ceramic capacitors broaden uses

While new types of capacitors are appearing on the market, some exotic uses have been developed for standard multilayer ceramic capacitors. Donald Hamer, director of Research and Development, Materials Research Lab., Erie Technological Products, Inc., mentioned for the first time new high-voltage high-current multilayer alumina capacitors for rf transmission applications. With their heavy silver leads, these new devices minimize series resistance as well as inductance. Current ratings range from 8 to 20 A at 30 MHz and maximum peak rf voltages vary from 1.5 to 10 kV at 2 MHz. Capacitance values go from 3 to 750 pF, while power ratings are 7.5 or 10 kVA.

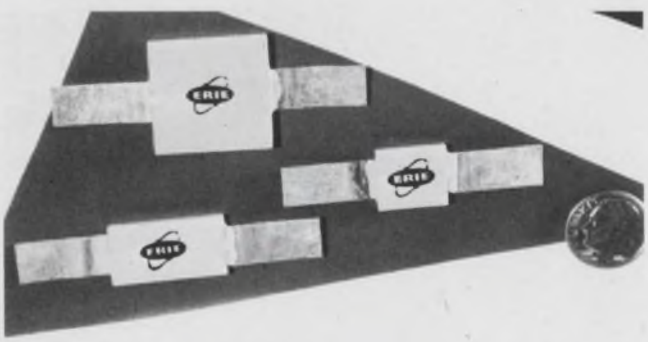
"There is nothing sacred about the planar construction of the multilayer ceramic capacitor," notes Hamer. Discoidal capacitors—circular discs with a center hole—can be used in low-inductance feed-through applications where high capacitance is desired to pass low frequencies. Curved bank constructions are also possible

With a working voltage rating of 200 V per mil, ceramic capacitors, even in chip form, can be used in many high-voltage applications. The monolithic multilayer ceramic capacitor, for instance, minimizes the problem of surface arc-over. Hamer explains that this is because "the electrodes are neatly and cleanly encapsulated in an excellent insulation material, the dielectric itself." In addition, individual electrode edges are surrounded by a material with a uniform dielectric constant and reduce electric field intensity at these points.

Hamer foresees a steady price drop of 20 to 30% per year for multilayer chip capacitors. This means that a low-capacitance chip currently selling for about 6¢ will eventually cost only 2¢. It is at this price breakpoint that Hamer feels the automotive and consumer markets will be attracted. He also expects volumetric efficiency to improve by a factor of three or four in the next 10 years.

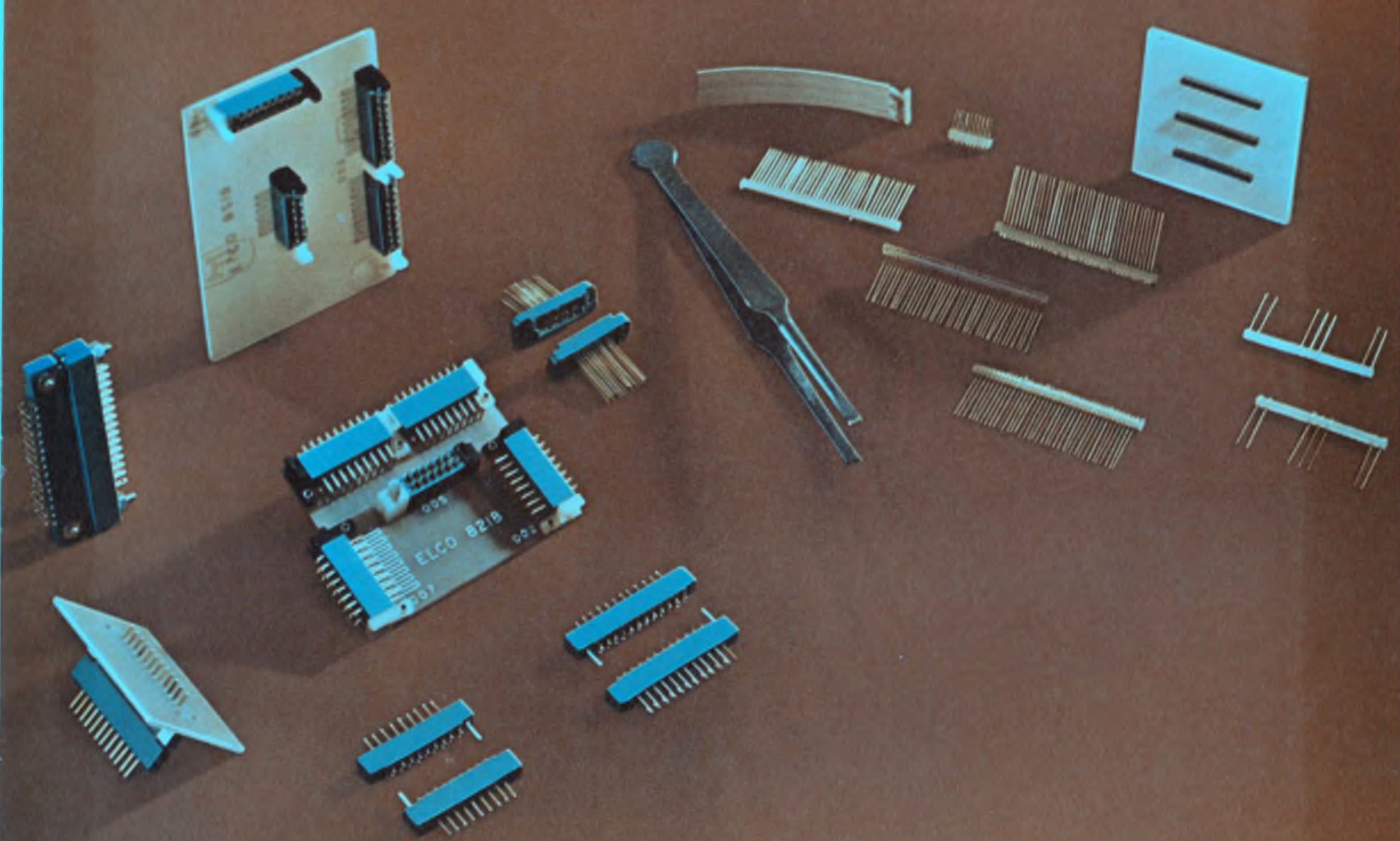
Where to get papers

The proceedings of the 1969 Electronic Components Conference contains all the papers presented. It is available for $7 from the Order Dept. of the IEEE, 345 E. 47th St., New York, N.Y. 10017.■■



Designed for rf transmission applications, a new line of multilayer alumina capacitors handle currents as high as 20 A at 30 MHz and voltages up to 10 kV at 2 MHz.

Curved-bank ceramic capacitors are highly complex in their construction. Both single-layer and multilayer devices can be intricately formed.



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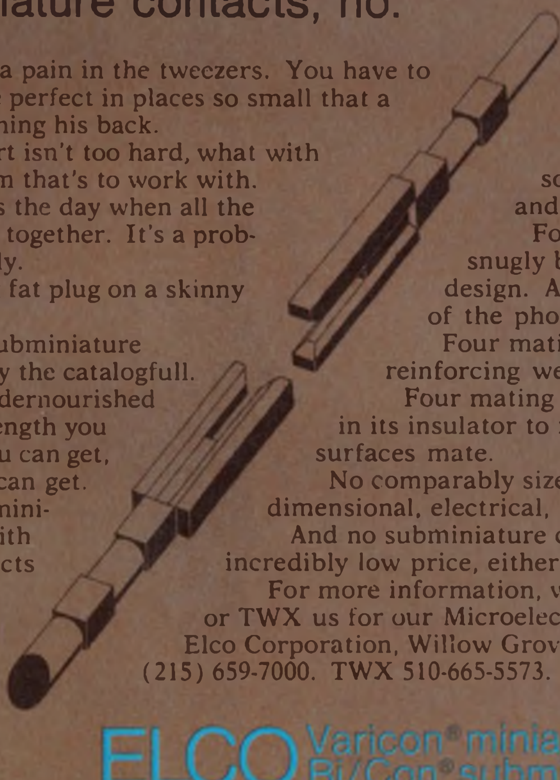

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Military programs under scrutiny

Washington Report

CHARLES D. LAFOND
WASHINGTON BUREAU

Cheyenne axed—more victims to follow?

With the cancellation of the Army's AH-56A Cheyenne helicopter production contract, Defense Secretary Melvin R. Laird revealed a new posture in his department. Not only is Defense not through with program cuts, but increased use of R&D in military projects before commitment to full-scale production is indicated. The attitude is, in other words, a retraction from the McNamara policy of single or total package procurement, in which one contractor was awarded a contract for R&D test and evaluation, and initial production—with, usually, an option clause calling for follow-on production.

The Army originally had planned to buy 375 of the highly advanced armed helicopters. The cancellation—a $1 billion potential loss to Lockheed-Calif. Co.—was felt at once by the mother firm, Lockheed Aircraft, with a sharp drop in its stock value. The reverberations are reflected through the aerospace industry, as prime contractors fear for the safety of other programs currently being reviewed by the Pentagon.

Other programs under critical review include the F-14 and F-15 fighter aircraft, the S-3 (SX) antisubmarine aircraft, the entire navy shipbuilding program, the Army's Main Battle Tank (MBT-70) and Sheridan tank, plus several missile programs including the Navy's Condor air-to-surface weapon.

Rumors that the Cheyenne programs would be cancelled on May 16 began during the recent annual American Helicopter Society meeting in Washington. The day came and went with no action by the Defense Department, and the industry began to breath a little easier. However, the following Monday, May 19, the announcement was made. The Army declared that Lockheed was in "default for not living up to the performance terms of the contract." D. J. Haughton, Lockheed chairman of the board, quickly called the action "unfair" and said there would be a heavy personnel layoff, but indicated that his firm will fight the action in court. In Congress, Rep. Otis G. Pike (D.-N.Y.), a vigorous critic of the Cheyenne program, declared he was delighted with the cancellation but indicated "it's a great tragedy that the action didn't occur at least $1/4 billion ago."

Expenditures on the program are confused. The Army says it has spent $90 million for R&D, but Rep. Pike estimates $193.5 million. The Army estimates total production costs—including spares, ground support equipment and other associated items—at $798 million, while Rep. Pike figures the production would cost $1.06 billion.

In addition to the production contract cancellation, Army Secretary Stanley R. Resor revealed that a "cure notice" also may be issued on the remaining R&D portion of the contract. This would, in effect, detail present deficiencies in the Cheyenne effort and require Lockheed to indicate its plan to correct all technical problems. Such a cure notice, issued on April 10, was a precursor of the production contract cancellation.

Are Polaris subs safe from attack?

Complete confidence that our Polaris missile-carrying submarine fleet cannot be tracked by the Soviet navy was expressed by Rear Adm. Levering Smith, director of the U. S. Navy's Strategic Systems Projects. In an interview with Jim Ottaway, Jr., publisher of the New Bedford, Mass., *Standard Times*, the admiral also indicated his skepticism over reports that the Soviet Union informed the U. S. of the location of the nuclear submarine Scorpion, which sank last May while returning from the Azores.

Not only does the admiral claim that Soviet submarines cannot track and follow our nuclear submarines at present, but he also stated his belief that the new-generation Russian submersibles also will not be able to do the job. He is quoted as saying that the Soviet navy has "no specific new antisubmarine warfare methods" that would make the Polaris fleet vulnerable. He also denied the practicability of satellite detection of submarines while submerged.

But others in Washington do not share the admiral's confidence. This reporter talked with several Navy officials, who requested anonymity. They observe that, while U.S. intelligence reports have not revealed any far-reaching advances made by the Soviet Union in long-range sonar detection, there was evidence that its scientists are making a concerted effort in such research. They indicate that the Soviet navy has dramatically increased its design capability for the production of quiet, deep-diving, long-endurance attack submarines.

They also see no reason why the Soviet Union could not develop an underwater-launched submarine-to-submarine missile equivalent to our Subroc. They argue that the apparent strategy of the Soviet navy today is defensive and thus is pushing to expand the Russian nuclear attack-submarine forces. In belying Soviet tracking skills, Adm. Smith referred to reports, never confirmed by the Navy, to the effect that the Soviets informed this country of the Scorpion's location. These stories appeared this year in *Parade* magazine and in the Washington, D.C., *Evening Star* editorial page in a column by James J. Kilpatrick.

RCA shows family of ground terminals

A family of five super-high-frequency ground terminals, ranging in size from a 1-1/4-ton transportable shelter to a man-pack receiving unit, was demonstrated in Washington last month by RCA's Defense Communications System Division. The equipment was developed for use with the experimental Tactical Satellite Communications spacecraft now in synchronous orbit (in line with the center of the U.S.). RCA won a contract from the Army Satellite Communication Agency, Fort Monmouth, N.J., in the summer of 1967 to develop the five terminals. The other self-contained units, to be carried by jeep, aircraft, and team pack, are two-way communication systems. The fifth unit is a new pack capable of receiving only.

While a reasonable amount of uniformity has been used in the various terminal designs, all have different capabilities to fit the varying demands of tactical operations. For example, the AN/TSC-80 transportable shelter includes a low-noise, uncooled, parametric amplifier, built-in self-test circuitry and considerable modulation-signal flexibility. It operates on fm voice with both high and low deviations and a variety of digital modes. The terminal includes a 500-watt-output transmitter, a receiver, a four-foot-diameter paraboloidal-reflector antenna (with a ring focus feed), a teleprinter and a reperforator.

At the other extreme the compact AN/TRR-30 man-pack terminal includes all the necessary equipment for receiving digital messages. Completely solid-state, and making heavy use of integrated circuits, it has a rugged low-noise tunnel-diode amplifier at the front end.

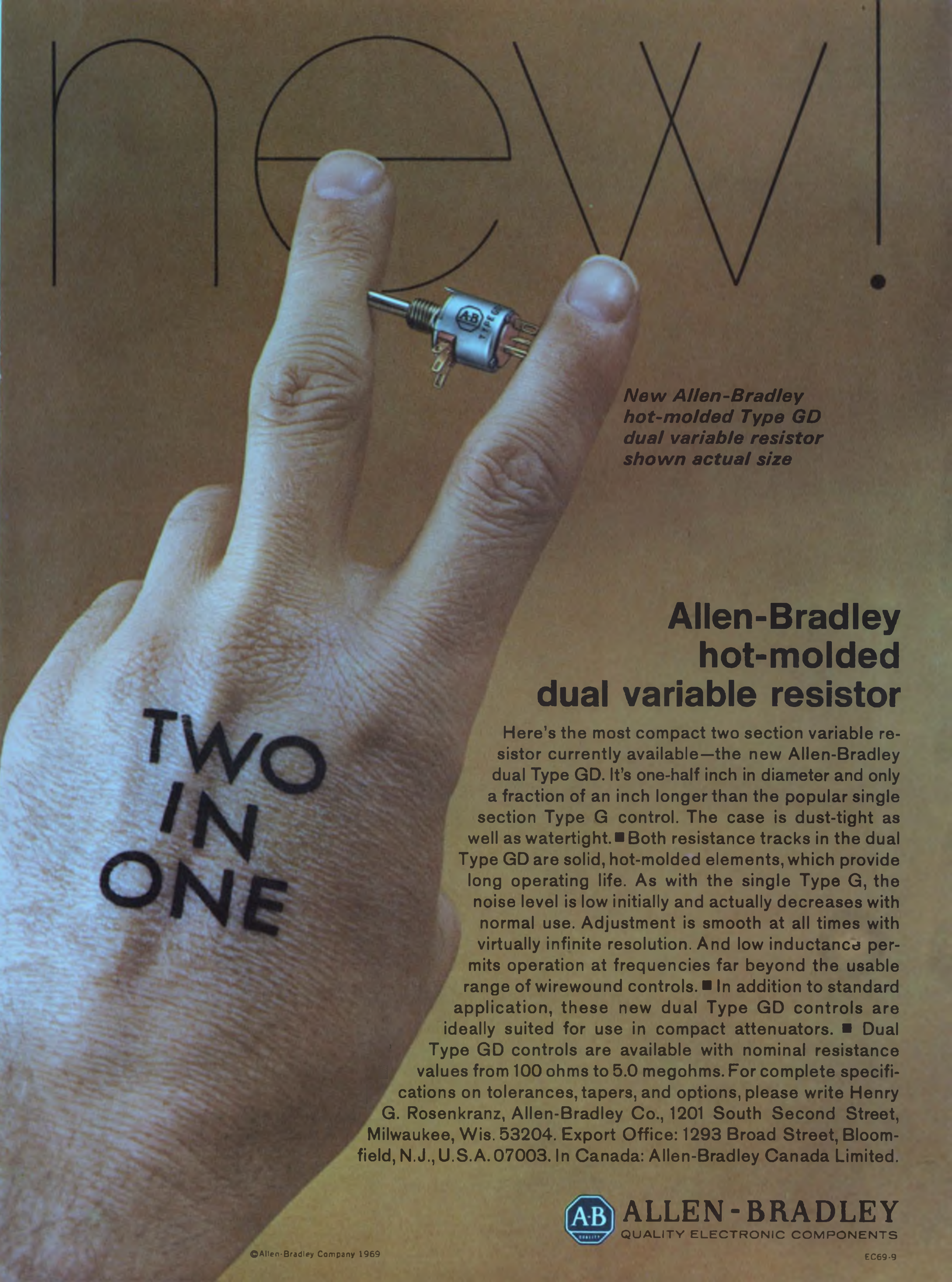
NASA asks for Earth Resources proposals

In preparation for a launch in late 1971 or early 1972, of a spacecraft for the Earth Resources Technology Satellite System, NASA has requested 12 U. S. firms to submit proposals. Two spacecraft are involved, and requests are made both for the definition and design of the spacecraft and for the study of a supporting ground data-handling system. Responses are due by June 18 at Goddard Space Flight Center, Greenbelt, Md.

Present plans call for the first spacecraft to be used for R&D for the test of sensors and of techniques used in collecting data. (The second spacecraft is for backup in case the first one fails.) Later data analysis is planned to check the effectiveness of an earth survey from space.

The first space vehicles must be designed for at least a one-year operating lifetime. This, says NASA, will provide the coverage necessary to judge the effectiveness of year-round observations of the same surface area of the earth.

The vehicle, weighing roughly 1000 pounds, will be placed in a circular, near-polar orbit at about a 500-mile altitude. The launch trajectory is intended to make the path sun-synchronous—that is, the sun will be directly behind the spacecraft during daylight orbit. As the craft passes over the earth in each revolution, it should view a segment about 100 miles wide.


new!
New Allen-Bradley hot-molded Type GD dual variable resistor shown actual size
TWO IN ONE
Allen-Bradley hot-molded dual variable resistor
Here's the most compact two section variable resistor currently available—the new Allen-Bradley dual Type GD. It's one-half inch in diameter and only a fraction of an inch longer than the popular single section Type G control. The case is dust-tight as well as watertight. ■ Both resistance tracks in the dual Type GD are solid, hot-molded elements, which provide long operating life. As with the single Type G, the noise level is low initially and actually decreases with normal use. Adjustment is smooth at all times with virtually infinite resolution. And low inductance permits operation at frequencies far beyond the usable range of wirewound controls. ■ In addition to standard application, these new dual Type GD controls are ideally suited for use in compact attenuators. ■ Dual Type GD controls are available with nominal resistance values from 100 ohms to 5.0 megohms. For complete specifications on tolerances, tapers, and options, please write Henry G. Rosenkranz, Allen-Bradley Co., 1201 South Second Street, Milwaukee, Wis. 53204. Export Office: 1293 Broad Street, Bloomfield, N.J., U.S.A. 07003. In Canada: Allen-Bradley Canada Limited.
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INFORMATION RETRIEVAL NUMBER 26

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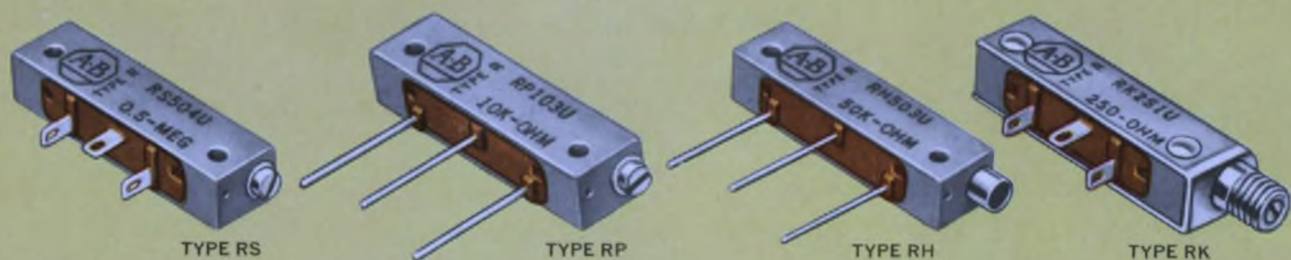
Allen-Bradley Type R Adjustable Fixed Resistors—Shown actual size



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266E-2

Materials analysis, the easy way

Charles A. Harper, the materials specialist, is back in ELECTRONIC DESIGN again after a little more than a year's absence. This time Charlie has taken the knotty subject of insulating materials and made it simple. In Charlie's words, "The report should enable the electronic designer to zero in on the best material candidates and cut through all of the confusing names, especially in plastics, where confusion is so easy." The report stresses material capability and performance rather than chemical characteristics.

When not attending to his duties with Westinghouse Electric Corp.'s Aerospace Div., where he is a Fellow Engineer, Charlie is busy leading technical sessions on materials or writing magazine articles or books. His report is adapted from a chapter he wrote in "Handbook of Electronic Packaging," published by McGraw-Hill.

The front cover of this issue (photo courtesy of Union Carbide Corp.) shows a micrograph of bismuth A, used in a variety of electronic applications. The title page of the report—a collection of raw insulating materials—was photographed by Bill Alvarez of ED's art staff.

Author Harper presents his material in a way that is particularly meaningful and useful to the electronic engineer.

The case of the company report

ELECTRONIC DESIGN's own sleuth can be found investigating a company financial report on p. 112. Why? Because our editors believe that design engineers and their managers will benefit from reading and analyzing annual reports. The article will clue you in on what a financial statement can tell you.

As an added attraction, a section called "Annual Reports" makes its debut on page 119. Happy detecting!

Cimron leapfrogs the DVM industry —and there's a reason!

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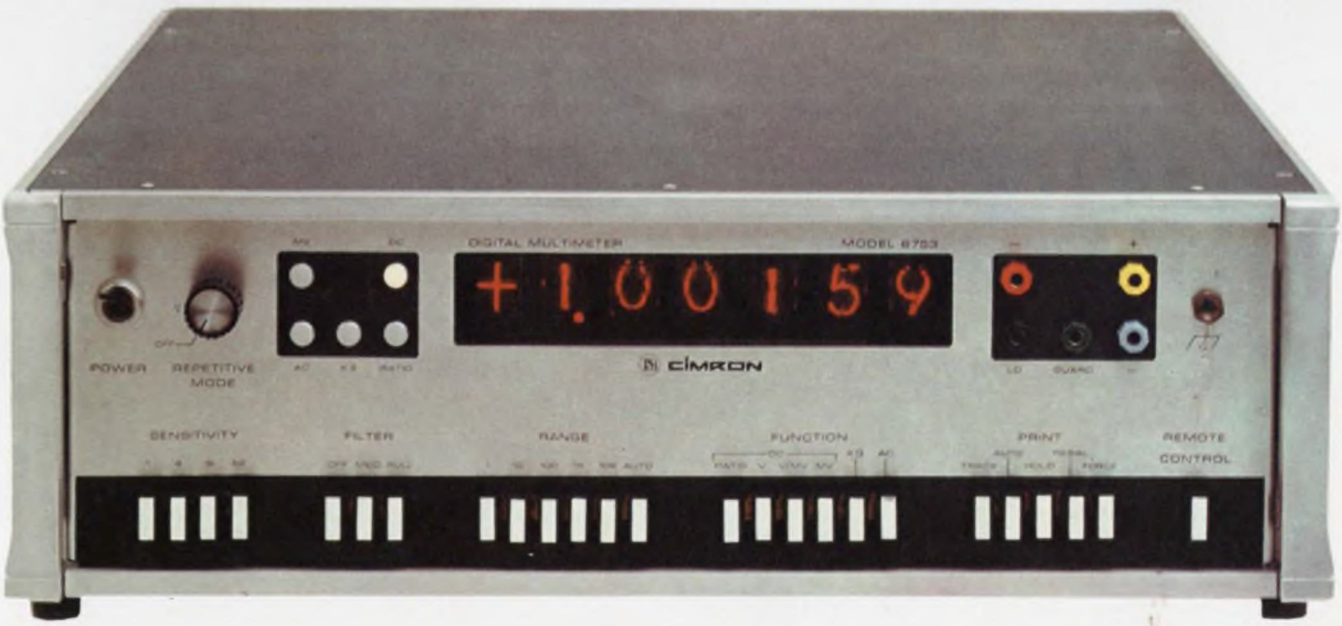

INFORMATION RETRIEVAL NUMBER 29

EDITORIAL

It's the alumni's turn to demonstrate

Is your engineering school making today's headlines?

Mine is. I'm a graduate of the City College School of Engineering in New York, class of '44.

I've been concerned, and I know many of you share the same emotion, with the growing unrest and disorders on campuses throughout the country. Our newspapers, magazines and TV screens display vividly the growing conflict between radical and conservative, black and white, student and faculty, youth and Establishment—and now between the engineering student and his liberal arts schoolmate.

Why does the engineering student demonstrate against the closing of colleges, while his liberal arts friend fights to keep them shut? A recent series of interviews at CCNY and Columbia point to some fundamental differences in behavior and attitude between these two types of students:

- The engineering student is aware of his career commitment. As stated by Wesley J. Hennessy, dean of Columbia School of Engineering: "Engineering students know where they're going. They're not trying to find themselves. They've never been lost. They've made their decision to join the Establishment, usually long before they leave high school. Liberal arts students look upon their four years at college as a time to find themselves."
- The engineering student admits he is more conservative than his liberal arts schoolmate. But, as one student complained: "Just because you believe in existing law, that makes you a conservative. If you believe in throwing bricks, you're a liberal."
- The engineering student cannot risk missing daily classroom lectures or laboratory experiments and still hope to pass. Liberal arts students admit that a flurry of activity toward the end of the term is often sufficient to achieve passing grades.

A rather pessimistic theory was offered by Columbia's Prof. Samuel Eilenberg, who suspects that liberal arts students feel the world is being taken over by a complex technology and that anyone who is not expert in technology will become a second-rate citizen. This attitude, he believes, has fostered antagonism between the two groups.

Are there solutions for the campus problems? Sure—about as many sure-fire ones as there are so-called experts anxious to get their names in print. Judges, policemen, businessmen, politicians, housewives—everyone seems to be getting into the act.

There are dedicated faculty and administrative officials who can provide workable solutions. Why not spend some time reviewing the status of our alma maters and take a position. If we don't like what they're doing, let's tell them. And if we are solidly behind them, let's give them our encouragement to solve this pressing problem.

But don't sit back and lament that sad bunch of college kids. They may turn up as your new boss 10 years from now.

HOWARD BIERMAN

◄ INFORMATION RETRIEVAL NUMBER 30

The wreckless rechargeable.

Sonotone's Fastback® battery won't wreck itself. Even under fast charging. Over and over and over again.

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The Fastback's safe, too. In laboratory tests, it's been deliberately overcharged for montns at the 3-hour rate. Without overheating or blowing its top. Even after that, it delivers full rated output under load.

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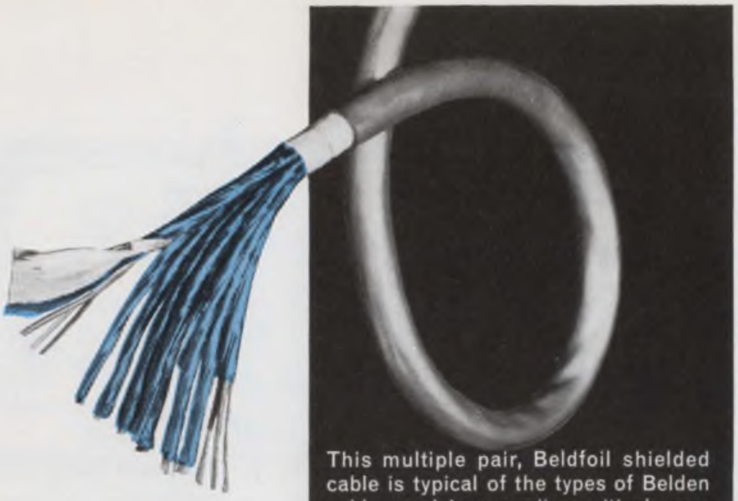

This multiple pair, Beldfoil shielded cable is typical of the types of Belden cable used in recording critical measurements on the Goldstone tracking antenna.

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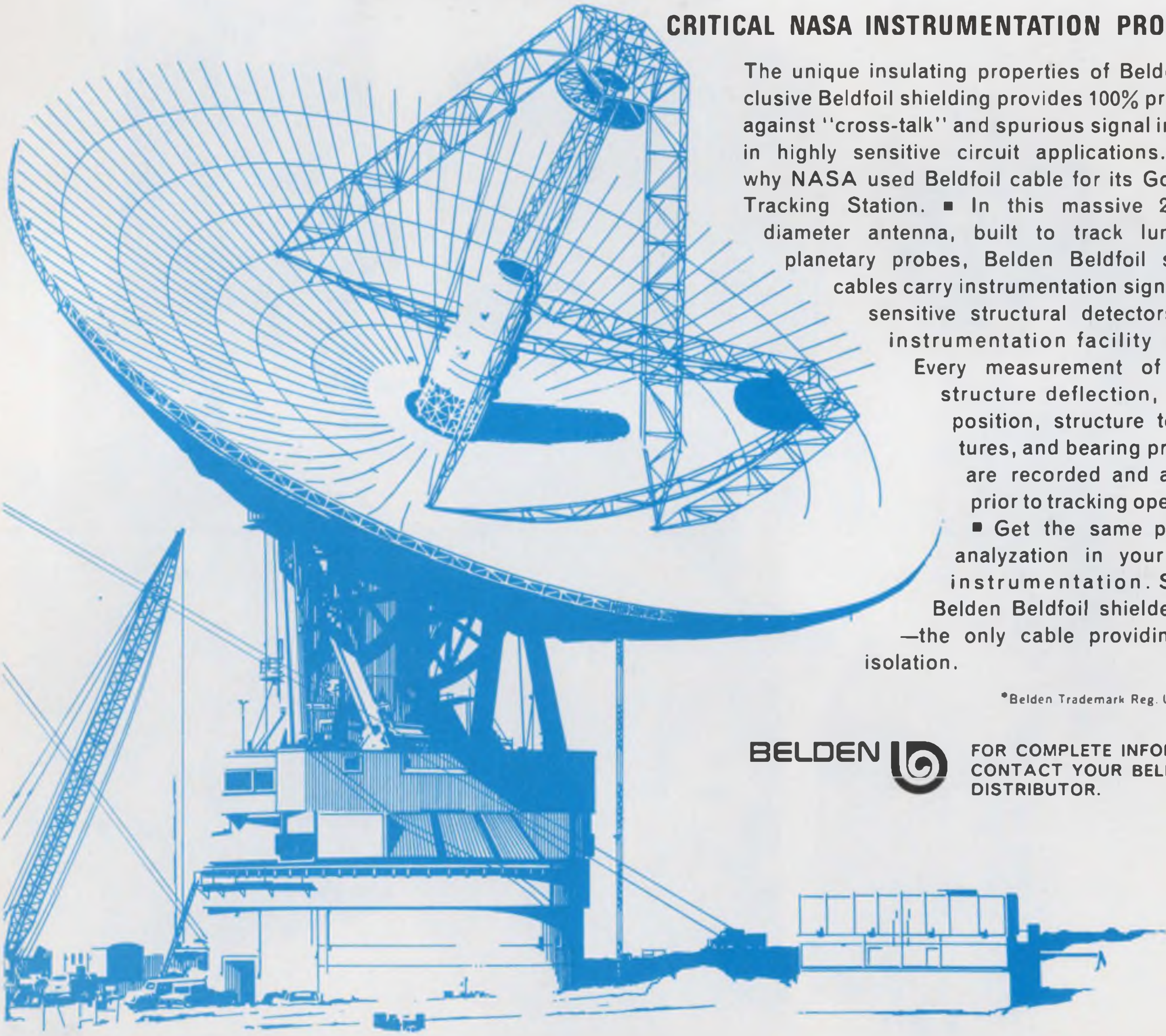
CRITICAL NASA INSTRUMENTATION PROBLEM!



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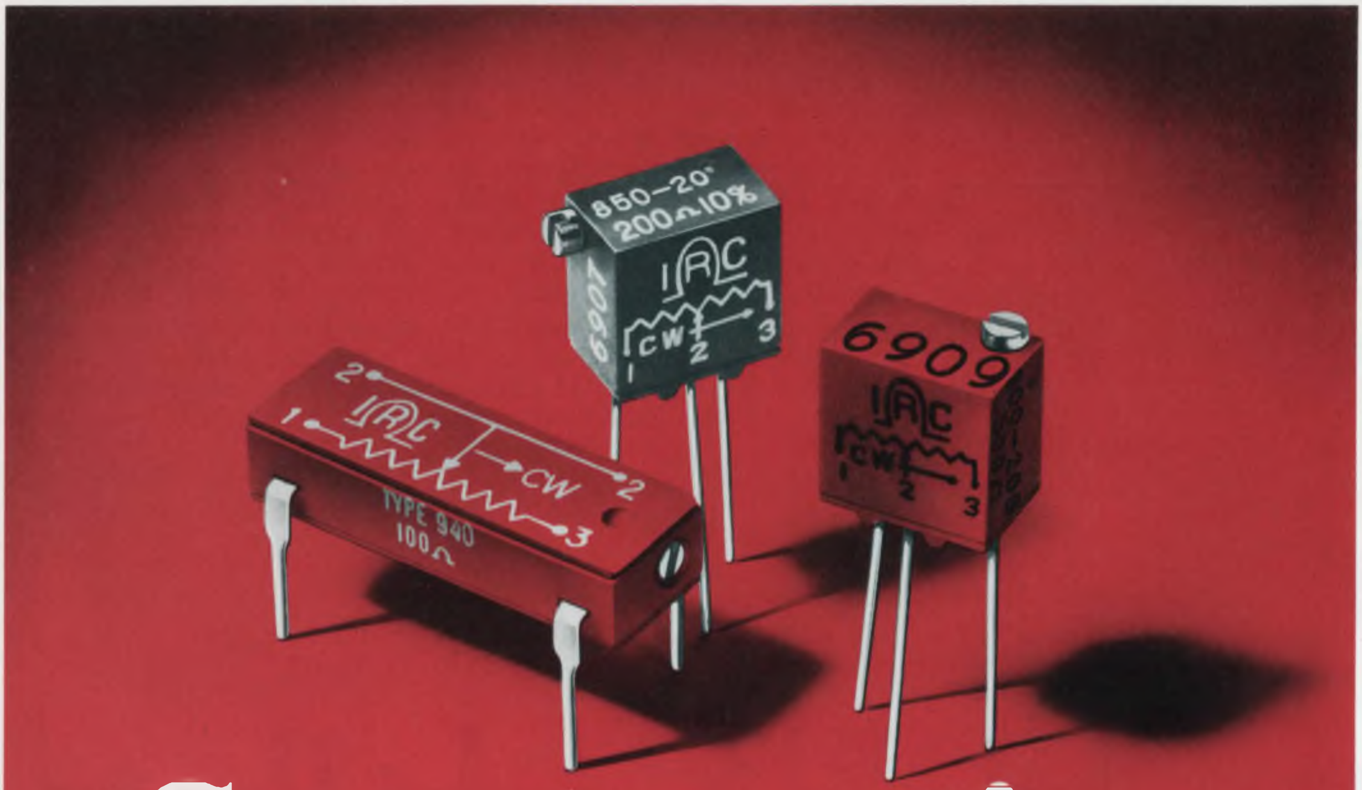


Space-saving trimmers

DIP construction matches IC size. Cuts assembly costs.

IRC's new precision wirewound trimmer in dual-in-line package simplifies PC board layout. Pin spacing is the same as the popular TO-116 size integrated circuit. It is fully compatible with high-speed automatic inserting equipment.

The sealed, moisture-resistant units meet the environmental requirements of MIL-R-27208. Maximum height is only .200 inches. 1 watt @ 40°C. 10Ω to 20K. ±10% tolerance. TC is ±50ppm/°C.

5/16″ doubles performance of 1/4″ trimmer—cuts cost almost in half.

Pin spacing of these 5/16″ square trimmers matches the 1/4″ square unit. Only .062″ larger on each side, they can cut your cost almost in half and give you three times the power rating of the 1/4″ and 40% better resolution.

Two types are available—precision wirewound and infinite resolution Metal Glaze. Both are fully sealed and impervious to common industrial solvents because of a silicone rubber shaft seal and epoxy bonding at all seams.

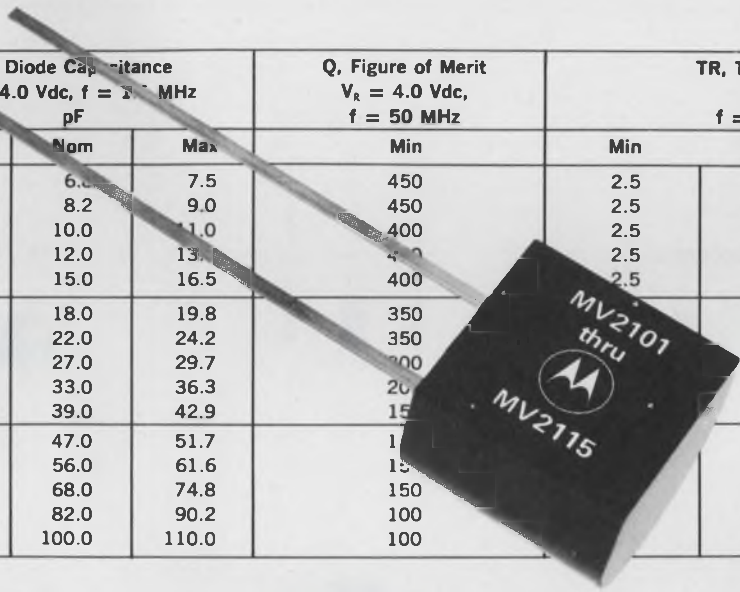
For data and prices, see your IRC Industrial Distributor or write IRC St. Petersburg Division of TRW INC., 2801 72nd Street, North, St. Petersburg, Florida 33733

IRC

DIVISION OF TRW INC.

INFORMATION RETRIEVAL NUMBER 36

Two Leads To Low Cost— High Performance For Volume Tuning Diode Applications



	C_T, Diode Cap[illegible]itance [illegible] = 4.0 Vdc, f = [illegible] MHz pF			Q, Figure of Merit V_R = 4.0 Vdc, f = 50 MHz	TR, Tuning Ratio C_2/C_{30} f = 1.0 MHz		
Device	Min	Nom	Max	Min	Min	Typ	Max
MV2101	6.1	[illegible]	7.5	450	2.5	2.7	3.2
MV2102	7.4	8.2	9.0	450	2.5	2.8	3.2
MV2103	9.0	10.0	[illegible]	400	2.5	2.9	3.2
MV2104	10.8	12.0	[illegible]	[illegible]	2.5	2.9	3.2
MV2105	13.5	15.0	16.5	400	2.5	2.9	3.2
MV2106	16.2	18.0	19.8	350	[illegible]	2.9	3.2
MV2107	19.8	22.0	24.2	350	[illegible]	2.9	3.2
MV2108	24.3	27.0	29.7	[illegible]	[illegible]	3.0	3.2
MV2109	29.7	33.0	36.3	[illegible]	[illegible]	3.0	3.2
MV2110	35.1	39.0	42.9	[illegible]	[illegible]	3.0	3.2
MV2111	42.3	47.0	51.7	[illegible]	[illegible]	3.0	3.2
MV2112	50.4	56.0	61.6	[illegible]	[illegible]	3.0	3.3
MV2113	61.2	68.0	74.8	150	[illegible]	3.0	3.3
MV2114	73.8	82.0	90.2	100	[illegible]	3.0	3.3
MV2115	90.0	100.0	110.0	100	[illegible]	3.0	3.3

High Q Assures Sharp Response, Low Prices Assure Top Economy

High performance electronic tuning for FM radio and TV, AFC, and general frequency control plus large-volume industrial applications is now a practical, preferable reality with Motorola's new MV2101 — MV2115 series EPICAP* tuning diodes.

It's practical because the two-lead plastic Unibloc* package is economical both at purchase and in use. Prices are low, and the package design is perfect for high-speed automatic production line handling.

It's preferable because assured minimum Q's up to 450 provide sharp response at high frequencies and high, controlled tuning ratios allow tuning over wide frequency ranges.

They offer all standard nominal capacitance values from 6.8pF to 100pF and uniform capacitance vs. voltage change from 2 thru 30 volts.

It's reality because devices are available off-the-shelf from your franchised Motorola Semiconductor Distributor or your Motorola Sales Office. Motorola's virtually unlimited plastic tuning diode production capacity can match your volume requirements. Inquire today.

*Trade-Mark Motorola, Inc.

—where the priceless ingredient is care!

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Tuning Diodes

Motorola Semiconductor Products Inc., P.O. Box 20912 / Phoenix, Arizona 85036

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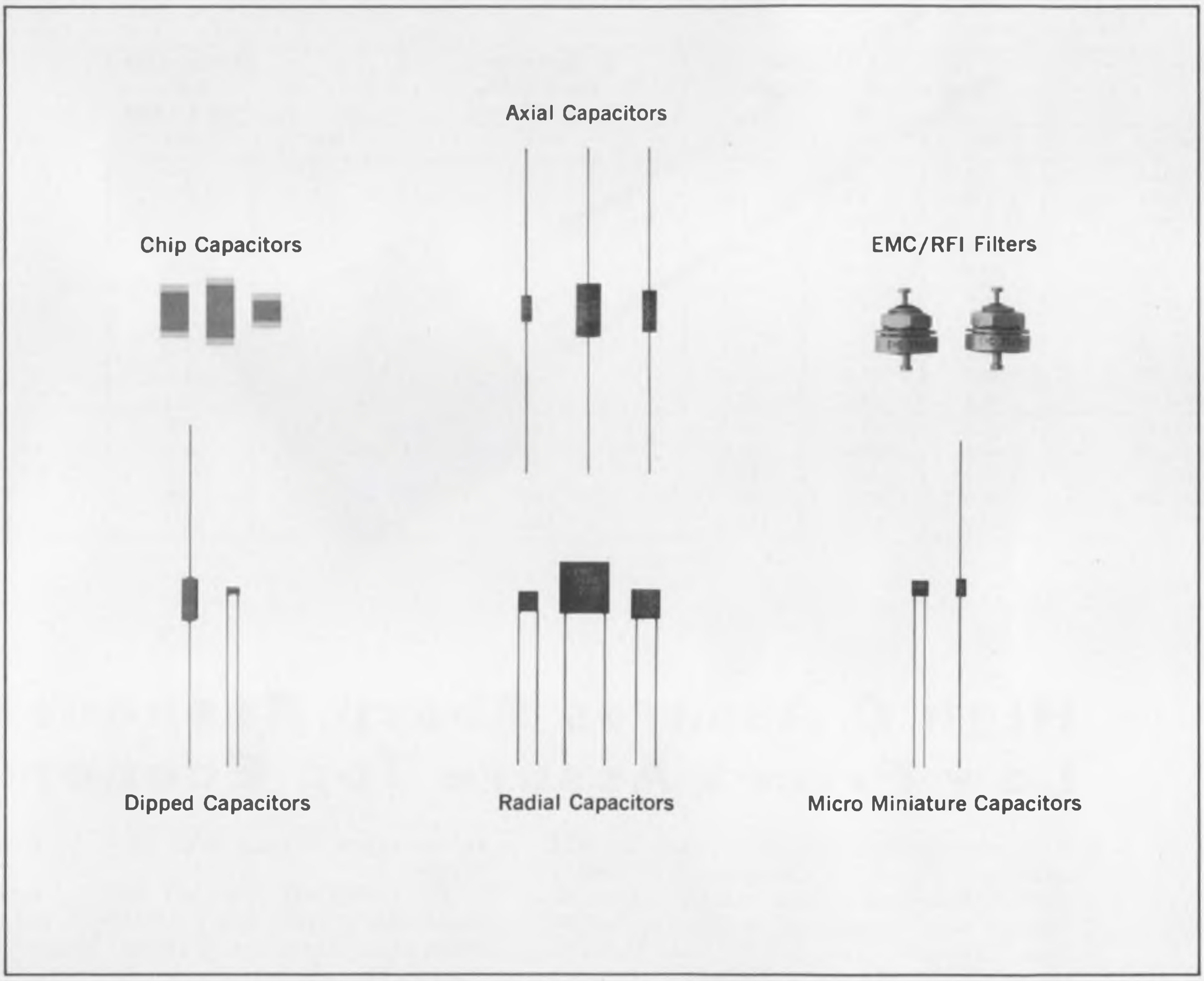
We spent a bundle developing these filters and capacitors.



Information about them is free.

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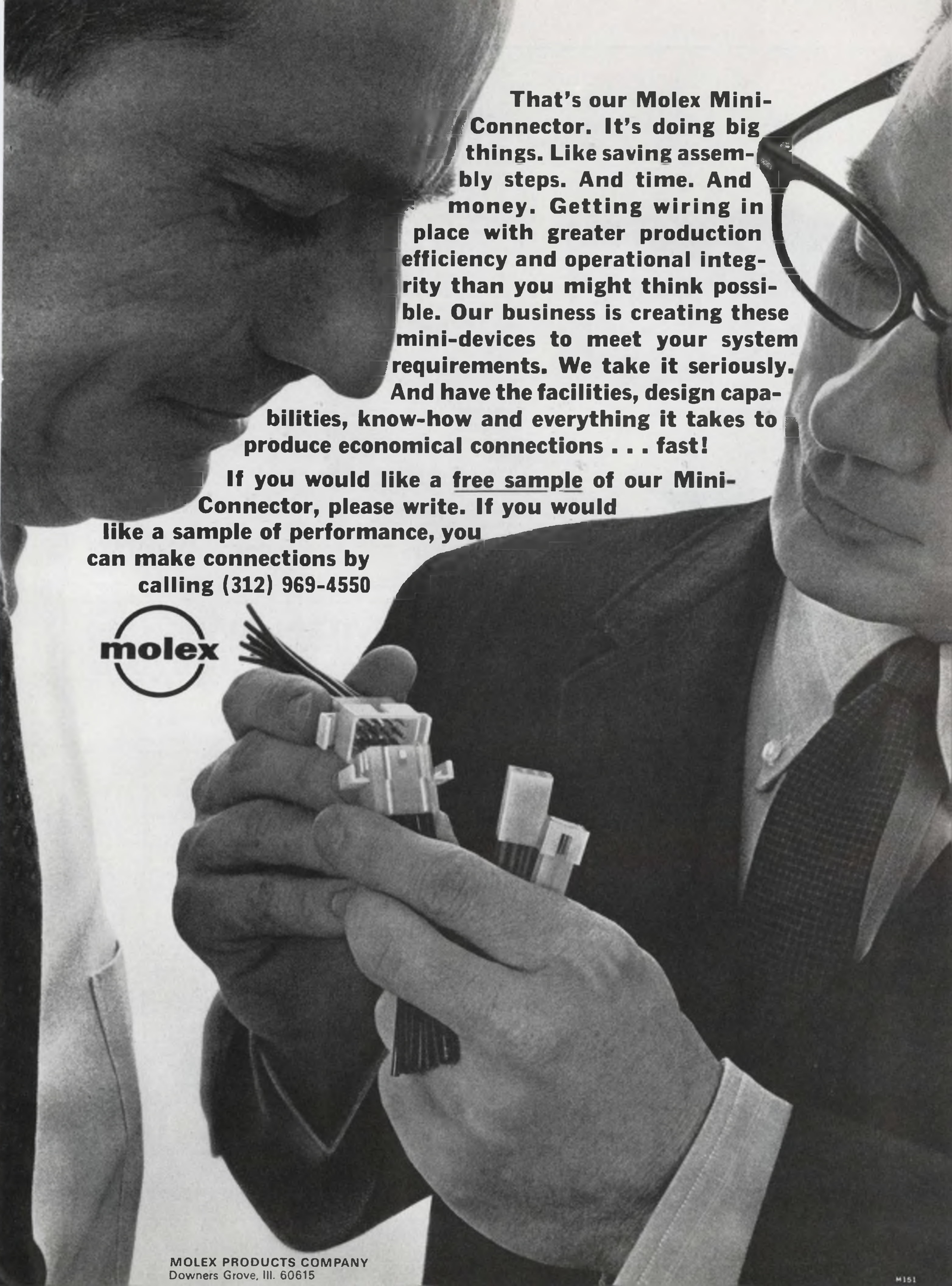
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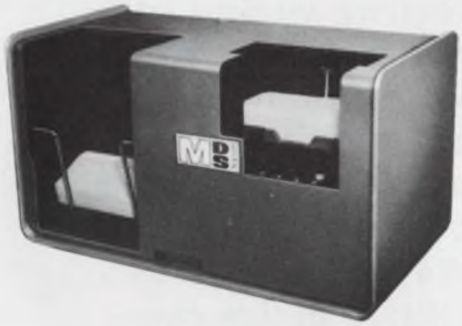
BIG PRINT-OUT CAPACITIES COME IN SMALL MDS PACKAGES



MDS Series 6002 Card Reader

Requiring less than 2 square feet of space (a trifle larger than a typewriter), the low-cost MDS Series 6002 Card Reader offers many plus features common to more expensive models. Thus it is ideal for peripheral use with small computers or in remote terminals and data communications systems.

Input and output hoppers each hold 500 cards, face-up, and can be replenished during operation. No adjustments are necessary for different types of cards.

The same reliable, proven picker/reader head used in larger MDS Card Readers is used in the 6002, combining picker mechanism, a pneumatic picker throat, photoelectric read station and metering capstans in a single, precision-built assembly. This enables simple interface and flexible operation when combined with end-fed reading and pick-on-demand card processing.

Cards are driven through the read station by metering capstans which also provide 16 precise clock pulses for each column of card motion. These signals . . . and those from sensors which detect the leading and trailing edge of the card . . . enable highly accurate column registration ($\pm 0.0054''$) as well as a check of known vs. measured card length.

The 6002 80-column Card Reader is available with or without logic circuitry (Series 6001 is without) and with options accommodating 51-column cards.

Modular design enables fast, easy interchangeability for many assemblies. Maintenance and servicing problems are minimal . . . MDS sealed units are noted for their ability to withstand rugged, prolonged usage.

You'll be pleased with this true, low-cost compact Card Reader and its built-in "plus" features.

Ask for: MDS folder-file on the low-cost 6002 Reader . . . more complete information and specifications.

FOR MORE — MEET YOUR MAN FROM MDS

Compactness of 6002 Card Reader mechanism is shown (cover raised). Unit measures only 12½" high x 12½" wide x 23" long.

MOHAWK DATA SCIENCES CORPORATION

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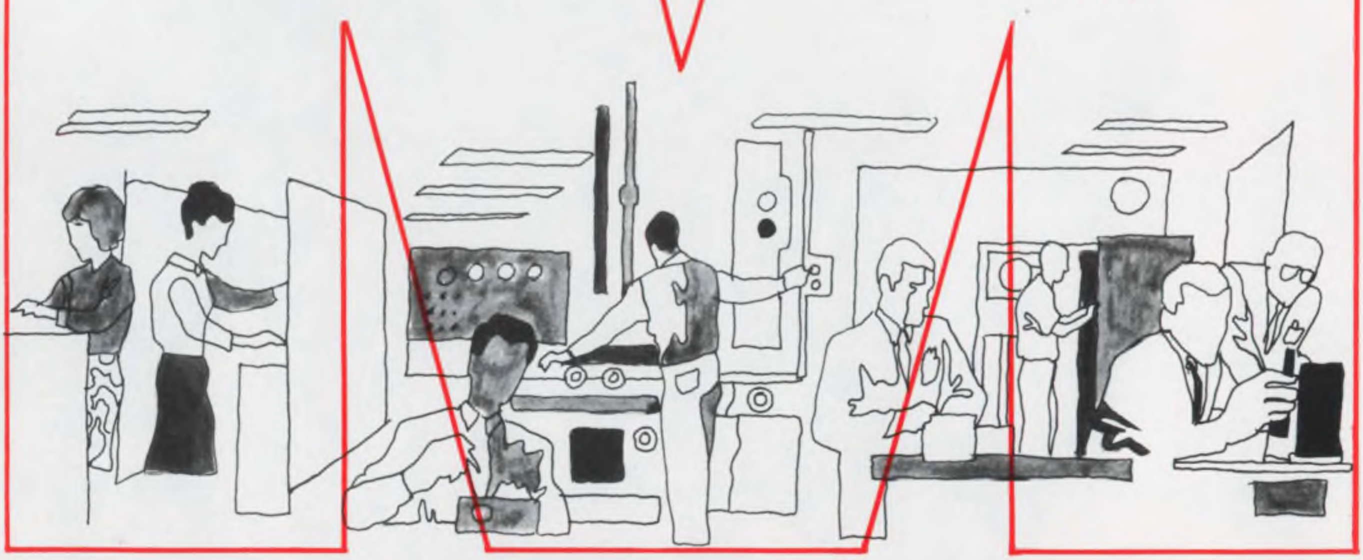

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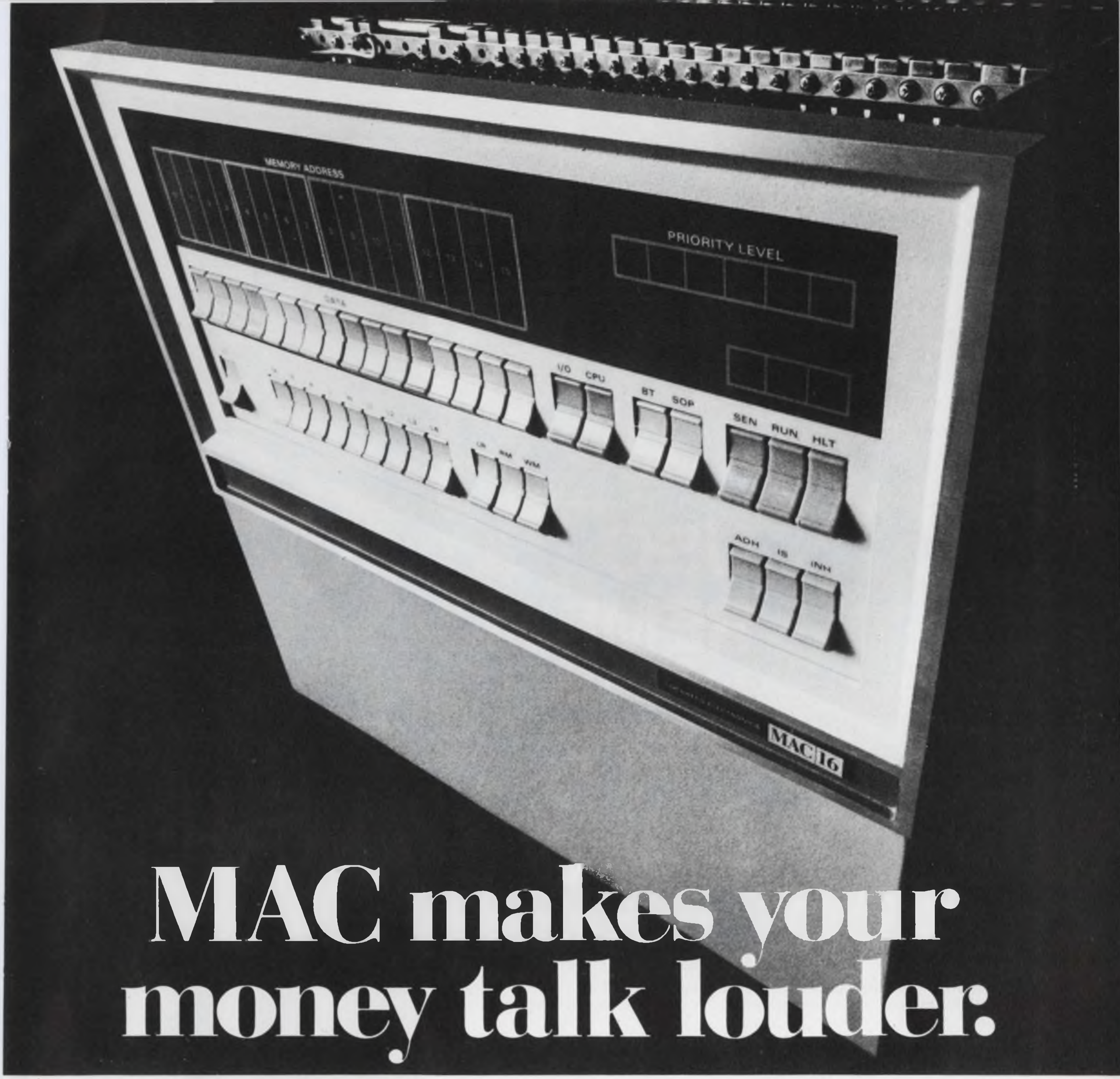


MAC makes your money talk louder.

Putting out $11,950 for MAC won't make you a big spender. Just a smart one. With MAC in the middle of your real-time system, you've scored.

First, the price is a steal. And it includes teletype. Which makes you a hero with the comptroller — he knows you're watching the shop instead of budget-busting.

Then, you spike the chance of later hang-ups. If the system needs stretching or changing, MAC is capable, flexible and expandable.

Where else, for instance, can $11,950 buy a basic 4K memory of 16-bit words expandable to 64K with 8K in the mainframe? At 1 μsec cycle time? With 72 basic hardware instructions? And who else gives you options you want but can't always get, like hardware multiply/divide, automatic bootstrap, and direct memory access channel? Plus an I/O bus with 255 device addresses, and 4 hardware priority interrupt levels, expandable to 64?

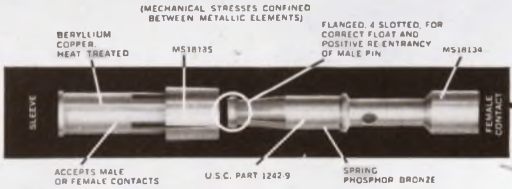
That's bare-bones hardware. But MAC also has the gamut of third-generation software — ready now — including some eye-opening Lockheed exclusives.

Put it this way: If there's a bigger pack of computer value than MAC anywhere near the price, we haven't been watching the shop.

Write to MAC, Lockheed Electronics Company, Data Products Division, 6201 East Randolph Street, Los Angeles, California 90022.

LOCKHEED ELECTRONICS COMPANY
LEC A Division of Lockheed Aircraft Corporation

***REmovable REntrancy MIniature Connector**



US Components
Printed Circuit Connectors
RWG-37F (Actual size) WG-37M (Actual size)

A modern Navy torpedo is a complex seagoing craft in itself. It requires an extremely reliable electro-mechanical "crew" to seek out and destroy enemy subs.

When Westinghouse Electric Corporation was assigned the job of building the wire-guided Mark 48 torpedo, it selected USC REMI* two-unit printed circuit connectors RWG-37F and WG-37M to serve on board. Westinghouse designed these USC REMI* connectors into its vital analog and amplifier circuits of its intricate guidance systems.

Major manufacturers such as Westinghouse know connectors can make a *big* difference in how well a completed product or system performs. That's why they specify USC where *ER*** helps simplify designs, save space, enhance reliability and reduce assembly costs.

Makes USC connectors worth investigating, doesn't it?

***USC Established Reliability can do!*

No. of Contacts: 37
Wire Sizes Accommodated: Female Connector. AWG #14 to #30 and MIL-W-16878A #16 to #37. REMI Contacts are ordered separately. Crimping by MIL-T-22570A (WEP) Class I or II tools.
Military Specifications: (Contacts) MIL-C-23216, MIL-C-26636, MS3190. (Connectors) MIL-C-23353, MIL-C-21097. (Latest revisions) U. S. Patent No. 2,979,689 •

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INFORMATION RETRIEVAL NUMBER 42

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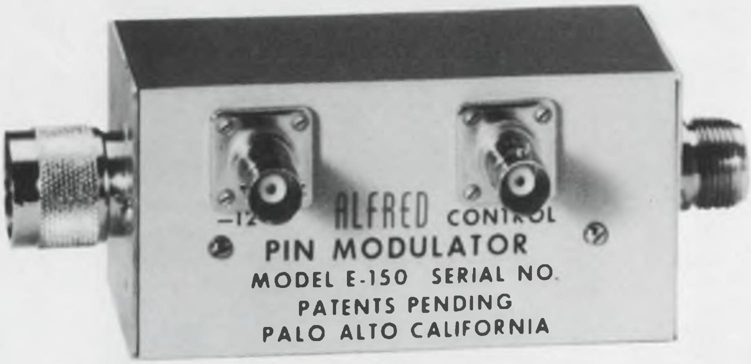
SUPER PIN

Actual Size



Model E-150 PIN Modulator

Model E-150P PIN Controller

Full 250 MHz to 12.4 GHz attenuation and modulation in a single unit for only $550.

That's the basic story of the Alfred PIN Modulator, Model E-150. For less than half of what you would pay elsewhere, the Model E-150 provides electronically controllable attenuation in one unit from 250 MHz to 12.4 GHz with wide dynamic range and low SWR at all attenuation levels.

Both input and output are matched at all attenuation levels. Because of its compact size, the unit is well suited to both laboratory and systems applications. The E-150 replaces four single band units for maximum economy and flexibility.

The Model E-150P PIN Controller provides control and power signals for one or two PIN modulator units. In this way attenuation or modulation can be varied continuously with the E-150P front panel controls and electronically by applying a control signal to the E-150P MOD jack. Two E-150 units can be operated in series to give increased attenuation and dynamic range. The PIN Controller provides both local and remote operation.

Price of the Model E-150 is $550; Model E-150P, $175. To arrange a demonstration and secure complete technical information, please call your Alfred sales engineer (listed in EEM and EBG) or write us directly. Please address Alfred Electronics, 3176 Porter Drive, Palo Alto, California 94304. Phone: 415-326-6496. TWX: 910-373-1765.

ALFRED ELECTRONICS

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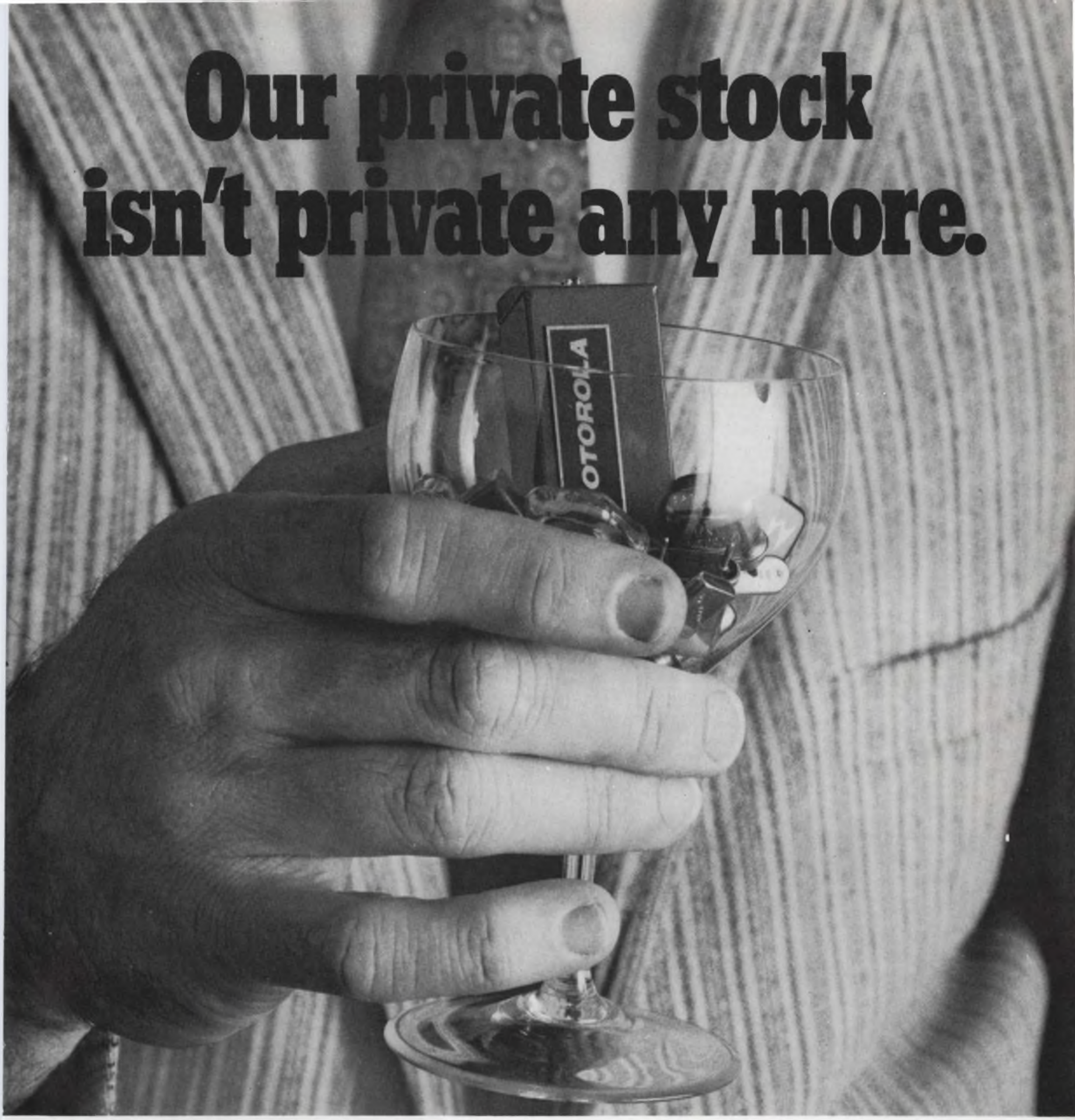


Motorola's Frequency Control Products are now on the market.

They say that if you want a thing done right, you do it yourself. And so we did. For thirty years, we've been designing and manufacturing our own frequency control components. Because they had to be good enough to use in our own products.

We've been selfish long enough. Now our precision crystals, oscillators, filters, and tone modules are available to designers and manufacturers throughout the electronics industry. And if the mile-long list of components isn't long enough, our designers and engineers are ready to go to work on custom projects.

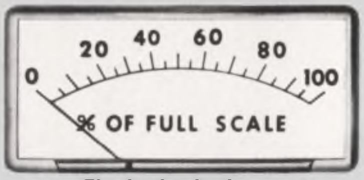
For additional information on existing products and design potentials, write to Motorola Communications & Electronics Inc., 4501 W. Augusta Boulevard, Chicago, Illinois 60651. Ask for Bulletin TIC-3401.

MOTOROLA

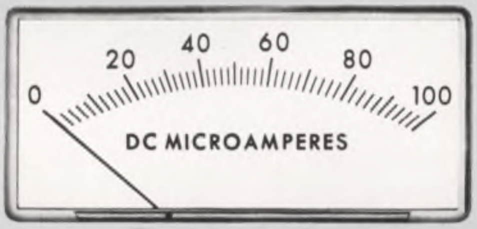
The Readable Little Meters

You can even read the littler little one at arm's length.

(Actual sizes)



The littler little one.



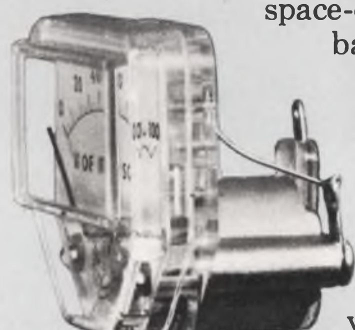
The bigger little one.

Put your left thumb here.

Put your right thumb here.

Honeywell's new Series 80T Panel Meters take up about half the panel space of full-size meters.

But hold this ad out at arm's length and see how easy the meters are to read. (How we ever got such large scales on such small faces without cluttering them, only our designers know.) And we've set the dial up front, so you can see it clearly, even from an oblique angle.



Behind the small face is Honeywell's unique taut-band mechanism – with about 50% fewer parts than a pivot-and-jewel. (One of the parts that's missing is the old space-consuming plastic barrel on the back of the meter.)

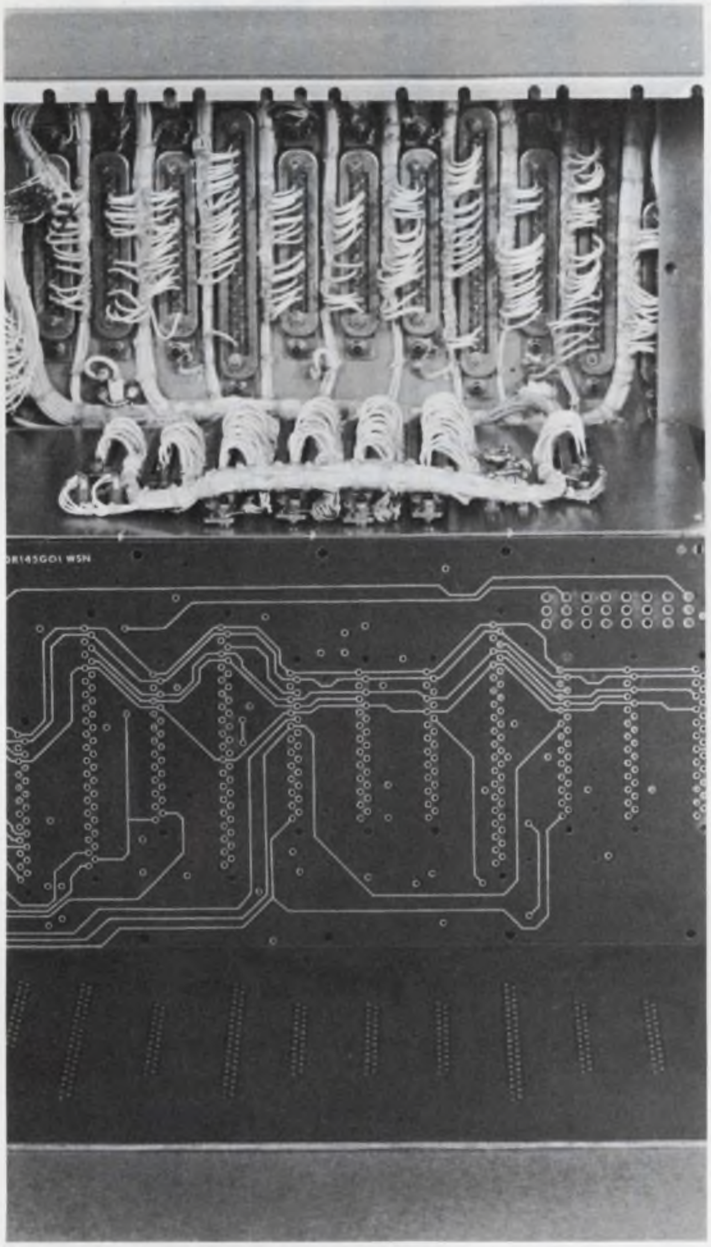
The new Series 80T Panel Meters come in 33 standard ranges. And they cost no more than pivot-and-jewel meters. So you don't have to pay a lot to get a little.

(We'd like to send you a catalog. Write Honeywell Precision Meter Division, Manchester, New Hampshire 03105.)

It takes all kinds of meters to make the Honeywell line.

Honeywell

Technology



Electric insulating materials are as important to equipment design as they are numerous. But help for the bewildered designer is at hand. p. 65

Be your own sleuth. Learn how to spot seven clues to value in any company's annual report. p. 112

Also in this section:

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KTI Model FS-20 Hybrid UNIVERSAL Active Filters.

Band-pass, high-pass and low-pass outputs simultaneously.
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Company ______________________
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City ______________________
State ____________ Zip ____________

My application is
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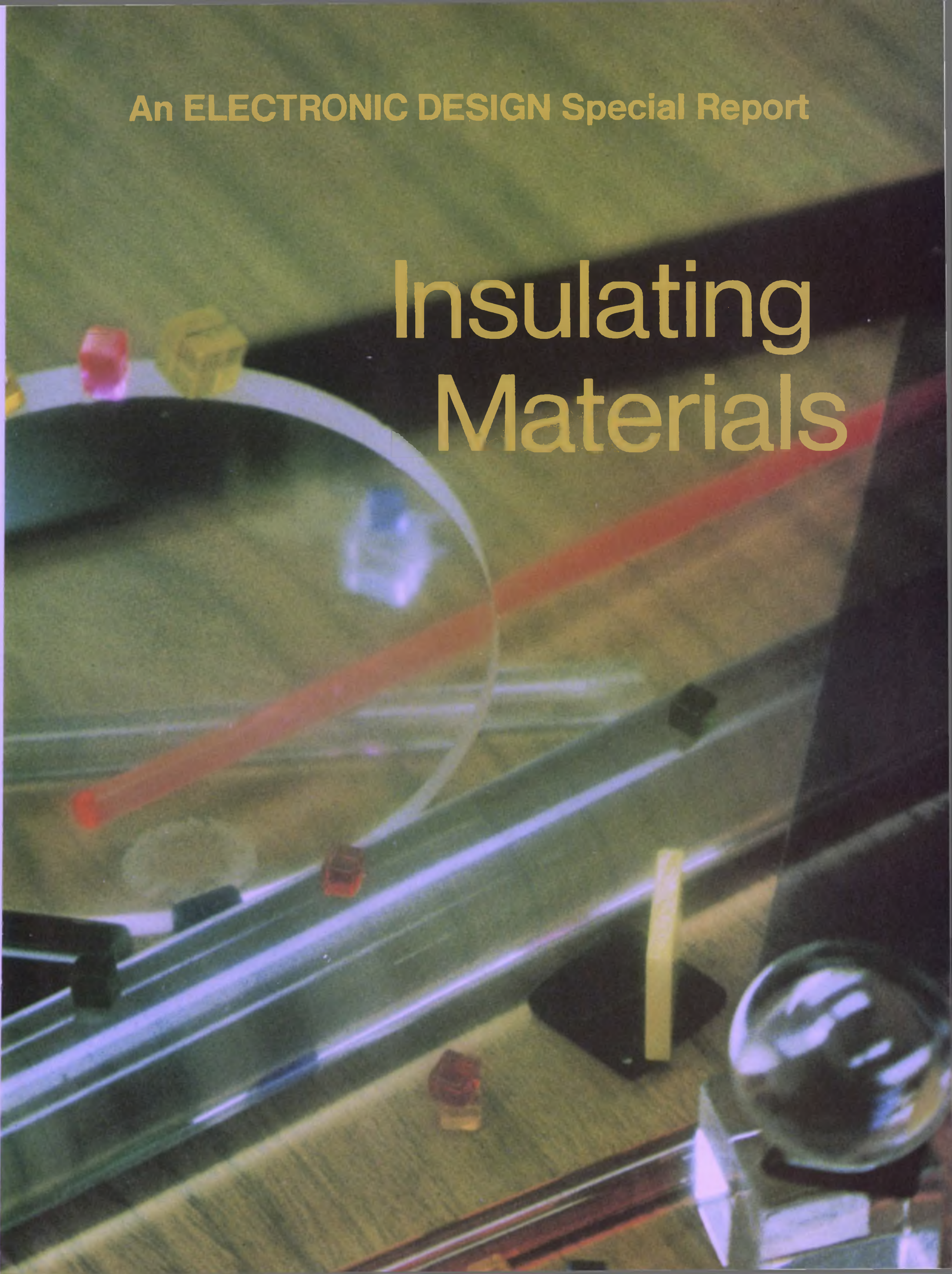
INFORMATION RETRIEVAL NUMBER 47

An ELECTRONIC DESIGN Special Report

Insulating Materials



Smart designers keep pace with insulating materials

Acknowledgement: This report is adapted from a chapter of the *Handbook of Electronic Packaging*, Charles A. Harper, Editor, McGraw-Hill Book Co., New York, N.Y., May 1969.

Things are getting tougher all the time for electronic components and equipment. Not only must they perform increasingly sophisticated functions, but they have to do so under multifarious conditions—such as exist in outer space, under the sea, or even under the hood of a car. As a consequence, materials of all types are becoming increasingly important in the design of advanced electronic equipment. And whether the designer likes it or not, the success of his equipment or systems is affected just as much by the materials he chooses as by the circuits and design techniques he employs.

This is especially true for electrical insulating materials, which are being used more and more to meet a widening range of functional objectives. When a designer selects a connector, a circuit board, a plastic IC, or even wire and cable, he is not just specifying parts to implement his design, he is also choosing insulating materials. And no longer will *any* insulating material do. There are simply too many types available—each with its own characteristics, advantages and disadvantages.

In essence, then, it is essential for electronic design engineers to be aware of the state of the art of insulating materials, and this Special Report is offered as an aid. It presents useful, basic design and selection guidelines in understandable and, for the most part, nonchemical terminology. For ease of use, the material is broken down into the following categories:

- Thermosetting plastics.
- Ceramics, ceramoplastics and glasses.
- Thermoplastics.
- Elastomers.

Written by **Charles A. Harper,** Westinghouse Electric Corp., Baltimore, Md.

Dielectric and thermal properties define operation

Although insulating materials have many important properties and characteristics, which are discussed in detail in this report, there are two basic categories which should be mentioned at this time. These are dielectric characteristics and thermal classification.

The primary dielectric, or insulating, characteristics are dielectric strength, resistance and resistivity, dielectric constant, power factor and dissipation factor, and arc resistance. The definitions of these terms, and their significant features, are given in Table 2. (See page 68.)

Thermal classifications of electrical insulating materials are particularly important in modern electronic systems, which often have to operate at elevated temperatures. Most electrical properties of insulators are a function of temperature. Depending on the material, these properties may vary gradually in a given direction with temperature, may alternate to some degree over a temperature range, or may change drastically beyond a critical temperature region.

For example, resistance and resistivity values generally decrease as temperature increases. Dissipation factor and dielectric constant on the other hand generally increase with temperature, although for many plastics they increase rapidly beyond a critical temperature region, which is different for each material.

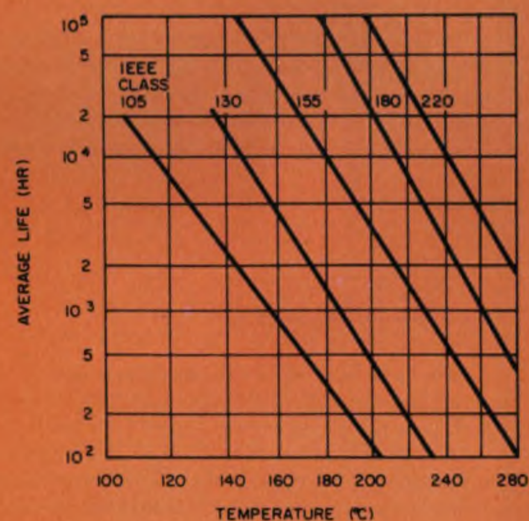
In addition to the stability of electrical properties with temperature variation, physical stability as a function of temperature is also an important factor in analyzing the performance of insulating materials. This physical stability, together with the electrical stability, often is expressed by the *continuous-use temperature.* Although this rated value implies no specific property at the stated temperature, it is generally accepted that a material will perform without major physical or electrical instability at the specified continuous-use temperature.

Another widely accepted temperature classification system is the IEEE thermal classification of electrical insulating materials, shown in Table 1. A material properly rated into one of these classifications can be expected to operate continously and reliably, in an electrical insulating application, up to the maximum operating temperature of its classification for a predetermined period (usually 20,000 hours but sometimes up to 100,000 hours). It should be noted that this system implies performance only as electrical insulation and does not necessarily cover satisfactory mechanical performance. The IEEE classification system has especially wide use in rating wire insulation, as shown by the typical curves of Fig. 1.

Table 1. IEEE thermal classifications

IEEE class*	Typical materials
90	Cotton, silk, paper, lowest-temperature plastics.
105	Cotton, silk, or paper, impregnated or coated, or immersed in dielectric liquid, and low-temperature plastics.
130	Mica, glass fiber, asbestos, epoxies, polyesters, melamines.
155	Mica, glass fiber, asbestos, epoxies, modified polyesters.
180	Silicones, mica, glass asbestos, polyimides, TFE fluorocarbons.
220	Glass or asbestos-reinforced silicones, polyimides, TFE fluorocarbons, and ceramoplastics.
Over 220	Mica, porcelain, glass, quartz, ceramics.

*IEEE class designations correspond to rated temperature (degrees C) for each class.



1. **Typical life curves** for IEEE thermal classes of insulated magnet wire.

Table 2. Basic electrical insulation properties

Property and definition	Significance of values
Dielectric strength All insulating materials fail at some level of applied voltage for a given set of operating conditions. The dielectric strength is the voltage an insulating material can withstand before dielectric breakdown occurs. Dielectric strength is normally expressed in voltage gradient terms, such as volts per mil. Normally, breakdown occurs at a much higher volt-per-mil value in very thin pieces (a few mils thick) than in thicker sections (1/8 in. thick for example).	The higher the value the better the insulator. Dielectric strength of a material (per mil of thickness) usually increases considerably with decrease in insulation thickness. Materials suppliers can provide curves of dielectric strength vs thickness for their insulating materials.
Resistance and resistivity Resistance of an insulating material, like that of a conductor, is the resistance offered by the conducting path to passage of electrical current. Insulating materials are very poor conductors, offering high resistance. For insulating materials, the term "volume resistivity" is more commonly applied. This is the electrical resistance between opposite faces of a unit cube for a given material at a given temperature. The relationship between resistance and resistivity is expressed by the equation $\rho = RA/l$ where ρ = volume resistivity in ohm-cm, R = resistance in ohms between faces, A = area of the faces, and l = distance between faces of the piece on which measurement is made. This is not resistance per unit volume, which would be ohm/cu cm—although this term is sometimes erroneously used. Other terms are sometimes used to describe a specific application or condition. One such term is surface resistivity which is the resistance between two opposite edges of a surface film 1-cm square. Since the length and width of the path are the same, the centimeter terms cancel. Thus, units of surface resistivity are actually ohms. However, to avoid confusion with usual resistance values, surface resistivity is normally given in ohms/sq. Another broadly used term is insulation resistance which, again, is a measurement of ohmic resistance for a given condition, rather than a standardized resistivity test.	The higher the value, the better for a good insulating material. The resistance value for a given material depends upon a number of factors. It varies inversely with temperature, and is affected by humidity, moisture content of the test part, level of the applied voltage, and time during which the voltage is applied. When tests are made on a piece that has been subjected to moist or humid conditions, it is important that measurements be made at controlled time intervals during or after the test condition has been applied, since dry-out and resistance increase occur rapidly.
Dielectric constant The dielectric constant of an insulating material is the ratio of the capacitance of a capacitor containing that particular material to the capacitance of the same electrode system with air replacing the insulation as the dielectric medium. The dielectric constant is also sometimes defined as the property of an insulation which determines the electrostatic energy stored within the solid material. The dielectric constant of most commercial insulating materials varies from about 2 to 10, air having the value 1.	Low values are best for high frequency or power applications, to minimize electrical power losses. Higher values are best for capacitance applications. For most insulating materials, dielectric constant increases with temperature, especially above a critical temperature region which is unique for each material. Dielectric constant values are also affected (usually to a lesser degree) by frequency.
Power factor and dissipation factor Power factor is the ratio of the power dissipated (watts) in an insulating material to the product of the effective voltage and current (volt-ampere input), and is a measure of the relative dielectric loss in the insulation when the system acts as a capacitor. Power factor is nondimensional and is a commonly used measure of insulation quality. It is of particular interest at high levels of frequency and power in such applications as microwave equipment, transformers, and other inductive devices. Dissipation factor is the tangent of the dielectric loss angle. For the low values ordinarily encountered in insulation, dissipation factor is practically the equivalent of power factor, and the terms are used interchangeably.	Low values are favorable, indicating a more efficient system, with lower power losses.
Arc resistance Arc resistance is a measure of an electrical breakdown condition along an insulating surface, caused by the formation of a conductive path on the surface. It is a common measurement with plastic materials, because of the variations among plastics in the extent to which a surface breakdown occurs. Arc resistance is measured as the time, in seconds, required for breakdown along the surface of the material being measured. Surface breakdown (arcing or electrical tracking along the surface) is also affected by surface cleanliness and dryness.	The higher the value, the better. Higher values indicate greater resistance to breakdown along the surface due to arcing or tracking conditions.

Thermosetting plastics

As the name implies, thermosetting materials —or thermosets as they are sometimes called— are cured, set or hardened into a permanent shape. This curing is an irreversible chemical reaction, known as cross linking, which usually occurs under heat. For some thermosetting materials, however, curing is initiated or completed at room temperature. Even here, though, it is often the heat of the reaction that actually cures the plastic material.

Although the cured part can be softened by heat, it cannot be remelted or restored to the flowable state that existed before curing. Hence, these plastics are normally more thermally stable than are thermoplastics, which are covered later.

Application information for thermosetting plastics is presented in Table 3. Included are listings of the major application considerations for each material class, the forms in which the material is available to the designer, and typical suppliers and product trade names. This information should help the designer make a coarse selection of candidate materials. Final selection can then be made from actual design values (Tables 4 and 5), which give the important electrical, physical, mechanical and thermal properties of the thermosetting materials.

It should be mentioned that much tailoring of materials can be done by suppliers, and better than average compounds exist for nearly any

Table 3. Major application considerations for thermosetting plastics

Material	Major application considerations	Common available forms	Typical suppliers and trade names*
Alkyds	Excellent dielectric strength, arc resistance, and dry insulation resistance. Low dielectric constant and dissipation factor. Good dimensional stability. Easily molded.	Compression moldings, transfer moldings	Allied Chemical Corp. (Plaskon), American Cyanamid Co. (Glaskyd)
Aminos (melamine formaldehyde and urea formaldehyde)	Available in an unlimited range of light stable colors. Exhibit hard glossy molded surface, and good general electrical properties, especially arc resistance. Excellent chemical resistance to organic solvents and cleaners and household-type cleaners.	Compression moldings, extrusions, transfer moldings, laminates	Allied Chemical Corp. (Plaskon), Monsanto Co. (Resimene); American Cyanamid Co. (Cymel for melamine, Beetle for urea)
Diallyl phthalates (DAP) (allylics)	Unsurpassed among thermosets in retention of properties in high humidity environments. Also, have among the highest volume and surface resistivities in thermosets. Low dissipation factor, and heat resistance to 400°F or higher. Excellent dimensional stability. Easily molded.	Compression moldings, extrusions, injection moldings, transfer moldings, laminates	FMC Corp. (Dapon), Allied Chemical Corp. (Diall)
Epoxies	Good electrical properties, low shrinkage, excellent dimensional stability and good to excellent adhesion. Extremely easy to compound, using nonpressure processes, for providing a wide variety of end properties. Useful over a wide range of environments. Bisphenol epoxies are most common, but several other varieties are available for providing special properties.	Castings, compression moldings, extrusions, injection moldings, transfer moldings, laminates, matched-die moldings, filament windings, foam	Shell Chemical Co. (Epon), Celanese Co. (Epi-Rez); Dow Chemical Co. (D.E.R.); Ciba Products Co. (Araldite), Union Carbide Corp. (ERL); 3M Co. (Scotchcast)
Phenolics	Among the lowest-cost, most widely used thermoset materials. Excellent thermal stability to over 300°F generally, and over 400°F in special formulations. Can be compounded to a broad choice of resins, fillers, and other additives.	Castings, compression moldings, extrusions, injection moldings, transfer moldings, laminates, matched-die moldings, stock shapes, foam	Union Carbide Corp. (Bakelite), Hooker Chemical Corp. (Durez)
Polyesters	Excellent electrical properties and low cost. Extremely easy to compound using nonpressure processes. Like epoxies, can be formulated for either room temperature or elevated temperature use. Not equivalent to epoxies in environmental resistance.	Compression moldings, extrusions, injection moldings, transfer moldings, laminates, matched-die moldings, filament windings, stock shapes	Pittsburgh Plate Glass Co. (Selectron); American Cyanamid Co. (Laminac); Rohm & Haas Co. (Paraplex)
Silicones (rigid)	Excellent electrical properties, especially low dielectric constant and dissipation factor, which change little up to 400°F and over	Castings, compression moldings, transfer moldings, laminates	Dow Corning Corp. (DC Resins)

*This listing is only a very small sampling of the many possible suppliers. No preferences are implied or intended.

Table 4. Room-temperature electrical properties of thermosetting plastics

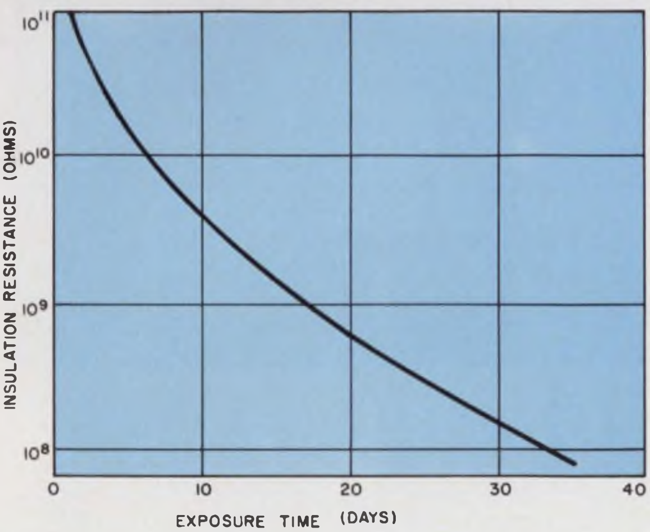
Property	Alkyd		Melamine		Urea cellulose	Polyester glass
	Mineral filled	Glass filled	Cellulose filled	Glass filled		
Volume resistivity 50% RH (ohm-cm)	10^{13}–10^{15}	10^{15}	–	2.0 x 10^{11}	10^{12}–10^{13}	10^{12}–10^{15}
Dielectric strength (V/mil)						
Short time, 1/8-in.	350–450	350	350–400	170–300	300–400	345–420
Step-by-step, 1/8-in.	300–350	300	250–350	170–240	220–300	275–390
Dielectric constant						
60 Hz	5.1–7.5	5.7	6.2–7.6	9.7–11.1	7.0–9.5	5.3–7.3
1 kHz	5.0–6.2	5.4	6.0–7.5	–	7.0–7.5	4.68
1 MHz	4.6–5.5	5.2	4.7–7.0	6.6–7.5	6.8	5.2–6.4
Dissipation factor						
60 Hz	0.009–0.06	0.010	0.019–0.033	0.14–0.23	0.035–0.043	0.011–0.041
1 kHz	0.007–0.03	0.007	0.013–0.034	–	0.025–0.035	–
1 MHz	0.006–0.04	0.008	0.032–0.060	0.013–0.015	0.25–0.35	0.008–0.022
Arc Resistance (s)	75–190	180	95–135	180	80–150	120–240

Property	Diallyl phthalate		Epoxy		Phenolic		Silicone	
	Mineral filled	Glass filled	Mineral filled	Glass filled	Wood flour filled	Glass filled	Mineral filled	Glass filled
Volume resistivity 50% RH (ohm-cm)	10^{13} +	10^{13}–10^{16}	>10^{14}	>10^{14}	10^{9}–10^{13}	7 x 10^{12}	10^{14}	10^{10}–10^{14}
Dielectric strength (V/mil)								
Short time, 1/8-in.	395–420	395–450	300–400	300–400	200–400	140–400	200–400	200–400
Step-by-step, 1/8-in.	390–400	395–400	300–400	300–400	100–375	120–270	380	125–300
Dielectric constant								
60 Hz	5.2	4.3	3.5–5.0	3.5–5.0	5.0–13	7.1	3.5–3.6	3.3–5.2
1 kHz	4.8–5.3	4.1–4.4	3.5–5.0	3.5–5.0	4.4–9.0	6.9	–	3.2–5.0
1 MHz	3.9–4.0	3.4–4.5	3.5–5.0	3.5–5.0	4.0–6.0	4.6–6.6	3.4–6.3	3.2–4.7
Dissipation factor								
60 Hz	0.03–0.06	0.01–0.05	0.01	0.01	0.05–0.30	0.05	0.004–0.005	0.004–0.03
1 kHz	0.03–0.10	0.004–0.009	0.01	0.01	0.04–0.20	0.02	–	0.0035–0.02
1 MHz	0.02–0.04	0.009–0.014	0.01	0.01	0.03–0.07	0.012–0.026	0.002–0.005	0.002–0.02
Arc resistance (s)	140–190	125–180	150–190	120–180	Tracks	To 190	250–420	150–250

Table 5. Physical and mechanical properties of thermosetting plastics

Property	Diallyl phthalate		Silicone		Epoxy		Alkyd and polyester		Phenolic		Melamine	
	Mineral filled	Glass filled	Mineral filled	Glass filled	Mineral filled	Glass filled	Mineral filled	Glass filled	Flock filled	Glass filled	Flock filled	Glass filled
Mold shrinkage, in./in.	0.004–0.006	0.002	0.006–0.007	0–0.005	0.001–0.008	0.001–0.002	0.004–0.010	0.002–0.006	0.004–0.009	0.0001–0.001	0.006–0.007	0.001–0.004
Specific gravity	1.50–1.60	1.55–1.70	1.81–2.82	1.68–2.0	1.6–2.06	1.8–2.0	1.60–2.30	1.8–2.3	1.32–1.45	1.75–1.95	1.50–1.55	1.8–2.0
Tensile strength, psi	3000–8000	5000–10000	3000–3500	4000–5000	5000–7000	–	3000–8000	4000–10000	6500–9000	5000–10000	7000–9000	5000–10000
Compressive strength, psi	18000–25000	20000–30000	15000–18000	10000–15000	18000–25000	–	18000–25000	20000–30000	22000–36000	17000–26000	30000–35000	20000–35000
Flexural strength, psi	6000–10000	10000–20000	7000–8000	10000–14000	10000–15000	–	6000–10000	12000–20000	8500–12000	10000–16000	13000	15000–23000
Impact strength (ft-lb/in. of notch) (½ x ½ in. notched bar izod test)	0.30–0.50	1.0–10.0	0.26–0.35	3–15	0.25–0.40	–	0.30–0.50	1.5–16.0	0.24–0.60	10–50	0.4–0.45	4.0–6.0
Water absorption (24 hr, 1/8 in. thickness), %	0.2–0.3	0.1–0.3	0.13	0.1–0.2	0.1	0.05–0.095	0.05–0.05	0.06–0.28	0.3–1.0	0.1–1.2	0.16–0.3	0.09–0.21
Thermal conductivity, 10^{-4} cal per sec per sq cm per °C per cm	7.0–10.0	7.0–10.0	–	7.51–7.54	7–18	7–10	7.0–15.0	7.0–10.0	4–7	–	–	11.5
Thermal expansion, 10^{-5} per °C	2.0–3.0	2.0–3.0	–	0.8	2.5–5.0	1.1–3	3.5–5	2.5–3.3	3.0–4.5	1.6	–	1.5
Resistance to heat, °F (continuous)	350–450	350–500	>600	>600	300–500	330–500	300–350	300–350	360–500	350–500	250	300–400

Diallyl phthalate is used in a variety of electronic parts, including connectors, memory frames and equipment housings. (photo courtesy FMC Corp.)



2. **Effect of 95% humidity** at 60°C on the 500 Vdc insulation resistance of an alkyd molding compound.

given design feature. Further, material improvements are constantly being made. Hence, consultation with suppliers is always advised in cases where any doubt exists.

As shown in Table 3, the principal thermosetting materials are the

Alkyds	Phenolics
Aminos	Polyesters
Diallyl phthalates	Silicones
Epoxies	

Alkyds are good for molded parts

Alkyds are widely used for molded electrical parts, since they are easy to mold and economical to use. Molding dimensional tolerances can be held to within ±0.001 inch per inch. Post molding shrinkage is small. Their greatest limitation is in extremes of temperature (above 350°F) and in extremes of humidity. In these respects silicones and diallyl phthalates are superior—silicones especially with respect to temperature, and diallyl phthalates with respect to humidity. The electrical insulation resistance of alkyds decreases considerably in high, continuous humidity conditions, as shown in Fig. 2.

Alkyds are chemically somewhat similar to polyester resins. Normally, the term alkyds is used to denote liquid resins, or low-pressure molding compounds. Alkyd molding compounds are commonly available in putty, granular, glass-fiber-reinforced and rope form.

Aminos are durable

Amino molding compounds are economical to mold, and they result in parts that are hard, rigid, abrasion-resistant, and have high resistance to deformation under load. They can be exposed to sub-zero temperatures without embrittlement, and have excellent electrical insulation characteristics. In addition, they are unaffected by common organic solvents, greases and oils, and weak acids and alkalies.

Of the two major types of aminos, namely melamines and ureas, melamines are superior to ureas in resistance to acids, alkalies, heat and boiling water, and are preferred for applications involving cycling between wet and dry conditions or rough handling. Both provide excellent heat insulation, and temperatures up to the destruction point will not cause parts to lose their shape.

When amino moldings are subjected to prolonged elevated temperatures, a loss of certain strength characteristics occurs. Some electrical characteristics are also adversely affected. Arc resistance of some industrial types, though, remains unaffected after exposure at 500°F.

Ureas are unsuitable for outdoor exposure, while melamines experience little degradation in electrical or physical properties after outdoor exposure, although color changes may occur.

Diallyl phthalates shine at high temperatures

Diallyl phthalates are among the best of the thermosetting plastics with respect to high insulation resistance and low electrical losses. They maintain these favorable properties up to 400°F or higher, and in the presence of high humidity environments. This makes them an excellent choice for use in environmental-type connectors (Fig 3). Diallyl-phthalate resins are also easily molded and fabricated.

There are several chemical variations of diallyl-phthalate resins, but the two most commonly used are basic diallyl phthalate (DAP) and diallyl-isophthalate (DAIP). The primary application difference is that DAIP will withstand somewhat higher temperatures than will DAP.

The excellent dimensional stability of diallyl phthalates is demonstrated in Fig. 4, which compares them to other materials at various temperatures. The excellent electrical properties of diallyl phthalates are shown in Figs. 5 through 8.

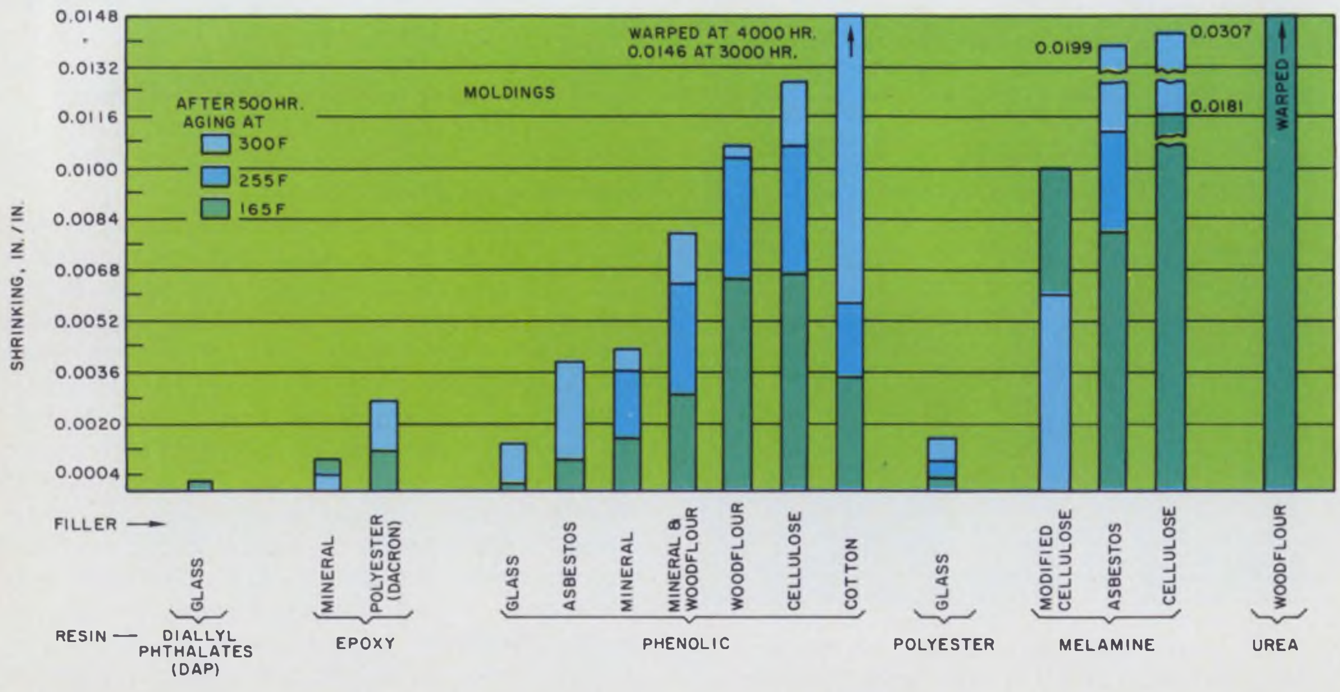
Epoxies are extremely versatile

For electronic applications, epoxies are among the most versatile and widely used plastics. This is primarily because of the wide variety of formulations possible, and the ease with which they can be used. Formulations range from flexible to rigid in the cured state, and from thin liquids to thick pastes in the uncured state. Conversion from the uncured to the cured state is made by use of hardeners and/or heat.

The main uses of epoxies in the electronics field are for embedding applications (potting, casting, encapsulating and impregnating) and in laminated constructions, such as metal-clad laminates for printed circuits and unclad laminates for various types of insulating and terminal boards.

Epoxies are available for the most part as liquid or solid resins, and as powdered molding compounds. The molding compounds are widely used to mold boxes for electronic modules, and

3. **Miniature connector uses a glass-filled diallyl phthalate** (DAP) molding compound to provide insulation between all of the 61 pins. Designed by Microdot, the multi-pin insert has a recommended working voltage of 750 V rms. (photo courtesy FMC Corp.)

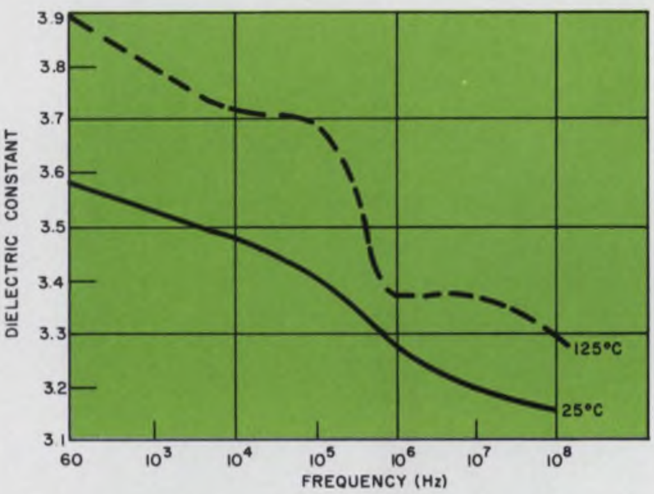


4. **Shrinkage of various thermosetting molding materials** as a result of heat aging.

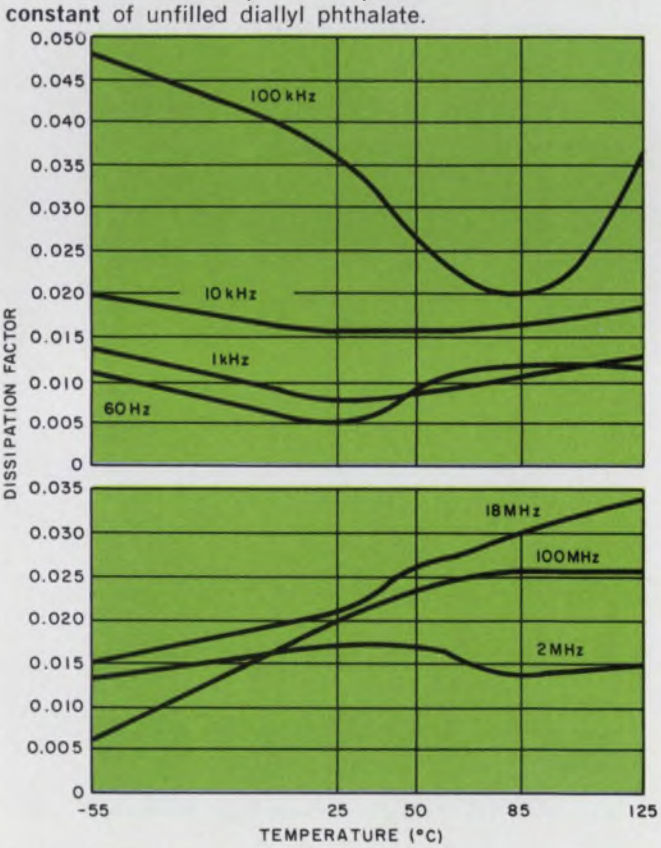
even more widely to directly mold modules by the transfer molding technique (Fig. 9). They are also used for transfer and compression molding of many other types of electrical parts. The liquid resins find their broadest use in embedding applications and in the fabrication of laminate boards. Advanced multilayer circuit boards are almost exclusively based on epoxies.

In addition to their versatility and good electrical properties, epoxies are also outstanding in their low shrinkage, their dimensional stability and their adhesive properties. Their shrinkage is often less than 1%, and the "as-molded" dimensions of an epoxy part change little with time or environmental conditions, other than excessive heat. Because of the low shrinkage and good strength properties of epoxies, cured epoxy parts resist cracking—both upon curing and in thermal shock—better than most other rigid thermosetting materials.

Based on the excellent bonds that can be obtained to most substrates with epoxy resins, epoxy formulations are broadly used as adhesives in electronic-equipment applications. Even when not specifically used as adhesives, epoxies have bonding properties that often provide a better seal around inserts, terminals and other interfaces than do most other plastic materials.



5. **Effect of frequency and temperature on the dielectric constant** of unfilled diallyl phthalate.

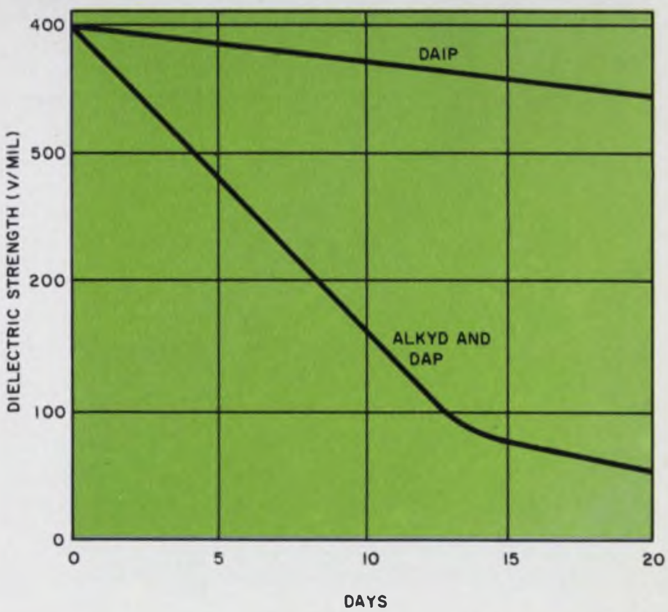


6. **Effect of frequency and temperature on the dissipation factor** of unfilled diallyl phthalate is shown for a frequency span of 60 Hz to 100 MHz.

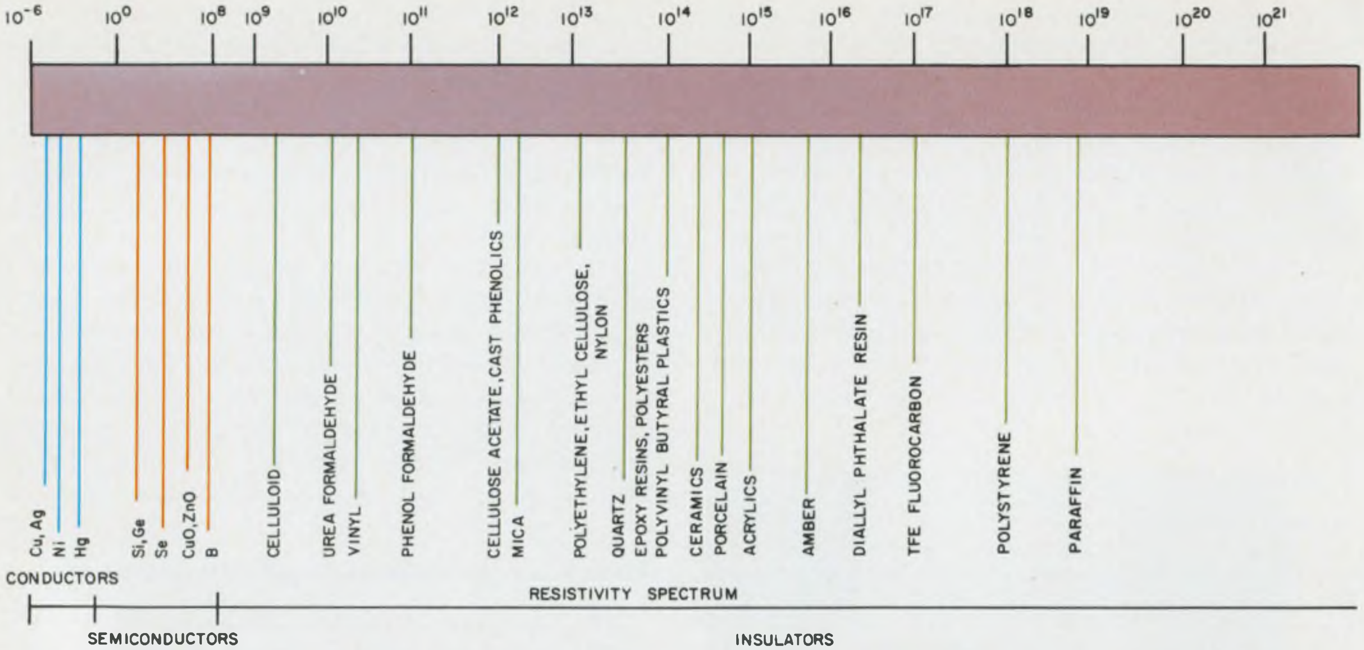
Phenolics have widespread general-purpose use

Phenolics are among the oldest and best known general-purpose molding materials. They are also among the lowest in cost and the easiest to mold. An extremely large number of phenolic materials is available, based on the many resin and filler combinations. Though phenolics are broadly used for general-purpose insulating uses, it should be noted that many special-purpose electrical grades are now available, including low-loss types.

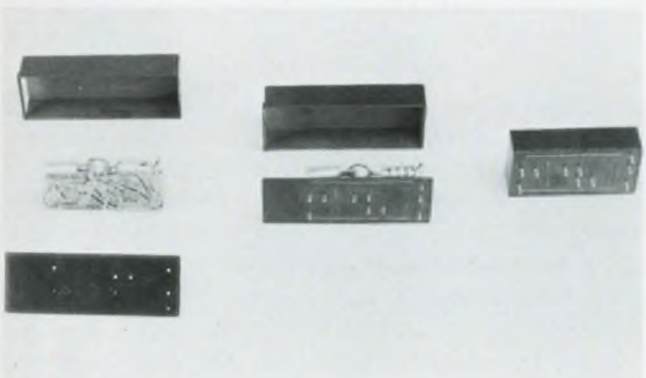
While it is possible to get various grades of phenolics for different applications, they are, generally speaking, not equivalent to a diallyl phthalates and epoxies in resistance to humidity, shrinkage, dimensional stability, and retention of electrical properties in extreme environments. Phenolics are, however, quite adeqate for many applications where the electrical requirements



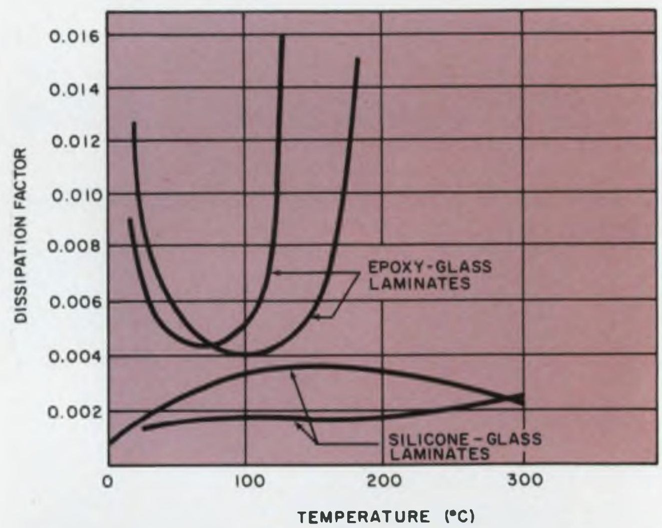
7. **Effect of heat aging** at 400°F on the dielectric strength of diallyl phthalate (DAP), diallyl isophthalate (DAIP) and alkyd molding materials.



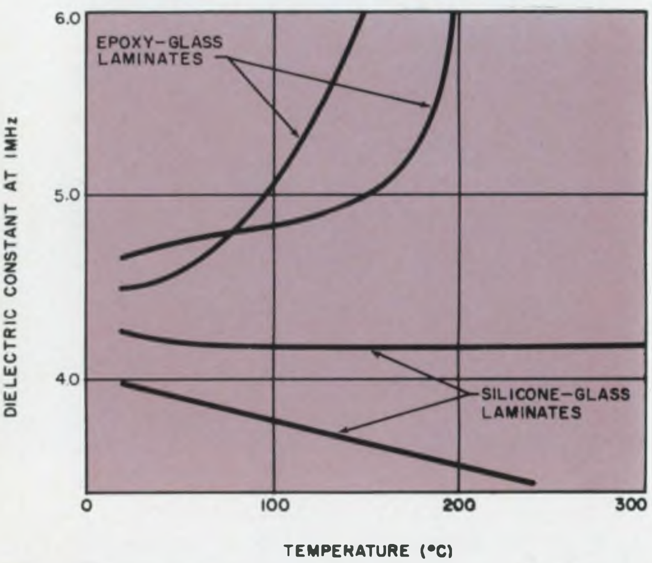
8. **Resistivity spectrum** for a variety of engineering materials shows that diallyl phthalate, TFE fluorocarbon and polystyrene rate highest among insulating materials, all having resistivities in excess of 10^{16} ohm-cm. The values shown, which are expressed in ohm-cm, are for the case of unfilled resins.



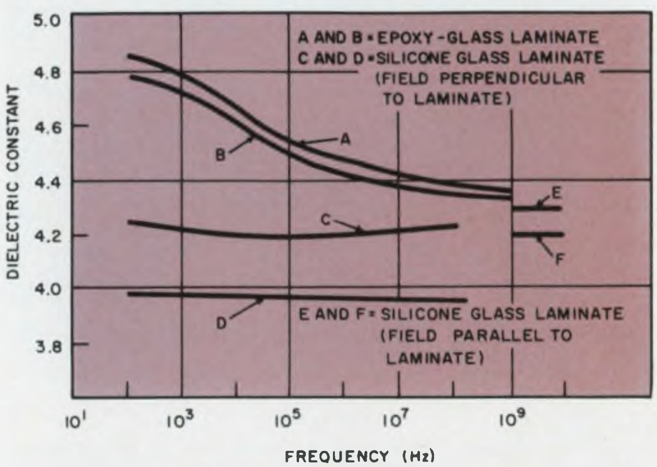
9. **Epoxy molding material** can be used for module cases (left), as well as for directly molded modules (right). (photo courtesy Westinghouse Electric Corp.)



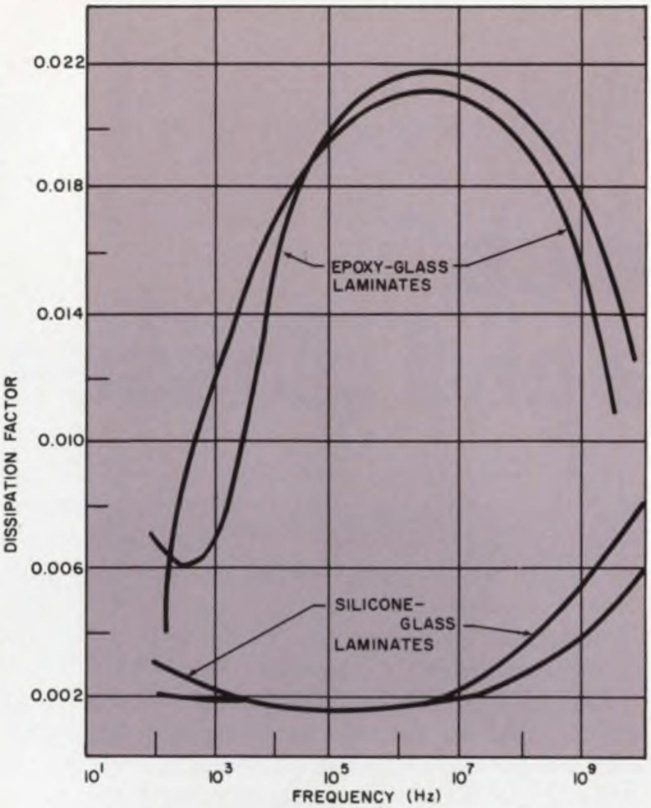
11. **Dissipation factor vs temperature** for silicone-glass and epoxy-glass laminates.



10. **Dielectric constant vs temperature** for silicone-glass and epoxy-glass laminates.



12. **Dielectric constant vs frequency** at room temperature for silicone-glass and epoxy-glass laminates.



13. **Dissipation factor vs frequency** at room temperature for silicone-glass and epoxy-glass laminates.

14. **Four spiral antennas** used for space-vehicle applications take advantage of the low-loss properties of silicone laminates. The antennas, made by Westinghouse, consist of copper strips, etched to form a spiral pattern, and bonded to a silicone-glass laminate. (photo courtesy Dow Corning Corp)

are not too severe. Further, the glass-filled, heat-resistant grades are outstanding in thermal stability up to 400°F and higher.

Polyesters compete with epoxies

Polyesters are versatile resins that, from a chemical standpoint, are similar to the alkyds and from a handling and application standpoint are much like the epoxies. They are available in forms ranging from low-viscosity liquids to thick pastes or putties. The liquids are used for embedding applications and laminated products, much like the epoxies, and the pastes are used for molding applications.

The major advantages of polyesters over epoxies are lower cost and lower electrical losses for the best electrical-grade polyesters. Some important disadvantages of polyesters, as compared to epoxies, are lower adhesion to most substrates, higher polymerization shrinkage, a greater tendency to crack during cure or in thermal shock, and greater change of electrical properties in a humid environment.

Silicones resist temperature aging

Silicones are thermosetting polymers that can be classified as elastomers, when the cured product is rubberlike, classified as embedding materials, when the basic plastic form is a castable liquid (either rubberlike or rigid), or classified as molding compounds, especially low-pressure transfer molding compounds for electronic module embedment. They find wide usage, not only in electronic packaging, but for laminated products, molded parts and adhesives.

The most important properties of silicones for electronic applications are excellent electrical properties, which do not change drastically with temperature or frequency over the materials' safe operating temperature range. This is shown in Figs. 10 through 13, which compare epoxy and silicone laminates. In addition, silicones are among the best of all plastic materials in resistance to temperature-aging effects. Usable temperatures of 500°F - 700°F are possible with available silicone materials. Hence, silicones are very well suited for high-temperature electronic applications, especially those applications requiring low electrical losses.

The mechanical properties of silicone molding compounds are not as stable with increasing temperature as are the electrical properties. Most mechanical properties, however, are stable in other extreme environments, such as humidity and vacuum. This has led to the wide use of silicones both in military and space applications. A good example of silicone design capabilities for extreme conditions is shown in Fig. 14.

Ceramics, ceramoplastics and glasses

Ceramics, ceramoplastics and glasses are inorganic, electrical insulating materials that offer some special design features to the electronic designer. All of these materials have higher temperature capabilities and greater dimensional stability than plastics. However, they differ from each other in important engineering and application respects.

Ceramics must be chosen for electrical properties

Like plastics, ceramics are good electrical insulators, although they have much better thermal conductivity than do plastics. This characteristic makes ceramics very useful in applications requiring electrically insulated heat sinks. Ceramics do not, in general, have low dielectric constants, and do not rate as well as many plastics in this respect.

In addition to their good thermal and electrical properties, ceramics offer greatly improved dimensional stability over most plastics—especially at slightly elevated temperatures. This is true in both thermal expansion and physical distortion properties, such as flatness and warpage. Although ceramics are generally harder and more brittle than plastics, they can often be machined, assembled, and fabricated with comparative ease. Further, ceramics can be metalized or coated and thus fabricated into many useful electronic items.

Ceramics are widely used as substrates for thick and thin film circuits, and for electronic packages, such as integrated-circuit flat packs. In addition, certain ceramic materials—notably those based on titanates such as barium titanate —can be made with a controlled dielectric constant over a wide range, making possible their use as capacitors.

Included in the broad category of ceramic materials are aluminas, steatites, forsterite, zircons, titania, titanates, cordierite, lava, magnesia, magnesium silicate, silicon carbides, zirconia, beryllia, porcelain, mullite, spinel, quartz and boron nitride. Some of these ceramics are available in various compositions and degrees of purity so that the materials must be fairly well defined when making comparisons. Also, some of these ceramics, while good insulators, do not have other properties required for high-reliability performance of electronic equipment in extreme environments, such as humidity.

Hence, it is the electrical-quality ceramics that are of greatest interest to electronic designers. Basic properties of some of these are shown in Table 7. Variations of dielectric constant and dissipation factor with frequency and temperature are shown in Fig. 15 for one alumina and one beryllia. These two types are among the most widely used ceramics in electronics.

Aluminas are harder, stronger and more resistant to wear than most other ceramics and are better electrical insulators, especially at higher temperatures and higher frequencies. These properties are responsible for their widespread use in avionic radomes (Fig. 16). Although aluminas are usually in the form of dense ceramics, they can also be obtained in porous forms, which are easily outgassed and find wide use as electron-tube insulators.

Steatites are usually easier to manufacture into final product form than the aluminas, and therefore are generally more economical. For many years they were the top performers in technical ceramics, and they still have a wide field of usefulness. In many applications it is worthwhile to study the characteristics of steatites (Table 6) to see if they meet the needed performance requirements. This may help prevent the needless use of a more expensive ceramic.

Forsterite serves well where the primary requirement is for very-low-loss insulators. It is somewhat difficult to form and frequently requires grinding to meet close dimensional requirements. The high coefficient of expansion matches that of several metals, but at a sacrifice in thermal shock resistance.

Titania has high mechanical strength and great hardness. It is excellent for mechanical applications requiring wear and chemical resistance. It

Table 6. Properties of representative ceramics*

Property	Steatite $MgO \cdot SiO_2$ Alsimag 665 L-533	Forsterite $2MgO \cdot SiO_2$ Alsimag 243 L-723	Zircon $ZrO_2 \cdot SiO_2$ Alsimag 475 L-514	Cordierite $2MgO \cdot 2Al_2 \cdot O_3$ $5SiO_2$ Alsimag 701	Lava (natural stone) grade A, aluminum silicate	Alumina Al_2O_3 Alsimag 753 L-724	Beryllia(3) BeO Alsimag 754 L-623
Water absorption, %	0	0	0	0.02-1	2–3	0	0
Specific gravity	2.7	2.8	3.7	2.3	2.3	3.85	2.88
Safe temperature at continuous heat	1000 °C	1000 °C	1100 °C	1200 °C	1100 °C	1650 °C	1600 °C
Hardness, Moh's scale	7.5	7.5	8	8	6	9	9
Thermal expansion, 25–300 °C	6.9×10^{-6}	10×10^{-6}	4.3×10^{-6}	2.4×10^{-6}	3.3×10^{-6}	7.1×10^{-6}	6×10^{-6}
Thermal conductivity, 300 °C(1)	0.006	0.008	0.012	0.008	0.005	–	0.28
Dielectric strength, 60-cycle ac, volts/mil	230	240	220	225	80	230	240
Volume resistivity, ohm/cm							
25 °C	$>10^{14}$	$>10^{14}$	$>10^{14}$	1.0×10^{14}	$>10^{14}$	$>10^{14}$	$>10^{14}$
100 °C	1.0×10^{14}	5×10^{13}	2×10^{13}	2.5×10^{11}	6×10^{11}	$>10^{14}$	$>10^{14}$
Dielectric constant, 1 MHz, 25 °C(2)	6.3	6.2	8.8	5.3	5.3	9.4	6.4
Dissipation factor, 1 MHz, 25 °C(2)	0.0008	0.0004	0.0010	0.0047	0.010	0.0001	0.0001
Loss factor, 1 MHz, 25 °C(2)	0.0050	0.002	0.009	0.025	0.053	0.0009	0.0006

(1) Conversion factor figures are in cal/(cm) (s) (cm^2), one of which equals 2902 Btu/(in.) (hr) (ft^2) (°F.)
(2) AlSiMag 243, 475, and 665 measured wet at 1 MHz, after immersion in water for 48 hr (MIL-I-10A).
(3) In working with beryllia ceramics, personnel should avoid exposure to dust- or fume-producing operations, such as sawing and grinding, in moist atmospheres at high temperatures. Specialized equipment is necessary to prevent the dispersal of the dust and fumes into the air.
*Courtesy American Lava Corp.

Table 7. Properties of some representative glass-bonded micas*

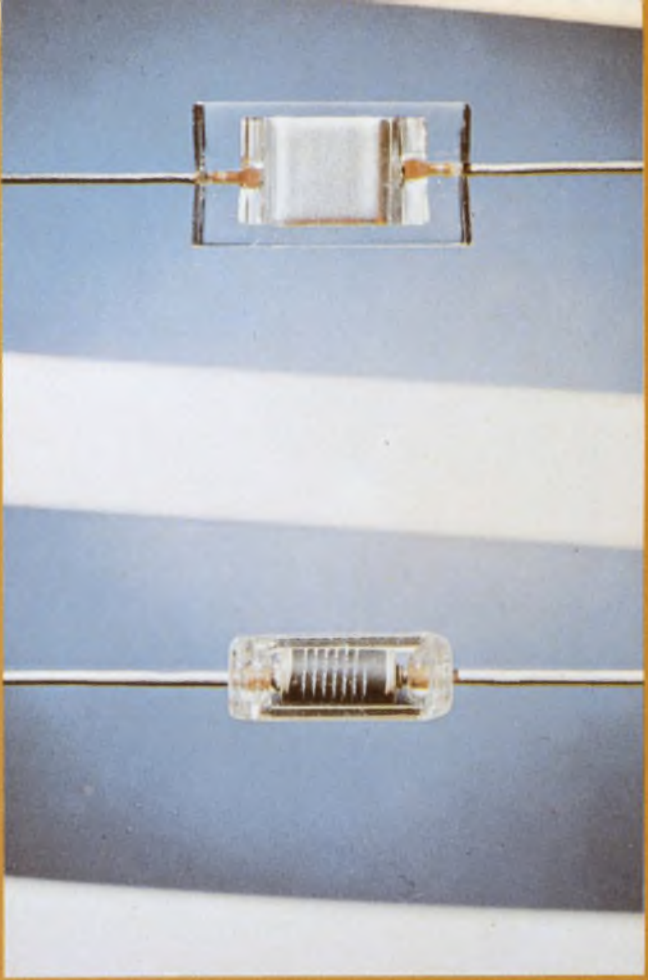
Property	Units	Machining grades, sheets and rods			Custom injection molded grades		
		Mykroy 750	Mykroy 1100	Mykroy 1116	Mykroy 761	Mykroy 777	Mykroy 1001
General:							
Specific gravity	–	3.3	3.2	3.2	3.6	3.9	3.1
Moisture absorption	–	Nil	Nil	Nil	Nil	Nil	Nil
Max. continuous temp.	°F	750°	1100°	1100°	750°	790°	1100°
Coefficient of expansion	$\times 10^{-6}$ °F	5.6	5.2	5.2	6.0	5.1	5.0
Electrical:							
Volume resistivity	ohm-cm	10^{13}	10^{14}	10^{14}	10^{14}	10^{14}	10^{13}
Dielectric, 1/8 in.	volts/mil	350	400	400	350	350	400
Dielectric constant	1 MHz	7.1	7.50	7.4	8.2	9.2	6.8
Dissipation factor	1 MHz	0.0014	0.0012	0.0019	0.0011	0.0016	0.0011
Loss factor	1 MHz	0.0099	0.016	0.014	0.009	0.015	0.008
Surface resistivity, dry	ohm	10^{16}	10^{16}	10^{16}	10^{15}	10^{15}	10^{15}
Surface resistivity, wet	ohm	10^{10}	10^{11}	10^{12}	10^{9}	10^{10}	10^{9}

*Courtesy Molecular Dielectrics, Inc.

Table 8. Properties of representative commercial glasses*

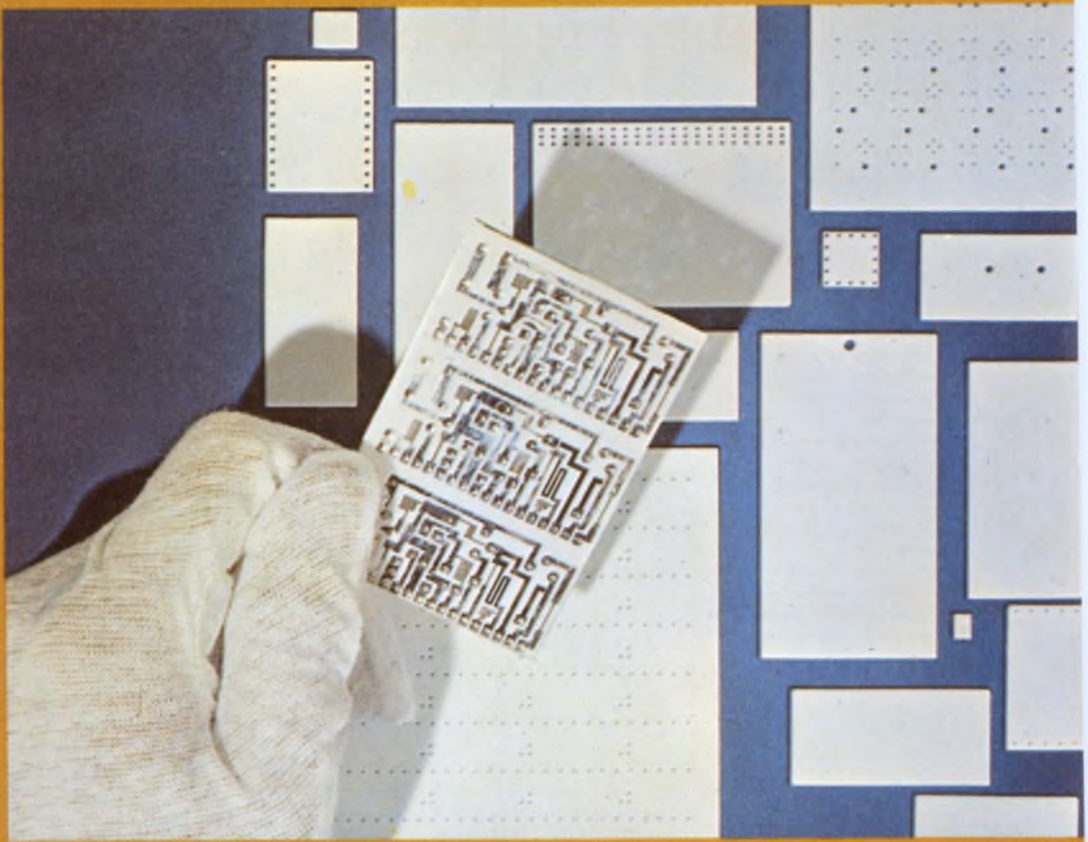
Type of glass	Coefficient of expansion per °C, 0–300 °C	Density, g/cm³	Refract. index, sodium D line	Electrical properties			
				Log^{10} vol res., ohm-cm		Dielectric properties 1 MHz, 20 °C	
				250 °C	350 °C	Power factor	Dielectric constant
Silica glass (fused silica)	5.5×10^{-7}	2.20	1.458	12.0	9.7	0.0002	3.78
96% silica glass, 7900	8×10^{-7}	2.18	1.458	9.7	8.1	0.0005	3.8
96% silica glass, 7911	8×10^{-7}	2.18	1.458	11.7	9.6	0.0002	3.8
Soda-lime, elect lamp bulbs	92×10^{-7}	2.47	1.512	6.4	5.1	0.009	7.2
Lead silicate, electrical	91×10^{-7}	2.85	1.539	8.9	7.0	0.0016	6.6
Lead silicate, high lead	91×10^{-7}	4.28	1.639	11.8	9.7	0.0009	9.5
Aluminoborosilicate apparatus	49×10^{-7}	2.36	1.49	6.9	5.6	0.010	5.6
Borosilicate, low expansion	32×10^{-7}	2.23	1.474	8.1	6.6	0.0046	4.6
Borosilicate, low electrical loss	32×10^{-7}	2.13	1.469	11.2	9.1	0.0006	4.0
Borosilicate, tungsten seal	46×10^{-7}	2.25	1.479	8.8	7.2	0.0033	4.9
Aluminosilicate	42×10^{-7}	2.53	1.534	11.4	9.4	0.0037	6.3

*Courtesy Corning Glass Works



Glass is used as a sealer for this resistor and capacitor. The resistor element itself is a glass rod onto which a tin-oxide film is fused. (photo courtesy Corning Glass)

Applications for metalized ceramics include microcircuit packaging and power-transistor header discs. (photo courtesy of Coors Porcelain Co.)



Alumina is widely used as a substrate for thick- and thin-film circuits. Here, a substrate with circuitry already deposited is shown above a field of bare substrates. (photo courtesy of Coors Porcelain Co.)

also lends itself to close-tolerance work, and is often produced in controlled finishes measured in micro-inches. Normally an excellent electrical insulator, titania can be processed to become a partial conductor to assist in control of static electricity.

Cordierites have a low coefficient of expansion and excellent resistance to heat shock. They are used mostly in the extruded form for insulators in products such as heating elements and thermocouples. They also lend themselves to dry pressing.

Lava is a mined natural mineral (aluminum silicate or magnesium silicate), which can be machined and then kiln-fired with little change in size. It has good electrical properties and good heat resistance. It is often used in prototypes, or where small quantities of a technical ceramic are needed.

Magnesia (magnesium oxide) ceramics are principally used as crushable ceramics for metal-sheathed heaters, range units, etc. Magnesias are available in medium purity for commercial uses, or in extremely high purity to meet certain AEC specifications.

Beryllia, or beryllium oxide, is a material that insulates electrically as a ceramic does but conducts heat as a metal does. Its thermal conductivity is 62% that of copper, compared to aluminum's 55% and steatite's 0.9%. A component insulated with beryllia, therefore, is isolated electrically, although thermally it is the same as though the component were grounded. Beryllia is unique among practical insulators in this respect, although the diamond exhibits this same combination of properties.

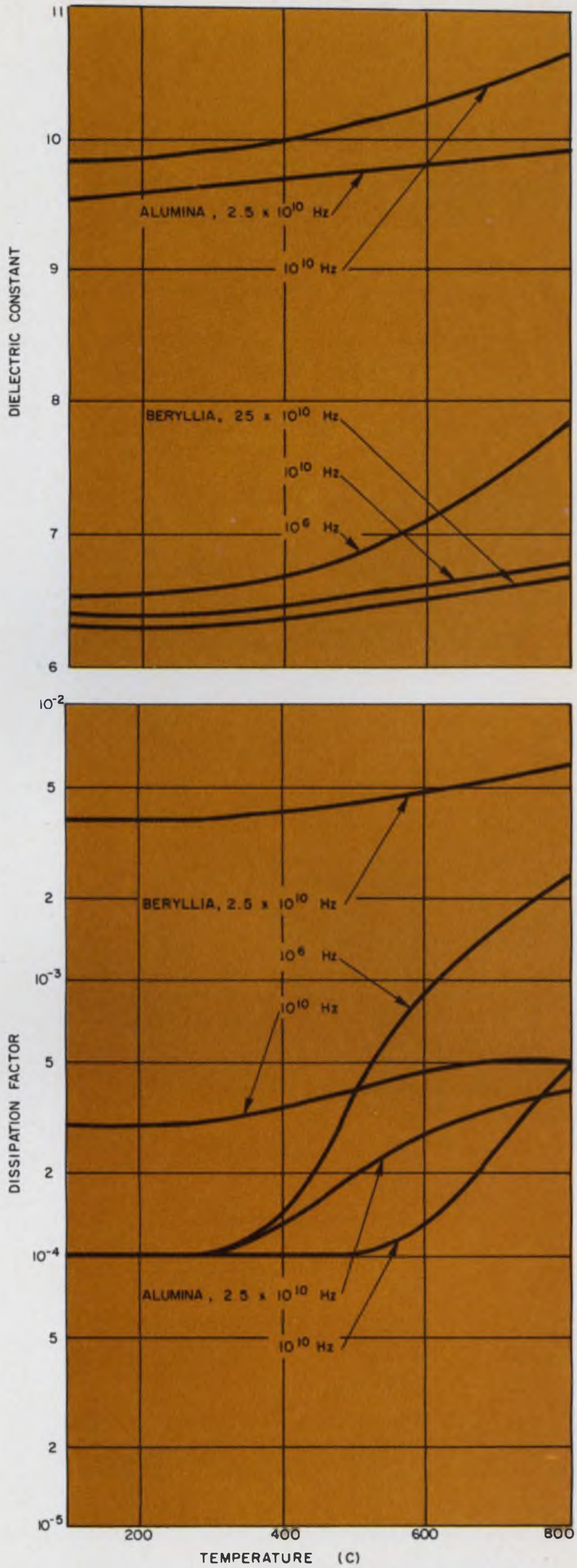
Care must be taken when machining beryllia because of possible toxicity problems with beryllia dust. Usually, though, the supplier can either machine for the user or advise on machining.

Boron nitride is useful for a variety of electronic applications. It has excellent high-voltage resistance properties (Fig. 17), and is used in wafers for thermal conductivity mountings, coil forms, waveguide windings, etc. Since there are variations in the moisture absorption of boron nitride materials, the appropriate grade should be chosen for a given design objective.

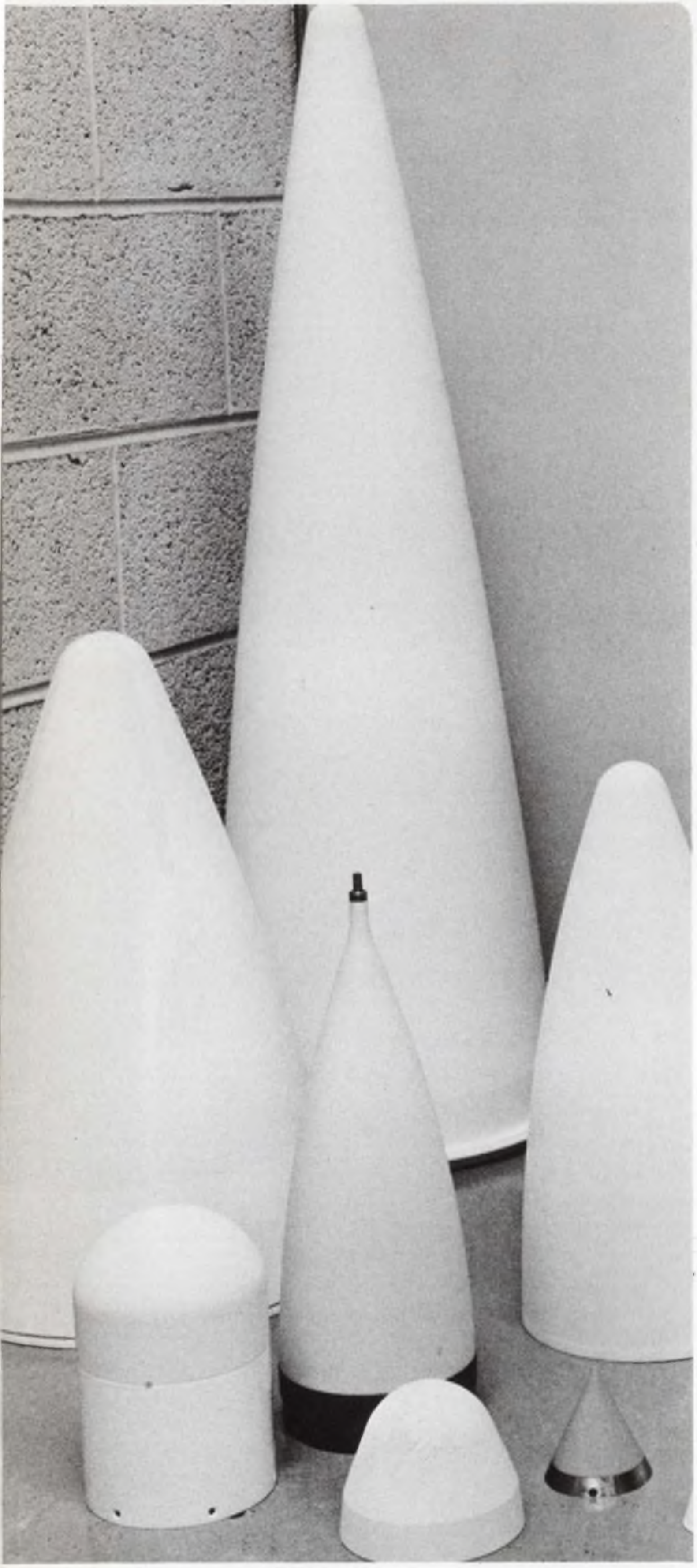
Ceramoplastics combine attractive features

Ceramoplastics are inorganic materials that can be molded or processed like plastics, but which have properties more closely resembling ceramics. The useful application temperatures for ceramoplastics lie between those of plastics and ceramics.

The most common form of ceramoplastic is glass-bonded mica. This is composed of finely powdered mica, natural or synthetic, bonded with



15. **Effect of temperature on electrical properties** are shown for a 99.5% alumina (Alsimag 753) and a 99.5% beryllia (Alsimag 754), which are among the most widely used ceramics. (photo courtesy of American Lava Co.)



16. **Alumina is used in many styles of radomes.** The material is transparent at microwave frequencies and has very high temperature capabilities. It can also be manufactured to very close tolerances. (photo courtesy Coors Porcelain Co.)

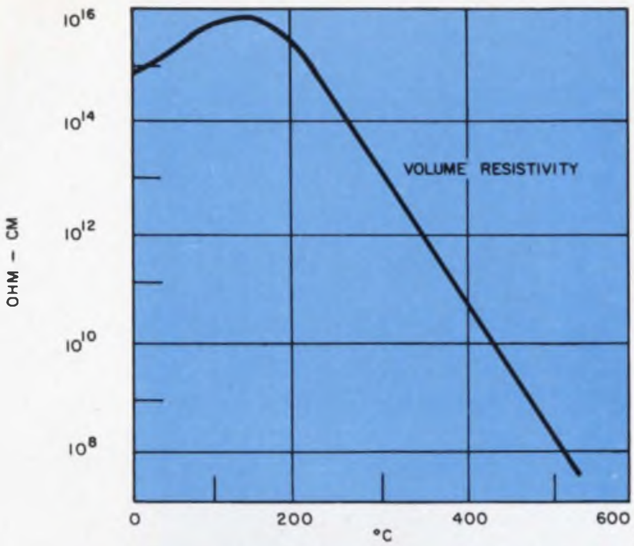
17. **Dielectric strength capabilities of boron nitride** are demonstrated by detouring a 10,000-volt arc with a 1/32-inch thin strip of the material.

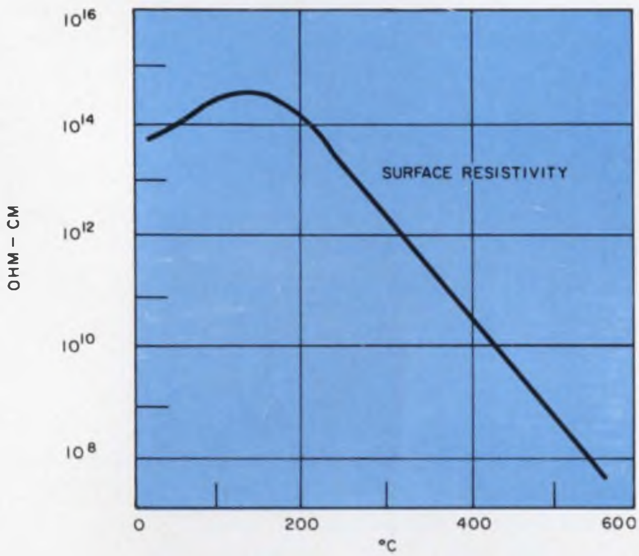
special glasses. To achieve certain properties, ceramics, glasses, and inorganic fibers or fillers may be combined. (Fig. 18).

Molding of glass-bonded mica parts is performed at relatively high temperatures, commonly in the 1000 to 1500°F range. Close tolerances can be held, however, even in complex shapes or with inserts. Glass-bonded mica is available in custom-molded shapes, or in sheet or bar stock.

The important properties of some representative machining grades and some representative molding grades of glass-bonded mica are shown in Table 7. Outstanding features of the material are as follows:

- Higher thermal endurance.
- Arc resistance.
- Radiation resistance.
- Low thermal expansion.
- Moldability, with delicate insert inclusion.
- Excellent electrical values.





18. **Resistivity as a function of temperature** is shown for a representative glass-bonded mica. Values for both volume resistivity and surface resistivity are given.

19. **An example of the role of glasses in modern electronics** is Corning Code 9013 lead-free glass, which is used for its constant dielectric properties.

- Machinability, which is better than ceramics, with no firing after machining.
- Corona resistance (in finished parts).
- Moldability with true hermetic seal.
- High dimensional stability.

Another, especially useful, property of glass-bonded micas is their relatively low linear coefficient of thermal expansion, especially among moldable products.

There are various electrical grades of glass-bonded micas, and some grades have relatively stable values of dielectric constant and dissipation factor up to frequencies of 8500 MHz or higher, and up to 250 to 350°C. Their resistivity, like that of plastics, decreases with temperature.

Types of glasses abound

Glasses come in hundreds of varieties, each with distinguishable property differences, but only some of these are of importance for electronic use. Properties of typical glasses are given in Table 8. The data given includes electrical, mechanical and physical characteristics.

In glasses, current is carried by the migration of ions, as in electrolytics, rather than by free electrons, as in the case of metals. For this reason mobile ions, such as sodium ions, have a significant influence, and resistivity values tend to decrease with an increase in the sodium content.

Resistivity, dissipation factor and dielectric constant of glasses are affected by temperature, with the resistivity decreasing and the dissipation factor and dielectric constant increasing at higher temperatures.

An example of how glasses can be tailored as insulation for modern electronic equipment is shown in Fig. 19, which illustrates the use of lead-free glass in transistor headers.

Thermoplastics

Thermoplastics differ from thermosets in that they do not cure or set under heat. When heated, thermoplastics merely soften to a flowable state in which, under pressure, they can be forced or transferred from a heated cavity into a cool mold. Upon cooling they harden and take the shape of the mold.

Thermoplastics can be remelted and rehardened by cooling many times. However, thermal aging, brought about by repeated exposure to the high temperatures required for melting, causes eventual degradation of the material and so limits the number of re-use cycles. Essentially, then, all thermoplastics are processed by being heated to a soft state, and then shaped by applying pressure and being cooled. Common techniques include injection molding, extruding and thermoforming.

Basic applications information for the various thermoplastics is presented in Table 9. Physical and mechanical properties of the different types are listed in Table 10, and electrical properties are detailed in Table 11.

ABS plastics offer good mechanical properties

ABS plastics are derived from acrylonitrile, butadiene, and styrene. They offer hardness and rigidity, without brittleness, and at moderate cost.

While ABS plastics are used largely for mechanical purposes, they also have good electrical properties, which are fairly constant over a wide range of frequencies. These properties are affected little by temperature and humidity over the materials' rated operating temperature range.

Acetals are moderately attractive electrically

The acetals resemble nylon in appearance. They are good insulators, having relatively low dissipation factors and dielectric constants over their rated operating temperature range. All of the electrical properties of acetals are largely retained under exposure to high humidity and water immersion.

The most outstanding properties of acetals are high tensile strength and stiffness, resiliency, good recovery from deformation under load, and toughness under repeated impact. In addition, acetals have low static and dynamic coefficients of friction, and are usable from the standpoint of their mechanical properties over a wide range of environmental conditions.

Acrylics shine for optical uses

Acrylics, which are also known as polymethylmethacrylates, are primarily known for their exceptional clarity and excellent light transmission. This optical clarity, together with their good electrical and mechanical properties and their ready availability in a wide range of shapes and forms, makes acrylics attractive for various special application areas.

Acrylics have high resistance and excellent tracking characteristics, which make them a good choice for certain high-voltage applications, such as circuit breakers. In addition, they are one of the few plastics that exhibit an essentially linear decrease in dielectric constant and dissipation factor with increase in frequency (Fig. 20).

Mechanically, acrylics are strong, rigid and resistant to sharp blows. Their physical properties are not affected by outdoor weathering, and they do not become exceptionally brittle at low temperatures.

Cellulosics susceptible to extreme environments

Cellulosics have relatively good electrical insulating properties, although the properties vary depending on the specific type and formulation of material. A definite disadvantage of the cellulosics is that they are not as resistant to extreme environments as are many other thermoplastics. They are, therefore, not used too frequently in electronic applications. Cellulose acetate is generally useful in the approximate temperature range of —25 to +175°F, while the top tempera-

Table 9. Major application considerations for thermoplastics

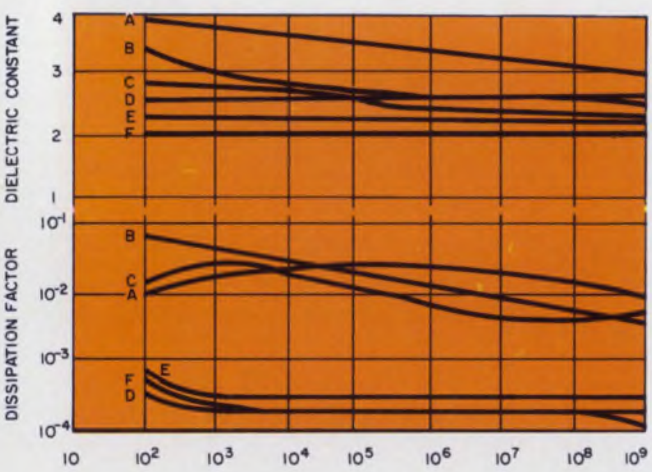
Material	Major application considerations	Common available forms	Typical suppliers and trade names*
ABS (acrylonitrile-butadiene-styrene)	Extremely tough, with high impact resistance. Can be formulated over a wide range of hardness and toughness properties. Special grades available for plated surfaces with excellent pull-strength values. Good general electrical properties, but not outstanding for any specific electric applications.	Blow moldings, extrusions, injection moldings, thermoformed parts, laminates, stock shapes, foam	Borg-Warner Corp. (Marbon Cycolac); Monsanto Co. (Lustran); Goodrich Chemical Co. (Abson)
Acetals	Outstanding mechanical strength, stiffness, and toughness properties, combined with excellent dimensional stability. Good electrical properties at most frequencies, which are little changed in humid environments up to 125°C.	Blow moldings, extrusions, injection moldings, stock shapes	Du Pont, Inc. (Delrin); Celanese Corp. (Celcon)
Acrylics (polymethyl-methacrylate)	Outstanding properties are crystal clarity and resistance to outdoor weathering. Excellent resistance to arcing and electrical tracking.	Blow moldings, castings, extrusions, injection moldings, thermoformed parts, stock shapes, film, fiber	Du Pont, Inc. (Lucite); Rohm and Haas Co. (Plexiglas)
Cellulosics	There are several materials in the cellulosic family, such as cellulose acetate (CA), cellulose propionate (CAP), cellulose acetate butyrate (CAB), ethyl cellulose (EC), and cellulose nitrate (CN). Widely used plastics in general, but not outstanding for electronic applications.	Blow moldings, extrusions, injection moldings, thermoformed parts, film, fiber, stock shapes	Eastman Chemical Co. (Tenite); Dow Chemical Co. (Ethocel-EC); Celanese Corp. (Forticel-CAP)
Chlorinated polyethers	Good electrical characteristics; but most outstanding properties are corrosion resistance and good physical and thermal stability by thermoplastic standards.	Extrusions, injection moldings, stock shapes, film	Hercules Powder Co. (Penton)
Ethylene-vinyl acetates (EVA)	Excellent flexibility, toughness, clarity, and stress-crack resistance. Somewhat like a tough synthetic rubber or elastomer. Not widely used in electronics. Comparatively low resistance to heat and solvents.	Extrusions, injection moldings, thermoformed parts	U.S. Industrial Co. (Ultrathene); Du Pont, Inc. (Alathon); Union Carbide Corp. (Bakelite EVA)
Fluorocarbons			
a. Chlorotrifluoroethylene (CTFE)	Excellent electrical properties and relatively good mechanical properties. Somewhat stiffer than TFE and FEP fluorocarbons, but does have some cold flow. Widely used in electronics, but not quite so widely as TFE and FEP. Useful to about 400°F.	Extrusions, isostatic moldings, injection moldings, film, stock shapes	3M Co. (Kel-F); Allied Chemical Corp. (Plaskon CTFE)
b. Fluorinated ethylene propylene (FEP)	Very similar properties to those of TFE, except useful temperature limited to about 400°F. Easier to mold than TFE.	Extrusions, injection moldings, laminates, film	Du Pont, Inc. (Teflon FEP)
c. Polytetrafluoroethylene (TFE)	Electrically one of the most outstanding thermoplastic materials. Exhibits very low electrical losses, and very high electrical resistivity. Useful to over 500°F and to below −300°F. Excellent high-frequency dielectric. Among the best combination of mechanical and electrical properties but relatively weak in cold-flow properties. Nearly inert chemically, as are most fluorocarbons. Very low coefficient of friction. Nonflammable.	Compression moldings, stock shapes, film	Du Pont, Inc. (Teflon TFE); Allied Chemical Corp. (Halon TFE)
d. Polyvinyl fluoride	Mostly used as a weatherable, architectural facing sheet. Not widely used in electronics.	Extrusions, injection moldings, laminates, film	Du Pont, Inc. (Tedlar)
e. Polyvinylidine fluoride (PVF_2)	One of the easiest of the fluorocarbons to process. Stiffer and more resistant to cold flow than TFE. Good electrically. Useful to about 300°F. A major electronic application is wire jacketing.	Extrusions, injection moldings, laminates, film	Pennsalt Chemicals Corp. (Kynar)
Ionomers	Excellent combination of toughness, solvent resistance, transparency, colorability, abrasion resistance, and adhesion. Based on ethylene-acrylic copolymers with ionic bonds. Not widely used in electronics.	Film, coatings, injection moldings	Du Pont, Inc. (Surlyn A); Union Carbide Corp. (Bakelite)
Nylons (polyamides)	Good general purpose for electrical and nonelectrical applications. Easily processed. Good mechanical strength, abrasion resistance, and low coefficient of friction. There are numerous types of nylons; nylon 6, nylon 6/6, and nylon 6/10 are most common. Some nylons have limited-use due to moisture-absorption properties. Nylon 6/10 is best here.	Blow moldings, extrusions, injection moldings, laminates rotational moldings, stock shapes, film, fiber	Du Pont, Inc. (Zytel); Allied Chemical Corp. (Plaskon); Union Carbide Corp. (Bakelite)
Parylenes (polyparaxylylene)	Excellent dielectric properties and good dimensional stability. Low permeability to gases and moisture. Produced as a film on a substrate, from a vapor phase. Such vapor-phase polymerization is unique in polymer processing. Used primarily as thin films in capacitors and dielectric coatings. Numerous polymer modifications exist.	Film coatings	Union Carbide Corp. (Parylene)
Phenoxies	Tough, rigid, high-impact plastic. Has low mold shrinkage, good dimensional stability, and very low coefficient of expansion for a thermoplastic. Useful for electronic applications below about 175°F. Useful in adhesive formulations.	Blow moldings, extrusions, injection moldings, film	Union Carbide Corp. (Bakelite Phenoxy)
Polyallomers	Thermoplastic polymers produced from two monomers. Somewhat similar to polyethylene and polypropylene, but with better dimensional stability, stress-crack resistance, and surface hardness than high-density polyethylene. Electronic application areas similar to polyethylene and polypropylene. One of the lightest commercially available plastics.	Blow moldings, extrusions, injection moldings, film	Eastman Chemical Products, Inc. (Tenite)
Polyamide-imides and polyimides	Among the highest-temperature thermoplastics available, having useful operating temperatures between about 400°F and about 700°F or higher. Excellent electrical properties, good rigidity, and excellent thermal stability. Low coefficient of friction. Polyamide-imides and polyimides are chemically similar but not identical in all properties. They are difficult to process, but are available in molded and block forms, and also as films and resin solutions.	Films, coatings, molded and/or machined parts, resin solutions	Du Pont, Inc. (Vespel fabricated blocks, Kapton film, and Pyre-M.L. Resin)

*This listing is only a very small sampling of the many possible suppliers. No preferences are implied or intended.

Table 9. Major application considerations for thermoplastics (continued)

Material	Major application considerations	Common available forms	Typical suppliers and trade names*
Polycarbonates	Excellent dimensional stability, low water absorption, low creep, and outstanding impact-resistance. Good electrical properties for general electronic packaging application. Available in transparent grades.	Blow moldings, extrusions, injection moldings, thermoformed parts, stock shapes, film	Mobay Chemical Co. (Merlon); General Electric Co. (Lexan)
Polyethylenes and polypropylenes (polyolefins or polyalkenes)	Excellent electrical properties, especially low electrical losses. Tough and chemically resistant, but weak to varying degrees in creep and thermal resistance. There are three density grades of polyethylene: low (0.910-0.925), medium (0.926-0.940), and high (0.941-0.965). Thermal stability generally increases with density class. Polypropylenes are generally similar to polyethylenes, but offer about 50°F higher heat resistance.	Blow moldings, extrusions, injection molding, thermoformed parts, stock shapes, film, fiber, foam	Du Pont, Inc. (Alathon Polyethylene); U.S.I. Chemical Co. (Petrothene Polyethylene); Allied Chemical Corp. (Grex H.D. Polyethylene); Hercules Powder Co. (Hi-Fax H.D. Polyethylene); Hercules Powder Co. (Pro-Fax Polypropylene); Eastman Chemical Co. (Tenite Polyethylene and Polypropylene)
Polyethylene Terephthalates	Among the toughest of plastic films with outstanding dielectric strength properties. Excellent fatigue and tear strength and resistance to acids, greases, oils, solvents. Good humidity resistance. Stable to 135–150°C.	Film, sheet, fiber	Du Pont, Inc. (Mylar)
Polyphenylene oxides (PPO)	Excellent electrical properties, especially loss properties to above 350°F, and over a wide frequency range. Good mechanical strength and toughness. A lower-cost grade (Noryl) exists, having somewhat similar properties to PPO, but with a 75–100°F reduction in heat resistance.	Extrusions, injection moldings, thermoformed parts, stock shapes, film	General Electric Co. (PPO and Noryl)
Polystyrenes	Excellent electrical properties, especially loss properties. Conventional polystyrene is temperature-limited, but high-temperature modifications exist, such as Rexolite or Polypenco crosslinked polystyrene, which are widely used in electronics, especially for high-frequency applications. Polystyrenes are also generally superior to fluorocarbons in resistance to most types of radiation.	Blow moldings, extrusions, injection moldings, rotational moldings, thermoformed parts, foam	Dow Chemical Co. (Styron); Monsanto Co. (Lustrex); American Enka Corp. (Rexolite); Polymer Corp. (Polypenco Q-200.5)
Polysulfones	Excellent electrical and mechanical properties to over 300°F. Good dimensional stability and high creep resistance. Flame-resistant and chemical-resistant. Outstanding in retention of properties upon prolonged heat aging, as compared to other tough thermoplastics.	Blow moldings, extrusions, injection moldings, thermoformed parts, stock shapes, film sheet	Union Carbide Corp. (Polysulfone)
Vinyls	Good low-cost, general-purpose thermoplastic materials, but not specifically outstanding electrical properties. Greatly influenced by plasticizers. Many variations available, including flexible and rigid types. Flexible vinyls, especially polyvinyl chloride (PVC) widely used for wire insulation and jacketing.	Blow moldings, extrusions, injection moldings, rotational moldings, film sheet	Diamond Alkali Co. (Diamond PVC); Goodyear Chemical Co. (Pliovic); Dow Chemical Co. (Saran)

*This listing is only a very small sampling of the many possible suppliers. No preferences are implied or intended.



20. **Effect of frequency on dielectric constant and dissipation factor** of several thermoplastic materials is shown under room-temperature conditions. A, nylon; B, acrylic; C, CTFE fluorocarbon; D, polystyrene; E, polyethylene; F, TFE fluorocarbon.

ture limit for special cellulosics will normally not exceed 200°F.

Toughness and transparency, at moderate cost, are probably the outstanding characteristics of cellulosics.

Chlorinated polyether has limited electronic use

Chlorinated polyether is better known for its use in piping and hardware in the chemical processing industry than for its use in electronic applications. Nevertheless, it does have properties that can be useful in the electronic area. Both the dielectric constant and dissipation factor do not change much over the frequency range of 60 to 5 $\times$ 10^7 Hz, nor are they much affected by immersion up to 20 hours in boiling water. The dissipation factor, though, does increase considerably over the temperature range of 73 to 250°F. The dielectric constant increases only to about 3.5 at 250°F.

The mechanical creep properties of chlorinated polyether are generally good, with the percentage creep remaining below 4% after over 10,000 hours of a sustained 2000 psi load at 75°F.

Fluorocarbons are extremely important

Due to their excellent electrical properties, which are relatively unaffected by most of the extreme environments encountered by modern electronic systems, fluorocarbons are extremely important to the electronic designer. Probably the most widely used fluorocarbon is polytetrafluoroethylene, or TFE fluorocarbon. This was the original fluorocarbon, and is still known to many as Teflon. Correctly speaking, however, Teflon is the trade name for Du Pont TFE and FEP fluorocarbon only.

Although all fluorocarbons have excellent electrical properties, TFE and FEP fluorocarbons, in particular, have low dielectric constants and dissipation factors, which change little with frequency or temperature. The dielectric strength of TFE and FEP resins is high, and it does not vary with temperature and thermal aging. Initial dielectric strength is very high, as measured by the ASTM short-time test, and, as with any material, the value drops as the thickness of the specimen increases (Fig. 21).

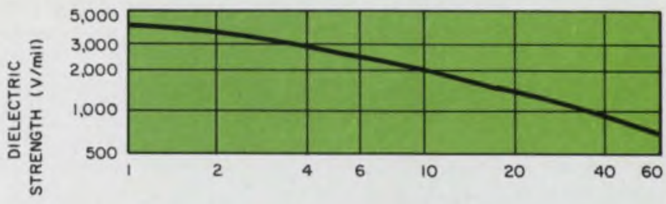
Material life at high dielectric stresses is dependent on corona discharge. As shown in Fig. 22, the absence of corona permits very high voltage stress without damage to either TFE or FEP resins. Changes in ambient relative humidity or in the physical stress imposed upon the material do not diminish life at these voltage stresses.

Surface arc resistance of TFE and FEP resins is high and is not affected by heat aging. When these resins are subjected to a surface arc in air, they do not track or form a carbonized conducting path. When tested by the procedure of ASTM D495, they pass the maximum time of 300 seconds without failure.

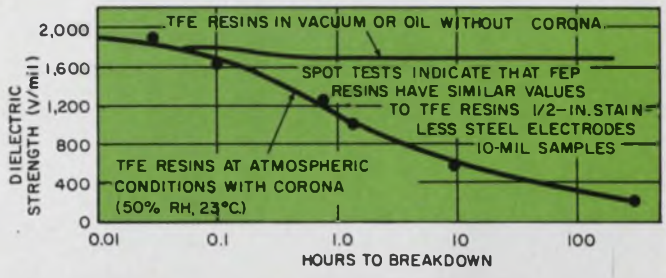
Volume resistivity greater than 10^{18} ohm-cm and surface resistivity greater than 10^{16} ohm-sq for both FEP and TFE resins are at the top of the measurable range. Neither resistivity is affected by heat aging or temperatures up to the recommended service limits.

TFE fluorocarbon is the most commonly used fluorocarbon in electronic packaging. It is a semisoft plastic that exhibits some cold flow properties, as well as considerable thermal expansion. This expansion is linear with increasing temperature (Fig. 23).

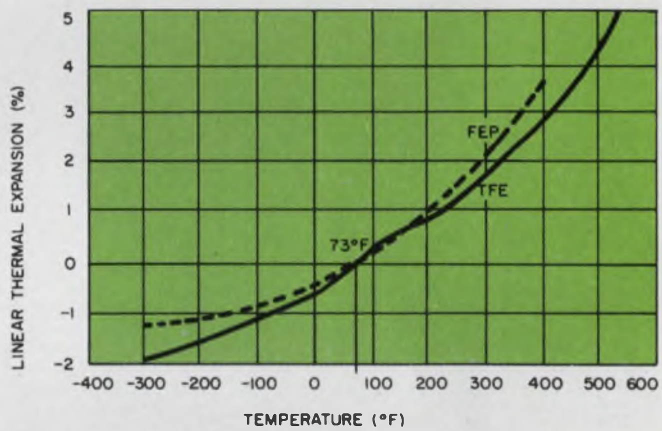
One of the most recent, and expanding, uses of fluorocarbons in current electronic design is the use of FEP fluorocarbon as flexible circuits or wiring, as shown in Fig. 24. The electrical properties, resistance to extreme electronic sys-



21. **Short-time dielectric strength** of TFE fluorocarbon vs thickness of test sample.



22. **Insulation life vs continuously applied voltage stress** for TFE and FEP fluorocarbons.



23. **Linear thermal expansion** of TFE and FEP fluorocarbons as a function of temperature.

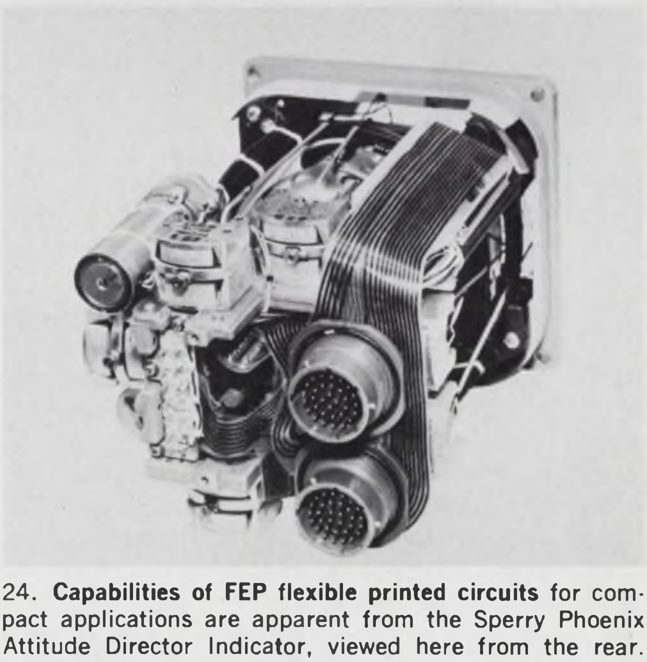

24. **Capabilities of FEP flexible printed circuits** for compact applications are apparent from the Sperry Phoenix Attitude Director Indicator, viewed here from the rear. (photo courtesy DuPont Corp.)

Table 10. Physical and mechanical properties of thermoplastics

Material	Coefficient of thermal expansion, (in./in.) (°C x 10^{-5})	Thermal conductivity, (cal/(cm²) (s) (°C) (cm) x 10^{-4}	Water absorption 24 hr, %	Flammability (in./min) 0.125 in.	Specific gravity	Price range per lb	Heat resistance, continuous, °F
Acetal	0.25	1.6	0.25	1.1	1.410–1.425	$0.65	185
ABS	3–10.5	4–9	0.2–0.5	1.0–2	1.01–1.07	$0.33–0.43	160–235
Acrylic	–	1.4	0.3	9–1.2	1.18–1.19	$0.455–0.75	130–195
Acrylic, high impact	6.5–10.5	4.0	0.2–0.3	1.1–1.2	1.11–1.18	$0.525–0.70	140–195
Cellulose acetate	8–18	4–8	1.7–4.4	0–2	1.22–1.34	$0.40	140–175
Cellulose acetate butyrate	11–17	4–8	0.9–2.2	0.5–1.5	1.15–1.22	$0.62	140–175
Cellulose propionate	11–16	4–8	1.2–2.8	0.5–1.5	1.16–1.23	$0.62	140–175
Chlorinated polyether	8	3.13	0.01	Self-extinguishing	1.4	$2.50	250–275
Ethyl vinyl acetate	10–20	8	<0.01	Slow burning	0.93–0.95	$0.2775–0.3575	120–170
Chlorotrifluoroethylene	5–7	4–6	Nil	Nil	2.09–2.14	$4.70	390
Fluorinated ethylene propylene	8.3–10.5	5.9	<0.05	Nonflammable	2.16	$5.60–9.60	400
Polytetrafluoroethylene	5.5 (25–60°C)	6	0.01	Nonflammable	2.13–2.18	$3.25	500
Nylon 6	4.6–5.8	5.9	1.5	Self-extinguishing	1.13–1.14	$0.86–1.19	250
Nylon 6/6	8.1	5.8	1.3	Self-extinguishing	1.13–1.15	$0.84–0.875	250
Nylon 6/10	10	5.5	–	Self-extinguishing	1.07–1.09	$1.26	220
Polyallomer	8–11	2–4	0.4	Slow burning	0.90–0.906	$0.28	250
Polycarbonate	6.7–7	4.6	0.15	Self-extinguishing	1.2	$0.90–3.05	250
Polyethylene, low-density	10–20	8	<0.05	Slow burning	0.910–0.925	$0.1525–0.29	140–175
Polyethylene, medium-density	10–20	8	<0.05	Slow burning	0.926–0.940	$0.17–0.235	150–180
Polyethylene, high-density	10–20	1.9–3.3	<0.01	Slow burning	0.941–0.965	$0.18–0.32	180–225
Polyethylene, high molecular weight	13	8	<0.01	Slow burning	0.93–0.94	$0.26–0.50	180–225
Polyimide	–	–	0.32	–	1.43	–	500–600
Polypropylene	3.8–9	2.8–4	<0.01	Slow burning to nonburning	0.90–1.24	$0.19–0.55	250
Polystyrene	6–8	8	0.03–0.05	0.5–2.5	1.05–1.06	$0.145–0.245	150–190
Polystyrene, high-impact	6.5–8.5	1–3	0.05–0.10	0.5–2.5	1.04–1.06	$0.16–0.27	130–180
Polyurethane	10–20	7.4	0.60–0.80	Slow to self-extinguishing	1.11–1.26	$1.19–1.60	190
Polyvinyl chloride (flexible)	7–25	3–4	0.15–0.75	Self-extinguishing	1.15–1.80	$0.16–0.455	150–175
Polyvinyl chloride (rigid)	5–10	3–5	0.07–0.40	Self-extinguishing	1.33–1.58	$0.21–0.42	160–165
Polyvinyl dichloride (rigid)	7–8	3–4	0.07–0.11	Self-extinguishing	1.50–1.54	$0.50–0.53	195–210
Styrene acrylonitrile (SAN)	7	3	0.23–0.28	0.4–0.7	1.07–1.08	$0.26–0.30	170–210
Ionomer	12–13	5.8	0.1–1.4	0.9–1.1	0.94–0.96	$0.47–0.49	140
Phenoxy	3.2–3.8	–	0.13	Slow burning, self-extinguishing	1.17–1.34	$0.75–1.00	–
Polyphenylene oxide	5.2	–	0.06	Self-extinguishing	1.06	$1.15	250
Polysulfone	3.1–10^{-5} in./in. °F	1.8 Btu/(hr) (ft) (°F) (in.)	0.22	Self-extinguishing	1.24–1.25	$1.00–1.25	300

tem environments (especially humidity), and formability by melt bonding techniques make FEP ideal for this application.

Nylon is a good general-purpose insulation

Nylon is widely used for general-purpose electrical and electronic applications, since it is very easily processed and has excellent all-around electrical and physical properties. It is not, however, outstanding in any of the extreme environments required for many advanced electronic systems, nor is it recommended for high-frequency, low-loss applications (Fig. 20).

Since all nylons absorb moisture, this characteristic must be considered when using or designing with them. They will absorb anywhere from 0.5% to nearly 2% moisture after 24 hours of water immersion.

Nylon, like all thermoplastic materials, exhibits some creep when subjected to stress. The extent depends on stress level, temperature and time. A part that is subjected to long-time stress must be designed accordingly, so that deformation with time is not excessive for the application and so that fracture will not occur. For nylon, most cold flow takes place during the first 24 hours. This is a useful checkpoint for testing parts under load.

Nylon parts having exceptional wear characteristics and dimensional stability can be made by a special compression and sintering process. In addition, various fillers such as molybdenum disulfide and graphite can be incorporated into nylon to give special low-friction properties. Nylon can also be reinforced with glass fibers to give it considerably added strength. One application of glass-reinforced nylon is shown in Fig. 25.

Parylenes can be deposited as insulating films

Parylene is the generic name for members of a thermoplastic polymer series developed by Union Carbide. These polymers are unique in that they are polymerized in the vapor phase, and deposited as films on some substrate material. They can also be deposited onto a cold condenser, then stripped off as free film; or they can be deposited onto the surface of objects as a continuous, adherent coating in thicknesses ranging from 0.2 micron (about 0.008 mil) to 3 mils or more. Deposition rate is normally about 0.5 micron per

Table 11. Electrical properties of thermoplastics

Material	Volume resistivity, ohm-cm	Dielectric constant, 60 Hz	Dielectric strength, (st),* 1/8-in. thickness, volts/mil	Dissipation or power factor, 60 Hz	Arc resistance, s
Acetal	$1-10^{14}$	3.7–3.8	500	0.004–.005	129
ABS	$10^{15}-10^{17}$	2.6–3.5	300–450	0.003–.007	45–90
Acrylic	$>10^{14}$	3.3–3.9	400	0.04–.05	No tracking
Acrylic high impact	$10^{16}-10^{17}$	3.5–3.7	450–480	0.04–.05	No tracking
Cellulose acetate	$10^{10}-10^{12}$	3.2–7.5	290–600	0.01–.10	50–130
Cellulose acetate butyrate	$10^{10}-10^{12}$	3.2–6.4	250–400	0.01–.04	–
Cellulose propionate	$10^{12}-10^{16}$	3.3–4.2	300–450	0.01–.05	170–190
Chlorinated polyether	1.5×10^{16}	3	400	0.01	–
Ethyl vinyl acetate	1.5×10^{8}	3.16	525	0.003	–
Chlorotrifluoroethylene	10^{18}	2.65	450	0.015	>360
Fluorinated ethylene propylene	$>10^{18}$	2.1	500	0.0002	>165
Polytetrafluoroethylene	$>10^{18}$	2.1	400	<0.0001	No tracking
Nylon 6	$10^{14}-10^{15}$	6.1	300–400	0.4–0.6	140
Nylon 6/6	$10^{14}-10^{15}$	3.6–4.0	300–400	0.014	140
Nylon 6/10	$10^{14}-10^{15}$	4.0–7.6	300–400	0.04–0.05	140
Polyallomer	$>10^{16}$	2.3	500–1000	0.0001–0.0005	–
Polycarbonate	6.1×10^{15}	2.97	410	0.0001–0.0005	10–120
Polyethylene, low-density	$10^{15}-10^{18}$	2.28	450–1000	0.006	Melts
Polyethylene, medium density	$10^{15}-10^{18}$	2.3	450–1000	0.0001–0.0005	Melts
Polyethylene, high-density	$6 \times 10^{15}-10^{18}$	2.3	450–1000	0.002–0.0003	Melts
Polyethylene, high molecular weight	$>10^{16}$	2.3–2.6	500–710	0.0003	Melts
Polyimide	$10^{16}-10^{17}$	3.5	400	0.002–0.003	230
Polypropylene	$10^{15}-10^{17}$	2.1–2.7	450–650	0.005–0.0007	36–136
Polystyrene	$10^{17}-10^{21}$	2.5–2.65	500–700	0.0001–0.0005	60–100
Polystyrene, high-impact	$10^{13}-10^{17}$	2.5–3.5	500	0.003–0.005	60–90
Polyurethane	2×10^{11}	6–8	850–1100	0.276	–
Polyvinyl chloride (flexible)	$10^{11}-10^{15}$	5–9	300–1000	0.08–0.15	–
Polyvinyl chloride (rigid)	$10^{12}-10^{16}$	3.4	425–1040	0.01–0.02	–
Polyvinyl dichloride (rigid)	10^{15}	3.08	1200–1550	0.018–0.0208	–
Styrene acrylonitrile (SAN)	10^{15}	2.8–3	400–500	0.006–0.008	100–150
Ionomer	$>10^{16}$	2.4–2.5	1000	0.001	–
Phenoxy	$2.75-5 \times 10^{-5}$	4.1	404–520	0.0012–0.0009	70
Polyphenylene oxide	10^{17}	2.58	400–500	0.00035	75
Polysulfone	5×10^{16}	2.82	425	0.008–0.0056	122

*Short-time.

minute (about 0.02 mil). On cooled substrates, the deposition rate can be as high as 1.0 mil per minute.

Parylenes are good dielectric materials, with the basic member of the series, Parylene N, having a dielectric constant of 2.65 and a dissipation factor that increases from 0.0002 to 0.0006 over the range of 60 Hz to 1 MHz. Another parylene, namely Parylene C, has a dielectric constant of 2.9-3.1 and a dissipation factor of 0.012-0.020 over the same frequency range.

Parylenes can be used both at elevated and cryogenic temperatures, although long-term (10-year) service in air is limited to about 140 to 175°F, depending on the type of polymer involved. Barrier properties to most gases is reported superior to many other films.

Polyethylenes, polypropylenes and polyallomers

Polyethylenes are among the best known plastics and come in three main classifications, based on density: low, medium, and high. These density ranges are 0.910 to 0.925, 0.925 to 0.940, and 0.940 to 0.965, respectively.

Polypropylene is chemically similar to poly-

25. **The rotor in this high-temperature rotary selector switch** is made from glass-reinforced nylon. Dimensional stability and high-temperature resistance are the key factors in this application. (photo courtesy CTS Corp.)

26. **Irradiated, cross-linked polyolefins** find use as heat-shrinkable cable boots. After being set in place, the oversized boot is heated, shrinking tightly around the cable. (photo courtesy Rayclad Tubes, Inc.)

ethylene, but has somewhat better physical strength at lower density—namely, 0.900 to 0.915.

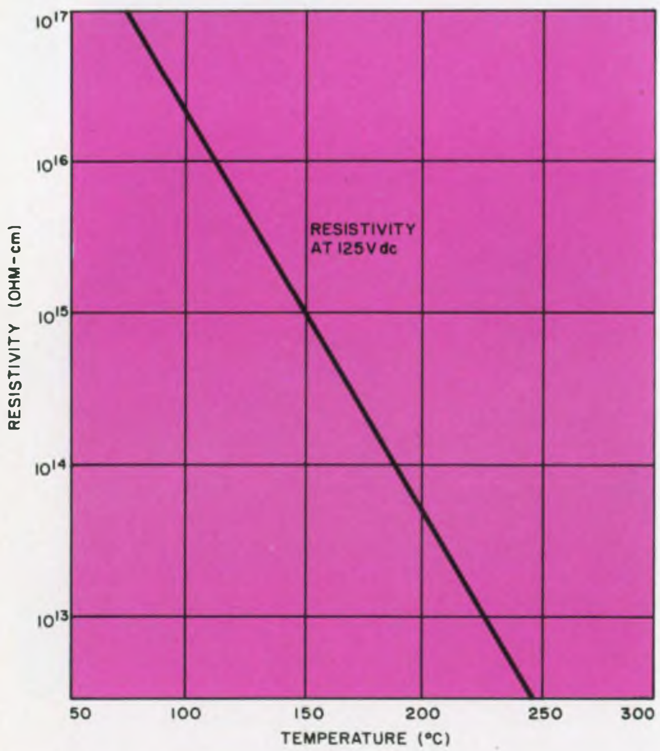
Polyallomers are crystalline thermoplastic polymers produced from two or more different base materials, such as propylene and ethylene. They offer selective mechanical advantages, such as rigidity, impact strength, and resistance to abrasion and fluxural fatigue. Selective processing advantages also exist in flow characteristics, softening point, stress-rack resistance and mold shrinkage.

The electrical properties of polyethylenes and polypropylenes are similar and equally excellent over the operating temperature range of the materials. The dielectric constants and dissipation factors of both remain very low over a wide range of frequencies. This is shown in Fig. 20 for polyethylene.

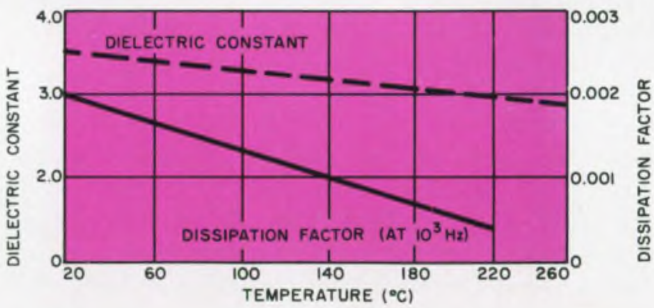
All polyethylenes are relatively soft, although hardness increases with density. In general, also, the higher the density the better are the dimensional stability and physical properties, particularly as a function of temperature. Thermal stability of polyethylenes ranges from 190°F for low-density material up to 250°F for the high-density material. Thermal stability of polypropylene ranges from 250°F to over 300°F.

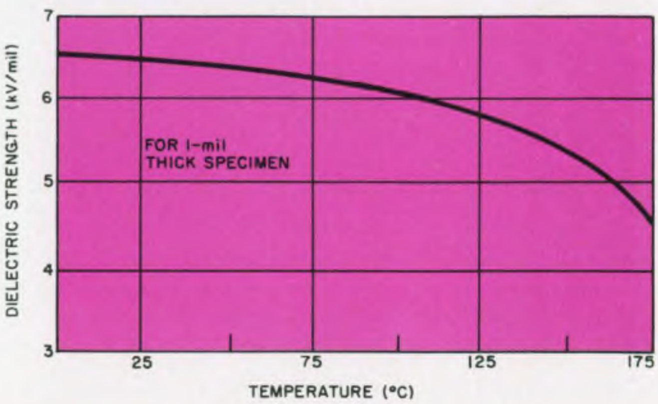
Cross-linked polyolefins are heat-shrinkable

While polyolefins, such as polyethylenes, etc., have many outstanding characteristics, they tend



27. **Important electrical properties** of polyimides as a function of temperature.





to creep or cold flow under the influence of temperature, load and time, as do all thermoplastics to some extent. To improve this and other properties, considerable work has ben done on developing cross-linked polyolefins—especially polyethylenes. The cross-linked polyethylenes offer improvements in thermal performance of up to 25°C or more. Cross linking has been achieved primarily by chemical means and by ionizing radiation, and products of both types are available.

Radiation cross-linked polyolefins have gained particular prominence in a heat-shrinkable form. This form is achieved by cross linking the extruded or molded polyolefin, using high-energy electron-beam radiation, heating the irradiated material above its crystalline melting point to a rubbery state, mechanically stretching it to an expanded form (up to four or five times the original size), and cooling the stretched material. Upon further heating, the material will return to its original size, tightly shrinking onto the object around which it has been placed. Heat-shrinkable boots, jackets, tubing, etc. of this type are widely used (Fig. 26).

Irradiated polyolefins also find considerable use in wire and cable jacketing applications especially where minimum wire weight is a primary requirement.

Polyamide-imides and polyimides are comers

These two groups of plastics have some outstanding properties for electronic applications and are therefore gaining rapidly in importance. Generally, polyamide-imides and polyimides are characterized by high temperature stability, good electrical and mechanical properties (which are generally stable to higher temperatures than those for most plastics) and dimensional stability in most environments.

While their electrical properties are not as good as those of TFE fluorocarbons, polyamide-imides and polyimides are nevertheless good electrical performers, and are better than TFE fluorocarbons in mechanical and dimensional stability properties. This provides advantages in many high-temperature electronic applications. Polyamide-imides and polyimides are also useful at very low (negative) temperatures.

The electrical properties of polyimides as a function of temperature are shown in Fig. 27.

A potentially weak point of polyamide-imides and polyimides is moisture absorption in high humidities, with its attendant effects on physical and electrical properties. This characteristic varies with the material and its condition, and it should be investigated for any given application.

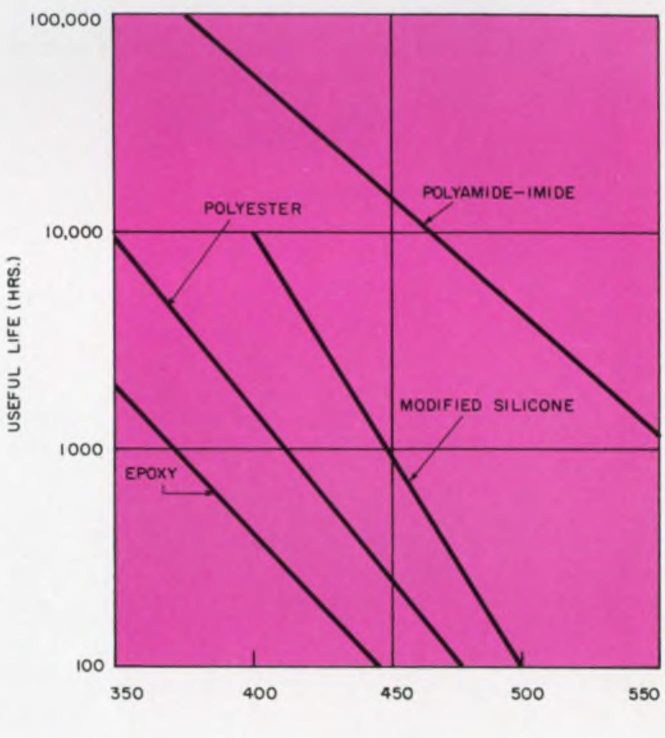
The thermal stability of these polymers is outstanding, as shown by the data for insulating coatings on magnet wire given in Fig. 28. Some amide-imides are chemically etchable, especially in caustic solutions, and this provides some unique electronic design opportunities.

Molded polyimides have good wear and low friction properties, which can be improved even more by addition of fillers, such as graphite or molybdenum disulfide. The use of such fillers, however, slightly degrades other physical properties.

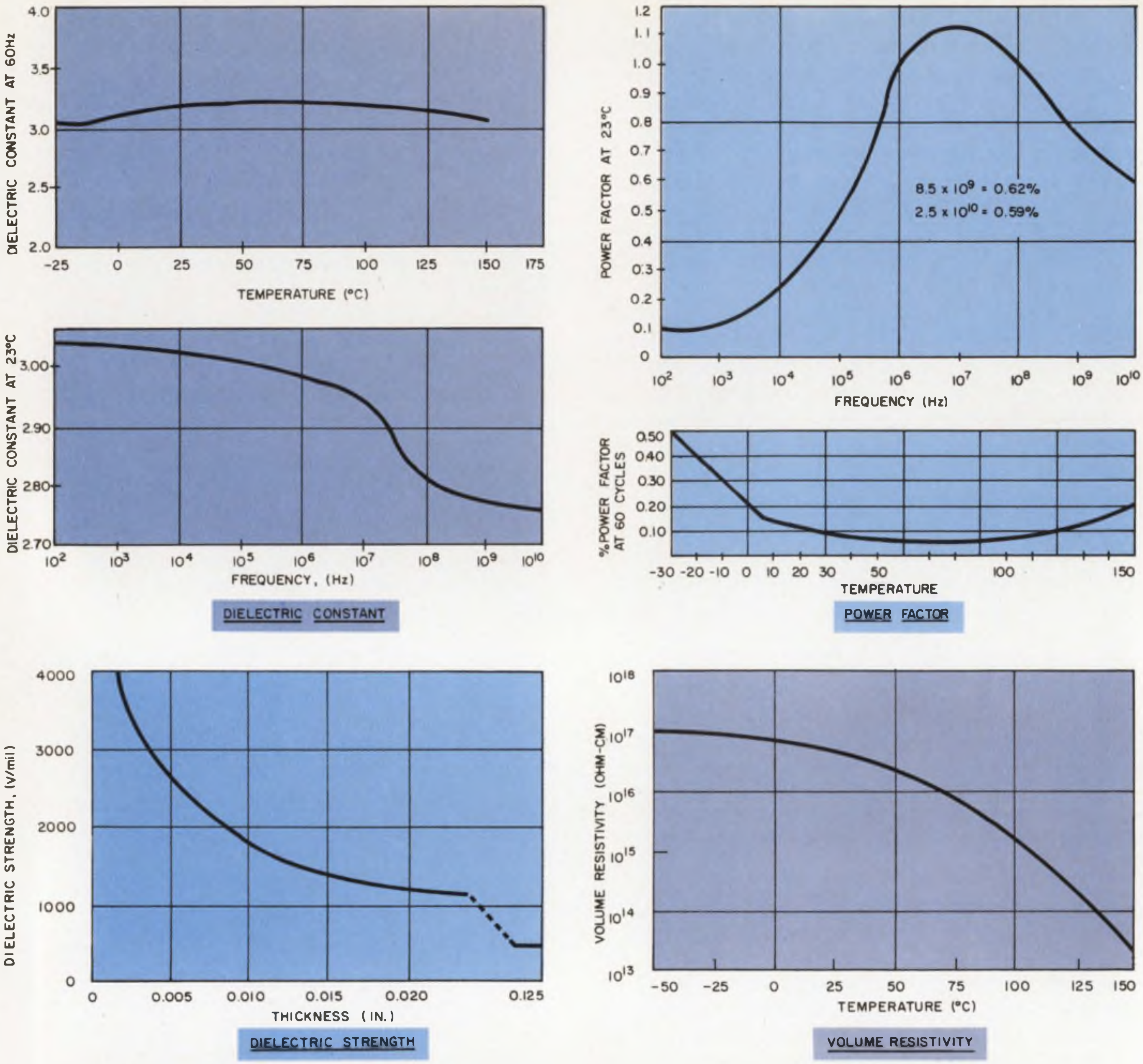
Polycarbonates combine useful properties

Polycarbonates have an excellent combination of properties for use in electronic applications. Their basic electrical properties are very good (Fig. 29) and remain reasonably stable up to about 150°C, as well as in high humidity environments. The dielectric constant value changes little up to nearly 10^8 cycles, whereas the power factor or loss factor does increase somewhat in this frequency range.

Mechanically, polycarbonates excel in impact strength, heat resistance under load, dimensional stability, creep resistance, outdoor weatherability and low-temperature strength. The Izod notched-impact strength is approximately four times better than that of nylons or acetals. The useful upper temperature limit of polycarbonates, from the standpoint of their mechanical properties, is 250°F or higher, slightly exceeding that of acetals and exceeding that of nylons by a larger margin.



28. **Thermal life of amide-imide wire enamels** compared to other electrical insulation coatings.



29. **Important electrical properties** of polycarbonates.

30. **Glass-reinforced polycarbonate** is used in the body housing and shaft hubs of this H. H. Controls Co. optical shaft encoder. Dimensional stability over the operating temperature range and light weight were two major factors in this application. (photo courtesy Fiberfil, Inc.)

Polycarbonates are also available in glass-reinforced compositions (Fig. 30).

Polyphenylene oxides are relatively new

The polyphenylene oxides represent another relatively new and important class of plastics that are very useful for electronic applications. They are products of General Electric Co. and are known as PPO and Noryl. Polyphenylene oxides have good all-around mechanical and electrical properties, with some of the PPO materials being especially good in their combination of mechanical properties and high-frequency electrical properties. For electronic application purposes, polyphenylene oxides would compete with acetals, polycarbonates, polysulfones and nylons (polyamides) .

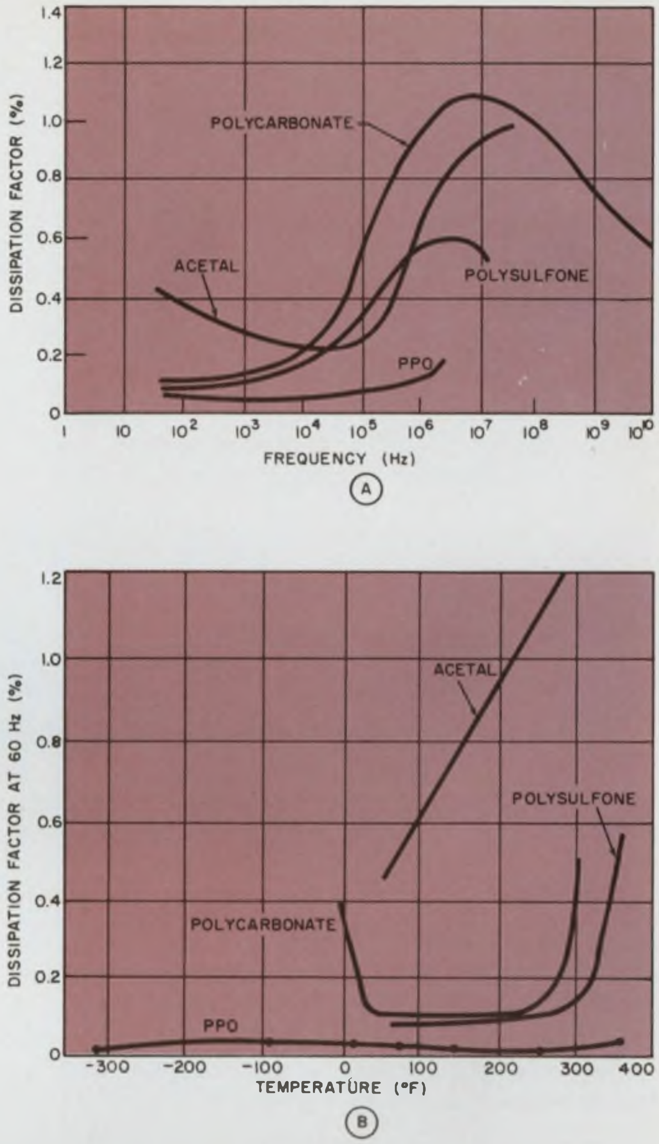
The electrical properties of polyphenylene oxides remain relatively constant with frequency and temperature over the material's rated temperature range. The electrical properties are also relatively unaffected by humidity. The effects of frequency and temperature on dissipation factor for polyphenylene oxide and other materials are shown in Fig. 31.

The heat deflection temperature of the polyphenylene oxides ranks high among the more rigid thermoplastics. Polyphenylene oxides also rate well in tensile strength vs temperature, tensile modulus and tensile creep. Water absorption is relatively low, as is the attendant change in dimensions and weight associated with water absorption. Impact strength, however, is not as good as that of polycarbonates at elevated temperatures.

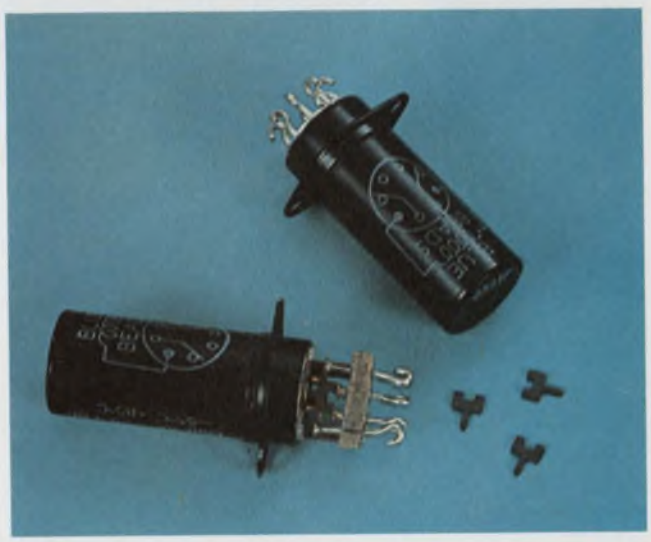
Polystyrenes used widely at high frequencies

Polystyrenes are an important class of thermoplastic materials for the electronics industry because of their very low electrical losses. They have excellent dielectric strength and resistivity properties, as well as an exceptionally low dissipation factor and dielectric constant. Their mechanical properties are adequate, although they are somewhat temperature-limited, having normal temperature capabilities below 200°F. Polystyrenes can be cross-linked to produce higher temperature materials, as noted in Table 9, but these are somewhat brittle.

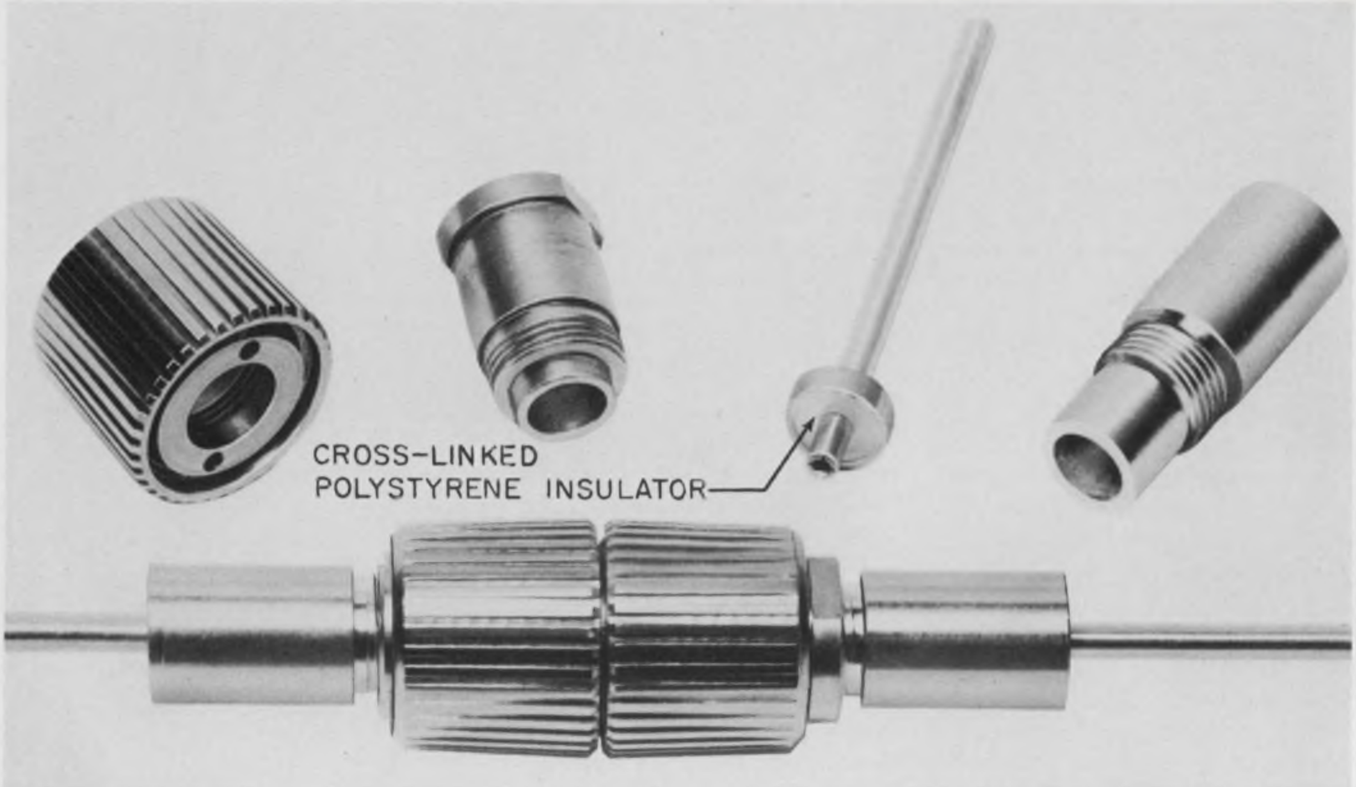
The low dissipation factor and dielectric constant of polystyrene as a function of frequency are shown in Fig. 20. (When referring to the illustration, it should be noted that the dielectric constant of some polystyrenes increases rapidly above 10^9 - 10^{10} Hz). This low dissipation factor, coupled with the relative rigidity of polystyrene compared to polyethylene and TFE, gives polystyrene advantages in many electronic applica-



31. **Effect of frequency** on dissipation factor (A), and of temperature on 60-Hz dissipation factor (B) of several engineering thermoplastics.



Polyimide resin has replaced a filled phenolic composition in the actuator portion of this Allied Control Co. relay. (photo courtesy E. I. Du Pont de Nemours)



32. **Low-loss insulator** made of cross-linked polystyrene, indicated by arrow, is used in this Amphenol microwave connector. (photo courtesy Brand-Rex Division, American Enka Corp.)

tions that require material hardness and extremely low electrical losses, particularly at high frequencies. The cross-linked polystyrenes are especially serviceable here. These materials are widely used in microwave applications, such as the connector shown in Fig. 32.

Polysulfones maintain properties after heat aging

Polysulfones are relatively new and very useful thermoplastics for electronic design applications. They have excellent strength vs temperature properties, good electrical properties (though not outstanding for high frequency) and outstanding strength retention over long periods of aging up to 300°F or over. The electrical properties of polysulfones are maintained to approximately 90% of their initial values after exposure at 300°F one year or more. The properties are generally stable up to about 350°F, and under exposure to water or high humidity.

The dissipation factor vs frequency as well as temperature for polysulfones is shown in Fig. 31. The dielectric constant of the material is approximately 3.1 up to 10^6 Hz, and decreases slightly at 10^7 Hz.

The heat-deflection temperature of polysulfones rates high among engineering thermoplastics, as does the flexural modulus vs temperature. The tensile-strength properties of polysulfones are generally similar to those of polycarbonates and polyphenylene oxides, as are the dimensional changes due to absorbed moisture. The retention of strength properties after prolonged heat aging is perhaps the most outstanding feature of polysulfones.

Vinyls are useful—but not outstanding

Vinyls are good general-purpose electrical insulating materials, although not outstanding from an electronic applications viewpoint. Perhaps their biggest use in electronics is as insulation for hookup wire and as sleeving.

There are many grades and types of vinyls, but the special electrical grades are the ones that should be considered for electronic applications. In addition to the various basic classifications, vinyls may be rigid, flexible or foamed. Further, they may be filled in many ways, alloyed with other plastics, or plasticized with various plasticizers.

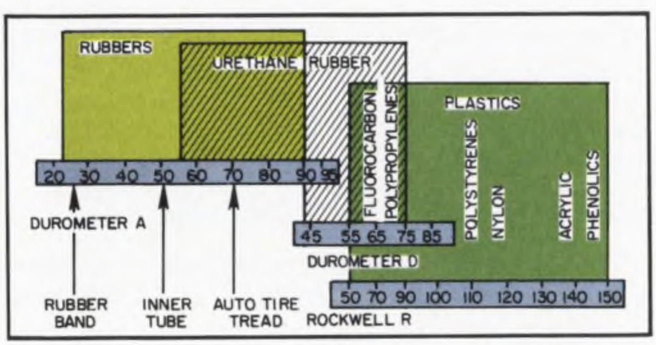
Some vinyls have unusual resistance to corrosive chemicals, such as plating baths, etc. One convenient-to-use form of vinyl is the polyvinylchloride dispersion which is available in liquid form and solidifies upon application of heat. Hence, these dispersions can be used for casting, potting and dip-coating applications—somewhat like RTV silicones except that they have considerably different properties. Properties favor silicones, and costs favor the vinyl dispersions.

Elastomers

At one time, when natural rubber and a few synthetic rubbers constituted the primary types of rubberlike materials in use, the term "rubber" was used predominantly to describe this group of materials. However, thanks to developments in the field of polymer chemistry, numerous rubberlike materials have been developed whose chemical composition bears no resemblance to the chemical composition of either natural rubber or the early synthetic rubbers. These newer materials often exhibit vast improvements over the early rubbers in many respects, while still being basically rubberlike or elastic in character. The term "elastomer" has, therefore, come to be used to encompass the broadened range of such materials.

The ASTM definition of an elastomer is "A material which at room temperature can be stretched repeatedly to at least twice its original length and upon immediate release of the stress will return with force to its approximate original length."

There are currently over a dozen recognized classes of elastomers, a number of which are useful in electronic assemblies. These are often used for cushioning materials, for vibration damping, and for gasketing and sealing, as well as for applications where rubberlike properties coupled with some selected combination of mechanical, electrical or fluid-resistant properties are required.



33. **Hardness comparison** for various elastomers and plastics.

Elastomers are sometimes known by their popular name, sometimes by their chemical name and sometimes by the ASTM designation or some other previously used symbol. Table 12 is a cross reference of these various identifications. Further, there are ASTM-SAE application classifications for various elastomers. These are:

- Type R—non-oil-resistant
- Type S—resistant to petroleum chemicals
  - Class SA—very low-volume swell
  - Class SB—low-volume swell
  - Class SC—medium-volume swell
- Type T—temperature-resistant
  - Class TA—high and low temperature-resistant
  - Class TB—hot air and oil-resistant

The properties of elastomers may be defined and specified in a manner similar to that commonly used for plastics. In addition, though, there are some other properties of particular value in identifying these materials. One of these is hardness, and in fact, is often the primary description used in identifying the characteristics of an elastomer.

The hardness of an elastomer is related to its degree of vulcanization, or cure, and to the presence or absence of filler materials. The softer the rubber, the lower the hardness as normally measured by means of a durometer test. A comparative hardness guide is shown in Fig. 33.

Compression set is another property often specified for elastomeric materials. According to ASTM test D-395, compression set is the residual decrease in the thickness of a test specimen observed after 30 minutes of rest following the removal of a specified compressive loading applied under established conditions of time and temperature.

Elongation and tensile strength are also often used to describe elastomers. Elongation is the amount the material is stretched at the moment of rupture. The amount of force necessary to rupture the material is the tensile strength, which is normally expressed in terms of the original cross section of the specimen tested.

Table 12. Nomenclature and major property considerations for elastomers

ASTM D 1418 designation	Tradename or common name	Chemical description	General properties
NR	Natural rubber	Natural polyisoprene	Excellent physical properties; good resistance to cutting, gouging and abrasion; low heat, ozone, and oil resistance. Electrical grades have excellent electrical properties at room temperature.
IR	Synthetic natural	Synthetic polyisoprene	Same general properties as natural rubber; requires less mastication in processing than natural rubber.
CR	Neoprene	Chloroprene (polychloroprene)	Excellent ozone, heat, and weathering resistance; good oil resistance; excellent flame resistance. Not as good electrically as NR or IR. However, the combination of generally good electrical and environmental properties make CR very suitable for electrical wire and cable jackets.
SBR	GRS, Buna S	Styrene-butadiene	Good physical properties; excellent abrasion resistance; not oil, ozone, or weather resistant. Electrical properties generally good but not outstanding in any area.
NBR	Buna N, Nitrile	Acrylonitrile-butadiene	Excellent resistance to vegetable, animal, and petroleum oils; poor low-temperature resistance; electrical properties not outstanding.
IIR	Butyl, chlorobutyl	Isobutylene-isoprene, Chloro-isobutylene-isoprene	Excellent weathering resistance; low permeability to gases; good resistance to ozone and aging; low tensile strength and resilience. Electrical properties generally good but not outstanding.
BR	Cis-4	Polybutadiene	Excellent abrasion resistance and high resilience; used principally as a blend in other rubbers.
–	Thiokol (PS) (Thiokol chemical)	Polysulfide	Outstanding solvent resistance; widely used for potting of electrical connectors.
R	EPR, EPT	Ethylene propylene, Ethylene propylene terpolymer	Good aging, abrasion, and heat resistance; not oil resistant. Good general electrical properties.
CSM	Hypalon (HYP) (Du Pont)	Chlorosulfonated polyethylene	Excellent ozone, weathering, and acid resistance; fair oil resistance; poor low-temperature resistance; not outstanding electrically.
SIL	Silicone	Polysiloxane	Excellent high- and low-temperature resistance; low strength; high compression set. Excellent electrical properties; especially good stability of dielectric constant and dissipation factor at elevated temperatures.
–	Urethane (PU)	Polyurethane di-isocyanate	Exceptional abrasion, cut and tear resistance; high modulus and hardness; poor moist-heat resistance. Generally good electrical properties. Special high-quality electrical grades are available.
–	Viton (FLU)	Fluorinated hydrocarbon	Excellent high-temperature resistance, particularly in air and oil. Not outstanding electrically.
ABR	Acrylics	Polyacrylate	Excellent heat, oil, and ozone resistance; poor water resistance. Not outstanding for or widely used in electrical applications.

Two other important design characteristics of elastomers are low-temperature stiffening and high-temperature service limits. Data for these limits are given in Table 13 and Fig. 34, respectively.

As with plastic materials, a broad range of properties can often be obtained with any given type of elastomer by compounding or modifying the basic material. Some representative electrical data ranges for the various elastomer classes can nevertheless be shown, as in Table 14.

Chlorosulfonated polyethylene has special uses

This unique elastomer has outstanding resistance to oxidizing chemicals, heat, abrasion, sunlight and weathering. It is almost completely inert to ozone, and it is one of the few elastomers that can be compounded in any color or shade. The electrical properties of chlorosulfonated polyethylene are generally good but not outstanding. The combination of excellent physical properties and good insulating properties make the material a promising candidate for special insulation applications.

Ethylene-propylenes are on the upsurge

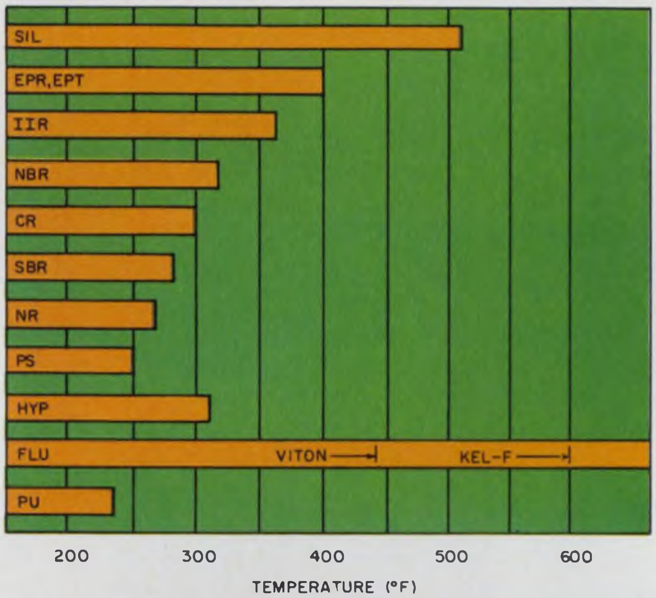
EP elastomers, whose usage is on the increase, are general-purpose synthetic rubbers having broad end-use potentials similar to those of natural rubber and SBR. The EP elastomers are highly resistant to attack by ozone, have excellent heat resistance, low-temperature flexibility (down to —70°C) and electrical properties—particularly as used in high-voltage cabling and insulation. Applications of EP elastomers include insulation for wire and cable.

Fluorocarbons rate only fair electrically

These specialty elastomers are relatively high-cost materials that have excellent resistance to chemicals and temperature extremes. Their mechanical properties are comparable to those of other synthetic rubber materials. Significant

Table 13. Stiffening temperature and brittle points for elastomers

Elastomer	Stiffening temp. (°F)	Brittle point (°F)
Natural rubber	−20 to −50	−70
SBR	−10 to −50	−80
Butyl	0 to −40	−75
Polysulfide	−10 to −40	−65
Buna N	+15 to −35	−70
Neoprene	0 to −30	−60
Chlorosulfonated polyethylene (Hypalon)	−30 to −50	−60
EPR and EPT	−20 to −50	−80
Polybutadiene (Cis 4)	−35 to −60	−90
Silicone	−50 to −90	−100
Fluorocarbon	+15 to −25	−55
Polyurethane	− 5 to −25	−60



34. **High-temperature service limits for elastomers.** See Table 12 for the trade names or common names of these elastomers.

properties of fluorocarbons are good physical performance at 200°C and higher; resistance to most oils, chemicals, solvents and exotic fuels at 200°C and above; good mechanical properties; excellent resistance to ozone, oxygen and weathering; and fair electrical characteristics.

Nitriles are highly oil-resistant

The nitriles, which are among the most widely used elastomers, are known for their good oil resistance, and particularly for retention of tensile strength and abrasion resistance after immersion in oils. They have a lower and more temperature-sensitive resiliency than natural rubbers. Many different blends of the two basic chemical ingredients (acrylonitrile and butadiene) are available, and the proportion of each affects the properties of the end product.

The higher the acrylonitrile content of the rubber, the higher its tensile strength and its resistance to solvent attack and thermal degradation, and the lower its compression set. The higher the butadiene content, the greater the resilience and low-temperature flexibility of the end product. Most commercial nitrile rubbers contain 20 to 40% acrylonitrile. The presence of acrylonitrile introduces a molecular polarity that degrades electrical properties, compared to SBR and butyl rubber.

Polyacrylates have good physical properties

Acrylic elastomers, or polyacrylate rubbers, are primarily noted for resistance to high temperatures, oxidation, sunlight and ozone. They are particularly resistant to sulfur-bearing oils, even at temperatures of 175°C and higher. These elastomers do not have outstanding electrical properties, but they are used as wire insulation where environmental resistance properties are also important.

Polychloroprenes are most resilient

Polychloroprenes, or neoprenes, are the most resistant of all synthetic rubbers, and among the best known. They are flame-resistant and relatively inert chemically, as well as generally superior to natural rubber in resistance to oxidation, sunlight, and to solvent attack by mineral and vegetable oils. Polychloroprenes are generally inferior to natural rubber in tensile and tear strength and in electrical properties. Principal electrical uses of polychloroprenes are wire insulation and cable jackets.

Polysulfides broadly used for connector potting

Polysulfide rubbers have good electrical properties at room temperature, excellent resistance to ozone, oil, and solvents, and good resistance to gas permeation. Compared with most elastomers, they have relatively low mechanical strength and high cold flow. Optimum operating temperature of polysulfides is below 100°C, but they can be used as high as 125°C if lesser physical and electrical properties are acceptable. The electrical properties of polysulfides can be improved by the addition of epoxy resins. This, however, increases hardness.

Polysulfide rubbers are available as solid materials, which are processed similarly to natural rubber, as softened crude rubber stock, and as liquids. They are broadly used for low-voltage potting or sealing of connectors.

Polyurethanes have unexcelled abrasion resistance

Polyurethane, or urethane, elastomers have excellent mechanical strength and are unexcelled among elastomers in abrasion resistance. They have high tensile and tear strength and good re-

Table 14. Typical electrical properties of elastomers

Material	Dielectric constant 10^6 Hz	Power factor x 10^2, 10^6 Hz	Volume resistivity, ohm-cm	Surface resistivity, ohms	Dielectric strength, volts/mil
Natural rubber	2.7–5	0.05–0.2	10^{15}–10^{17}	10^{14}–10^{15}	450–600
Styrene-butadiene rubber	2.8–4.2	0.5–3.5	10^{14}–10^{16}	10^{13}–10^{14}	450–600
Acrylonitrile-butadiene rubber	3.9–10.0	3–5	10^{12}–10^{15}	10^{12}–10^{15}	400–500
Butyl rubber	2.1–4.0	0.3–8.0	10^{14}–10^{16}	10^{13}–10^{14}	400–800
Polychloroprene	7.5–14.0	1.0–6.0	10^{11}–10^{12}	10^{11}–10^{12}	100–500
Polysulfide polymer(1)	7.0–9.5	0.1–0.5	10^{11}–10^{12}	–	250–325
Silicone	2.8–7.0	0.10–1.0	10^{13}–10^{17}	10^{13}	300–700
Chlorosulfonated polyethylene(2)	5.0–11.0	2.0–9.0	10^{13}–10^{17}	10^{14}	400–600
Polyvinylidene fluoride-co-hexafluororpropylene(3)	10.0–18.0	3.0–4.0	10^{13}	–	250–700
Polyurethane(4)	5.0–8.0	3.0–6.0	10^{10}–10^{11}	–	450–500
Ethylene propylene terpolymer(5)	3.2–3.4	0.6–0.8	10^{15}–10^{17}	–	700–900

(1) Thiokol, Thiokol Corp. (2) Hypalon, DuPont, Inc. (3) Viton A, DuPont, Inc. (4) Adiprene, DuPont, Inc. (5) Nordel, DuPont, Inc.

sistance to ozone. Their resistance to solvent attack by oils is between that of neoprene and nitrile rubbers.

The electrical properties of polyurethanes are good but not exceptional. Like polysulfides, they can be blended with epoxies to improve electrical properties.

Silicones are attractive for many uses

Silicone rubbers are among the best known and most widely used elastomeric materials in the electronics industry. They have excellent electrical properties (Fig. 35), including low electrical losses and good resistance to corona discharge. They also have excellent stability of electrical and elastomeric properties over the temperature range of −60 to above +260°C.

The main advantage of silicone rubber in electrical applications is that it retains its good electrical properties, such as dielectric strength, power factor and insulation resistance at elevated temperatures where other insulation degrades.

Silicone rubber's fatigue life under continuous stress is high. Organic polymers comparable to silicone rubber in initial dielectric strength exhibit a far more rapid decrease in this characteristic when subjected to voltage for a prolonged period of time.

Properly compounded and cured silicone rubber has excellent resistance to moisture absorption. As a consequence, excellent electrical characteristics are maintained under humid service conditions. Also, surface breakdown and arc resistance are high. ■■

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Don't experiment with ferrite beads - -

design with them. Get more predictable high-frequency performance by learning how these inductors work.

Ferrite bead inductors, as many designers know, provide a convenient means for adding high-frequency insertion loss to a circuit. They are small, introduce no dc losses and are installed simply by slipping them onto component leads.

But their use originated by trial and error, and it is still largely that, since there are no handbooks to explain just how the beads work. Can the circuit performance be predicted with some degree of reliability? Yes, if designers understand the equivalent circuit analysis of ferrite beads.

R and L are frequency dependent

Ferrite beads can provide up to 10 dB of insertion loss over the frequency range of 1 MHz to 1 GHz. When inserted on a line, a bead has an equivalent circuit of a resistance in series with an inductance (Fig. 1). The values of both R and L depend heavily on the line frequency and current. The line current is the lesser of these two considerations, since it must be kept below about 5 A to avoid saturation of the bead.

To calculate R and L, refer to Fig. 2. (All symbols are defined in the box.) The total flux, ϕ, within the ferrite core on a wire results from integration over the core volume, or

$$\phi = \int_0^s \int_{r_1}^{r_2} B ds dr = (\mu_r \mu_o I s / 2\pi) \ln (r_2 / r_1).$$

For the bare wire in air without the bead ($\mu_r = 1$ for air),

$\phi_o = (\mu_o I s 2\pi) \ln (r_2 / r_1)$,

So the change in flux due to placement of the ferrite bead on the wire is:

$\Delta\phi = \phi - \phi_o = (\mu_o I s / 2\pi)(\mu_r - 1) \ln (r_2 / r_1)$.

The corresponding inductances (for $n = 1$) of the ferrite plus wire (L), the bare wire (L_o) and the ferrite alone (ΔL) are:

$L = \phi / I = (\mu_r \mu_o s / 2\pi) \ln (r_2 / r_1)$,

$L_o = \phi_o / I = (\mu_o s / 2\pi) \ln (r_2 / r_1)$, and

$\Delta L = L - L_o = (\mu_r - 1) L_o$.

Robert B. Cowdell, Manager, Systems Engineering, Genisco Technology Corp., Compton, Calif.

The change in impedance due to insertion of the ferrite core is

$\Delta Z = j\omega \Delta L = j(\mu_r - 1) L_o$.

Because of losses in the magnetic material, the effective relative permeability, μ_r, must be expressed in complex form (this is explained in detail later):

$\mu_r = \mu' - j\mu''$

So a complex ferrite impedance results; namely

$\Delta Z = j\omega(\mu' - j\mu'' - 1) L_o$

$= j\omega L_o(\mu' - 1) + \omega\mu'' L_o$

$= j\Delta X + \Delta R$

where

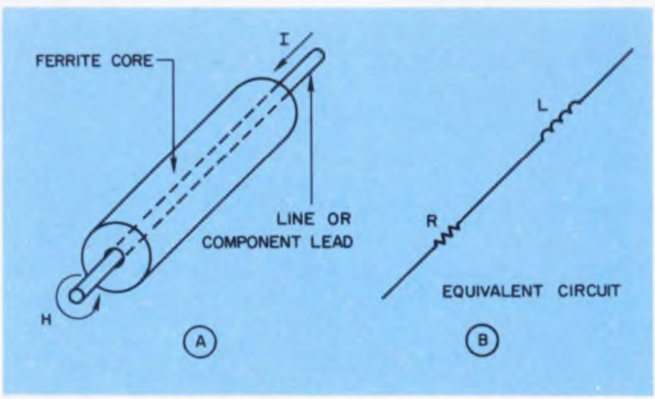
$\Delta R = \mu'' \omega L_o =$ effective resistance

$\Delta X = (\mu' - 1)\omega L_o =$ effective reactance.

The equivalent resistance and inductance of a ferrite bead can be measured by winding a single coil turn around the bead. The lumped impedances are then determined with either a Maxwell-Schering bridge or a mutual inductance bridge to yield the impedance of the bead plus the line, or

$Z = R + jX$.

As long as only a single ferrite bead is involved (rigorously speaking, as long as the line length through a bead or an array of beads does not become a significant portion of a quarter wavelength), line impedance (Z_o) can be ne-



1. **Ferrite bead inductors** (A) have the simple equivalent circuit shown in (B).

glected. The measurement therefore effectively determines the contributions to resistance and reactance due to the ferrite bead.

Complex permeability is convenient

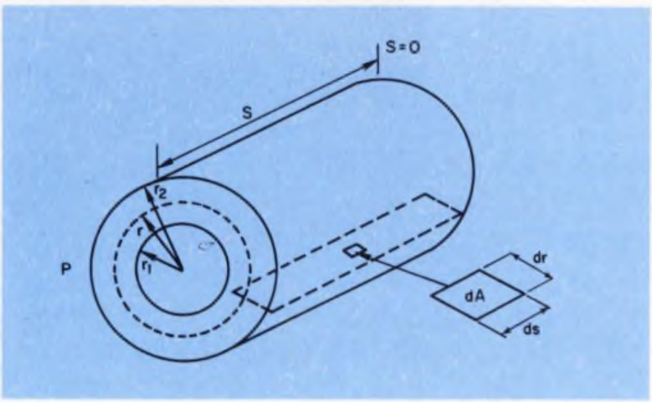
When voltage is applied to a single-turn coil around a ferrite bead, a phase difference exists between the applied ac field and the resulting magnetization within the core. This suggests treating the core permeability as a complex vector quantity (as previously mentioned). The real part gives rise to inductance, while the imaginary part is associated with a residual core loss (the damping effect within the core causes energy dissipation). Measured data (Fig. 3) shows the variation in ΔR and ΔX with frequency for an actual ferrite bead. The real and imaginary parts, μ' and $-j\mu''$, respectively, of the permeability, μ_r, then follow from:

$\mu'' = \Delta R/\omega L_o$

$\mu' = \Delta X/(\omega L_o - 1)$

where L_o is accessible from calculation or measurement.

A sample permeability calculation for the bead inductors depicted in Fig. 3 follows. For the example, $\mu_o = 4 \times 10^{-7}$ H/m, bead length is 0.118 in. $(0.118 \times 2.54/100)$m, and from Fig. 1,



2. **Total flux within a ferrite bead** is found by integration over the bead volume.

Symbol definitions

H = magnetic field intensity at core radius r for $n = 1$ turn
= $1/2\,\pi r$

B = magnetic flux density at point with radius r
= $\mu H \mu_r \mu_o H$, where
μ_o = absolute permeability in air
μ_r = relative permeability

ϕ = BA=total flux at radius r, with A=core cross section

$d\phi$ = $Bdsdr$ = flux through differential area element dA

L = inductance

Z = impedance

R = resistance

X = reactance

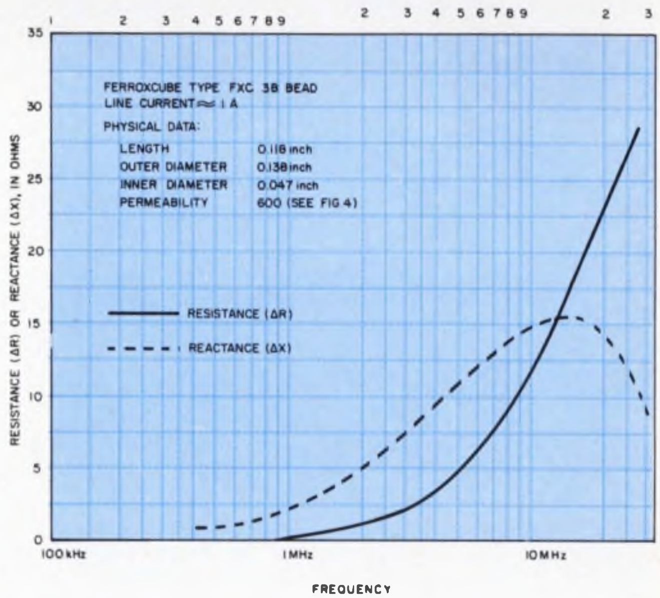
ω = frequency

I = ac line current

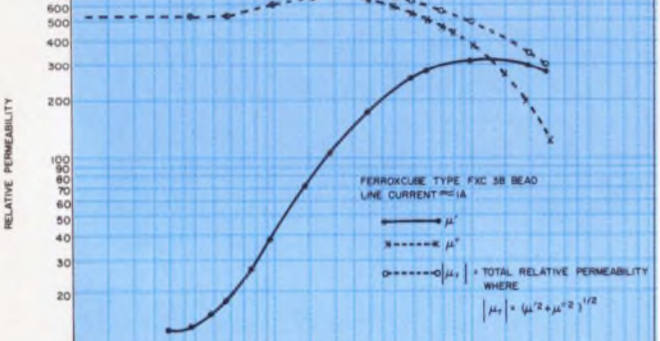
$j^2 = -1$

$(\ )_o$ = refers to quantities without the ferrite core.

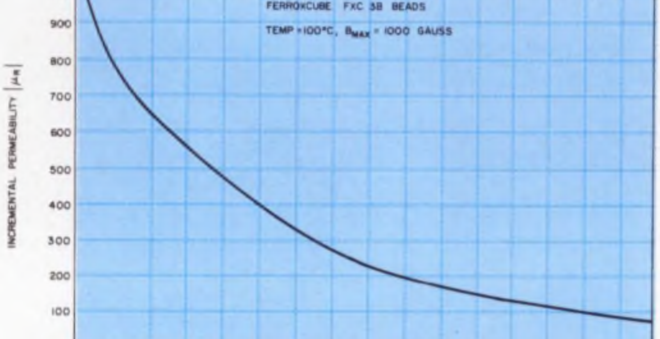
Δy = refers to a differential change of a quantity, y, due to the ferrite core.



3. **Resistance and reactance measurements vs frequency** for a ferrite bead can be plotted in graph form and then used to determine bead permeability.



4. **Total bead permeability,** μ_r, consists of a real component, μ', and an imaginary component, $-j\mu''$.



5. **Line current, I, has a significant effect** on the permeability of a ferrite bead.

$\ln(r_2/r_1) = 1.04$. Hence,

$L_o = (\mu_o s/2\pi)\ \ln\ (r_2/r_1) = 600\mu\text{H}$

and from Fig. 3, at 5 MHz,

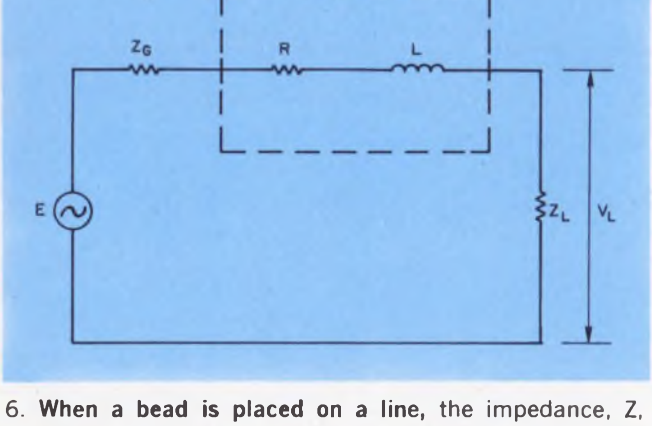
$\Delta R = 4.8\ \Omega$ and $\Delta X = 11\ \Omega$.

Substituting, therefore,

$\mu'' = \Delta R/2\pi f\ L_o = 256$

$\mu' = \Delta X/2\pi f\ L_o = 583.$

The variation of complex permeability with frequency, as computed in this manner, is shown in Fig. 4. Note that this data assumes a specific value of line current. The permeability, as a function of frequency, changes drastically as line current increases, as shown in Fig. 5.



6. **When a bead is placed on a line,** the impedance, Z, of the bead and line adds to the existing circuit impedances, Z_G, and Z_L.

Note from Fig. 5 that for a single-turn coil, the magnetic field intensity is given by $H = I/P$, where $P = \pi(r_1 - r_2)$ is the average length around the periphery of the ferrite bead. With $r_1 = 0.47$ in. and $r_2 = 0.138$ in., $P = 1.47$ cm. For the beads depicted in Fig. 4, the curves show that the permeability should not be less than 530 in the effective operating range for best performance. Figure 5 therefore demonstrates that H cannot be larger than about 713 mA/cm. The allowable line current, I_{max}, thus turns out to be:

$I_{max} = H_{max}\ P = (713)\ (1.47) = 1050$ mA.

This means that the permeability values of Fig. 4 are true as long as the line current does not exceed 1 A. For larger line currents, permeability decreases rapidly. Consider, for example, $I = 3$ A; then $H = I/P = 2045$ mA/cm, and Fig. 5 shows a drop in permeability from 530 (for 1 A current) to 175.

Insertion loss can be calculated

The insertion loss ratio (ILR) of a circuit containing ferrite beads is the ratio of load voltage with (v_o) and without (v_L) the inserted circuit (Fig. 6):

$$ILR = (E/v_o)/(E/v_1) = v_o/v_1$$
$$= (Z_G + Z_L)/(Z_G + Z_L + Z)$$

And if load and source impedances are matched, say, at 50 Ω, then $Z_G = Z_L = 50$.

Therefore,

$ILR = 100/(Z+100)$

Every ferrite bead strung on a wire introduces a series impedance $\Delta Z = \Delta R - j\Delta X$. If n beads are used, and if the highest frequency is low enough to keep the electrical line length below a significant fraction of a quarter wavelength, then the total series impedance of the n beads is $n\Delta Z = n(\Delta R - j\Delta X)$.

As an example, consider 30 Ferroxcube FXC 3B beads. Total length is 30 (0.118 in.) (0.254 m/in.) = 0.241 m. With 10 MHz as the highest frequency under consideration, the corresponding wavelength is 3 m, and line length represents (0.241/3) = 0.08 wavelength, which is much less than a quarter wavelength. For 10 MHz, Fig. 3 shows measured values of $\Delta R = 12.2$ Ω and $\Delta X = 15$ Ω; hence, $\Delta Z = 30\ (12.2 - j15) = 366 + j450$ Ω. With these numbers, we can now determine

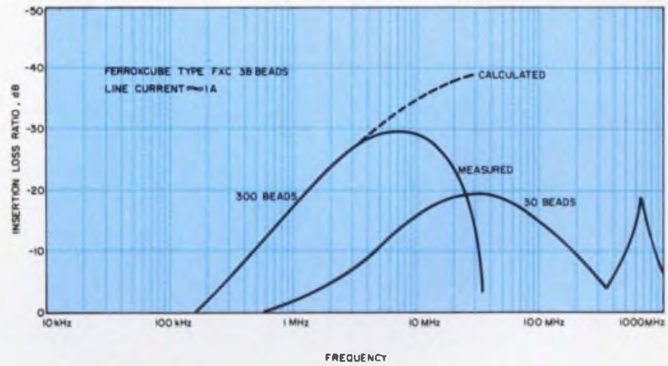
$$IRL(\text{dB}) = 20 \log_{10} \left| \frac{100}{Z + 100} \right| = -16.3 \text{ dB}$$

This yields one point on a curve of ILR vs frequency, which is plotted on Fig. 7. The slope of the measured ILR curve in Fig. 7 has abrupt changes at 350 and 650 MHz. At 350 MHz, line length has become slightly larger than a quarter wavelength; while at 650 MHz, line length is a half-wavelength.

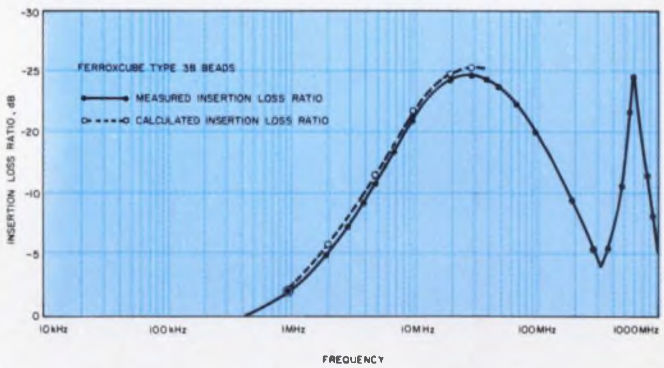
How many beads?

The use of ferrite beads for increased insertion loss has obvious limitations, as a quick estimate will readily show. Suppose the number is increased from 30 (in the previous example) to 300. The insertion loss at 10 MHz then increases from —16.3 dB to —35.4 dB. However, the frequency of minimum attenuation has now decreased by a factor of 10, from 350 MHz to 35 MHz. The comparison is shown in Fig. 8.

As a practical rule, ferrite strings should be kept short, and should be limited approximately to the 1 to 100 MHz frequency range. Long bead lengths cause severe insertion-loss degradation. ■■



7. **Insertion-loss ratio of 30 beads** strung on a line is very frequency-dependent.



8. **Increasing the number of beads on a line** shifts the insertion-loss vs frequency curve lower in frequency.

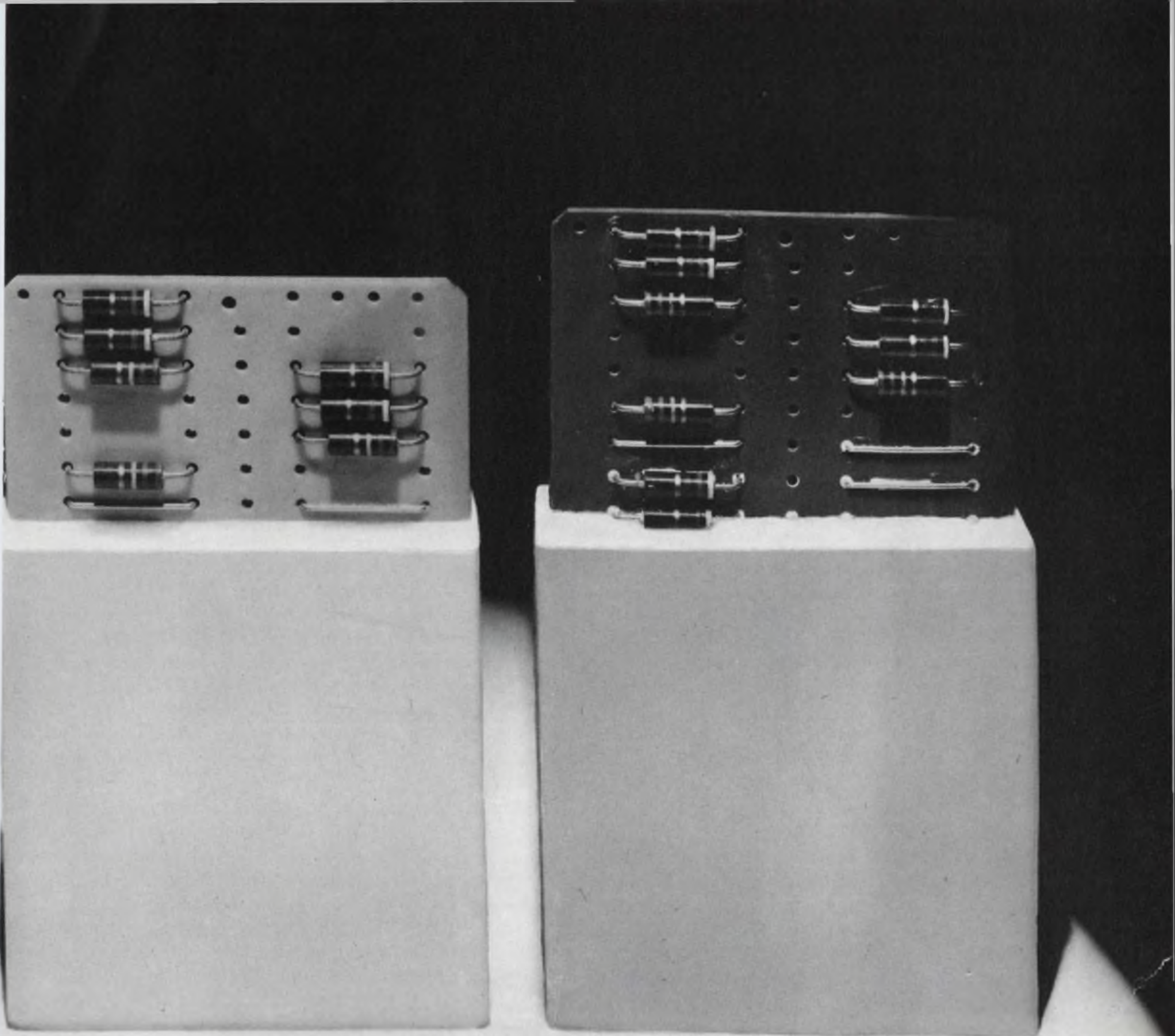
Test your retention

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 ferrite bead inductors used for?

2. What are the effects of line frequency and current on the characteristics of ferrite beads?

3. Why is there a practical limit to the number of ferrite beads that can be added to a line?



Go graphic with capacitive input filters.

Computer-generated curves allow you to optimize your designs in terms of both cost and performance.

The simple, capacitive input filter is widely used in dc power supplies. It is relatively inexpensive and lightweight, and has a minimum number of components (Fig. 1). Unfortunately, in the design of such a filter, the exact solution of output voltage as a function of load resistance and filter capacitance is quite complex, owing to the nonlinear characteristics of the power supply rectifiers.

This problem can be overcome, and capacitive input filters designed quickly and easily, by using the graphical solutions presented in Graphs 1 and 2. The data was synthesized on a computer for the case of a full-wave power supply having a driving-source frequency of 60 Hz and a driving-source output resistance of 1 ohm (Fig. 2). The data can also be used for power supplies having other frequencies and output resistances.

In Graph 1, the solution for minimum and maximum output voltage, in per cent of peak applied voltage, is plotted as a function of equivalent load resistance, (R_{eq}), and of equivalent filter capacitance, (C_{eq}). The minimum voltages are shown by solid lines, and the maximum voltages by dashed lines. For any particular solution, the difference between the minimum and maximum voltages is the ripple voltage.

To use Graph 1 for frequencies other than 60 Hz and driving-source resistances other than 1 ohm, corresponding values of R_{eq} and C_{eq} are found, as follows:

$$R_{eq} = R_{load}/R_1 \qquad (1)$$

$$C_{eq} = (R_1\,C_{filter})\,(f/60), \qquad (2)$$

where R_1 is the driving-source resistance, and f is the frequency.

In Graph 2, the solution for peak capacitor charge current, in terms of an equivalent charge resistance (R_{chg}), is plotted as a function of equivalent load resistance and equivalent filter capacitance. To determine the peak charge current, R_{chg} is found from Graph 2, and then inserted into the equation

$$I_{peak} = (V_{peak}/R_{chg})\,(1/R_1) \qquad (3)$$

where V_{peak} is the peak input voltage to the power supply.

The solutions presented in Graphs 1 and 2 are *exact* solutions (within the accuracy of the graphs) for a capacitive input power supply, and assume ideal diodes. Since a real diode develops a finite voltage drop, the voltage drop across the diodes (rectifiers) should be subtracted from the peak applied voltage before using the graphs. Similarly, since the diodes are in series with the driving source, the forward resistance of the diodes should be added to the output resistance of the driving source (transformer, etc.) before using the graphs.

It should be noted here that the graphs not only enable the designer to quickly and accurately determine the required component values for a given power supply; they also allow him to optimize the design of the supply in terms of cost and performance. As an example, it is evident from Graph 1 that adding additional capacitance to a filter capacitor will decrease the output ripple voltage; when, however, the filter capacitance exceeds the value of capacitance at the knee of the curves, an additional increase in capacitance will not cause an equivalent decrease in ripple voltage. The designer therefore can quickly evaluate the performance of a power supply in terms of filter capacitance and of its cost.

Examples demonstrate use of graphs

The use of Graphs 1 and 2 are clearly demonstrated by the following two examples:

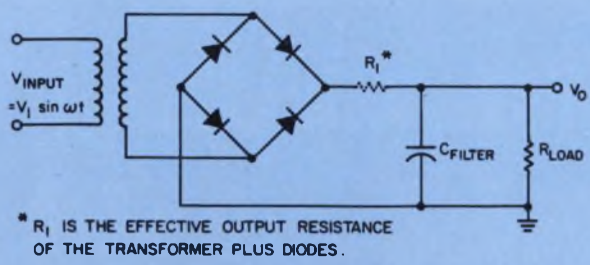
Example 1

What is the minimum output voltage, ripple voltage, and peak charging current for a capacitive input power supply (Fig. 1) having the following characteristics:

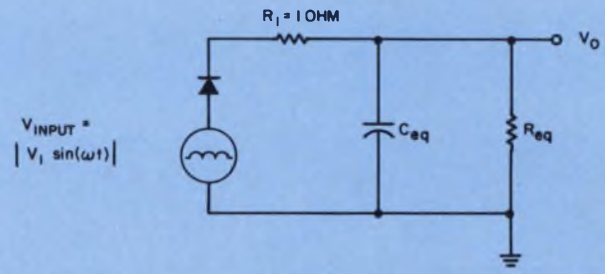
V_{input} = 35 V rms
$f_{applied}$ = 60 Hz
R_o (transformer) = 0.30 Ω
R_o (diode) = 0.05 Ω
R_{load} = 10 Ω
C_{filter} = 5000 μF

The solution is obtained as follows:

J. P. Stringham Jr., System Design, Ball Brothers Research Corp., Boulder, Colo.



1. **Basic capacitive input filter is conceptually very simple.** But the nonlinearity of the power supply rectifiers makes the exact solution of output voltage as a function of load resistance and filter capacitance quite complex.



2. **Equivalent circuit of capacitive input power supply** is based on a driving source output resistance of 1 ohm and a frequency of 60 Hz. Solutions can be obtained for other values also, as explained in the text.

a. Determine the driving source output resistance, R_1, from the output resistances of the transformer and diodes. Then normalize the load resistance and filter capacitance, using Eqs. 1 and 2.

$$R_1 = R_o\,(\text{transformer}) + 2 \times R_o\,(\text{diode})$$
$$= 0.30 + 2 \times 0.05 = 0.40 \text{ ohm}$$
$$R_{eq} = R_{load}/R_1 = 10/0.40 = 25 \text{ ohms}$$
$$C_{eq} = R_1 C_{filter}\,(f/60) = 0.40 \times 5000\ \mu F \times (60/60) = 2000\ \mu F$$

b. Using the values obtained for R_{eq} and C_{eq}, read V_{max} (%) and V_{min} (%) from Graph 1. Then, compute the peak source voltage, and the minimum and maximum output voltages.

$V_{max}\,(\%) \cong 89.5\%$ (Graph 1, dashed lines)
$V_{min}\,(\%) \cong 80\%$ (Graph 1, solid line)

$$V_{peak} = (1.414 \times V_{input} - 1.5^*)$$
$$= (1.414 \times 35 - 1.5) = 48 \text{ volts}$$
$$V_{max} = V_{max}\,(\%) \times V_{peak} = 0.895 \times 48$$
$$= 43 \text{ volts}$$
$$V_{min} = V_{min}\,(\%) \times V_{peak} = 0.800 \times 48$$
$$= 38.4 \text{ volts.}$$

*(Approximate voltage drop across the diodes.)

c. Determine the ripple voltage directly from V_{max} and V_{min}.

$$V_{ripple} = V_{max} - V_{min} = 43 - 38.4 = 4.6 \text{ volts}$$

d. Calculate the peak capacitor charge current through the diodes from Eq. 3, after obtaining the equivalent charge resistance from Graph 2.

$$R_{chg} \cong 7 \text{ ohms}$$
$$I_{peak} = (V_{peak}/R_{chg})\,(1/R_1) = (48/7)\,(1/0.4)$$
$$= 17.15 \text{ A}$$

Example 2

What is the minimum filter capacitance for a capacitive input power supply (Fig. 1) having the following requirements:

The minimum input voltage into a following transistorized regulator must be greater than 24 V. The input resistance of the regulator is 8 ohms. In addition, the power supply characteristics are:

$V_{applied} = 35$ V rms
$f_{applied} = 400$ Hz
R_o (transformer) $= 0.4\ \Omega$
R_o (diode) $= 0.05\ \Omega$

The solution is obtained as follows:

a. Determine the driving source output resistance, R_1, from the output resistances of the transformer and diodes; then, normalize the load resistance using Eq. 1.

$$R_1 = R_o\,(\text{transformer}) + 2 \times R_o\,(\text{diodes})$$
$$= 0.40 + 2 \times 0.05 = 0.5 \text{ ohm}$$
$$R_{eq} = R_{load}/R_1 = 8/0.5 = 16 \text{ ohms}$$

b. Calculate the peak source voltage. Then calculate the required minimum voltage, in per cent, of peak source voltage.

$$V_{peak} = (1.414\,V - 1.5^*) = (1.414 \times 35 - 1.5)$$
$$= 48 \text{ volts}$$
$$V_{min}\,(\%) = (V_{min} \times 100\%/V_{peak}) = 2400\%/48$$
$$= 50\%$$

*(Approximate voltage drop across the diodes.)

c. Using the values for V_{min}(%) and R_{eq} obtained previously, read C_{eq} from Graph 1.

$C_{eq} \cong 480\mu F$ (Graph 1, solid lines)

d. Using Eq. 2, calculate the minimum required filter capacitance for V_{min} equal to 24 V.

$$C_{filter} = (C_{eq}/R_1)\,(60/f) = (480/0.5)\,(60/400)$$
$$= 144\ \mu F$$

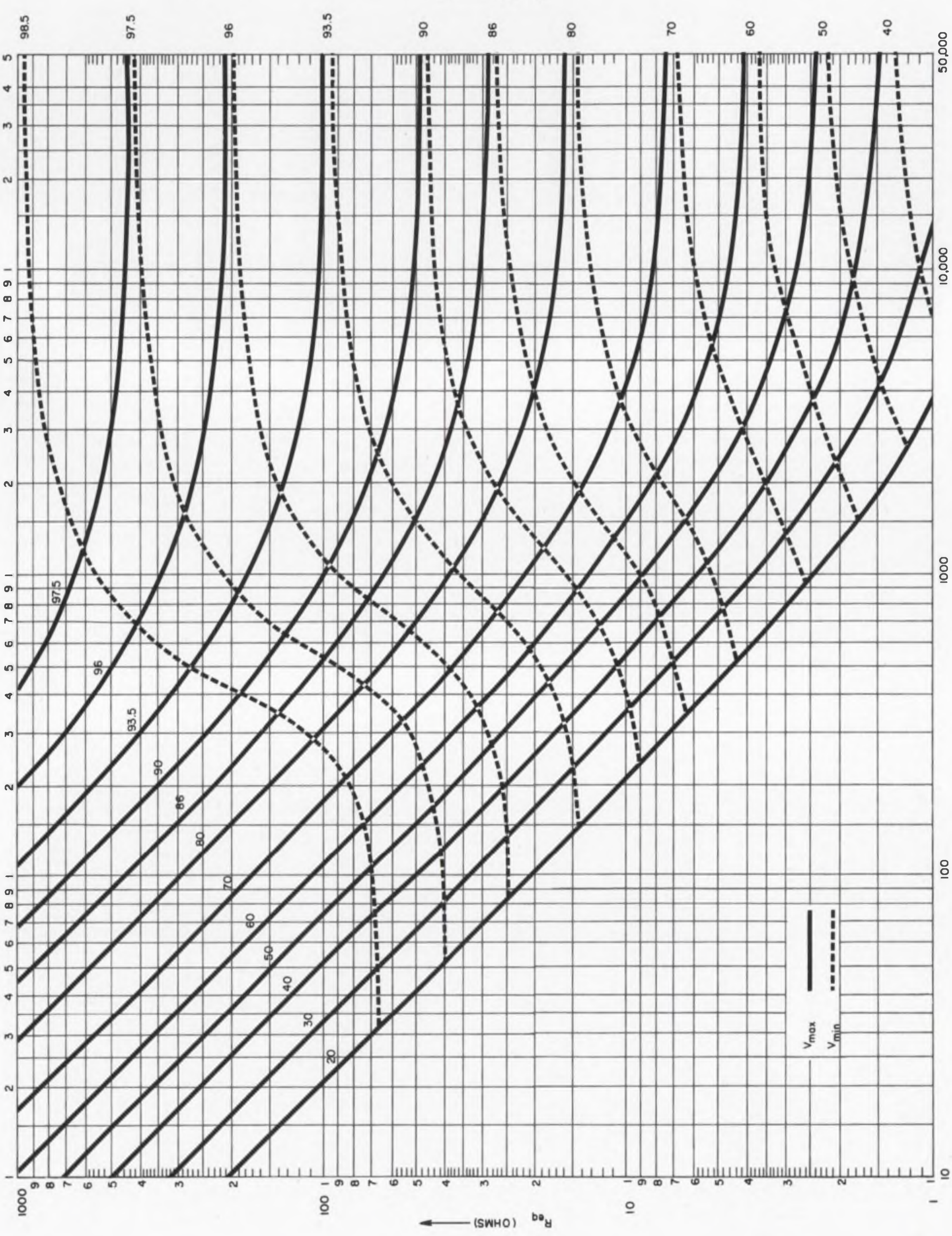
e. Calculate the peak charge current through the diodes from Eq. 3, after obtaining the equivalent charge resistance, R_{chg}, from Graph 2.

$$R_{chg} \cong 6.8 \text{ ohms}$$
$$I_{peak} = (V_{peak}/R_{chg})\,(1/R_1) = (48/6.8)\,(1/0.5)$$
$$= 14.1 \text{ A}$$

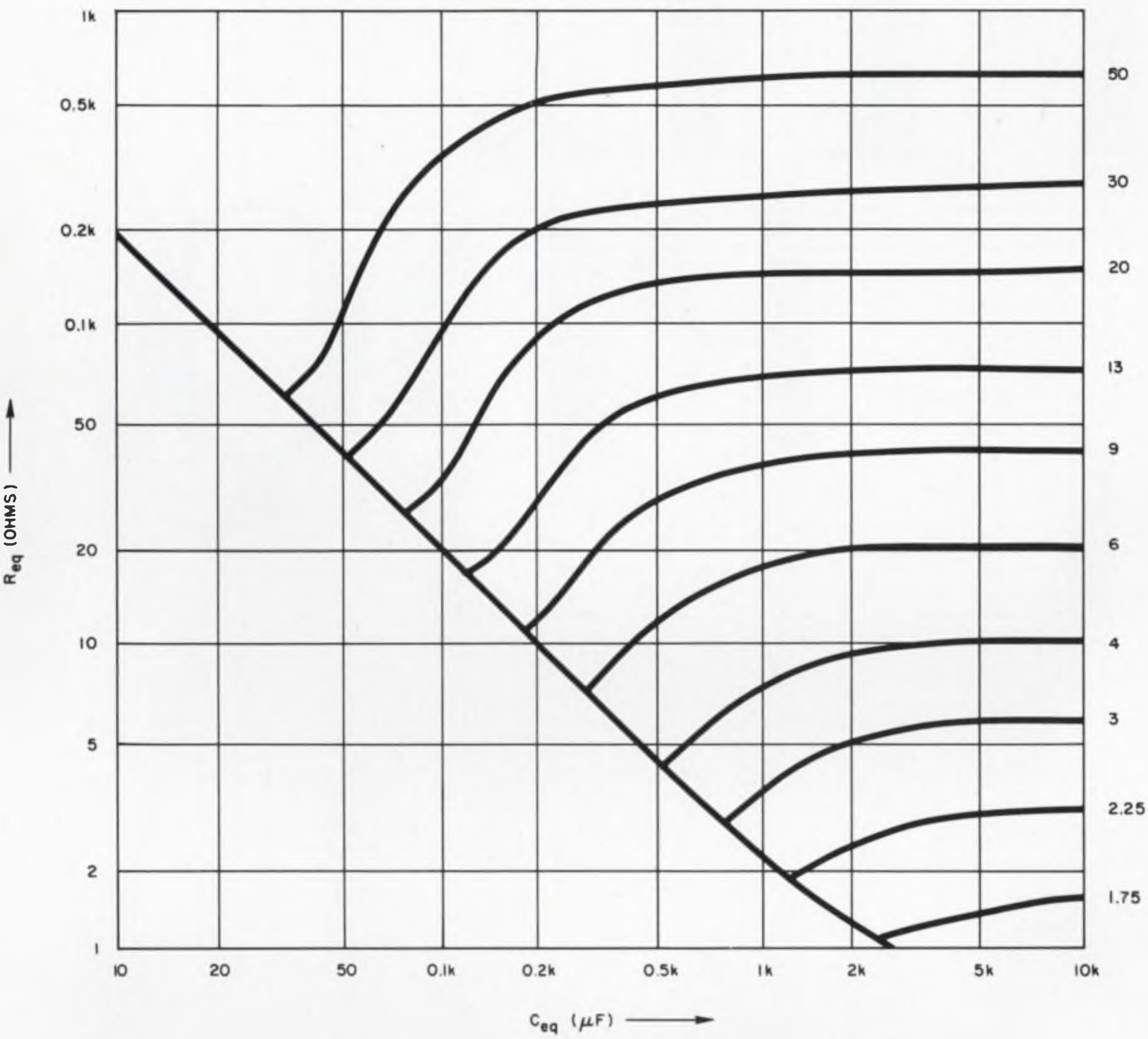
(The data upon which this article is based were obtained while the author was with the Space Systems Division of Hughes Aircraft, El Segundo, Calif.)

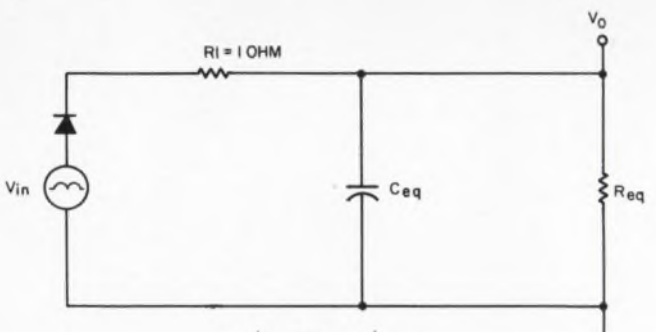
(Continued on next page.)

Graph 1

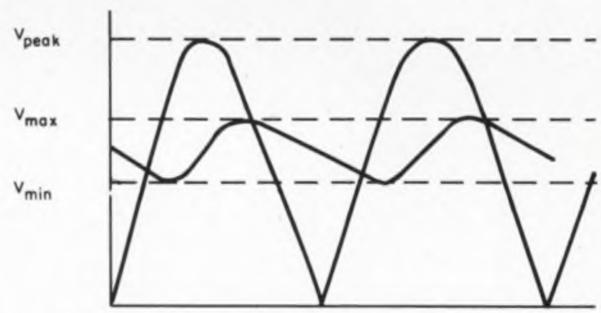


Graph 2

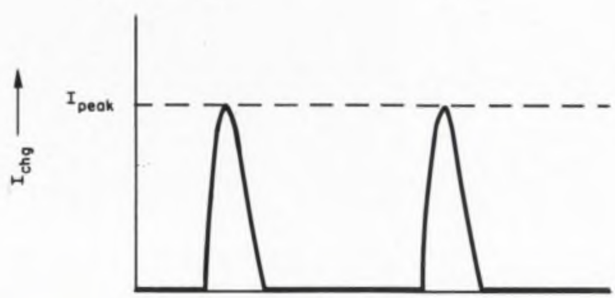




$V_{in} = |V_1 \times \text{SIN}(\omega t)|$



$V_{peak} = V_1 - V_{diode}$



$$R_{eq} = \frac{R_{load}}{R_1}$$

$$C_{eq} = (R_1 C_{filter})\left(\frac{f}{60}\right)$$

$$I_{peak} = \left(\frac{V_{peak}}{R_{chg}}\right)\left(\frac{1}{R_1}\right)$$

TTL.
PDQ.

RSVP: Your National distributor

Gates

DM8000N (SN7400N)	Quad 2-Input, NAND gate
DM8001N (SN7401N)	Quad 2-Input, NAND gate (Open Collector)
DM8003N (SN7403N)	Quad 2-Input, NAND gate (Open Collector)
DM8010N (SN7410N)	Triple 3-Input, NAND gate
DM8020N (SN7420N)	Dual 4-Input, NAND gate
DM8030N (SN7430N)	Eight-Input, NAND gate
DM8040N (SN7440N)	Dual 4-Input, Buffer
DM8050N (SN7450N)	Expandable Dual 2-Wide, 2-Input AND-OR-INVERT gate
DM8051N (SN7451N)	Dual 2-Wide, 2-Input AND-OR-INVERT gate
DM8053N (SN7453N)	Expandable 4-Wide, 2-Input AND-OR-INVERT gate
DM8054N (SN7454N)	Four-Wide, 2-Input AND-OR-INVERT gate
DM8060N (SN7460N)	Dual 4-Input expander
DM8086N (SN7486N)	Quad Exclusive-OR-gate

Flip Flops

DM8501N (SN7473N)	Dual J-K MASTER-SLAVE flip flop
DM8500N (SN7476N)	Dual J-K MASTER-SLAVE flip flop
DM8510N (SN7474N)	Dual D flip flop

Counters

DM8530N (SN7490N)	Decade Counter
DM8532N (SN7492N)	Divide-by-twelve counter
DM8533N (SN7493N)	Four-bit binary counter
DM8560N (SN74192N)	Up-down decade counter
DM8563N (SN74193N)	Up-down binary counter
DM8520N	Modulo-n divider

Decoders

DM8840N (SN7441N)	BCD to decimal nixie driver
DM8842N (SN7442N)	BCD to decimal decoder

Shift Registers

DM8570N	Eight-bit serial-in parallel-out shift register
DM8590N	Eight-bit parallel-in serial-out shift register

Miscellaneous

DM8200N	Four-bit comparator
DM8210N	Eight channel digital switch
DM8220N	Parity generator/checker
DM8820N	Dual line receiver
DM8830N	Dual line driver
DM8800H	Dual TTL to MOS translator
DM8550N (SN7475N)	Quad latch

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INFORMATION RETRIEVAL NUMBER 49

How to investigate a company,

or what every engineer and his manager should know about an annual financial report

Richard L. Turmail
Management & Careers Editor

You're an engineer and you have a problem to solve:

- You're about to be offered a job but you don't have a clue as to whether your prospective employer's administrative policies belong in the space age or the ice age, whether he's financially solvent or on the brink of bankruptcy.
- You want to invest in the stock market, but inexperience is making you a "Milquetoast." You can entrust your money to a stockbroker, but you'd feel more secure if you knew something about the art of investing.
- You'd like to supplement your vocabulary with terms like "liquidity ratio" so that the next time the office conversation turns to the stock market, you can make an intelligent contribution.

Where can you find the information you need to size up your employer, speculate on the stock market, and translate the language of investing? As Sherlock Holmes was given to say, "The answer is elementary, my dear Watson." For the solution to your problems is in knowing how to analyze a financial report.

Security analysts are able to determine the strengths and weaknesses of a company by analyzing its "balance sheet" and "income statement." But before you can subject a company to analysis, you must discover the "what," "why," and "how" of a financial report.

What is a financial report?

An abbreviated version of a balance sheet is shown at top right. It represents the financial picture of a company as it appeared on one particular day of operation. The complete report (on p. 116) including the income statement which shows how much business the company does, portrays a corporation's financial progress growing out of the soundness of its operations.

Why a report?

During the days when a town's business was the chief topic of conversation, there was little justification for detailed financial reports. The annual meeting was attended by all of the shareholders, who lived conveniently near their investment. But as corporations expanded, capital needs increased, and the number of share owners grew beyond the boundaries of a particular region, the expense or trouble of attending an annual meeting hardly seemed worthwhile. As a result, an age of greater financial disclosure was launched.

At the turn of the century, the Stock Exchange persuaded the first industrial company to publish an annual statement. One after the other, companies wanting to qualify for listing on the Exchange brought out their annual reports. Today, according to the New York Stock Exchange, more than 1200 leading corporations distribute an estimated 40 million copies of these reports to the press, company employes, schools of business administration, investment firms, other financial organizations, and—most important—to those people who own shares in American business.

(continued on page 114)

The trading floor of the New York Stock Exchange, where speculators bid for securities on the premise of a favorable company analysis.

Typical Electronics Corporation, Inc.

(Abbreviated Balance Sheet)

	1967	1966		1967	1966
Assets			**Liabilities**		
Total Current Assets	$ 48.4	$ 44.2	Total Current Liabilities	$ 21.6	$ 18.6
Total Other Assets	5.5	4.6	Reserves	3.6	2.5
Total Fixed Assets	105.2	93.4	Long-Term Debt	26.0	20.0
Less Accumulated Depreciation	−27.6	−25.0	Total Stockholders' Investment	80.3	76.1
Adjusted Total Fixed Assets	77.6	68.4			
Total Assets	$131.5	$117.2	Total Liabilities and Stockholders' Investment	$131.5	$117.2

How to read a report

When analysts scrutinize a financial report, they actually read between the lines in order to make value judgments. Before this is feasible, however, one must discover what the lines themselves mean. Like all other professions, accounting has a specialized vocabulary. The following list defines the terms used in a financial report.

Clues to Investing Terms

Terms	Definitions
	Assets
Current Assets	that which may readily be turned into cash
Cash	in the till, on deposit in the bank
Marketable Securities	investment of excess cash in securities that may be sold quickly when cash is needed
Accounts Receivable	amounts owed the company by its customers and others
Inventories	raw materials, goods in process of manufacture, finished goods
Prepayments	unexpended insurance, unused rentals
Good will, Patents, Trademarks	intangibles: the value varies considerably from one company to the next
Fixed Assets	that which is not intended for sale, and is used over and over again, such as land, buildings, machinery and equipment
	Liabilities
Current Liabilities	all debts that fall due within the coming year
Accounts Payable	money owed to regular business creditors
Notes Payable	money owed to a bank
Accrued Expenses Payable	unpaid amounts of wages, interest on funds borrowed, fees to attorneys, insurance premiums, pensions, etc.
Long-Term Liabilities	debts due after one year from the date of the report
	Stockholders' Equity
Capital Stock	shares in the proprietary interest in the company
Preferred Stock (cumulative)	shares having preference over other shares as regards dividends or in distribution of assets in case of liquidation or both. . ."cumulative" means that, if the dividend is not paid, it accumulates in favor of the shareholder
Common Stock	shares on the books at a par or stated value (market value is determined by sellers and buyers)
Capital Surplus	contributed assets, premium received from sales of stock over the par value
Earned Surplus	past retained earnings not paid in dividends
	Statement of Income
Depreciation and Depletion	provision from income for the reduction of the service life of machinery and buildings and the use of minerals in mines
Operating Profit	the remainder after deducting expenses from sales, but before interest charges and taxes
Interest Charges	amount required for interest on borrowed funds

How to analyze a report

There are no pat findings from the analysis of a financial report. A divergence of opinion exists even among the experts. For example: It was reported in the February issue of *Management Review* that some analysts believe that when a company is comprised of a number of firms, a single financial report has little significance. Others were reported to believe that the facts of a company's growth provide a better foundation for analysis than the data gathered from the company "satellites."

More light was shed on the area of disagreement by this analyst's comment: "A majority of companies should be analyzed apart from their industries . . . [for example] Drugs are considered a growth industry, yet 50% of the drug companies aren't growing."

Another analyst was quoted as saying, "An electronics corporation cannot succeed if its research and development program lags behind its competitors'. In the computer business, entire computer systems are outdated within a year or two as a result of R&D."

Because the operations and policies of companies differ, analysts are forced to devise "slide rules" to make meaningful appraisals.

You cannot expect to analyze a company as well as the man who earns his living at it. But you can get more out of a financial statement by applying ratios that focus attention on significant relationships in the statement of income and the balance sheet.

The New York Stock Exchange published an approach to this method of analysis. It is called "The 7 Keys to Value," and these are the keys:

1. Pre-tax Profit Margin

This is the ratio of profit, before interest and taxes, to sales. It is expressed as a percentage of sales and is found by dividing the operating profit by sales. It is usually assumed that an increase in sales will help widen the profit margin.

2. Current (or working capital) Ratio

This is the ratio of current assets to current liabilities. A 2-for-1 ratio is the standard, meaning that for each $1 of current liabilities, there are $2 in current assets to back it up. A gradual increase in the current ratio usually is a healthy sign of improved financial strength. But a ratio of more than 4 or 5 to 1 is regarded as unnecessary, and may be the result of an insufficient volume of business to produce a desirable level of earnings. The ability of a company to meet its obligations, expand its volume, and take advantage of opportunities is often determined by its working capital.

3. Liquidity Ratio

This is the ratio of cash and equivalent (marketable securities) to total current liabilities. It is also expressed as a percentage figure, and it results from dividing cash and equivalent by total current liabilities. This ratio is important as a supplement to the current ratio because the immediate ability of a company to meet current obligations or pay larger dividends may be impaired despite a higher current ratio. A decline in the liquidity ratio often takes place during a period of expansion and rising prices because of heavier capital expenditures and larger accounts payable. If the decline persists, the company may have to raise additional capital.

4. Capitalization Ratios

These are the percentages of the total company investment allotted to each type of investment. Specifically, the capitalization is made up of long-term debt, preferred stock, common stock, and surplus. Usually, the higher the ratio of surplus to common stock, the more assured is the position of the common stock, since there are fewer prior claims on corporate income in the form of debt securities or preferred stock. Companies in stable industries, such as electric light and power, may with safety have a higher proportion of debt financing than most industrial companies.

5. Sales to Fixed Assets

This ratio is computed by dividing the annual sales by the value before depreciation and amortization of plant, equipment and land at the end of the year. It is important because it helps determine whether or not the funds used to enlarge productive facilities are being spent wisely. A sizable expansion in facilities should lead to larger sales volume.

6. Sales to Inventories

This ratio is computed by dividing the year's sales by the year-end inventories. The so-called "inventory turnover" is important as a check on whether or not the enterprise is investing too heavily in inventories. Because inventories are a larger part of the assets of a merchandising enterprise than of most manufacturing companies, this ratio is especially worthy of note in the analysis of a retail business. A high ratio denotes a good quality of merchandise and correct pricing policies. A definite downtrend may be a warning signal of poor merchandising policy, poor location, or "stale" merchandise.

7. Net Income to Net Worth

This ratio is derived from dividing net income by the total of preferred stock, common stock and surplus accounts. It supplies the answer to the vital question: "How much is the company earning on the stockholders' investment?" A large or increasing ratio is favorable. In a competitive society an extraordinarily high ratio may invite more intense competition. An increase due to "inventory profits" may be short-lived because of rapid changes in commodity prices.

(continued on page 116)

Ready for Analysis

Now that you have adopted an investment vocabulary, and understand the "keys to value," you have a working knowledge of how to "investigate" a company. If you are ready to test your powers of detection, apply what you have learned to the complete financial report of Typical Electronics Co., Inc., by answering the questions at the right.

Typical Electronics Corporation, Inc., and Consolidated Subsidiaries

Balance Sheet — December 31, 19__

	1967	1966
Assets		
Current Assets		
Cash	$ 9.0	$ 6.2
Marketable Securities, at Cost (Market Value)	–	2.0
Accounts Receivable	12.4	11.4
Inventories	27.0	24.6
Total Current Assets	$ 48.4	$ 44.2
Other Assets		
Surrender Value of Insurance	$ .2	$ .2
Investments in Subsidiaries	4.7	3.9
Prepayments	.6	.5
Goodwill, Patents, Trademarks	–	–
Total Other Assets	$ 5.5	$ 4.6
Fixed Assets		
Buildings, Machinery & Equipment (at cost)	$104.3	$ 92.7
Less Accumulated Depreciation	–27.6	–25.0
	$ 76.7	$ 67.7
Land	.9	.7
Total Fixed Assets	$ 77.6	$ 68.4
Total Assets	$131.5	$117.2

	1967	1966
Liabilities		
Current Liabilities		
Accounts Payable	$ 6.1	$ 5.0
Notes Payable	1.0	.8
Accrued Expenses Payable	3.6	3.3
Federal Income Tax Payable	9.6	8.4
Dividends Payable	1.3	1.1
Total Current Liabilities	$ 21.6	$ 18.6
Reserves	3.6	2.5
Long Term Liabilities		
First Mortgage Bonds, 5% Interest Due 1975	26.0	20.0
Stockholders' Equity		
Capital Stock		
Preferred Stock, 5% Cumulative, $100 Par Value Each: 6,000 Shares	$ 6.0	$ 6.0
Common Stock, $5 Par Value Each; 300,000	18.3	18.3
Capital Surplus	9.6	9.6
Earned Surplus	46.4	42.2
Total Stockholders' Equity	$ 80.3	$ 76.1
Total Liabilities and Stockholders' Investment	$131.5	$117.2

7 Clues to Value

	1967	1966
Statement of Income		
Sales	$115.8	$110.0
(less) Costs and Expenses:		
Cost of Goods Sold	74.8	73.2
Selling, General, Administrative Expenses	14.2	13.0
Depreciation and Depletion	4.2	3.5
	$ 93.2	$ 89.7
Operating Profit	22.6	20.3
Interest Charges	−1.3	−1.0
Earnings before Income Taxes	$ 21.3	$ 19.3
Provision for Taxes on Income	−11.4	−9.8
Net Income for the Year	9.9	9.5
Dividend on Preferred Stock	−.3	−.3
Balance of Income Available for Common Stock	9.6	9.2
Statement of Earned Surplus		
Balance at Beginning of Year	$ 42.2	$ 37.6
Add – Net Income for the Year	+9.9	+9.5
	$ 52.1	$ 47.1
Less Dividends Paid on		
Preferred Stock	.3	.3
Common Stock	5.4	4.6
Balance at End of Year	$ 46.4	$ 42.2

1. Which year had a pretax profit margin of 19.5%? Evaluate.

2. The 1967 current ratio was 2.24 to 1. What was the ratio for the previous year? Evaluate both years.

3. What per cent was the liquidity ratio for 1967? Evaluate.

4. What were the capitalization ratios for 1966? Evaluate.

5. Which year has a higher ratio of sales to fixed assets? Evaluate.

6. Which year had a sales-to-inventories ratio of 4.3? Evaluate.

7. What was the net income-to-net worth ratio for each year? Evaluate.

(answers on next page)

(continued from page 117)

Only the Beginning

While interpreting the facts and figures of a financial report helps you determine the soundness of a company's operation and the attractiveness of its securities, it has been suggested by stock brokers Merrill Lynch, Pierce, Fenner and Smith, Inc., that selecting common stocks for investment requires careful study of factors other than those you can learn from financial statements. The economics of the country and the particular industry must be considered; the management of the company must be studied and its plans for the future assessed. These facts must be gleaned from the press or the financial services, or supplied by a research organization.

If you want to become a serious student of investing, knowing how to read and analyze a financial report is only the beginning. What you have uncovered here, however, may help you to determine what kind of company you may be getting into, what a financial statement can tell you, and, of course, to speak intelligently on such keys to value as "liquidity ratio." ■■

Answers to questions on report analysis.

1. 1967. Good. Profit margin widened. It is usually assumed that material increase in sales will help widen the profit margin. Certain costs are fixed, i.e., they do not rise or fall in the same proportion as changes in volume. Such costs are interest, rent and real property taxes. Ordinarily, because of their fixed costs, profits tend to increase and decline more rapidly percentagewise than sales.

2. 2.38 to 1. Fair. The company did not improve its position in this regard because it used substantial funds to increase its plant and equipment. The ratio could have been better if the company had spent less for additions to its productive facilities, or had raised more funds for this purpose through the sale of securities, or paid less in dividends. This particular case illustrates why the entire annual report and financial statement must be examined.

3. 41.7%. Fair. A decline in the liquidity ratio often takes place during a period of expansion and rising prices because of heavier capital expenditures and larger accounts payable. If the decline persists, it may mean that the company will have to raise additional capital.

4. Long-term debts 20.8%
Preferred stock 6.3%
Common stock and surplus 72.9%

Unchanged. The common-stock ratio was somewhat smaller than in the previous year, because of the issuance of additional debentures during the year. Since the surplus was also larger, due to reinvested earnings, the change was slight and the common-stock equity remained high.

5. 1966. Bad. In 1967 the company's ratio of sales to fixed assets amounted to approximately 1.1 to 1 compared with 1.2 to 1 in the previous year. Fixed assets are shown both as a gross figure and as a net figure, i.e., before and after accumulated depreciation. Sometimes the details appear in a footnote to the balance sheet which sets forth the costs of the buildings, machinery, equipment and land. For our computation we have used the gross figure for all fixed assets, $105.2 million in 1967 and $93.4 million in 1966. The ratio is low, which is not good for an electronics company that ordinarily has a larger sales volume in relation to plant investment.

6. 1967. Fair to bad. The company's sales-to-inventories ratio in 1967 was approximately 4.3 to 1 compared with 4.5 to 1 in 1966. This decline would have resulted from purchases of raw materials in anticipation of an increase in prices of a falling off in sales toward the end of the year.

7. 1966, 12.5%; 1967, 12.3%. Unchanged. According to general surveys of all manufacturing corporations in the United States, a return of over 10% appears to be better than average. Although the later year shows a 0.2% deficit from the preceding year, it is not as significant as the return on the stockholder's investment.

Company evaluation? Since the answer to that question would depend on what you plan to do with the information, we'll do the honorable thing leave the decision to you.

References:

1. "Understanding Financial Statements — 7 Keys to Value", New York Stock Exchange, September, 1968.
2. F. V. Huber, "How Security Analysts Size Up a Company's Strength", *Management Review*, February, 1969, pp. 32-37.
3. "How to Read a Financial Report", Merrill Lynch, Pierce, Fenner and Smith, Inc., February, 1968.

For those engineers who would like to read and analyze the financial reports of various electronics companies, ELECTRONIC DESIGN introduces a new section titled, "Annual Reports." (See opposite page.) Starting with the June 21st issue, "Annual Reports," which includes such information as the company's net sales, net income and total assets, will appear in the products section of the magazine. To receive a complete financial report, the reader can circle the information retrieval number.

Annual Reports

Aerospace Corp., P.O. Box 95085, Los Angeles, Calif: military systems and equipment; net income, $75,092,122; contact fees, $2,619,-095; total assets $9,998,319.

CIRCLE NO. 378

Airpax Electronics, P.O. Box 8488, Fort Lauderdale, Fla: industrial controls and instruments; net sales, $6,833,337; net income, $322,178; net income per share, 73¢; total assets, $3,975,766.

CIRCLE NO. 379

Applied Magnetics Corp., Santa Barbara Main Plant, 75 Robin Hill Rd., Goleta, Calif: magnetic and ferrite heads, memories, components; net sales, $11,971,406; net income, $1,033,693; assets, $5,584,704.

CIRCLE NO. 380

Astrosystems, Inc., 6 Nevada Drive, New Hyde Park, N.Y: computer peripheral equipment, test systems, instruments; net sales, $2,905,885; net income, $235,900; assets, $1,554,509.

CIRCLE NO. 381

Cohu Electronics, Inc., 5725 Kearny Villa Rd., San Diego, Calif; instruments, cameras, environmental test equipment; net sales, $9,289,986; net income, $294,378; assets, $6,325,003.

CIRCLE NO. 382

Cubic Corp., 9233 Balboa Ave., San Diego, Calif: computer peripherals, data processing, navigation, guidance and communications systems; net sales, $6,259,-000; net income, $202,000; assets, $2,934,000.

CIRCLE NO. 383

Damon Engineering, Inc., 115 Fourth Ave., Needham Heights, Mass: filters, medical instruments, plastics; net sales, $15,708,708; net income, $1,045,462; total assets, $6,954,266.

CIRCLE NO. 384

Dearborn Computer Corp., 100 W. Monroe St., Chicago, Ill: computer leasing, offshore drilling, marine equipment; total revenues $10,613,000; net income, $1,250,-000; total assets, $90,041,000.

CIRCLE NO. 385

Harris-Intertype Corp., 55 Public Square, Cleveland, Ohio: communications and information handling equipment, integrated circuits; net sales, $277,772,000; net income, $281,309; assets, $199,544.

CIRCLE NO. 386

IMC Magnetics Corp., 570 Main St., Westbury, N.Y: air transportation products, motors, airmovers; net sales, $9,396,340; net income, $455,887; total assets, $4,-342,679.

CIRCLE NO. 387

Indian Head Inc., 111 W. 40th St., New York City: information handling, textiles, consumer glass containers, automotive hardware; net sales, $369,531,000; net income, $12,072,000; assets, $248,-782,000.

CIRCLE NO. 388

International Business Machines Corp., Armonk, N.Y: data processing services, computers, business machines; gross income, $6,888,549,209; net earnings, $871,497,991; total assets, $6,743,-431,161.

CIRCLE NO. 389

North Atlantic Industries, Inc., Terminal Drive, Plainview, N.Y; interfaces for computers and automatic test equipment; net sales, $3,312,301; net income, $211,173; total assets, $1,894,526.

CIRCLE NO. 390

RCA, 30 Rockefeller Plaza, New York City: defense, aerospace, consumer products, components, broadcasting, communications, publishing; net revenues, $3,129,020,-000; net profit, $154,047,000; assets $1,356,287,000.

CIRCLE NO. 391

Republic Corp., 9601 Wilshire Blvd., Beverly Hills, Calif: components, packages, plastics, hardware, marketing services, film processing; net sales, $142,670,-000; net income, $9,157,000.

CIRCLE NO. 392

Rogers Corp., Rogers, Conn: electrical insulation, elastomers, plastics, sealing materials; net sales, $19,804,000; net income, $520,000; total assets, $9,933,000.

CIRCLE NO. 393

Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif: semiconductors, integrated circuits, semiconductor test equipment; net sales, $7,905,498; net income, $846,263; total assets, $4,956,713.

CIRCLE NO. 394

Statham Instruments, Inc., Statham Industrial Park, 2230 Statham Blvd., Oxnard, Calif: medical, industrial and aerospace transducers and instruments; net sales, $12,049,390; net income, $130,480; assets, $11,930,170.

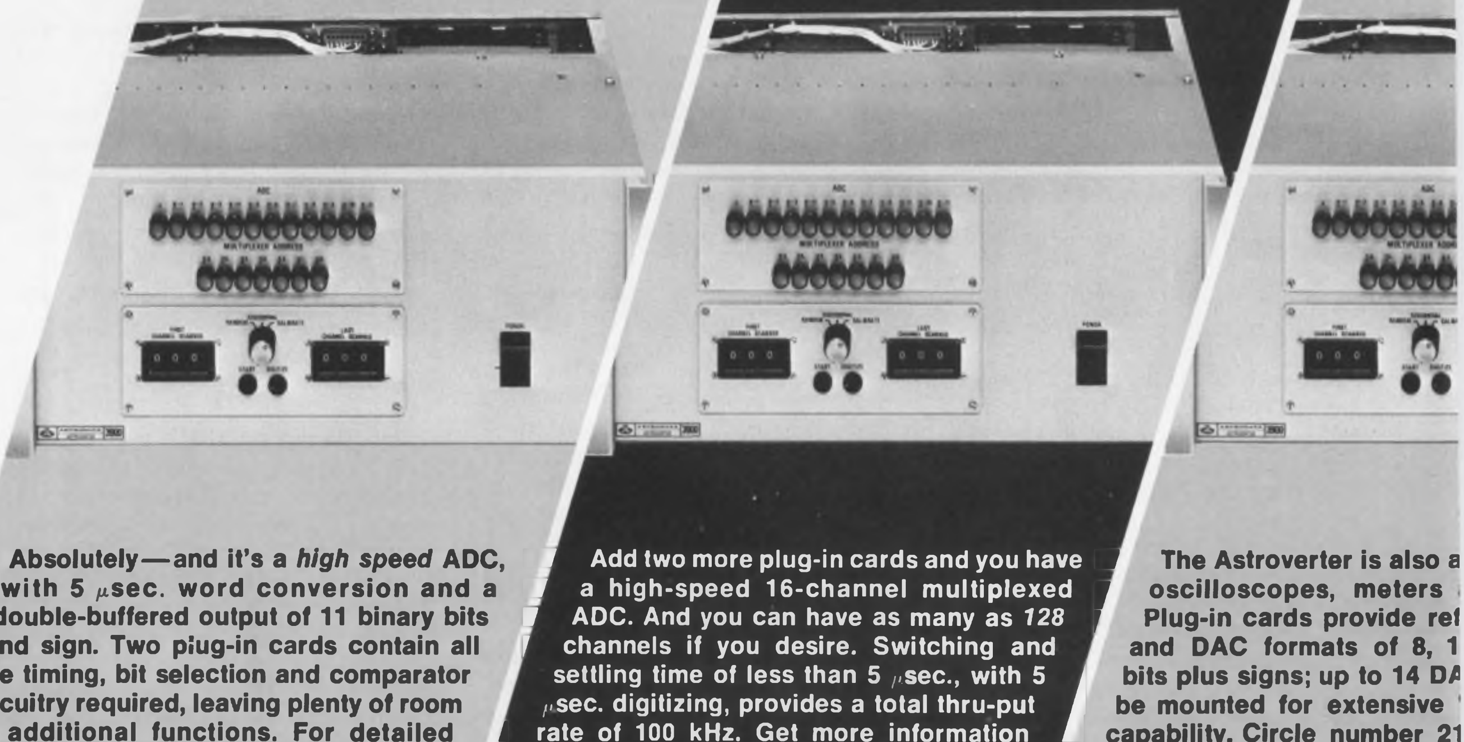
CIRCLE NO. 395

Systron-Donner Corp., 1 Systron Drive, Concord, Calif: sensors, instruments, systems/controls; net sales, $28,851,282; net income, $2,015,522; total current assets, $12,903,963.

CIRCLE NO. 396

Varian Associates, 611 Hansen Way, Palo Alto, Calif: instruments, microwave equipment, data processing, electrographics; net sales, $170,755,000; net income, $3,443,000; assets, $168,155,000.

CIRCLE NO. 397



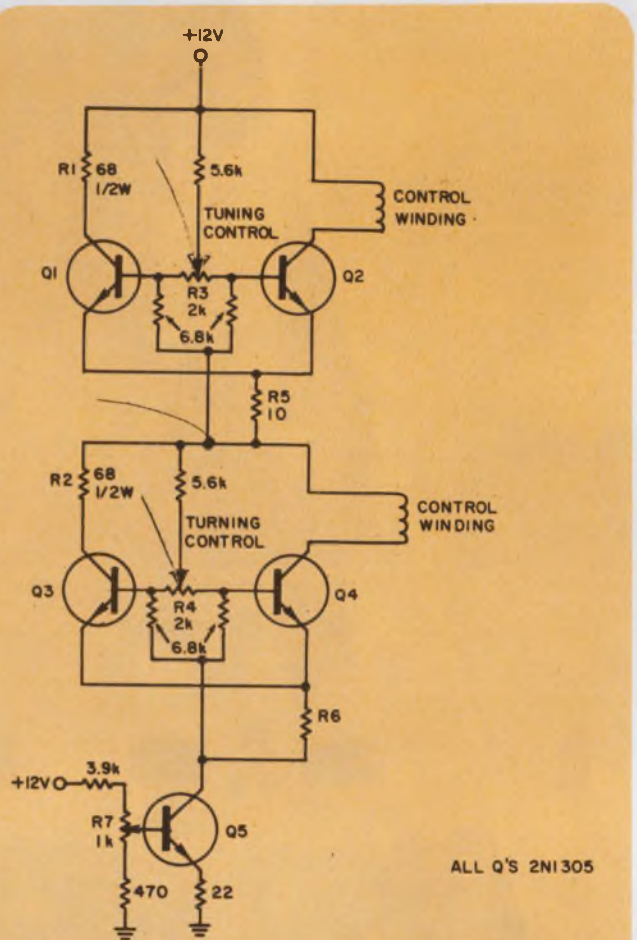
Series control technique cuts tuning power requirements

Current-variable inductors are excellent components for use as tuning elements in electronically tuned circuits. However, in applications where power requirements are critical, the current required to tune the inductors can often prohibit their use. Up to 100 mA at 2 to 6 volts is common with one such type of inductor.

With the tuning control circuit shown, it is possible to operate two or more control windings in series across the supply voltage and still have independent control of the currents. It is assumed that other considerations require a supply voltage of twice the maximum control winding voltage or greater. The total current required by all windings is the same as for only one winding. Thus, with two windings, the maximum current required is reduced to 1/2; with three windings it is reduced to 1/3, and so forth—as compared to the use of separate parallel tuning controls. For the circuit shown, the control windings require 60 mA each; using the series control circuit therefore reduces the maximum current from 120 mA to 60 mA.

As shown in the diagram, each control winding is connected as the collector load of one side of a differential amplifier. Resistors R_1 and R_2 should be about equal to the resistance of the control winding. The tuning controls, R_3 and R_4, actually control the relative bias on the differential transistor pairs, thus changing the current through the control windings. Resistors R_5 and R_6 provide negative feedback to keep constant the sum of the currents through each pair of transistors.

Q5 serves as a constant-current generator, with the maximum tuning current being set by R_7. In this example, the maximum current was set at 60 mA. The current in either winding could then be adjusted from 0 to 60 mA, with negligible effect on the current in the other winding.



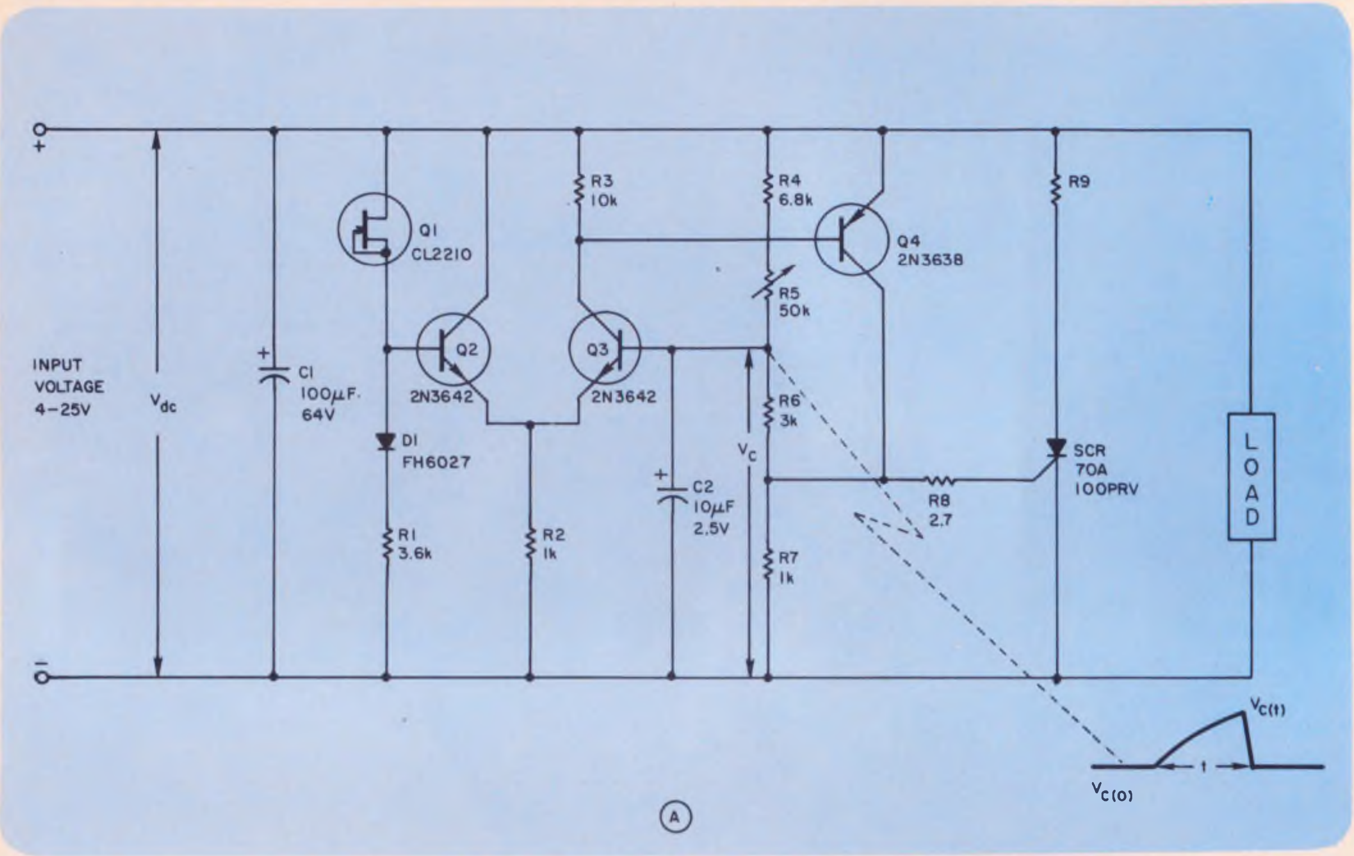
Although the two control windings are in series across the supply voltage, the current through each can be controlled independently.

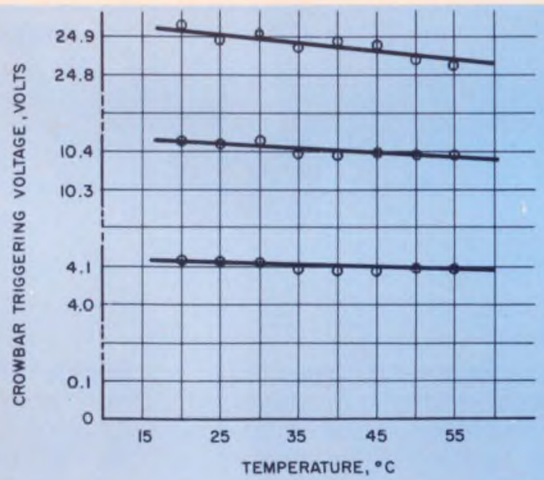
Merle E. Converse, Senior Research Engineer, Southwest Research Institute, San Antonio, Tex.

VOTE FOR 311

Power supply crowbar can be adjusted precisely

Crowbar circuits are often used in power supplies to protect loads against overvoltage conditions like those caused by a shorted series regulator. Voltage adjustability and continuous power drain are frequently important considerations in the design of such circuits. With the crowbar arrangement shown, overvoltage protection can be provided at voltage levels between 4 and 25 V.





The SCR turns on, providing crowbar protection for the load, when the base voltage of Q3 exceeds that of Q2 (A). This turn-on voltage is exceptionally stable with temperature (B).

The range can be extended up to 60 V (the breakdown voltage of *Q1*) by using transistors with higher voltage ratings. The power required by the circuit is less than 1.5 mA, continuous drain from the power supply being protected.

In operation, *Q1* supplies a basically constant current of 0.24 mA for drain-to-source voltages in the range 1.5 to 60 volts. The temperature coefficient of this current is 0.55 μA/°C, which is compensated for by the negative temperature coefficient of the voltage across diode *D1*.

The crowbar turns on as soon as the base voltage of *Q3*, which is equal to $4.0/(R_5+10.8)$ of V_{dc} exceeds the base voltage of *Q2* (determined by $I_D R_1 + V_D = 1.36$ V). Conduction is then transferred from *Q2* to *Q3*, turning the SCR on, and establishing a virtual short circuit (1.0 V for the SCR used here) across the load. Positive feedback from the collector of *Q4* to the base of *Q3* ensures sufficient SCR gate current (50 mA for the large, low-cost, SCR used here). The crowbar turn-on voltage varies by less than 0.025%/°C over the temperature range of 20°C to 55°C, as seen from the accompanying curves (b).

The lower overvoltage limit at which the crowbar will be activated depends upon various characteristics of the monitored supply—in particular its response to sudden line and load changes. Capacitor C_2 permits the lower limit of the overvoltage margin to be adjusted to within 0.4% of the normal value of V_{dc}. Consequently, considering both the effects of temperature over the range indicated and an allowance for supply noise, overvoltages as small as (35) (0.00025) + 0.004 = 1.3% of the normal value of V_{dc} can

be detected and will operate the crowbar.

Unfortunately, C_2 masks short transient overvoltages of duration t, where

$$t = 2C_2(R_4+R_5) \times \left[\frac{V_c(t) - V_c(0)}{2(V_{dc}+\Delta V_{dc}) - V_c(t) + V_c(0)\left(\frac{(1+R_4+R_5)}{R_6+R_7}\right)} \right]$$

This expression for a rectangular pulse transient of duration t and amplitude just equal to the overvoltage margin is obtained by applying Kirchoff's Voltage Law to the network R_4, R_5, R_6, R_7, C_2, and integrating and expanding the logarithmic function in series form. In the expression, ΔV_{dc} is taken as being equal to $[V_c(t) - V_c(0)]$ $[1+(R_4+R_5)/(R_6+R_7)]$, since we are looking for the maximum transient duration maskable by C_2. Substituting $V_c(t) = 1.36$ V and $V_c(0) = 1.30$ V, it is found that $t = 6.2$ ms for $V_{dc} = 4.1$ V. Therefore, the supply filtering must be guaranteed to prevent impulses of duration larger than 6.2 ms.

An appropriate resistance, R_9, can be connected as shown if problems arise regarding current overload of the power supply or its meters when the crowbar is operated.

D. Protopapas, Graduate Student and K. C. Smith, Associate Professor, University of Toronto, Canada.

VOTE FOR 312

2-MHz square-wave generator uses two TTL gates

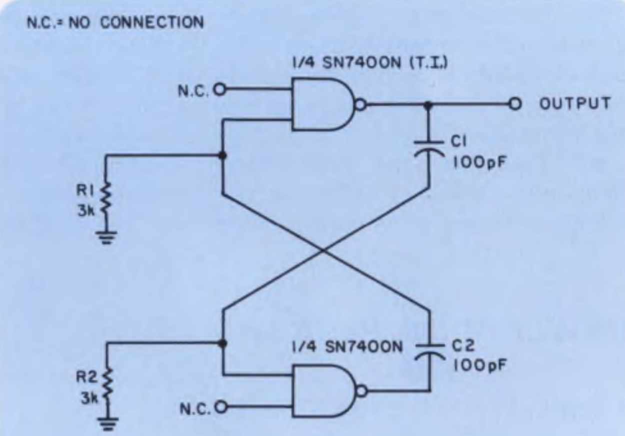
A simple 2-MHz square-wave generator can be built with two TTL NAND-gates, two resistors, and two capacitors. With the values shown (a), the circuit generates a 2-MHz symmetrical square-wave (b). Changing capacitors C_1 and C_2 to 0.01 μF results in a frequency of 500 Hz. For the particular integrated circuits and power supply voltages (5.0 V), the reliable operating range of $R_1 = R_2$ is 2 kΩ to 4 kΩ.

The circuit is used as a clock source for a digital system.

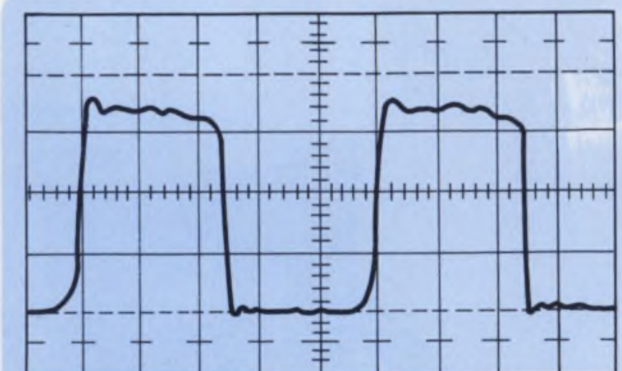
This work is supported by the U.S. Atomic Energy Commission.

A. Barna, D. Horelick, A. Johnson, Design Engineers, Stanford University, Stanford, Calif.

VOTE FOR 313



(A)



(B)

Frequency of the square-wave generator can be changed by changing the values of C_1 and C_2 (a). Output waveform from the circuit is shown in (b). Sweep speed was 0.1 μ/div and sensitivity 1 V/div.

VOTE

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Close piece-to-piece physical and magnetic uniformity often eliminates the need for final testing of the end product. These GE magnets are often the perfect answer for such precise applications as reed switches or magnetic pick-ups.

For more information, circle number 222.

New transmitter design gives high performance to IFF and ATC transponders

GE's new C2003C transmitter is a Microwave Circuit Module (MCM) containing a master oscillator and power amplifier using planar ceramic triodes.

It is just one of many MCM's now available from GE to help reduce design cycles, provide retrofit and lead to improved system performance.

Other benefits include: ☐ meets performance and military requirements of the transmitter portion of IFF transponder ☐ significantly smaller than earlier designs ☐ permits two transmitters to function in space formerly used by one ☐ light-weight ☐ simplified heat sinking ☐ excellent frequency stability with wide variations in antenna VSWR.

For more technical information on this and other MCM's from General Electric, circle magazine inquiry number 223.

GE makes the only 150-grid relay that performs the AND-logic function

GE's 3SBR 4-pole relay is the only one available that performs the AND-logic function without any additional circuitry or components. Nine different input conditions control the relay's operation.

The 3SBR is another addition to GE's proved family of 150-grid relays for mil spec applications. It features all-welded construction, small size and a low profile—only 0.32" high. The 3SBR is available with a choice of coil ratings, mounting forms and headers.

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Rf current probe is immune to interfering magnetic fields

In working with high-frequency antennas it is very important to know the current distribution within the antenna elements as well as in nearby conductors. A simple current probe, which measures relative rf current magnitudes without breaking the conductor, is ideal for this purpose.

When the probe (see a) is held next to an rf current-carrying conductor, the magnetic field of the conductor induces a voltage in the figure-eight loop. This voltage is detected by the germanium diode and indicated on a dc voltmeter.

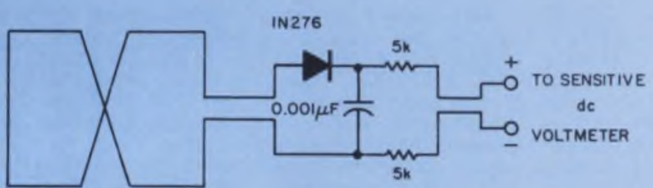
Since one half of the figure-eight loop is wound clockwise, and the other half counterclockwise, induced voltages arising from external fields of distant conductors will cancel out and consequently not be detected. When the probe is held close to a conductor, however, the encircling magnetic field from the conductor will thread the two loops in opposite directions, as shown in (b), and the induced voltages will add. This makes it possible for the probe to measure a relatively weak rf current without responding to the magnetic field of a strong current nearby.

The loop is formed from stiff wire, with no dimensions being critical; the two loops, of course, must be approximately equal in area. The components (germanium diode, capacitor and two resistors) can be mounted on a masonite board or on similar insulating material.

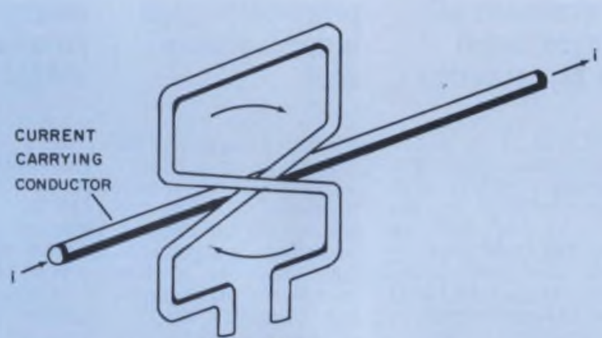
An actual probe is shown in c.

Frederick W. Brown, Design Engineer, Communications Research, Idyllwild, Calif.

VOTE FOR 314



A



B

C

Four components and a wire loop are the only parts required for the rf probe (a). When the probe is held close to a current-carrying conductor the magnetic field threads the loops in opposite directions (b). A probe can be built on masonite board (c).

IFD Winner for February 15, 1969
L. Dunbar, Assistant Section Chief, Grumman Aircraft Engineering Corp., Calverton, N.Y. His Idea "Use your slide rule as a quick dB calculator and a wire table" has been voted the Most Valuable of Issue Award.
Vote for the Best Idea in this Issue.

IFD Winner for February 1, 1969
Alan M. Hansel, Senior Development Engineer, E. F. Johnson, Waseca, Minn. His Idea "Complementary Schmitt trigger has zero output-offset voltage" has been voted the Most Valuable of Issue Award.
Vote for the Best Idea in this Issue.

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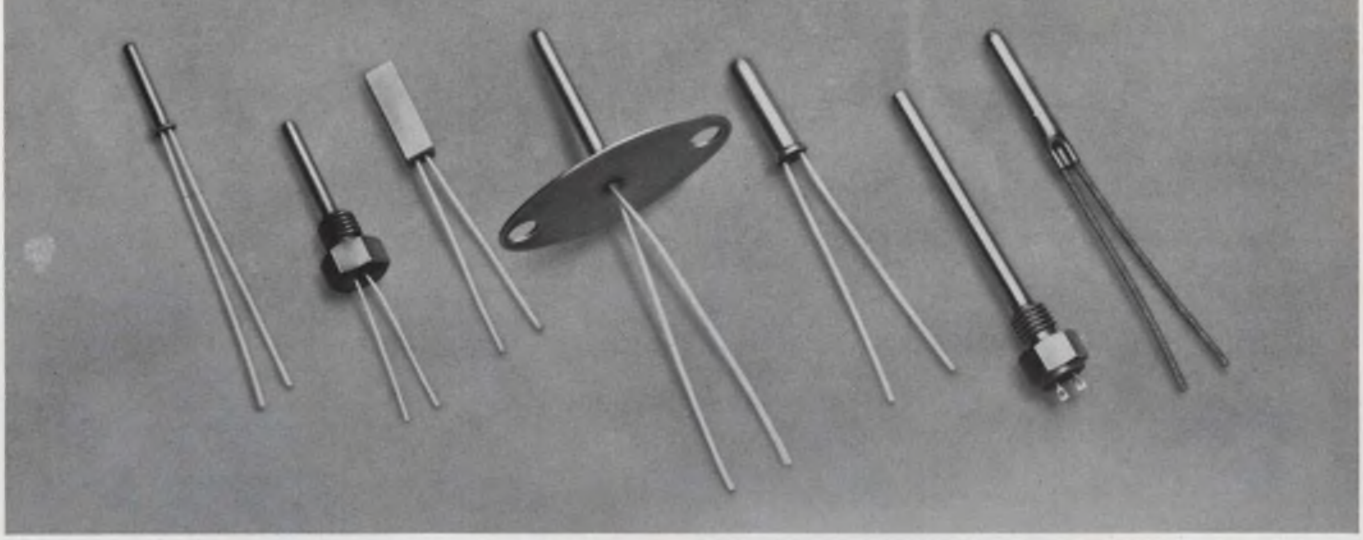
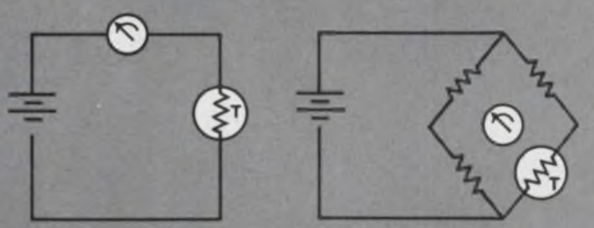


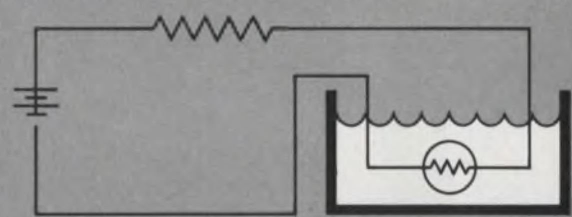
for temperature measurement



Circuit A   Circuit B

Combining high temperature sensitivity with high signal level, thermistors are ideally suited for temperature sensing. In circuit A, as the temperature of the thermistor increases, its resistance decreases, allowing more current to flow. If additional sensitivity is required, a bridge circuit like that shown at B may be used.

for liquid level detection



The thermistor is slightly self heated by passing a small current through the unit. The heat developed in the unit is dissipated more rapidly in the liquid than when the thermistor is above the liquid. The resulting change in body temperature results in a change in resistance. This in turn causes a change in the current in the circuit which can be detected by a relay or other means.

KEYSTONE TYPE	THERMISTOR RESISTANCE					
	0°C	25°C	37.8°C	104.4°C	150°C	232°C
370603-62.66-71-S	282.6	100	62.66	8.825	3.308	.8910
370603-119.1-85-S	631.2	200	119.1	14.01	4.800	1.174
370603-375.3-95-S	2132	650	375.3	39.48	12.76	2.826
0503-630-71-S	2750	1K	630.0	88.80	33.26	8.800
370603-1145-103-S	6733	2K	1145	111.1	33.78	6.607
370603-2801-120-S	18.23K	5K	2801	233.6	64.42	11.18
370603-4452-125-S	29.74K	8K	4452	356.2	96.61	16.29
060337-6266-71-S	28.26K	10K	6266	882.5	330.8	89.10
060337-11910-85-S	63.12K	20K	11.91K	1401	480.0	117.4
0503-16920-112-S	105.3K	30K	16.92K	1511	426.4	83.20
060337-37.53K-95-S	213.2K	65K	37.53K	3948	1276	282.6
0503-55.3K-125-S	361.0K	100K	55.30K	4420	1153	189.6
060337-114.5K-103-S	673.3K	200K	114.5K	11.11K	3378	660.7
060337-280.1K-120-S	1.823 meg	500K	280.1K	23.36K	6442	1118
060337-445.2K-125-S	2.974 meg	800K	445.2K	35.62K	9661	1629
050446-556.5K-125-S	3.717 meg	1 meg	556.5K	44.52K	12.08K	2037

All parts 260°C Max. operating temperature.

The probes illustrated above include stainless steel, aluminum, and chrome plated materials in a variety of configurations. Any thermistor listed at the left can be provided in one or all of the above illustrations. In addition, a variety of other designs are available. These probes are used in conjunction with solid state circuitry for liquid level measurement, and for use as sensors to measure temperature of liquids or surface temperatures. For full particulars, write, detailing your proposed application. Keystone Carbon Company, St. Marys, Pa. 15857.

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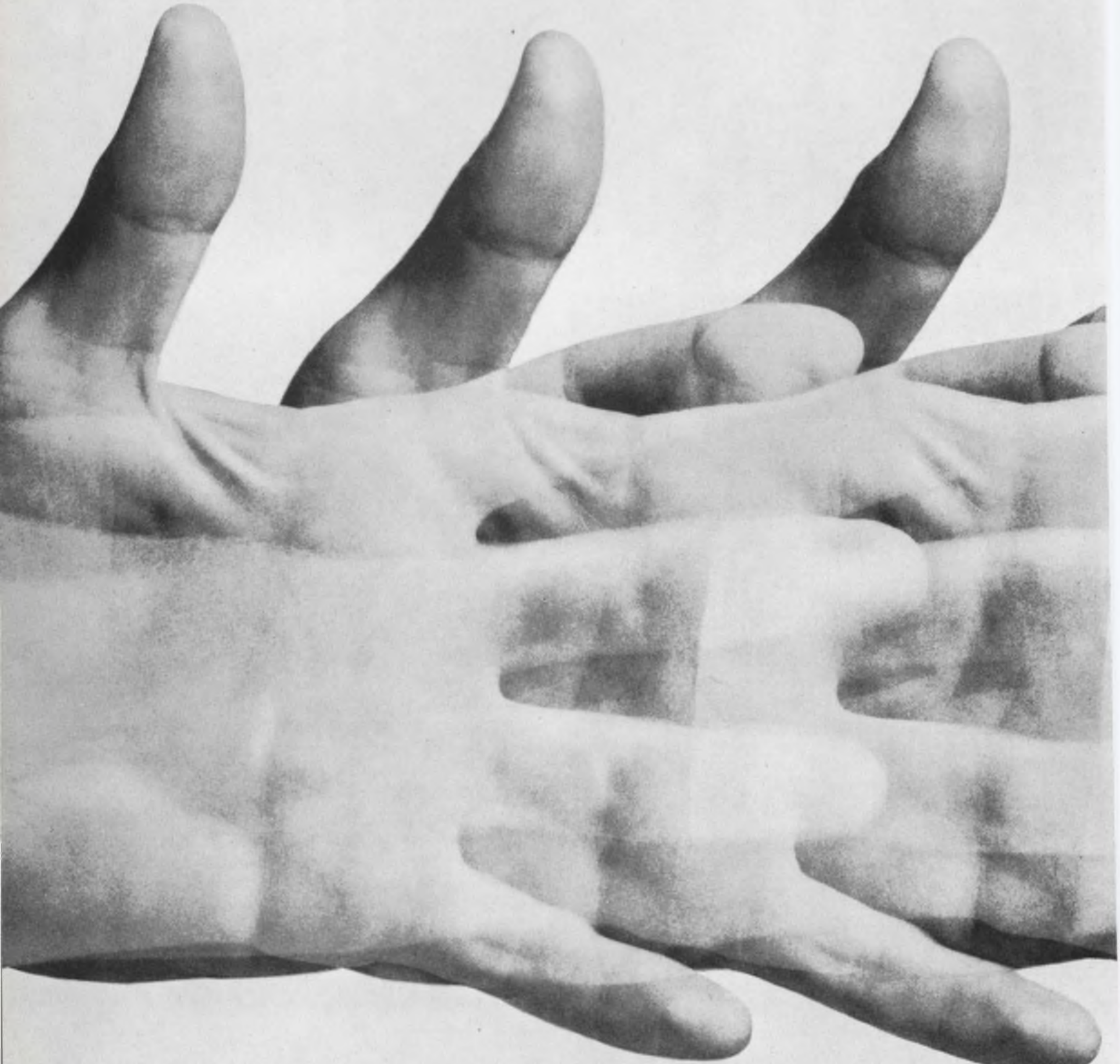
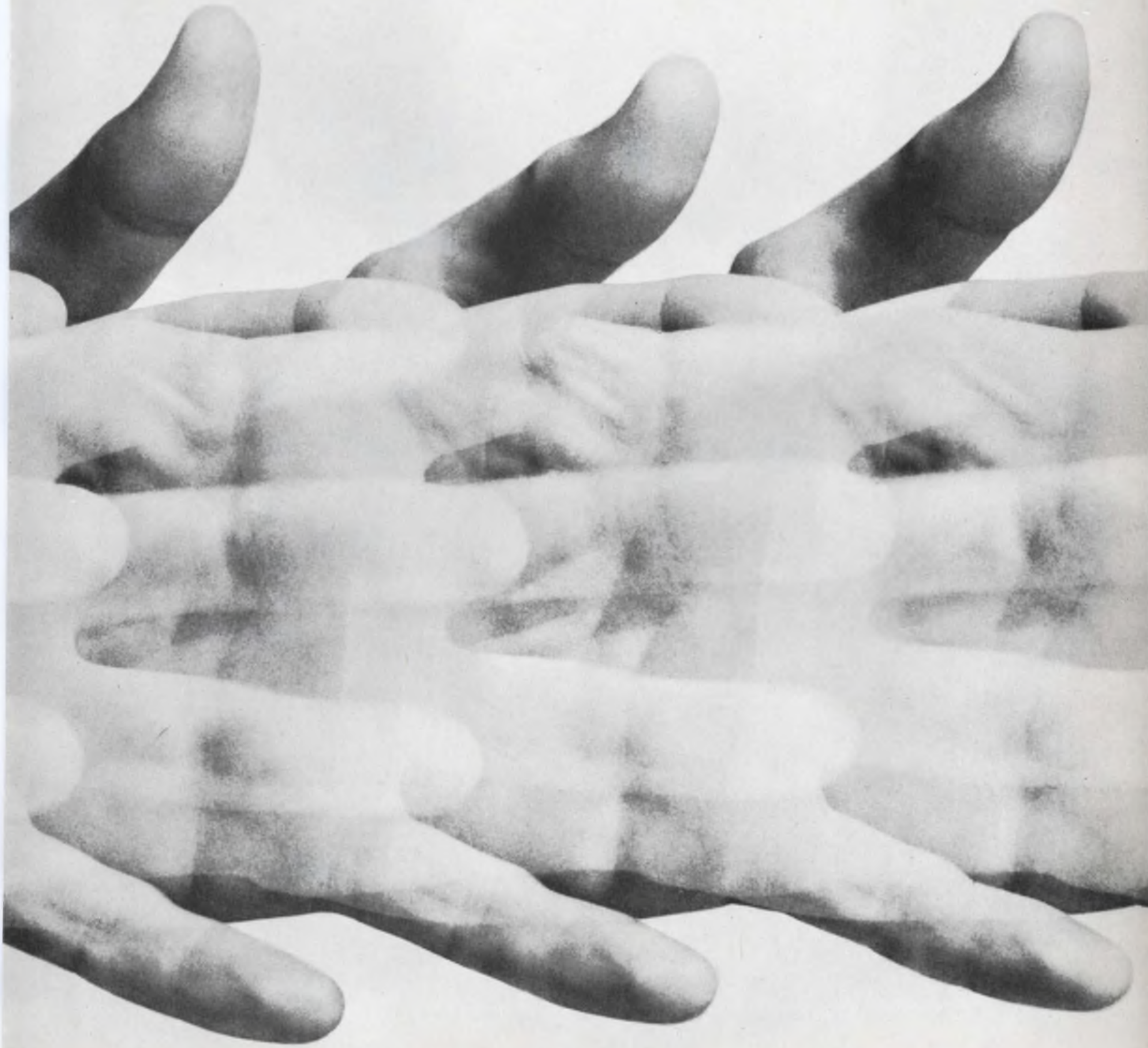


THE G



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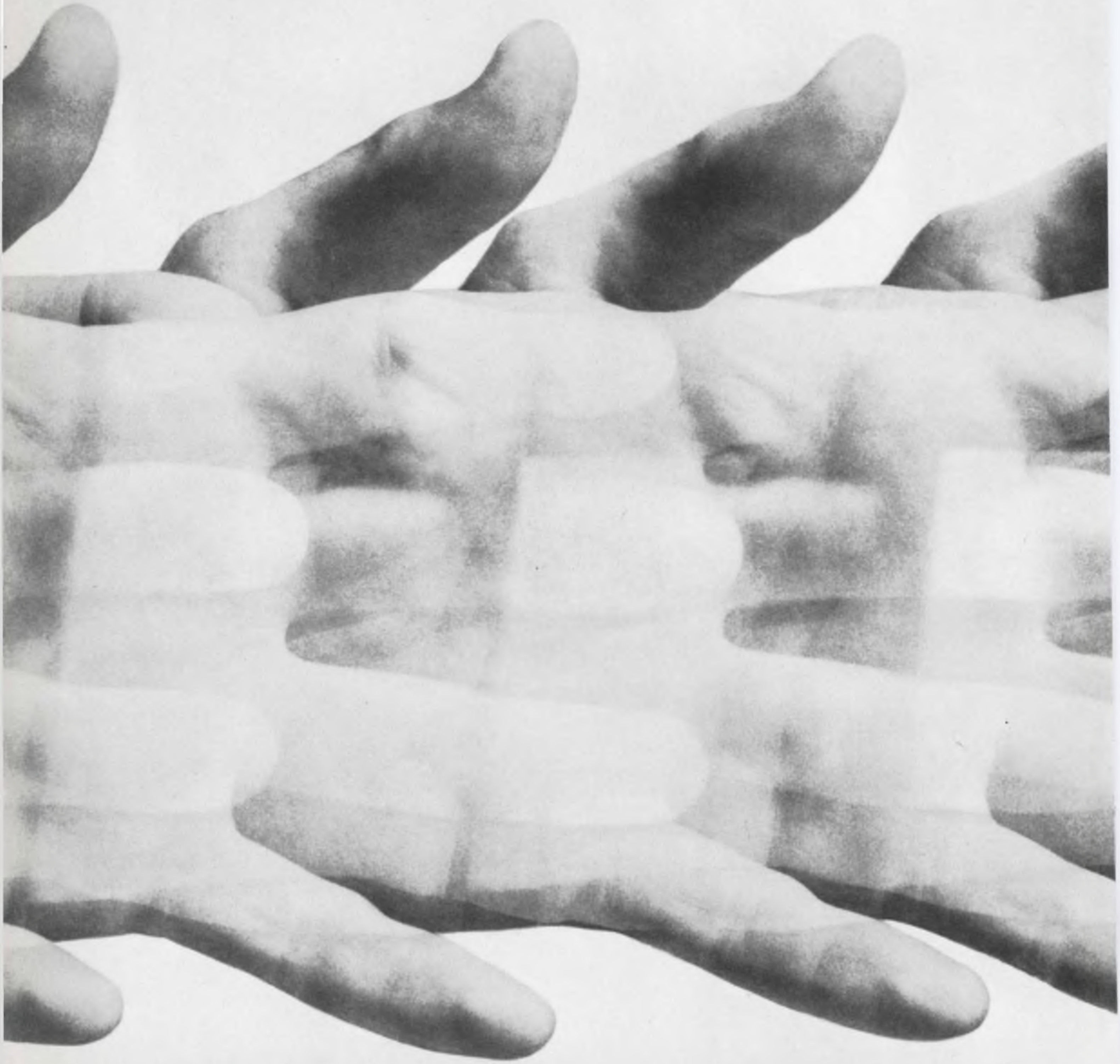

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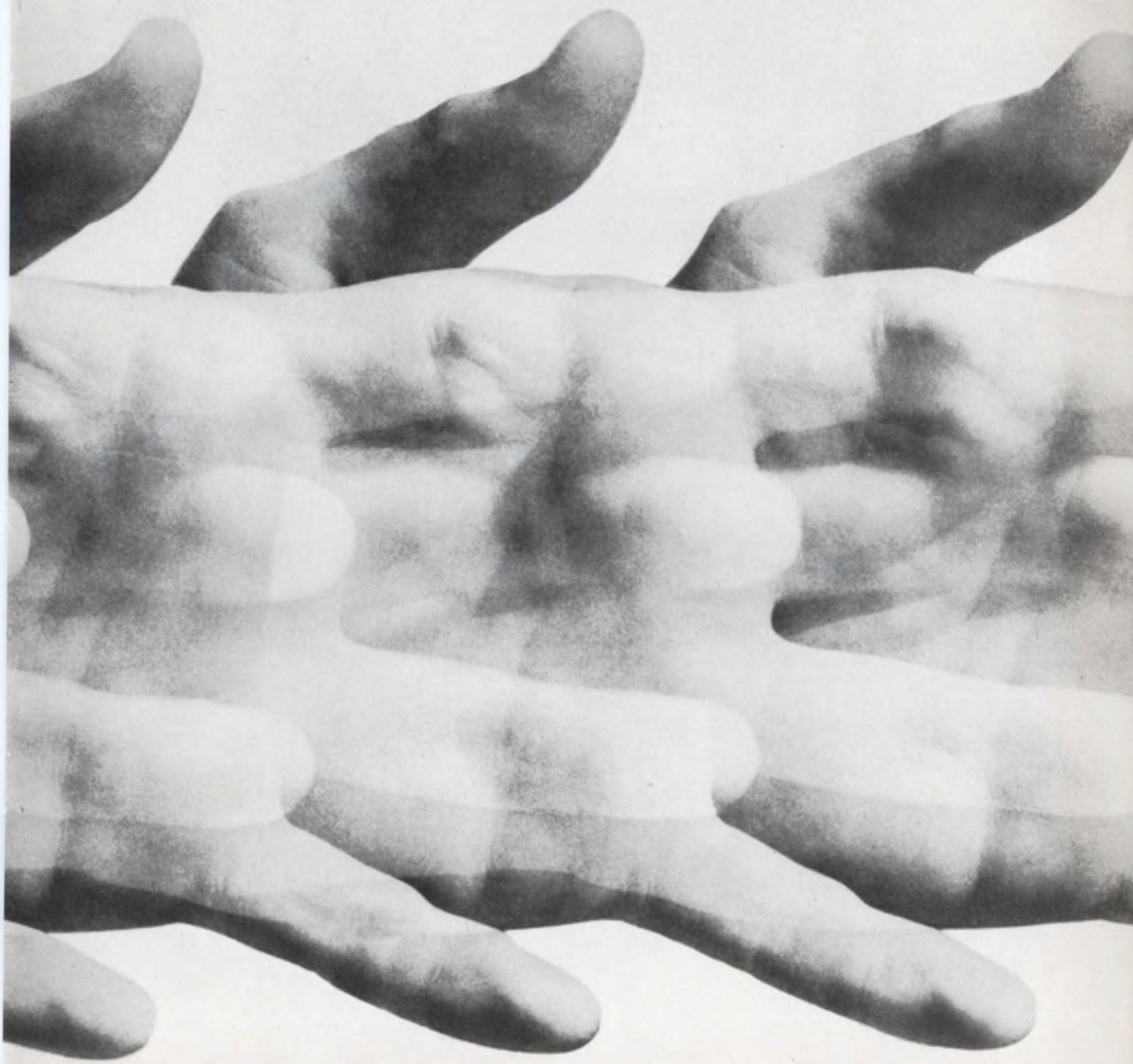

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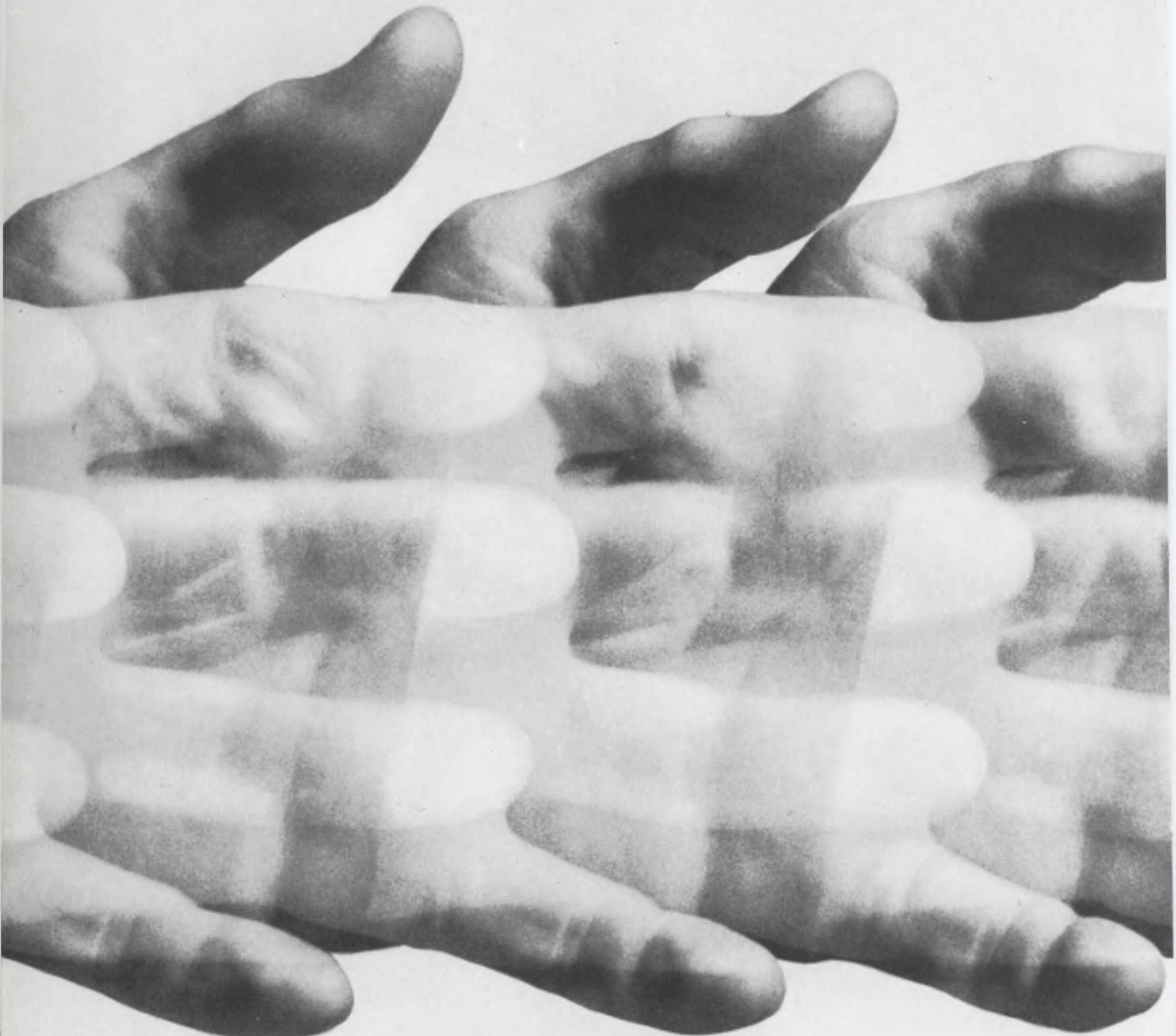
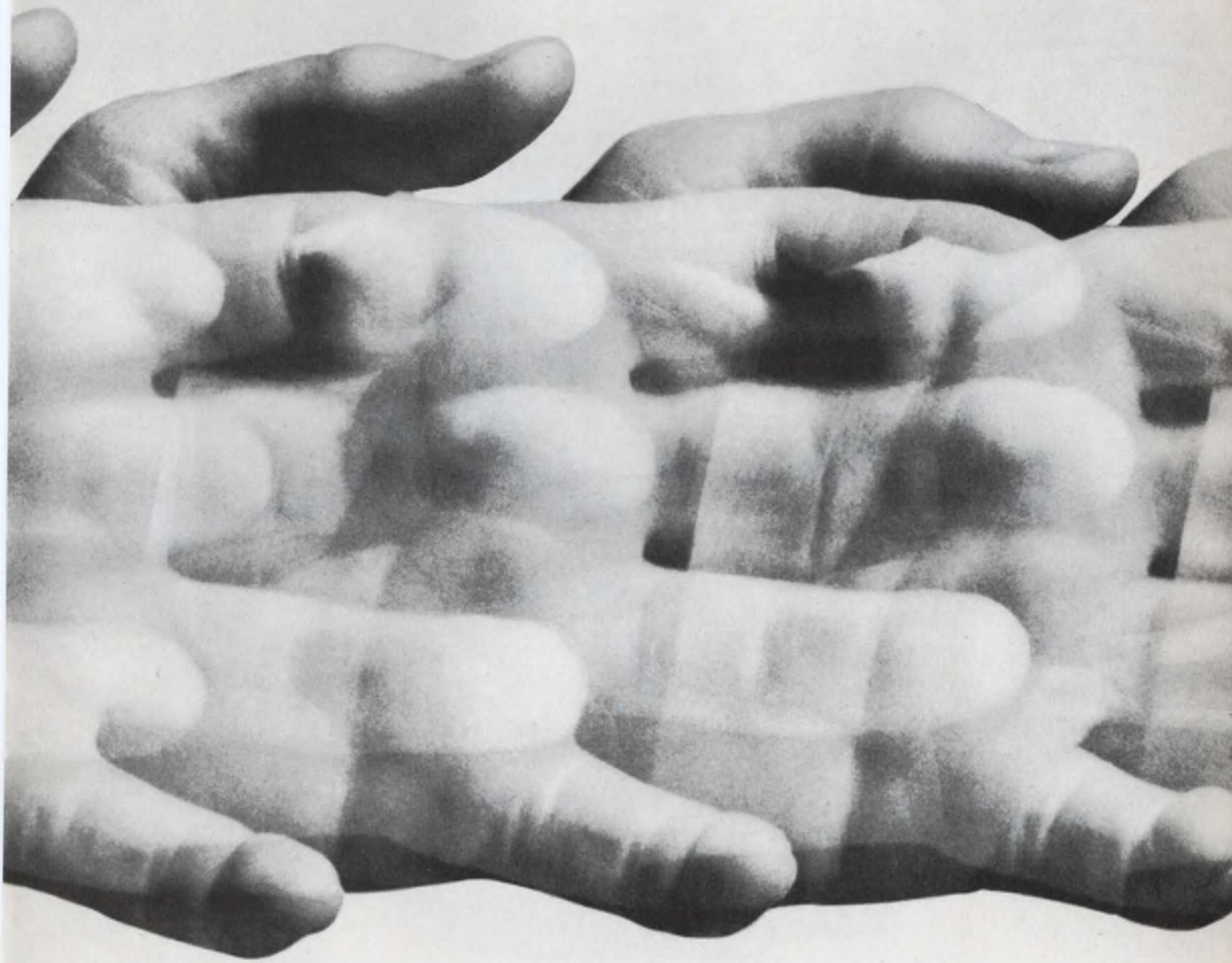


OWER



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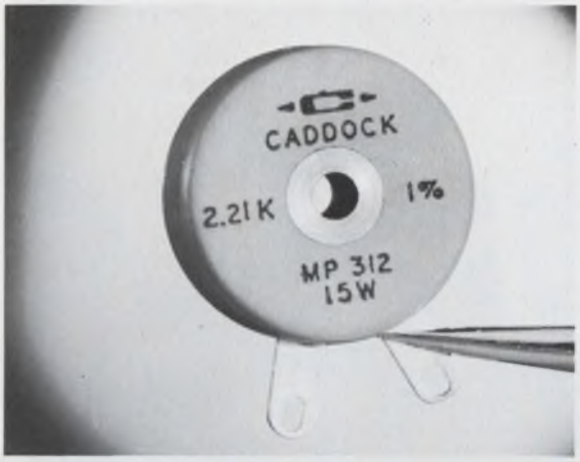
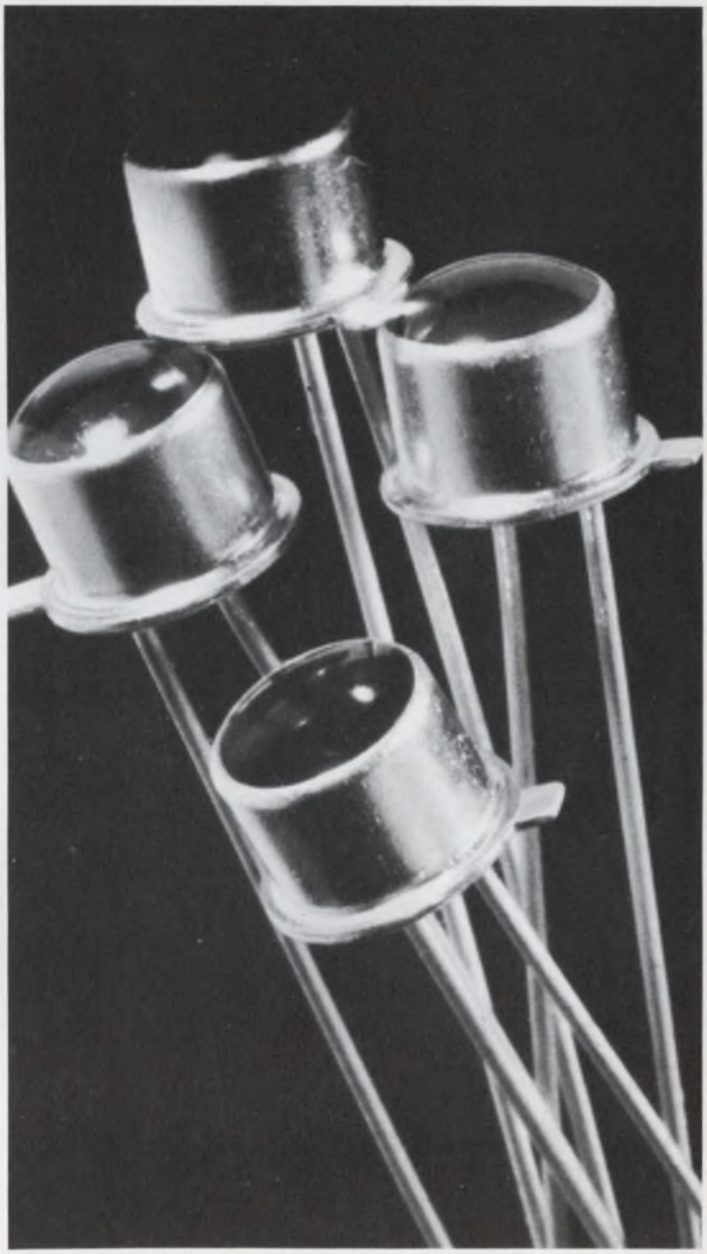


Low-profile disc power film resistors triple ratings and halve space. p. 141.

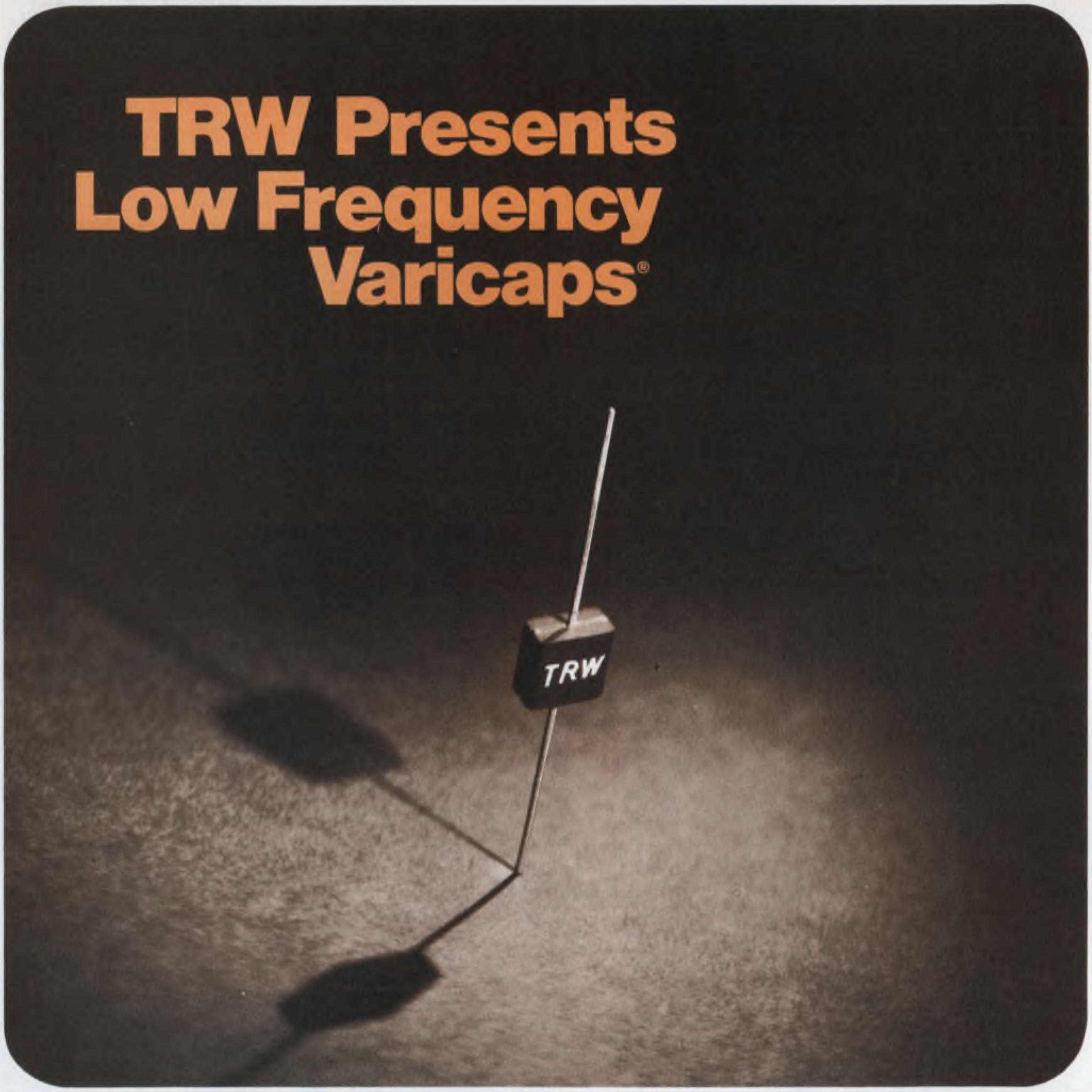
Data terminal prints up to 1200 words per minute over standard lines. p. 154.



Light-emitting diodes develop brightness of 120 foot-lamberts with 15-mW drive power. p. 148.

Also in this section:

Indicator lamp with built-in reflector acts like miniature spotlight, p. 141.
Low-cost compact 2-1/2-digit panel meter can be programed from the rear, p. 144.
Under-$10 operational amplifier delivers 5.5 mA at ±11 V, p. 160.
Design Aids, p. 174 . . . **Application Notes,** p. 178 . . . **New Literature,** p. 180.



High Capacitance... High Q... Low Noise

New TRW Varicaps make direct low frequency electronic tuning possible for the first time...from the high end of the broadcast band to 5 MHz and beyond.

Three high capacitance, single chip devices are available: PQ2150 at 150 pF, PQ2300 at 300 pF, and PQ2500 at 500 pF. All have less than 1 μA leakage, Q factor greater than 150, and 5:1 capacitance ratio over a 2 to 90 V sweep.

Ideal for electronic tuning in receivers, ADFs, NAVCOM systems, low frequency VCOs, TCXOs, and field strength instruments, these single element Varicaps provide inherent low noise and high stability.

Contact any TRW Distributor for complete information. TRW Semiconductors is a Subsidiary of TRW INC.

TRW®

INFORMATION RETRIEVAL NUMBER 54

Power film resistors circle out heat effects

Caddock Electronics, 3127 Chicago Ave., Riverside, Calif. Phone: (714) 683-5361. P&A: $3.60 or $4; 2 to 3 wks.

Maximizing heat transfer efficiency with a low-profile laminar disc configuration, series MP chassis-mounted power resistors can handle three times the power in less than half the space of conventional units. Model MP312 is a 15-W device that is half the size of previous 5-W resistors; model MP330 is a 30-W unit, only slightly larger than its 15-W counterpart.

Using a complex oxide resistive film called Micronox, the new resistors embody a radical new design. A ceramic washer with the Micronox film is placed on an aluminum disc that has a center post for screw mounting.

Contact is made with radial solder lugs, or with Teflon leads, and the entire structure is then molded with silicone. The bottom surface of the aluminum disc, however, remains exposed to transfer heat.

The solder-lug MP312 and its leaded sister, the MP311, have a maximum voltage rating of 600 V, and measure 0.6 in. in diameter by 0.188 in. high. The solder-lug MP330 and the leaded MP329 are rated at 1000 V. Their size is 0.85 in. in diameter by 0.25 in. high.

Resistances range from 10 Ω to 200 kΩ for the solder-lug versions, and from 50 Ω to 200 kΩ for the leaded units.

CIRCLE NO. 250

Miniature spotlight builds in reflector

Chicago Miniature Lamp Works, 4433 N. Ravenswood Ave., Chicago. Phone: (312) 784-1020. P&A: 52¢; stock.

Designated as CM38 Reflect-O-Lite, a new indicator lamp produces a controlled area of light output through the use of a built-in parabolic reflector. Available in standard 12-, 60- or 120-V models, the unit mounts in standard lamp holders and comes with a bayonet or candelabra base.

CIRCLE NO. 251

Coaxial T-3/4 lamp operates from ICs

Lamps, Inc., 17000 S. Western Ave., Gardena, Calif. Price: 88¢.

Only 0.093 in. in diameter, a new subminiature coaxial-contact lamp can be driven directly by ICs without buffer transistors. This unsupported-filament T-3/4 lamp uses a coaxial base for fast positive-contact installation without soldering. It is available in 1.5-V ratings with amperage of 0.01 or 0.015 A, and in 5-V ratings with amperage of 0.02, 0.06, 0.075, 0.08 or 0.115 A.

CIRCLE NO. 252

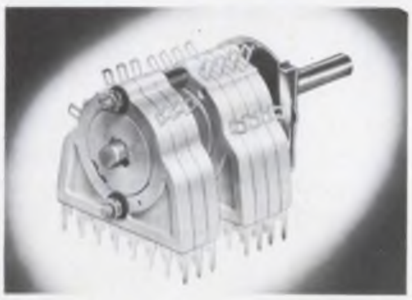
Ac/dc stepping motor moves 200 times/rev

IMC Magnetics Corp., 570 Main St., Westbury, N.Y. Phone: (516) 334-7195. Price: $40.

Useful as either an ac or dc device, a new motor achieves 200 steps per revolution in 1.8° increments when used as a dc stepper. As an ac synchronous motor, Tormax 200 can provide 72 rpm for a 60-Hz input and maintain remote devices in synchronism. As a dc stepper, it performs at rates as fast as 550 steps per second with a potential of over 1000 steps per second.

CIRCLE NO. 253

Molded wafer switches end contact problems



Standard Grigsby Co., div. of Standard Kollsman Industries, Inc., 920 Rathbone Ave., Aurora, Ill. Phone: (312) 897-8417. P&A: 40¢ to $3; 6 to 8 wks.

Using a new snap-lock rotor construction, series SKPC PC-board wafer switches eliminate the often faulty mechanical pressure linkage between stator and switch contact paths. These eight-terminal molded switch wafers with plug-in PC-board terminals have a one-piece metal stator contact path from the printed-circuit termination into the switching point.

CIRCLE NO. 254

Sixteen tiny lamps fit into 1 sq in.

Marco-Oak Industries, Oak Electro/Netics Corp., P. O. Box 4011, Anaheim, Calif. Phone: (714) 535-6037.

A new microminiature indicator light with a slide-based replaceable T-1 lamp is so tiny that 16 units can be mounted in a square inch. QT-Lite is available as a press-fit unit that can be serviced from the front panel without tools, or as a right-angle printed-circuit-terminal unit.

CIRCLE NO. 255

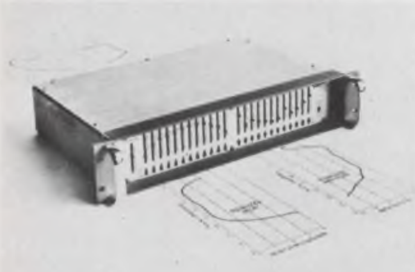
Subminiature pot is 0.35% linear

New England Instrument Co., Kendall Lane, Natick, Mass. Phone: (617) 873-9711.

A new 1/2-in.-dia precision rotary conductive-plastic potentiometer meets the high-accuracy requirements normally satisfied by larger units. Absolute standard linearities can be 0.35%, with special linearities as close as 0.15%. Resistance ranges from 250 Ω minimum to 130 kΩ maximum, and power rating is 1/2 W.

CIRCLE NO. 256

Signal conditioner equalizes data lines



Acton Laboratories, Inc., sub of Bowmar Instrument Corp., 531 Main St., Acton, Mass. Phone: (617) 263-7756. Price: $635.

Independently equalizing both amplitude and delay, a new line conditioner is designed for use in restricted-bandwidth information channels. Model 478A can condition any practical voice channel used for high-speed data transmission.

CIRCLE NO. 257

Low-cost compact DPM programs from rear

Digilin Inc., div. of Dura-Containers, Inc., 6533 San Fernando Rd., Glendale, Calif. Phone: (213) 246-8161. P&A: $139; 3 wks.

Selling for only $139, a new compact digital panel meter can be programed, from the rear panel, to measure dc voltage, current or resistance. Offering a 2-1/2 digit readout with 100% overrrange, model 250 has an accuracy of ±1% of reading, ±1 digit.

Using practically all-IC circuitry, the new meter achieves its price-performance breakthrough with a totally new sampling technique; the input is sampled and the display is changed 60 times per second.

Two stacked circuit boards inside the housing accommodate all components. One board contains the digital circuits, while the other has the analog circuits and the constant-current supply. As a result of this compact construction, the new meter occupies only 3.12 in. behind the panel. In addition, it is only 4.38 in. wide by 3.13 in. high.

Numeric plug-in Nixie-type tubes provide the digital readout, besides a numeral "1" indicator. Memory storage circuitry allows a non-blinking display.

The 250 DPM has a maximum range of 1000 V for voltage, 10 A for current and 100 kΩ for resistance. Maximum sensitivity is 10 mV, 100 nA and 10Ω, respectively.

Automatic zero adjustment eliminates drift and assures accuracy plus stability. Because of its self-contained power supply, the unit can operate directly from any ac line source. Response time is 20 ms.

CIRCLE NO. 258

INFORMATION RETRIEVAL NUMBER 59 ▶

ANOTHER BOURNS FIRST...

10 MIL-SPEC
TRIMPOT® POTENTIOMETERS

MIL-R-27208

MIL-R-22097

AVAILABLE FROM YOUR LOCAL BOURNS DISTRIBUTOR!

Bourns is the world's largest manufacturer of Adjustment potentiometers with 22 years of leadership. Bourns is also the largest manufacturer of MIL-Spec potentiometers backed by a total of 10 RT and RJ models in our line.

The 6 RT and 4 RJ models not only meet the specifications of MIL-R-27208 and MIL-R-22097, but each is designed and manufactured to consistently exceed each facet of these requirements.

As in the past, you can depend on Bourns to deliver the potentiometer you need. In this tradition of service, we now offer the MIL-Spec unit you may need for your next critical application with 10 RT and RJ models.

Full data is available from the factory, local field office, representative or your stocking distributor.

* Not yet stocked in depth by distributors.

BOURNS

BOURNS, INC., TRIMPOT PRODUCTS DIVISION
1200 COLUMBIA AVENUE, RIVERSIDE, CALIFORNIA 92507
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TRIMPOT® AND PRECISION POTENTIOMETERS • MINIATURE RELAYS • RESISTORS • ELECTRONIC MODULES • TRANSFORMERS • INDUCTORS AND CERAMICS

Transmission test set checks out noise too

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $625, 8 wks.

Replacing two or more voltage-measuring instruments, a new test set reads telephone transmission levels as well as message-circuit noise. Actually a voltmeter designed for telephone transmission quality measurements, model 35558 has wide bandwidth for transmission-level measurements and is rms-responding for noise measurements. Noise-weighting filters and impedance-matching transformers are built into the instrument.

CIRCLE NO. 259

Phase instrument has 40-dB range

Spectral Dynamics Corp., P. O. Box 671, San Diego, Calif. Phone: (714) 278-2501. P&A: $995; 1 wk.

A new phase meter, model SD110, features 40-dB dynamic range and a continuous frequency range from 5 Hz to 1 MHz. Over its 40-dB amplitude range (at 400 Hz) the meter provides an absolute detection accuracy of ±0.75 degrees. Signals as low as 30 millivolts are accepted, and offsets up to ±150 volts dc on each signal unusual feature of the instrument is a ΔCAL front-panel adjustment. input can be accommodated. An

CIRCLE NO. 260

Digital clock/calendars use ICs and Nixies

Chrono-log Corp., 2583 W. Chester Pike, Broomall, Pa. Phone: (215) 356-6771. Price: from $1040.

Costing approximately half as much as an equivalent transistor instrument, series 30,000 low-cost digital clock/calendars with Nixie display and buffered BCD outputs incorporate all-IC circuitry. The new instruments are available in over 7000 different combinations of options. This permits selecting a unit that will meet the requirements of virtually any system needing a digital output of time and date.

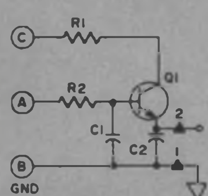
CIRCLE NO. 261

Programmable system measures 10-MHz inputs

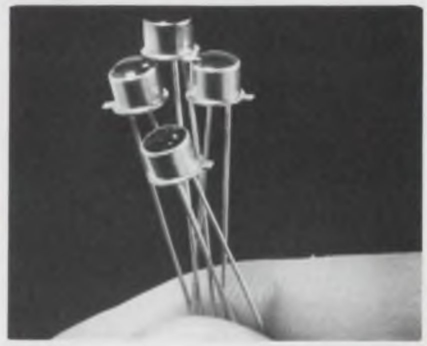
Singer Instrumentation Div., Ballantine Operation, 915 Pembroke St., Bridgeport, Conn. P&A: from $1950.

Offering both ac and dc converter capability coupled to a digital readout module, a new programmable measuring system is capable of making ac measurements to 10 MHz with a full-scale sensitivity of 10 mV. All panel functions are remotely programmable, and outputs can be interfaced with any analog or digital computer system. The readout is a four-digit display, plus overrange; automatic polarity sensing is standard.

CIRCLE NO. 262



Low-power LED brightens output

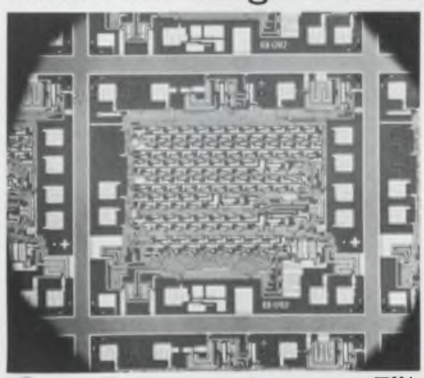


Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. Phone: (415) 326-7000. P&A: $4.90; stock.

With only 15-mW drive power (10 mA at 1.5 V), a new gallium-arsenide-phosphide light-emitting diode achieves a typical brightness of 120 foot-lamberts. Useful as a panel and circuit-status indicator, type 5082-4400 produces a bright red light with a wavelength of 660 nanometers. Allowable power dissipation is 85 mW continuous.

CIRCLE NO. 263

Dynamic register varies its length



Electronic Arrays, Inc., 501 Ellis St., Mountain View, Calif. Phone: (415) 964-4321. P&A: $16; stock.

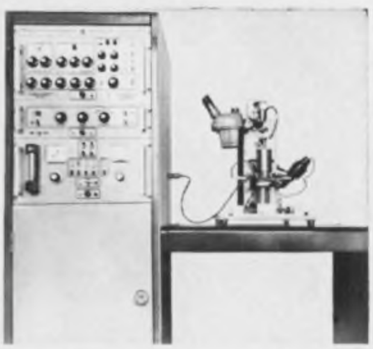
Said to be an industry first, an electronically adjustable dynamic MOS shift register can have a fixed or variable register length between 1 and 64 bits. This is implemented by the logic state of six register-length control inputs, while data input and output leads remain fixed. Model 1203 operates up to 1 MHz with a single-phase 9-V clock; model 1202 operates up to 3 MHz with a two-phase 24-V clock.

CIRCLE NO. 264

Introducing a new model— the AT-701A

See all the people who came to see our new Model AT-701*A*. Are *you* in the photo?

AT-701A, as you've probably guessed, is an improved version of our fabled, pioneering Model AT-701. Based, like the other S. S. White systems—the Model LAT-100 (the $6,000 system) and the Model AT-704 (the 4,000 per hour system)—on the proven Airbrasive® method for clean, shockless, and noiseless removal of resistance material, without altering the substrate. Precise electronics monitor resistance during the trimming cycle, give 'stop' command when preset value is reached.



Yes, it sells for less, but be a good chap and read the text of the ad anyway . . . please?

Accuracy with the AT-701A is *guaranteed* at ± 0.5%, with 0.1% frequently attainable. Capacity is up to 600 trims/hour; tolerances may be set from 0 through ± 11% with resolution of 0.1%. Final resistance values can be programmed through 5 digits and four multipliers giving four ranges from 0 to 10K and through 0 to 10M.

In fact, in performance, the AT-701A is exactly similar to its non-A predecessor, though it looks a bit different. What's interesting about it, though is this:

It sells for a lot less money. (The number to call (collect) is 212-661-3320. Ask for Hal Skurnick.)

Output of the Model AT-701A can be doubled via a new optional rotary feeding table. Table features automatic gripping of substrates up to 2" x 2", automatic indexing and positioning of substrate for trim. Operator has merely to drop in untrimmed substrates and pick out the trimmed ones. *Doubles production.*

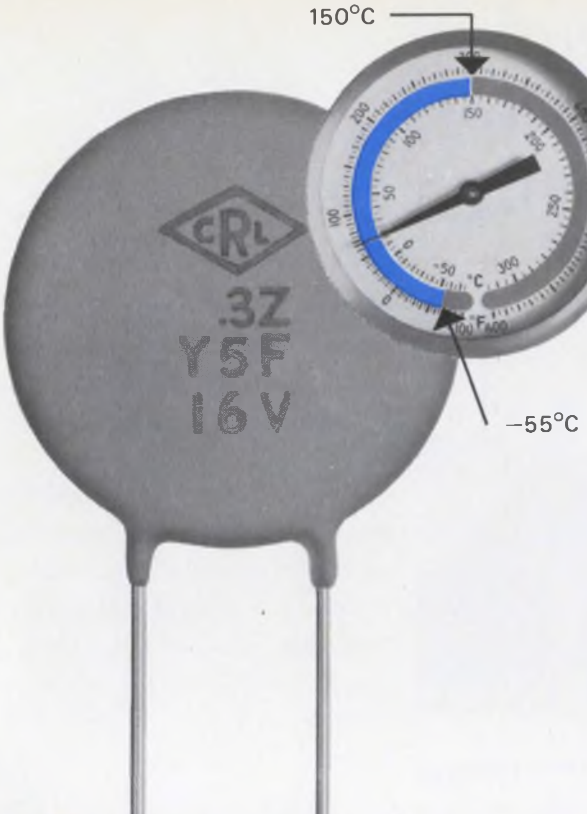
Modesty prevents our saying that the AT-701A, with its carousel feeder stole the IEEE show; it does not prevent our saying that many who came to visit us actually looked at the machine (instead of the pretty girls). If you missed the Show, you'll be happy to know that we will again be demonstrating the AT-701A at the Nep/Con show, June 10, 11, and 12, at the Coliseum.

New turntable for the Model AT-701A really zonks up feeding speed, output. By how much we don't know yet, but we estimate that it will double system's output.

S. S. White Division, Pennwalt Chemicals Corp., Dept. 28, 201 East 42nd Street, N.Y., N.Y. Tel.: 212-661-3320

PENNWALT
S.S.WHITE
INDUSTRIAL PRODUCTS

INFORMATION RETRIEVAL NUMBER 63



Centralab gives transistor circuits longer, more reliable performance with NEW 16, 25 & 50 volt Ultra-Kaps®

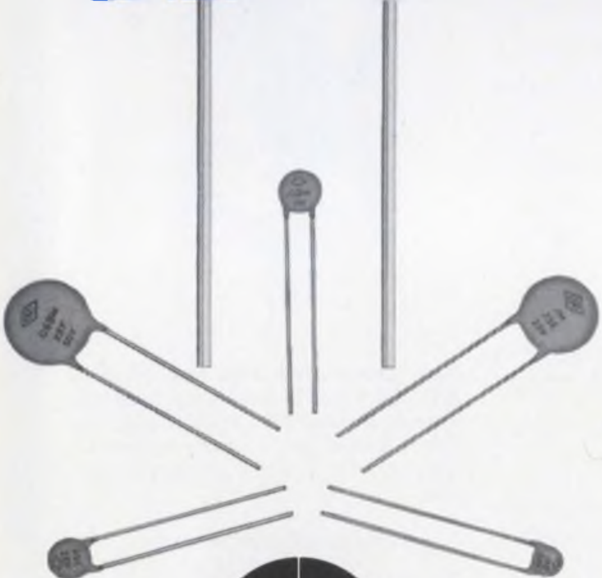
Centralab engineers have achieved a new degree of temperature stability in semiconductor type, low voltage ceramic disc capacitors with their development of temperature-stable Ultra-Kaps. The 16 and 25 volt units can hold a maximum capacitance change of ±4.7%; 50 volt units as little as ±7.5%.

Ultra-Kaps also exhibit other superior performance characteristics, such as low impedance; high capacitance density; and operation to temperatures as high as 150°C, as low as −55°C. In 50v ratings average dissipation factor is as low as 1.5%; leakage resistance of 1000 megohms, min.

the stable ones

Ultra-Kaps are ideal for use in transistor circuits because they are operable to a frequency of 1 MHz. And they're still low cost units that replace more expensive mylar and "Hi-K" ceramic capacitors. On quantity orders, they're priced as low as 2½ cents each with delivery as short as 4 to 5 weeks. We can send you samples immediately for your evaluation.

Don't let your design plans melt away because of inferior capacitor performance. Get the ultimate, Centralab's stable Ultra-Kaps.



	16 volt		25 volt		50 volt	
Max. Diameter	Max. Cap. MFD	Min. I.R. Megohms	Max. Cap. MFD	Min. I.R. Megohms	Max. Cap. MFD	Min. I.R. Megohms
.290	.02	5.0	.015	65.0	.01	1000
.390	.033	3.0	.022	45.0	.015	1000
.405	.05	2.0	.033	30.0	—	—
.485	—	—	—	—	.022	1000
.515	.068	1.5	.05	20.0	.033	1000
.590	0.1	1.0	.068	15.0	.047	1000
.690	0.15	0.65	0.1	10.0	.05	1000
.760	—	—	—	—	.068	1000
.820	0.2	0.5	0.15	6.5	—	—
.920	0.3	0.33	0.2	5.0	0.1	1000

*Thickness: .156 inches maximum
Lead spacing: Discs less than .500″ diameter, nominal lead spacing is .250″
Discs .500″ and larger, nominal lead spacing is .375″

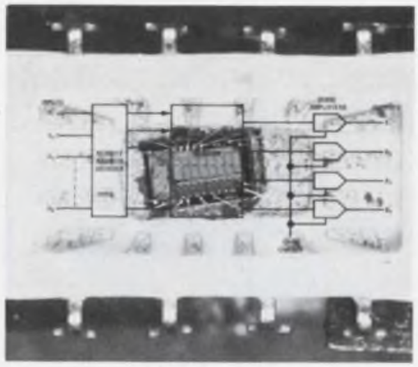
CENTRALAB
Electronics Division
GLOBE-UNION INC.
5757 NORTH GREEN BAY AVENUE
MILWAUKEE, WISCONSIN 53201

M-6901

FOR MORE INFORMATION AND/OR DESIGN ASSISTANCE, WRITE CAPACITOR SALES MANAGER, CENTRALAB.

INFORMATION RETRIEVAL NUMBER 64

MOS memory clocks itself

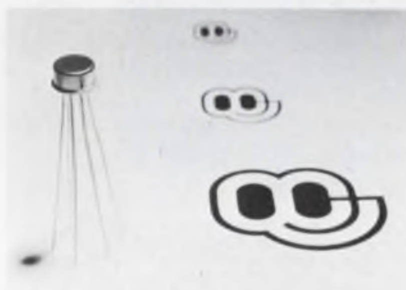


National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-4320. P&A: $54; 6 wks.

Arranged as 256 four-bit words, a new 1024-bit MOS read-only memory requires no external clock because of its on-chip dc-coupled logic. Completely compatible with DTL or TTL circuits, model MM521 has non-volatile data storage and operates in less than 1 μs. Gate protection diodes are used on all inputs to protect against static charge build up.

CIRCLE NO. 265

Dual npn transistors hold noise to 3 dB



Qualidyne Corp., 3699 Tahoe Way, Santa Clara, Calif. Phone: (408) 738-0120. Price: $1.75 to $7.30.

Featuring low noise, close matching and high voltage breakdown characteristics, a new series of npn dual transistors offer maximum noise figures of 3 dB at 1 kHz and breakdown voltages as high as 60 V. Types 2N2913 to -20 have a tracking accuracy of 10 μV/°C at 100 μA. Current gain is 150 minimum at 10 μA. They are packaged in six-lead TO-5 metal cans.

CIRCLE NO. 266

Miniature zeners take 250-W surge

Unitrode Corp., 580 Pleasant St., Watertown, Mass. Phone: (617) 926-0404. P&A: from $3.90; stock.

With voltage ratings from 10 to 220 V, a new series of miniature 5-W zener diodes can absorb surges as large as 275 W. Types JAN IN4958 through JAN IN4990 have tolerances of 5% and meet all the requirements of MIL-S-19500/356. The metallurgically bonded units have a fused-in-glass voidless construction that does not use plastic.

CIRCLE NO. 267

High-speed TTL ICs delay only 7 ns

RCA/Electronic Components, 415 S. Fifth St., Harrison, N. J. Phone: (201) 485-3900. Price: $1.45 to $4.55.

Providing 16 logic functions with a choice of two temperature ranges, a new digital high-speed TTL IC family of 48 diversified types offers basic gate propagation delays of 7 ns with an average power dissipation of only 11 mW. Series CD2400 circuits have input clamp diodes to prevent false triggering due to ringing and low impedance. Darlington output circuits provide high-capacity drive capability with balanced rise and fall delay times.

CIRCLE NO. 268

Transistors and ICs resist radiation damage

Texas Instruments Inc., Components Group, P.O. Box 5012, Dallas, Tex. Phone: (214) 238-2011.

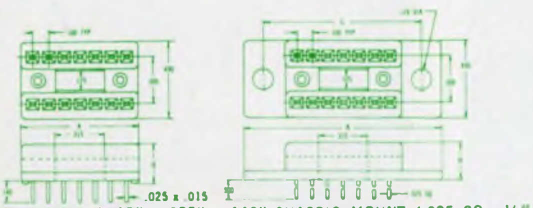
Ten new radiation-tolerant semiconductor devices include: two silicon small-signal transistors, 2N5332, 2N5399; two silicon power transistors, TIXP39, TIXP40; five DTL integrated circuits, RSN-15930, RSN15932, RSN15944, RSN15945, RSN15962; and one IC operational amplifier, RSN52709. All the circuits use dielectric isolation, thin-film NiCr resistors, optimized component geometries and layouts, oxide passivation, and aluminum interconnect systems.

CIRCLE NO. 269

DUAL-IN-LINE IC SOCKETS

14 and 16 CONTACT SOCKETS

- **Styles for PC** board or chassis mounting in the smallest overall size — ideally suited for prototype, test or production packaging.
- **For all** 14 and 16 lead IC packages with leads on .1" centers in row and .3" between rows.
- **Accepts any package** with round, square, rectangular, hollow or solid leads with a cross section of .008" to .023" and .090" minimum lead length.
- **Large** funneled lead entry holes with closed entry low insertion force contacts provide fast easy insertion.
- **All styles** have a .315" x .155" open-thru center section and a recess at either end to allow for a variety of package extraction methods.
- **Contacts** are captivated within the socket body and cannot be accidentally pulled or pushed out.
- **Choice** of Contact Terminations suitable for soldering into PCB's, or hard wiring of up to 3 wires per terminal.



PCB MOUNT (.015" x .025" x .140" LONG TERMINAL ILLUSTRATED) CHASSIS MOUNT (.025 SQ x ½" LONG TERMINAL ILLUSTRATED)

Part No.	No. Contacts	Termination	A	B
IC-143-SW	14	.025" SQ x ½" Long	.750"	.260"
IC-163-SW	16	.025" SQ x ½" Long	.850"	.260"
IC-143-S1	14	.015" x .025" x .140" Long	.750"	.250"
IC-163-S1	16	.015" x .025" x .140" Long	.850"	.250"

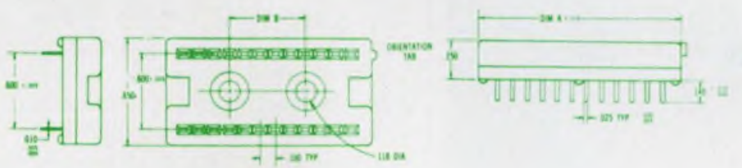
Part No.	No. Contacts	Termination	A	B	C
IC-143-CW	14	.025" SQ x ½" Long	1.275"	.240"	1.025"
IC-163-CW	16	.025" SQ x ½" Long	1.375"	.240"	1.125"
IC-143-C1	14	.015" x .025" x .140" LONG	1.275"	.230"	1.025"
IC-163-C1	16	.015" x .025" x .140" LONG	1.375"	.230"	1.125"

24 and 36 CONTACT SOCKETS

Part No.	No. of Contacts	A	B
IC-246	24	1.3"	.5"
IC-366	36	2."	1."

Tolerances: Decimals ±.005"; Fractions ±1/64" — unless otherwise specified

- **For all 24 and 36 lead IC packages** with leads on .1" centers in row and .6" between rows.
- **All styles have** a recess at either end to allow for a variety of package extraction methods.
- **Contact Terminations** suitable for soldering into PCB's, or hard wiring.



Robinson NUGENT INCORPORATED

802 EAST EIGHTH STREET NEW ALBANY, INDIANA 47150
AREA CODE: 812-945-0211

INFORMATION RETRIEVAL NUMBER 68

NEW!

$20.00 each

PROBE HEAD ASSEMBLY

DESIGNED FOR THICK AND THIN FILM APPLICATIONS

FEATURES:

- **"Snap-in" probe point**
- **Magnetic base**
- **6-1 ratio joystick for fine positioning**
- **Height and pressure adjustment**

Request Probe Head Assembly Bulletin 1068

Also available . . . the New **MP-0200 Microcircuit Prober** accommodates up to 34 Probe Head Assemblies on pre-wired ring. Features include an automatic vacuum system for substrate hold-down; an interchangeable chuck and a shielded double flat cable interface with connectors. Rate: 700-900 substrates/hour.

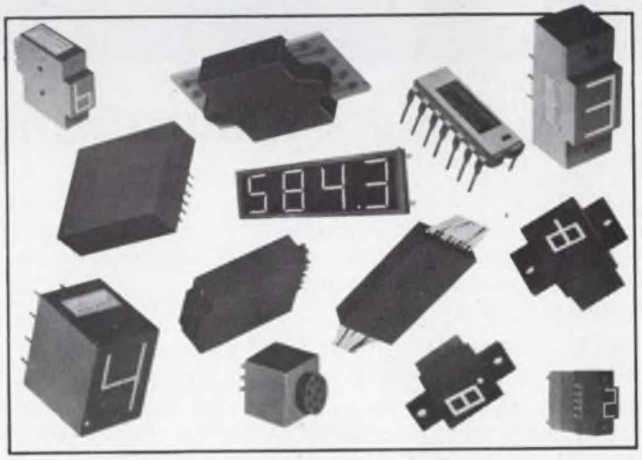
WENTWORTH LABORATORIES INC.

ROUTE 7, BROOKFIELD, CONN. 06804 — (203) 775-1750

INFORMATION RETRIEVAL NUMBER 69

DIGICATOR®

Numeric Readouts and Decoder/Drivers



YOUR SOURCE FOR THE MOST EXTENSIVE LINE OF:

BAR-MATRIX DISPLAYS AND DECODER/DRIVERS

★ MIL-SPEC AND COMMERCIAL
OFF THE SHELF DELIVERIES

DISCON CORPORATION

1150 NORTHWEST 70th STREET • FT. LAUDERDALE, FLORIDA 33309
PHONE: (AREA CODE 305) 933-4551

INFORMATION RETRIEVAL NUMBER 70

Fast electronic terminal ousts teletypewriters

General Electric Co., Specialty Control Dept., Waynesboro, Va. Phone: (703) 942-8161.

Through the use of a unique printing concept, a new electronic data communications terminal achieves speeds of 10, 15 and 30 characters per second—two to three times faster than other similar equipment. TremiNet 300 can be used in private and commercial time-sharing systems, as well as terminal-to-terminal communications. It is a completely self-contained unit, with all transmitting and receiving electronics contained in a single package about the size of an office typewriter.

CIRCLE NO. 270

Computer terminal prints 1200 words/min

Teletype Corp., 5555 Touhy Ave., Skokie, Ill. Phone: (312) 676-1000.

Capable of printing up to 1200 words per minute, a new high-speed terminal operates 12 times faster than conventional data communications equipment. Called Inktronic, the unit can operate over regular telephone lines, despite its very fast speed. Since it requires only voice-grade channels, computer time sharing is expected to be a large application.

CIRCLE NO. 271

Disc-drive synchronizer downs errors to 100 ns

Sequential Information Systems, Inc., 66 Saw Mill River Rd., Elmsford, N. Y. Phone: (914) 592-8810.

Providing precise speed/phase and indexing control of magnetic disc files, a new system permits an unlimited number of individual disc drives to be synchronized with a time displacement error between drives of less than 100 ns. Model DS360 disc-drive synchronization system couples individual drives with an external reference frequency that can be derived from the main computer clock.

CIRCLE NO. 272

Industrial computer is IBM compatible

General Automation, Inc., Automation Products Div., 706 W. Katella Ave., Orange, Calif. Phone: (714) 633-1091. P&A: from $20,000; summer, 1969.

Aimed at the burgeoning industrial automation market, the new 18/30 computer, which is fully compatible with the IBM 1800 and 1130 systems, can process over 400,000 instructions per second. This new computer will function as the supervisory computer system for automation projects in many industries. Its processor has a 960-ns memory that is available in sizes up to 32k words.

CIRCLE NO. 273

Data instruments perform at 180 kHz

Raytheon Co., Computer Operation, 2700 S. Fairview St., Santa Ana, Calif. Phone: (714) 546-7160. Price: $5800 to $8200.

Combining a multiplexer, a sample-and-hold amplifier and an analog-to-digital converter, three new instruments with 12-bit formats offer throughput rates of 90 kHz, 135 kHz and 180 kHz. Miniverter units can operate in a short-cycle mode for higher throughput at fewer bits resolution. All the instruments are capable of both sequential and random-address operation.

CIRCLE NO. 274

CRT display terminal has I/O compatibility

Delta Data Systems Corp., 613 W. Cheltenham Ave., Philadelphia. Phone: (215) 224-0700. P&A: $4500 to $7000; 90 days.

A new low-cost CRT display terminal features full computer-systems input/output and video compatibility. The Delta 1 video display terminal uses the same type of input/output logic circuitry as do small computer systems. In its graphics mode, the unit can display lines, circles, curves and characters.

CIRCLE NO. 275

Where the action is...

is where you need Tungsten and sintered metal contacts

Especially if the action calls for heavy duty performance. H. A. Wilson special powder metallurgy processes make possible contacts of sintered metals that cannot be alloyed. Tungsten offers the properties needed for higher voltages and currents. Contacts in rivet form, steelbacks, faced screws, discs, washers, and special shapes. Assemblies are available riveted, hot upset, welded and brazed.

Let the H. A. Wilson Technical Service Department advise you as to the best form, type and size of contact . . . type of material, method of attaching, and best spring to use.

ENGELHARD

ENGELHARD INDUSTRIES DIVISION
ENGELHARD MINERALS & CHEMICALS CORPORATION
2655 U. S. ROUTE 22, UNION, NEW JERSEY 07083

INFORMATION RETRIEVAL NUMBER 75

SNOB KNOB

The first new styling innovation in fifteen years!

900 Series Snob Knobs come in four bright, handsome models. Spun aluminum cap. Spun aluminum inlay. Decorative metallic ring. And Black. From 1/2" to 1 3/4" diameter.

Kurz-Kasch is known as the quality knob source by electronics manufacturers the world over. If you're not familiar with the outstanding Kurz-Kasch line, we'll send you a complete catalog. And if you're just anxious to see the new Snob Knob, we'll send you a free sample.

Kurz-Kasch, Inc.
Standard Parts Division • 1415 S. Broadway
Dayton, Ohio 45401 • Phone 223-8161

INFORMATION RETRIEVAL NUMBER 77

Self-equalized modem delivers 9600 bits/s

International Communications Corp., sub. of Milgo Electronic Corp., 7620 N. W. 36th Ave., Miami, Fla. Phone: (305) 691-1220. P&A: $11,500; December, 1969.

Transmitting information at the rate of 9600 bits per second, a new high-speed data set can operate over voice-grade telephone lines without requiring complex automatic equalizers. The new modem, model 5500/96, achieves this performance with a unique narrowband design.

CIRCLE NO. 276

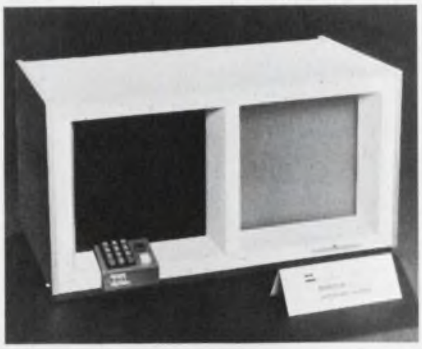
Video terminal is IBM compatible

Ultronic Systems Corp., Mt. Laurel Industrial Park, P. O. Box 315, Moorestown, N. J. Phone: (609) 235-7300. Price: $5000.

Said to offer dramatic savings over other currently available systems, a new low-cost general-purpose alphanumeric display system is both hardware- and software-compatible with IBM System-360 units. Videomaster 7000, which includes a display monitor and a standard alphanumeric keyboard, can present 960 displayable characters on its 74-in.² screen.

CIRCLE NO. 277

Microfilm console reads and displays



Microfilm Data Systems, Inc., Suite 1507, Palo Alto Office Center, Palo Alto, Calif. Phone: (415) 327-6495.

In a single cabinet, a new electronic console combines the advantages of a high-density microfilm reader with a computer display terminal. Called the Mindex, the automatic computer reader/terminal looks like a dual-screen television set. This ultrafilm (high-density microfilm) viewer also features automatic keyboard retrieval controls.

CIRCLE NO. 278

Disc pack coating resists static charges

3M Co., 3M Center, St. Paul, Minn. Phone: (612) 733-7297.

A new conductive coating for Scotch Brand 911 disc pack, which is compatible with all IBM 2314 drive systems, minimizes the development of static charges that cause phantom errors and collection of dust and contamination. The build-up of these charges is particularly critical in the 2314 systems because of the reduced thickness of the air-bearing film between the flying head and disc surface.

CIRCLE NO. 279

Low-cost amplifier supplies 5.5 mA

Data Device Corp., 100 Tec St., Hicksville, N.Y. Phone: (516) 433-5330. P&A: $9.75; stock to 3 wks.

Costing only $9.75 each, series D-2 operational amplifiers guarantee a minimum output of 5.5 mA at ±11 V. Voltage drift is 10 μV/°C and current drift is 0.2 nA/°C. At rated load, dc open-loop gain is 90 dB; frequency for full output is 50 kHz. All units have input overvoltage protection and output short-circuit protection. Unity-gain frequency is 1.5 MHz.

CIRCLE NO. 280

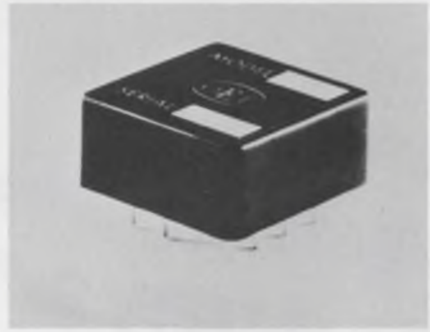
Thick-film network enhances Q factor

Kinetic Technology Inc., 17465 Shelburne Way, Los Gatos, Calif. Phone: (408) 356-2131. P&A: $12; 2 wks.

Useful from dc to 500 kHz, a new negative resistor is a Q-enhancement device designed for use with LC networks in telephone and tone signaling applications. Model HR-28 operates from a single supply and contains two identical thick-film active networks in a DIP configuration. Negative resistance values range from 4 to 300 kΩ.

CIRCLE NO. 281

Wideband op amp slews at 600 V/ μs



Optical Electronics Inc., P.O. Box 11140, Tucson, Ariz. Phone: (602) 624-8358. P&A: $95; stock.

With full output slewing of ±600 V/μs over video frequencies, a new operational amplifier settles to 0.1% of final output amplitude within 55 ns. Model 9186B has a minimum open-loop gain of 60 dB, a gain-bandwidth product of 1000 MHz, and a common-mode rejection of 70 dB at 1 MHz. Applications include high-speed d/a converters and integrators, as well as wideband amplifiers.

CIRCLE NO. 282

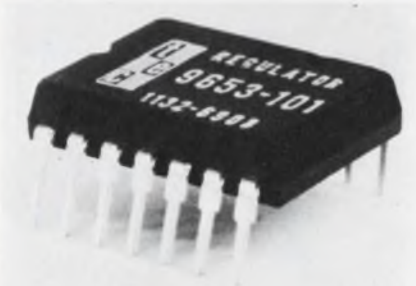
High-output amplifier maintains 5 × 10^5 gain

Analog Devices, Inc., 221 Fifth St., Cambridge, Mass. Phone: (617) 492-6000. P&A: $36 or $46; stock.

Delivering ±20-V output swing at 20-mA rated full-load current, a new differential amplifier sustains its open-loop dc gain of 500,000. Model 163 has a 50-kHz full-power inverting response, 6-V/μs slewing rate and 0.6-nA/°C maximum bias current drift. Voltage drift is ±5 μV/°C for model 163K and ±20 μV/°C for model 163A.

CIRCLE NO. 283

Thick-film regulators supply 250 mA output

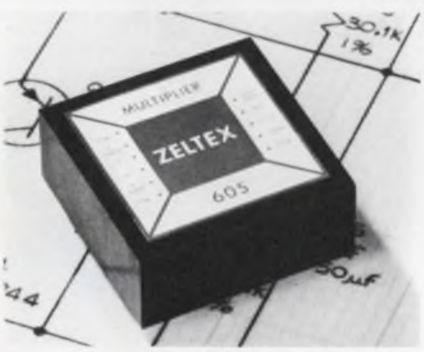


Transformer Electronics Co., P. O. Box 910, Boulder Industrial Park, Boulder, Colo. Phone: (303) 442-3837. Price: $27.50 to $29.50.

Without external pass devices, four new dual-in-line hybrid thick-film voltage regulators develop a maximum output current of 250 mA. Models VR1050, VR1150, VR120 and VR2150 offer fixed voltages of 5, 15, 20 and −15 V respectively. Typical load regulation, no load to full load is 300 μV; typical line regulation, for inputs of 22 to 40 V, is 2 mV.

CIRCLE NO. 284

Analog multiplier errs but 2%

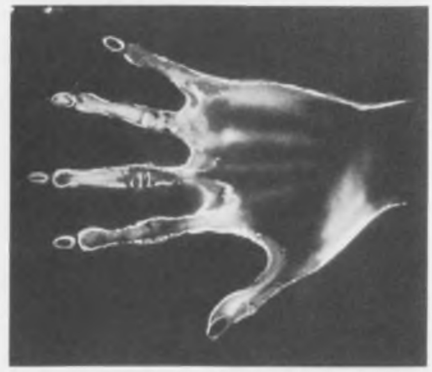


Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. Phone: (415) 686-6660. P&A: $48; stock.

With no external amplifiers or components, a new self-contained four-quadrant multiplier has a maximum error of only 2% (200 mV at ±10-V output). The addition of four external trim potentiometers to model 605 reduces error to 1% maximum. Output noise is only 1 mV rms from dc to 100 kHz. The unit can perform multiplication, squaring, division and square-root operations.

CIRCLE NO. 285

Liquid-crystal kits simplify handling

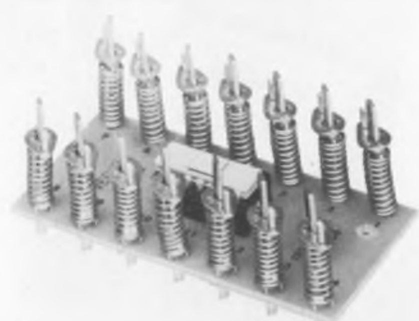


Edmund Scientific Co., 380 Edscorp Building, Barrington, N.J. Phone: (609) 547-3488. Price: $4 or $10.

Eliminating formerly messy processes as well as the danger of contamination, two new kits of encapsulated liquid crystals consist of tiny micron capsules that contain the liquid crystals and six mylar sheets. Each mylar sheet covers a specific temperature range. One kit, model 71143, has 6 by 12 in. sheets; the other, model 60756, has 4 by 6 in. sheets.

CIRCLE NO. 286

Solderless socket breadboards DIPs

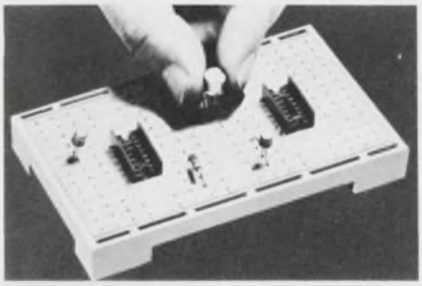


Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, Calif. Phone: (213) 365-9661. Price: from $3.95.

Designed for prototype work with 14-pin DIP integrated circuits, a new IC breadboard socket allows solderless connections to any terminal pin. Model 570G consists of an epoxy glass wafer on which is mounted a 14-pin dual-in-line socket with terminals soldered to two adjacent rows of solderless spring-type terminals.

CIRCLE NO. 287

IC breadboard accepts discretes



Intratec Div., British Aircraft Corp. (U.S.A.) Inc., 399 Jefferson Davis Highway, Arlington, Va. Phone: (703) 684-6404.

A new breadboarding kit uses standard push-in carriers to accommodate all types of IC packages as well as discrete components; double-leaf spring contacts permit components to be used again. Typical layouts of four 10-lead TO-5 packages or two DIP stations are provided for by 208 numbered contact points. Two models are available, the μ-DeCA and the μ-DeCB with two DIP sockets.

CIRCLE NO. 288

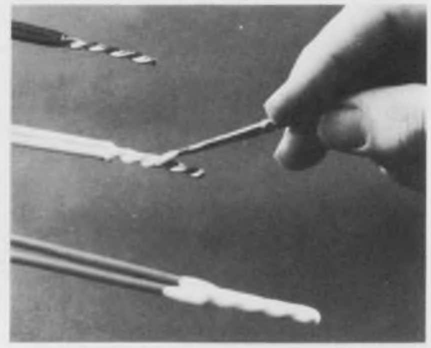
Water-soluble flux stays chloride-free

London Chemical Co., Inc., 240 Foster Ave., Bensenville, Ill.

Completely free of chloride, a new water soluble soldering flux is particularly useful in applications involving critical copper soldering. Its outstanding rinsability in water-wash after-soldering cleaning systems eliminates white spots and chemical dimpling on printed surfaces. Organo-flux AM-C-4 can be applied by dipping or brushing.

CIRCLE NO. 289

Non-corrosive silicones come ready to use



Dow Corning, Engineering Products Div., Midland, Mich. Phone: (517) 636-8510. Price: $8.80 or $11/lb.

Two new ready to use silicone insulating materials feature a room-temperature curing system (24 hours) that does not give off corrosive by-products. Type 3141 RTV coating is a white liquid rubber for use as a conformal coating or potting material. Type 3144 RTV adhesive/sealant is a translucent high-strength nonflowing material for sealing, mounting, insulating and bonding.

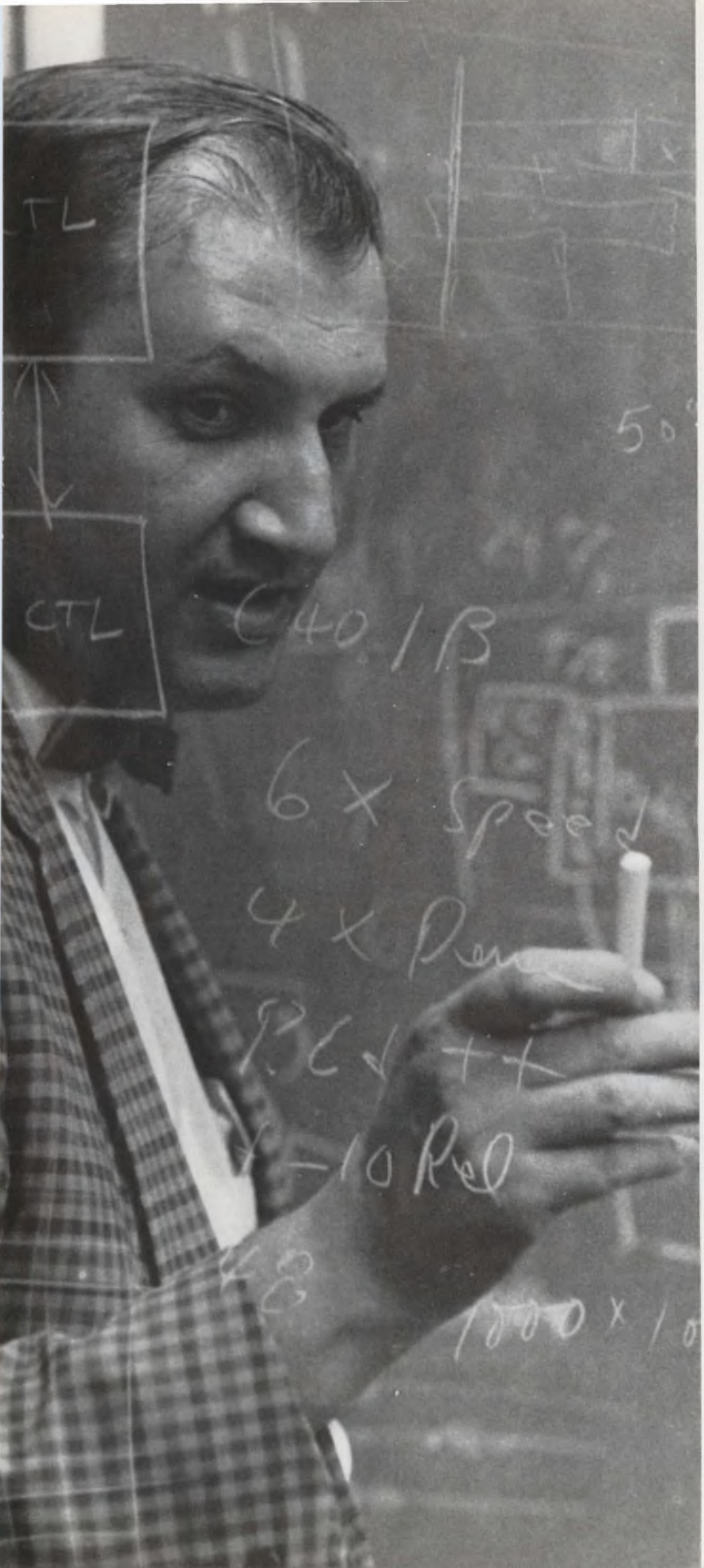
CIRCLE NO. 290

Small connectors are 14-pin DIPs

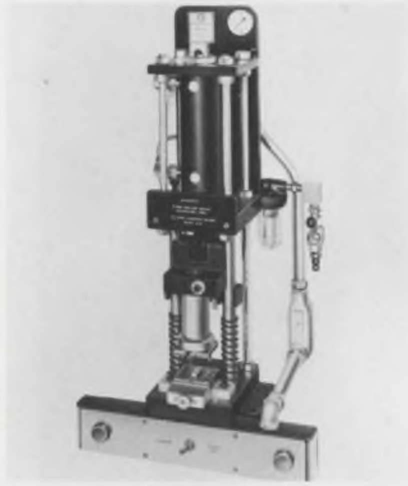
DPA, 1600 N. Arrowhead Ave., Suite 9, San Bernardino, Calif. P&A: 75¢; stock to 2 wks.

Accommodating wires as large as AWG #24, new miniature 14-pin connectors plug into dual-in-line IC sockets with standard 0.1 by 0.3-in. grids. The new DIP connectors may be used for mounting discrete components from pin to pin, as well as for connecting wires. All pins are gold-plated.

CIRCLE NO. 291



IC lead bender is air-operated

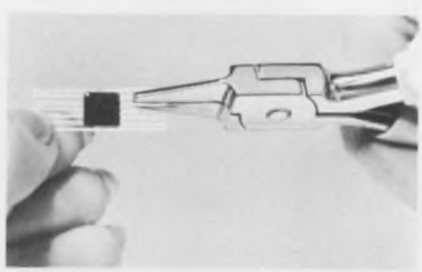


D-Vel Research Laboratories, Inc., 555 Bedford Rd., Bedford Hills, N. Y. Phone: (914) 666-3455.

Model 100-AC air-operated integrated-circuit lead bender achieves production rates of several hundred pieces per hour with little or no operator fatigue. The new bending press operates from 80 to 100 pounds of shop air pressure and can be supplied with self-contained pushbutton control for maximum operator safety or with a foot valve.

CIRCLE NO. 292

Flatpack cutter trims each lead



ETM Corp., 144 W. Chestnut Ave., Monrovia, Calif. Phone: (213) 359-8102.

With a tip width of 0.062 in., a new narrow-end cutter can trim individual flatpack leads to desired lengths. Its narrow tip allows adequate clearance between adjacent leads. Model 1018 can cut leads as large as 0.006 by 0.02 in. There is a stop screw in the shank to prevent overpressure.

CIRCLE NO. 293

Modular system draws in 3-D

Perspective Systems, Inc., 4400 Seventh Ave. South, Seattle, Wash. Price: $18,750 to $29,325.

Directed by an analog computer, the Illustromat 1200 drawing system creates a wide variety of drawings — axonometric, perspective, and three-dimensional stereo —as an operator traces two orthographic (blueprint) views. Built with a modular design, the new unit can be expanded into a more highly automated graphics system, with such sophisticated features as memory storage and playback, three-axis digitizer, and interface capability with existing digital systems.

CIRCLE NO. 294

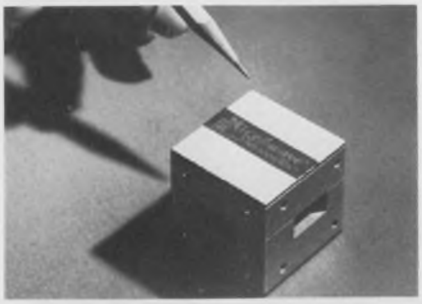
Beam-lead bonder accepts flip-chips

Micro Tech Mfg., Inc., a sub. of Sprague Electric Co., 703 Plantation St., Worcester, Mass. Phone: (617) 755-5215.

Developed for both the laboratory and the production line, the 1190 bonder can handle beam-lead devices, flip-chips or conventional eutectic die devices with substrates up to 2 in. square. Many adjustable operating features include wobble tool speed, angular rotation, pressure, tool temperature and substrate temperature controls.

CIRCLE NO. 295

Xb-band circulator handles 10-kW peak



Microwave Associates, Burlington, Mass. Phone: (617) 272-3000.

A high-performance Xb-band broadband circulator, the MA-8K267, features high isolation of 20 dB max., with low loss of 0.3 dB max over the 5.85- to 8.2-GHz bandwidth. Weighing approximately 2.3 lbs., this model has a peak power of 10 kW and a VSWR of 1.20 max. The MA8K267 is particularly suited for use in reconnaissance systems or laboratory applications where broadband transceiving is required.

CIRCLE NO. 296

Superhet receiver covers 1 to 2 GHz

HRB-Singer, Inc., Science Park, State College, Pa. Phone: (814) 238-4311.

A solid-state, automatically swept superheterodyne receiver covers the frequency range from 1 to 2 GHz. Using microstrip circuit techniques, the over-all receiver is contained in a package that measures 2-1/4 by 4-5/8 by 3/4 inches and weighs less than 6 ounces. The receiver provides a 1-MHz video output with crystal calibration markers at 125-MHz intervals, as well as a 10-MHz crystal video output.

CIRCLE NO. 297

Spdt coaxial switch handles 18 GHz

Electronic Specialty Co., 4561 Colorado Blvd., Los Angeles. Phone: (213) 246-6767.

Excellent rf performance is combined with very broad bandwidth in a lightweight, subminiature spdt coaxial switch. The 09-53 series switches have excellent VSWR (1.25:1 at 12.4 GHz), and provide high intechannel isolation from 0 to 18 GHz (60 dB min at 11 GHz and 55 dB to 18 GHz). Standard rf connectors are of the OSM type and project from a single surface (OSSM-type connectors are also available).

CIRCLE NO. 298

X-band adapter joins waveguide to microstrip

Tek-wave, Inc., Raymond Rd., Princeton, N.J. Phone: (609) 921-8910.

The first commercially available waveguide-to-microstrip adapter operates in X-band over 10% bandwidths. VSWR is 1:25 maximum when terminated into a 1.03 load. The adapter is for launching 50-Ω microstrip circuits on 0.025-in. Al_2O_3 ceramic substrates. The new transition completely eliminates the need for intermediate coax fittings normally necessary to accommodate conventional connecting devices.

CIRCLE NO. 334

Glass laser system has extended life

American Optical Corp., Technical Products Div., Southbridge, Mass. Phone: (617) 764-3211. P&A: $8388; 4 months.

A glass laser system provides 10 tc 100 times the flashlamp life of comparable ruby laser systems. It allows operators to achieve maximum energy output of 400 joules from the neodymium-glass rod with half the input energy necessary for similar laser systems. The AO 40 has a nominal threshold energy of 5000 joules and a nominal slope efficiency of 4%.

CIRCLE NO. 335

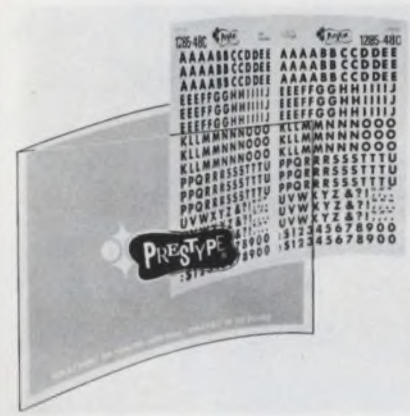
Junction circulator spans 1 to 2 GHz

Addington Laboratories, Inc., 1043 DeGiulio Ave., Santa Clar, Calif. Phone: (408) 248-5511.

A miniature junction circulator operating from 1 to 2 GHz can be used as an isolator simply by terminating one of its ports with a 50-Ω load. This miniature circulator/isolator has dimensions of 2.7 by 2.85 by 0.75 inches (exclusive of connectors). Specifications include 19-dB isolation, 0.5-dB insertion loss and 1.3:1 VSWR.

CIRCLE NO. 336

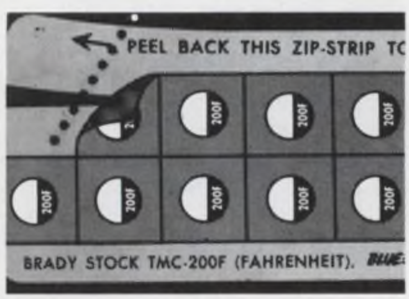
Evaluation Samples



Dry-transfer lettering

Evaluation samples of dry-transfer lettering sheets are available without charge to designers. These sheets are now packaged in large, transparent plastic envelopes for convenient storage and improved long-term protection. Sheets are available with opaque and transparent letters in a selection of six colors. Prestype, Inc.

CIRCLE NO. 337



Temperature indicators

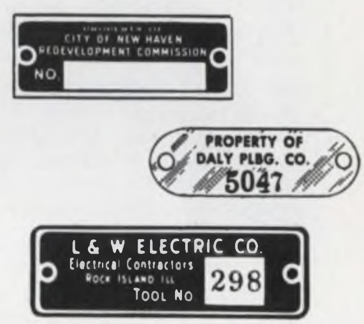
Able to irreversibly change color when a predetermined temperature has been reached, self-stacking temperature-monitoring labels provide an easy method to check electrical components and equipment. Priced from 5 to 12¢ each, twenty same-temperature Thermomarkers come mounted on a dispenser card. When their temperature threshold is exceeded, they turn black and show the word "over." Indication accuracy is ±3°; temperature ranges include 100 to 500°F and 40 to 300°C. Free samples are available. W. H. Brady Co.

CIRCLE NO. 338

Dual in-line patterns

Complete multiple pad patterns for dual in-line package configurations eliminate the need for time-consuming repetitive drawing in printed-circuit artwork preparation. The new dual in-line symbols make it possible to lay down the entire artwork pattern in one operation. Patterns are manufactured to an accuracy within ±.002 inch, for all common center-to-center and pad spacings. Patterns are available for 14- and 16-lead configurations in 1X, 2X, 4X and 5X scales. Packaged 100 and 250 to a roll, they are priced from $7.55 to $9.70, depending on size. Full technical data and free samples of these pressure-sensitive drafting symbols are available. Bishop Graphics, Inc.

CIRCLE NO. 339



Equipment nameplates

Free evaluation samples are included with descriptive literature on a line of nameplates and property identification tags. These tags are available with punched holes for mechanical fastening or with pressure-sensitive or solvent-activated adhesive backing. Indentification tags suitable for marking equipment, tools, jigs, dies, and instruments of all types are featured in the line. Seton Name Plate Corp.

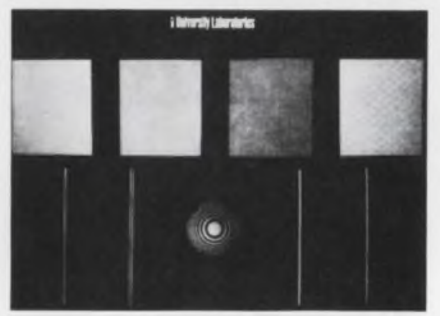
CIRCLE NO. 340

Design Aids

Panel-meter design kit

A boon to designers who specify panel meters with custom dials or insignia is offered in the form of a meter-modification portfolio. Nominally priced at $5, the package comprises sheets of paper, on which meter window outlines have been printed, and transparent acetate sheets printed with dial markings. By superimposing these elements, the user can quickly prepare a mockup of the desired custom panel. The transparent sheets can also be used to fabricate prototypes. Sample acetate sheets and descriptive literature are available from the manufacturer without charge. Modutec, Inc.

CIRCLE NO. 341



Laser demonstrator

Using coherent light from a helium-neon laser, at least seven experiments in diffraction can be performed with a transparency containing an assortment of diffraction-producing targets. Besides educational uses, the demonstrator is a must for showing He-Ne lasers to novices. With it, one can observe various light patterns produced by shining the laser beam through the hole patterns, double slits, single slits, zone plate, and sharp edge contained in the 2- × 2-in. transparency. An instruction leaflet suggests quantitative experiments to demonstrate the wave theory of light. Useful only to people having a He-Ne laser or planning to purchase one, the laser demonstrator is available free to qualified personnel. University Laboratories.

CIRCLE NO. 342

Bodine rotors and armatures are not the vibrating type. Dynamic balancing sees to that.

Vibration or noise in a Bodine motor is unthinkable. You wouldn't stand for it. And we know how to prevent it.

Precision balancing machinery handles this phase of our "quiet" program. The machines put the finger on unbalance in Bodine rotors and armatures—then indicate the exact means for restoring peaceful equilibrium. Armatures, in fact, go through the balancing act twice—before and after varnishing.

Our balancing tolerances run to the thousandths of an ounce-inch, so rotors and armatures in Bodine motors revolve without annoying vibration or noise. Longer bearing life is an extra benefit.

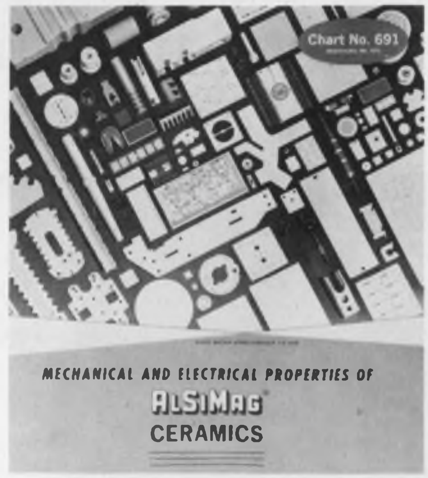
Dynamic balancing is just one of several noise control procedures followed in all stages of manufacture of Bodine fractional horsepower motors. Doesn't your product deserve motors of such quality? Bulletin S describes over 275 *stock* types and sizes from 1/2000 to 1/6 hp. Write Bodine Electric Company, 2528 West Bradley Place, Chicago, Illinois 60618.

Bodine motors wear out—it just takes longer

BODINE
fractional/horsepower
MOTORS
...the power behind the leading products

BODINE MAKES MOTOR CONTROLS, TOO—ASK FOR BULLETIN 1050

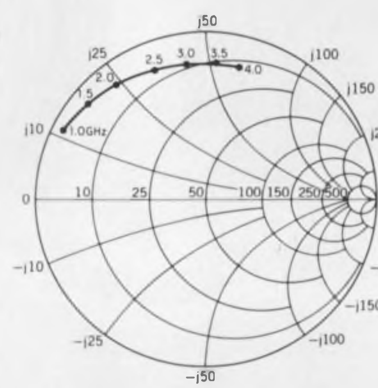
INFORMATION RETRIEVAL NUMBER 99



Ceramic property chart

A comprehensive data sheet on the properties of technical ceramics is offered as an aid to designers. Printed in four colors, the chart includes full data and specifications on steatite, forsterite, zircon, cordierite, lava, machinable magnesium silicate, crushable magnesia, alumina, beryllia, and leachable ceramics. American Lava Corp., sub. of 3M Co.

CIRCLE NO. 343



S-parameter charts

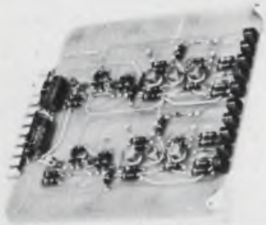
Permitting circuit optimization for amplifier or oscillator applications, S-parameter charts have an effective range of 100 MHz to 12.4 GHz, as compared to a Y-parameter range of dc to 500 MHz. Printed on 8-1/2 by 11-in. sheets, the charts are directly derived from the screen display on Hewlett-Packard's network analyzer equipment. They show four key impedance measurements for each of 15 microwave transistors. Two charts measure input and output performance. Fairchild Semiconductor.

CIRCLE NO. 344

DISPLAY
CIRCUIT MODULES

DYNAMIC FOCUS FUNCTION GENERATOR

FG100



Converts X and Y deflection current samples into parabolic voltage wave forms to maintain beam focus anywhere on the CRT face.

LINEARITY CORRECTOR

LC101A

Gives on-axis linearity correction for geometric distortion occurring when a flat-faced CRT is used. Ideal for line-scan applications.

CENTERING COIL CURRENT REGULATOR

CR200

Supplies highly stable constant current to two axes of centering, alignment or static astigmatic correction coils in CRT, storage tube or vidicon systems.

VIDEO AMPLIFIER

VA105

Linear, featuring high output capability, fast rise and fall time, excellent full power output and bandwidth. Unique damping control.

STATIC FOCUS CURRENT REGULATOR

SR1000

Provides a fully adjustable constant dc current supply to the static focus coil in magnetically focused systems. Low ripple, adjustable.

Celco YOKES

Constantine Engineering Laboratories Company

Mahwah, N. J. 201-327-1123

Upland, Cal. 714-982-0215

NICE SPLICE
it tells you when to crimp

That's because the see-thru "window" at splice midpoint lets you inspect inserted conductor before crimping. Funneled barrel ends make conductor entry fast and snag-proof . . . reducing installation time. Center wire stop prevents over-insertion of wires. Color-coded transparent nylon sleeve — over one-piece seamless insert — eliminates dielectric flashover. Midpoint indent helps locate splice in crimping tool. (You'll want to see our match-mated tooling, too.) Our Window Butt Splice is *the* answer to structural and tensile stresses, temperature extremes in the #22-10 wire range. For more answers (and evaluation samples) write or call ETC, Inc., Cleveland, Ohio 44103. A subsidiary of International Telephone and Telegraph Corporation.

ETC®

INFORMATION RETRIEVAL NUMBER 102

INFORMATION RETRIEVAL NUMBER 103

Application Notes

Threaded inserts

A technical bulletin gives design engineers information pertinent to any threaded wire insert, material shear strengths and bolt selection. By looking at one of the 30 charts, it is possible to determine the the length of an insert and strength of a screw required to safely support a given weight. If the designer knows two of four variables, he can obtain the other two from the charts. Heli-Coil Corp., Insert Products Div.

CIRCLE NO. 345

Directional relays

Relays for high-speed directional discrimination during faults on power systems are described in a 12-page brochure. The brochure gives complete application information, including a selector guide. Relay construction and operation are explained and illustrated, and characteristics are listed. Westinghouse Electric Corp., Relay Instrument Div.

CIRCLE NO. 346

Magnetic cores

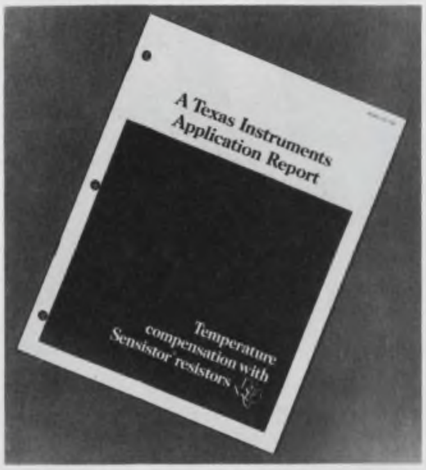
Material processing and quality-control challenges that may be encountered by process and production engineers in many fields are dealt with in an article on the manufacturer of ferrite cores. The article covers the basic process of producing magnetic ferrite cores for computer core memories. Ampex Corp.

CIRCLE NO. 347

Technical journal

A new quarterly journal will deal with the latest advances in test instrumentation. The first issue features an article on a new approach to wideband interference-free microwave spectrum analysis. In addition, there is a section on spectrum analyzer applications. Free copies are available. The Singer Co., Instrumetnation Div.

CIRCLE NO. 348



Temperature sensing

A comprehensive new application report shows how to use precision temperature-sensitive resistors. This 20-page booklet contains a section on compensating drift of transistor bias, due to temperature changes, through use of these resistors. A second section describes eleven sensing or control applications; a typical circuit is given for each application. A third section provides helpful circuit design information. Texas Instruments Inc.

CIRCLE NO. 349

Valve data

Complete engineering data on valves and flow control materials are given in a new 20-page bulletin. Detailed in the booklet are operating temperature ranges for seal and seat materials; material compatibility charts; metal specifications; seal materials and valve sizing data. Crane Co., Flomatics Div.

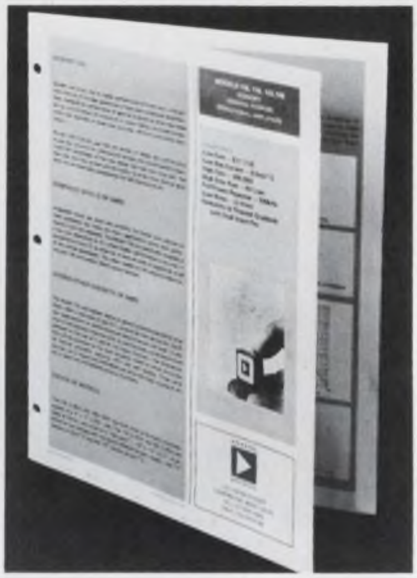
CIRCLE NO. 350

Plastic printed circuits

A four-page illustrated article reprint tells how to etch printed circuits from aluminum-clad plastic. The article presents solutions to problems encountered in processing aluminum-PPO laminate into microwave striplines. General Electric Co., Plastics Dept.

CIRCLE NO. 351

New Literature



Low-cost op amps

A four-page data sheet describes four new economy-type operational amplifiers employing artificially increased collector-impedance circuitry. This new design provides gain, stability, impedance, bandwidth, response, and common-mode characteristics that would have cost at least twice the price just one year ago. The amplifiers use the same fundamental circuit principles for all-round advanced performance, but feature variations in their output circuitry for a range of power ratings. Analog Devices, Inc.

CIRCLE NO. 386

Manual switches

Revised for the first time, a new 56-page manual switch catalog reviews eleven categories of lighted and unlighted pushbuttons, indicators, matrix-mounted switches and toggle switches. The publication contains over 500 photographs, diagrams and cutaway drawings of the manual switches, in addition to information on electrical ratings, terminals and colors. Also discussed are hand- and tool-relamping techniques, special circuitry, hermetic sealing and locking configurations. Micro Switch, a div. of Honeywell Inc.

CIRCLE NO. 352

Scientific furniture

A 16-page catalog of scientific furniture systems illustrates and describes a complete line of technical and research-work stations. The system of design illustrated in the catalog involves a modular concept built around a standard base unit. Thus, any laboratory or work area can actually be customized to the specific needs of the user. Nearly 150 different pedestal base combinations can be immediately constructed from components. Sturdilite Scientific Furniture Systems.

CIRCLE NO. 353

Compatible calculators

A complete line of calculators is presented in a compact 16-page booklet, describing the features and functions of each of the models. Typical application problems and keyboard solutions are detailed for individual calculator keyboards. Wang Laboratories, Inc.

CIRCLE NO. 354

FET-input comparator

A six-page foldout application note and data sheet lists full specifications for the model 350 FET-input comparator; explains the importance of key parameters in the quasi-digital circuits that use comparators; then goes on to outline some of the unusual application possibilities) besides conventional comparators) that can be based on this new unit. Analog Devices, Inc.

CIRCLE NO. 355

Components catalog

A 17-page catalog describes an extensive line of microwave, rf, and i-f receiving systems and components. The catalog includes sections on integrated circuits, microwave receivers, converters, and mixer preamplifiers. In addition, it describes a line of stripline components. Varian, LEL Div.

CIRCLE NO. 356

Fluid controllers

Standard fluidic controllers, as well as a complete integral family of high-performance easily interconnectable fluidic devices are presented in a 10-page condensed catalog. This product line is said to operate reliably for extended periods in the most adverse industrial environments. Fluidionics, Div. of I-T-E Imperial Corp.

CIRCLE NO. 357

◄ INFORMATION RETRIEVAL NUMBER 110

Switch catalog

Emphasizing the availability of a complete switch package from a single source, a 16-page selector switch catalog includes the ratings and specifications of wafer assemblies and index assemblies. Complete electrical and mechanical specifications, as well as special construction features, are presented for all switch types. CTS Corp.

CIRCLE NO. 360

Surface coatings

A four-page folder describes a line of surface coatings. This is the only broad line of electrically characterized and calibrated coatings available for both electronic applications and general surface protection. Coating types described in the folder include epoxies, urethanes, and low electrical loss hydrocarbons, covering a wide range of applications. Emerson & Cuming, Inc.

CIRCLE NO. 358

Laminated metals

Offering specifications on laminated sheet, strip, wire and tubing, an eight-page brochure contains a useful chart that relates precious metals, their properties and typical applications; outlines the advantages and disadvantages for each metal; and lists base metals on which they are usually laminated. The variations possible in fabricating a laminate are illustrated in drawings of each mill product, while dimensional manufacturing tolerances are given in chart form. In addition, there is a section on electrical contact tape. Improved Seamless Wire Co.

CIRCLE NO. 359

High-strength adhesive

A new 12-page bulletin describes a high strength, fast-setting material that bonds almost any combination of materials. This literature describes how Eastman 910 adhesive—a single-component, solvent-free cyanoacrylate system—joins almost any combination of materials. Metals, plastics, rubber, glass, ceramics, textiles and paper can be bonded. Tensile shear strengths over 5000 psi can be achieved on some substrates. Eastman Chemical Products, Inc. Chemicals Div.

CIRCLE NO. 361

Thermistor data

A series of eight data sheets give full specs on interchangeable curve-matched thermistors. A resistance-temperature conversion table is included to aid the designer in determining resistance-temperature for nonstandard thermistors. Fenwal Electronics.

CIRCLE NO. 362

Relays and controls

Condensed specifications, dimensions, and prices are given in a 24-page catalog for over 400 stock and standard relays and motor controls. Shown are 76 different basic types, including MIL-spec relays, dry and mercury-wetted reed relays, industrial plug-in and low-cost commercial-grade relays, 600-V power relays, timers, and general-purpose contactors and motor starters. Struthers-Dunn, Inc.

CIRCLE NO. 363

Temperature controllers

A four-page brochure illustrates and describes a new series of solid-state digital set-point temperature controllers. These units are designed for use in conjunction with SCR power controllers to provide a completely solid-state temperature control system for electric heating cartridges, furnaces, ovens, dies, molds, heat exchangers, etc. Loyola Industries, Inc.

CIRCLE NO. 364

Materials catalog

A 1969 catalog lists 2500 inorganic chemicals, ultra-pure chemicals, organometallics and high-purity metals. The catalog is color-coded into five sections with an integrated alphabetical listing for ready reference. Included are high-purity salts, pure metals, doping agents, and over 200 exclusive items. Alfa Inorganics, Inc.

CIRCLE NO. 365

Data compression

Three bibliographies covering the published literature on data compression are combined in one publication. A total of 177 titles, comprising the bulk of the literature written on this subject since 1950, are listed. These bibliographies are of particular interest to persons involved in processing data telemetered to ground stations from space vehicles or from aircraft undergoing flight testing. Scientific Data Systems.

CIRCLE NO. 366

Electroplating

A fully illustrated color brochure on precision electroplating describes a line of electrodes, and how they are used to improve quality, efficiency, and scope. Also discussed is plating simple or complex parts to higher standards economically, thus permitting parts to be designed to preferred values of utility, appearance and cost. Engelhard Minerals & Chemicals Corp.

CIRCLE NO. 367

Book Reviews

Packaging opus

Handbook of Electronic Packaging, ed. Charles A. Harper, (McGraw-Hill Book Co., New York, N. Y.) 1200 pp. $12.50.

This 1200-page volume elevates the technology of electronic packaging to a position of importance it has certainly earned. The handbook is divided into 15 well-organized chapters written by experts who represent the largest electronics companies in the industry.

Virtually all aspects of printed circuits, multilayer boards, flexible etched circuits, bonding techniques and basic materials are covered in the sections on materials and techniques. A second set of chapters covers mechanical, electrical and thermal design criteria and techniques for electronic packaging. Finally, a third group of chapters provides data and guidelines in the major application areas of aerospace, military and computer packaging.

CIRCLE NO. 368

Infrared-systems design

Infrared System Engineering, R. D. Hudson, Jr. (John Wiley & Sons, Inc., New York), 642 pp. $19.75.

This applications-oriented treatment of infrared engineering opens with a historical discussion of the infrared portion of the electromagnetic spectrum. Following a systems approach, the subsequent chapters explore the separate elements of infrared technology, then explain the functional interaction of the individual elements when combined in a system.

The second part of the book focuses on the application of infrared technology to the solution of military, industrial, medical and scientific problems. Nearly 1400 references to the literature of the field are included.

CIRCLE NO. 369

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Desired Salary	**Availability Date**

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Title			
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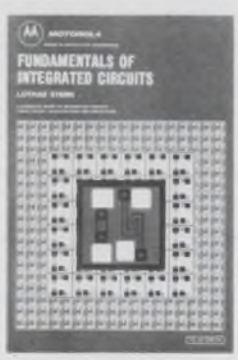

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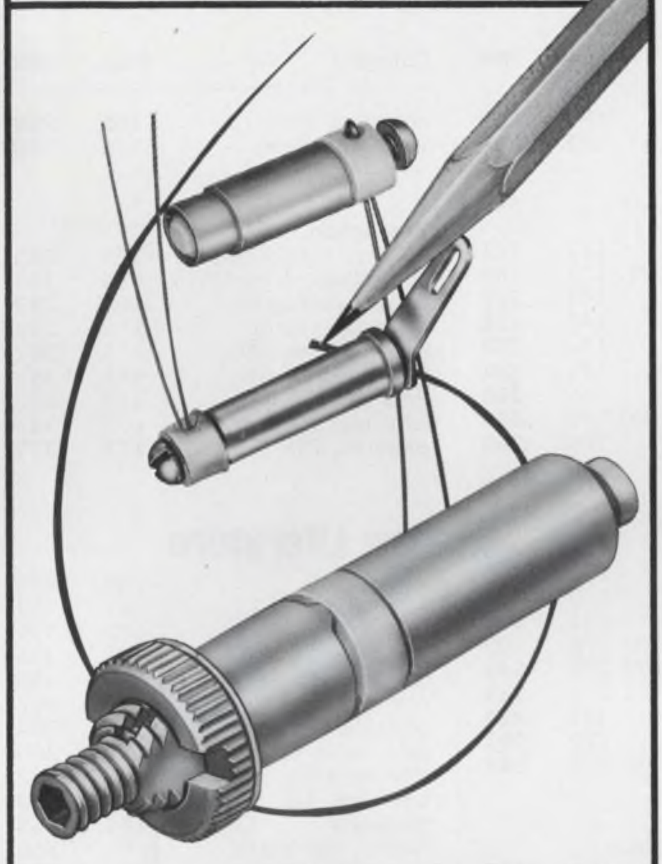
Advertisers' Index

New, miniature Teflon® trimmers



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INFORMATION RETRIEVAL NUMBER 116

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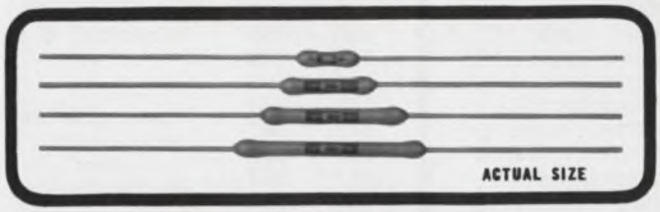

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MG 660	.6	1000	750	1 meg	10 meg	.500 ±.030	.094 ±.015	.025 ±.002
MG 680	.8	1500	750	1 meg	15 meg	.750 ±.030	.094 ±.015	.025 ±.002
MG 710	1.0	2000	750	1 meg	20 meg	1.000 ±.040	.094 ±.015	.025 ±.002
MG 721	2.0	2500	1000	1 meg	30 meg	1.000 ±.050	.240 ±.030	.040 ±.002
MG 750	3.0	3000	1000	3 meg	150 meg	2.125 ±.060	.315 ±.030	.040 ±.002
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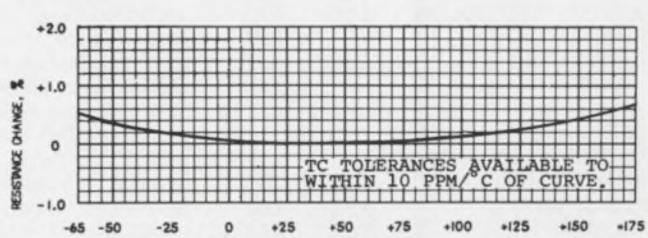

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All products, design aids (DA), application notes (AN), new literature (NL), and reprints (R) in this issue are listed here with Page and Information Retrieval numbers. Reader requests will be promptly processed by computer and mailed to the manufacturer within three days.

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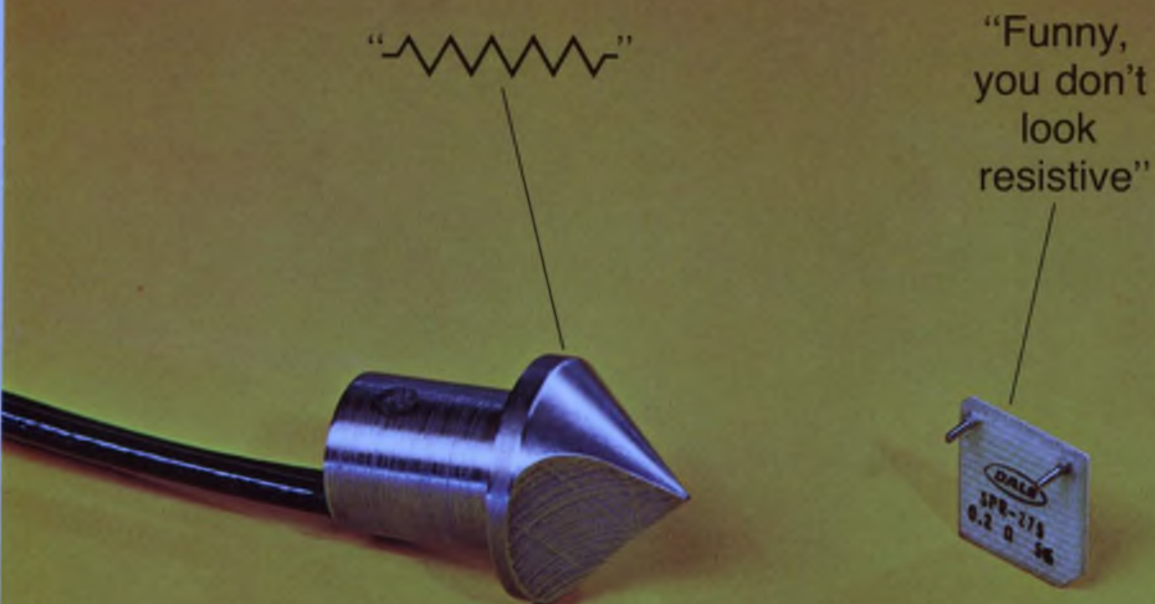

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INFORMATION RETRIEVAL NUMBER 243

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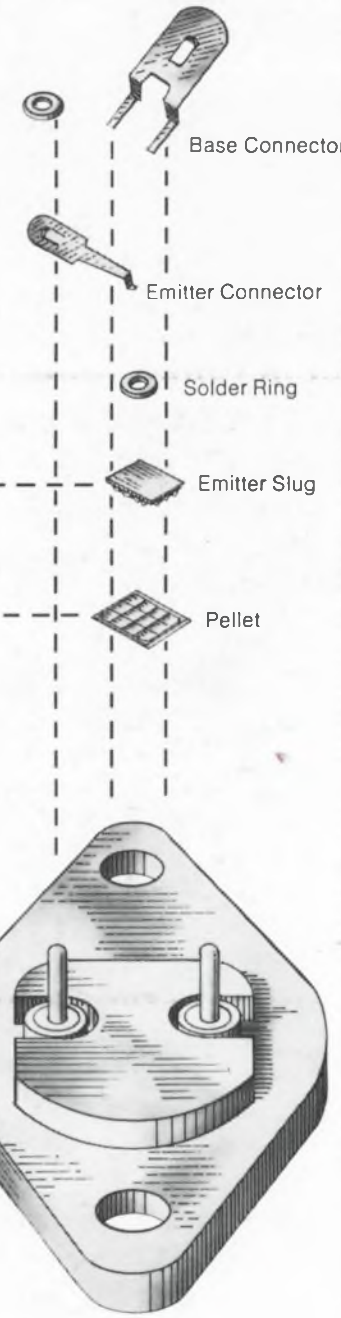
Now, RCA introduces the multiple-emitter chip, a concept using RCA "overlay" techniques, in 2N5038 and 2N5039—multi-epitaxial silicon transistors for high-speed switching circuits. On the inside is the pellet with 12 discrete emitter sites, interconnected by a 12-pronged heat-conducting copper slug. The use of individual emitter sites provides the excellent 20-ampere current handling capabilities of these devices by increasing the emitter periphery. The copper slug assures good temperature and voltage distribution among the emitter sites across the pellet, and further contributes to the current handling, *while adding significantly to the forward second breakdown capability of the device.* These concepts (discrete emitters and copper slug) eliminate the non-uniform current injection normally associated with high current interdigitated transistor structures.



For the design engineer, 2N5038 and 2N5039 represent the right combination of mechanical structure and performance characteristics. They have low saturation voltage (1.0 volt max. at 12 A for 2N5038 and at 10 A for 2N5039) and fast saturated switching times (turn-on less than 0.5 μs and turn-off less than 2 μs).

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