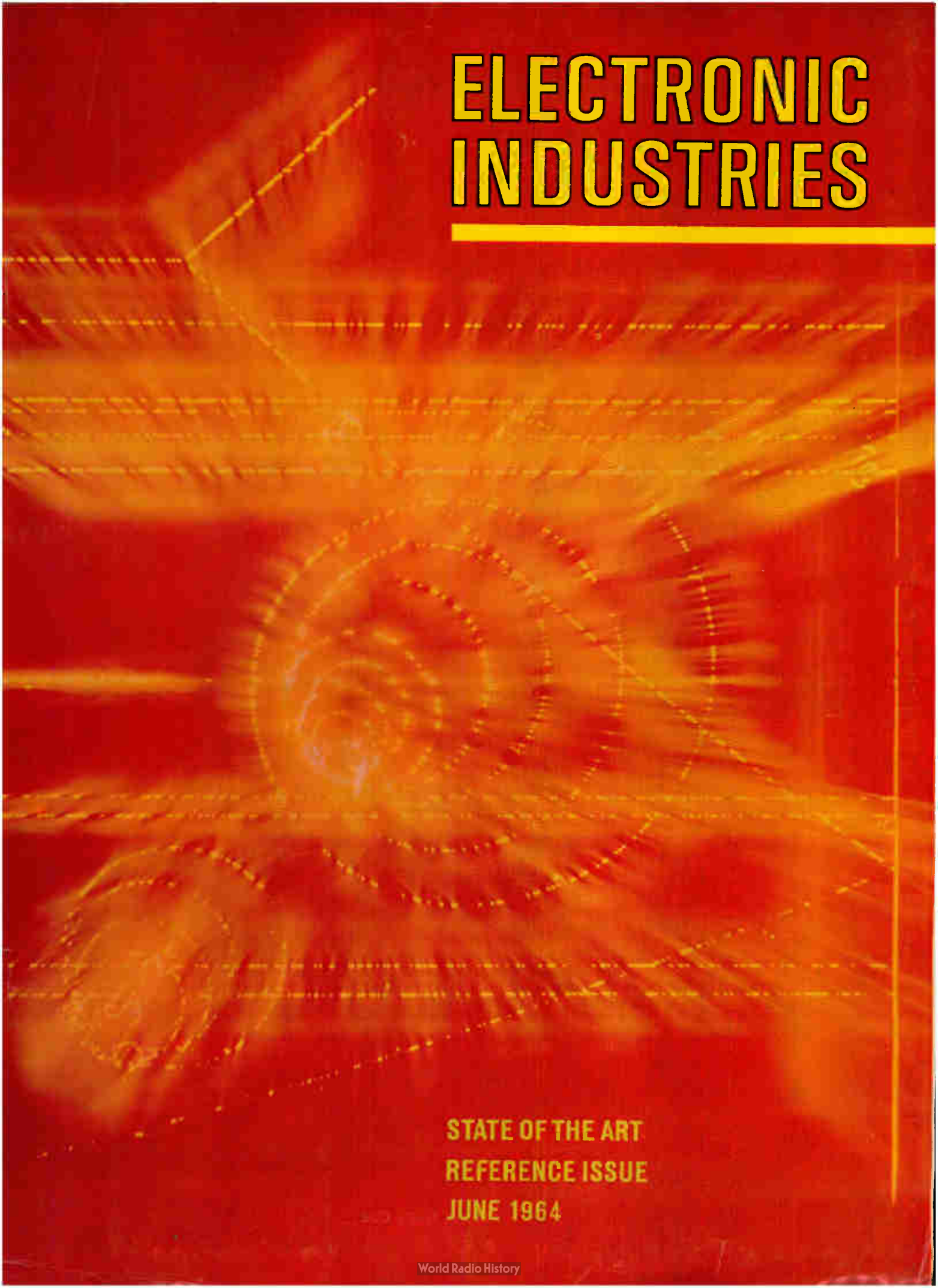
ELECTRONIC INDUSTRIES



STATE OF THE ART
REFERENCE ISSUE
JUNE 1964

Unmatched performance in a *standard* precision power wirewound resistor

You get a reliability bonus at no extra cost with Dale's RS Precision Power Resistor. Of all the wirewounds outside the specially-conditioned "Hi-Rel" category (where Dale's ARS Resistor is tops) the RS has been conclusively proven to be the most reliable. In tests, patterned after Dale's famous Minuteman High Reliability Development Program, the RS has passed the 22,000,000 hour mark at a 99.991% reliability level (60% confidence level, 100% rated power, 25° C ambient, 1% ΔR failure point). The RS Wirewound is just one example of Dale's *total* capability in precision resistance—a capability which includes giving you both performance and delivery which exactly match your requirements.

SPECIALS—ASK US

Dale has built over 400 special modifications of the RS Resistor. One of them may be the answer to your problem. If it isn't, we'll build one that is.

RS SPECIFICATIONS

- Applicable Mil. Spec: MIL-R-26C & MIL-R-23379 (A new Spec, designed especially for precision resistors)
- Wattage Sizes: ¼, ½, 1, 2, 2.5, 3, 5, 7, 10
- Tolerances: 0.05%, 0.1%, 0.25%, 1%, 3%
- Operating Temperature Range: -55°C to 350°C
- Resistance Range: .1 ohm to 240k ohms
- Load Life Stability: 1% max. ΔR after 1000 hours at full rated power
- Moisture Resistance: .5% max. ΔR after MIL-R-26C moisture test for insulated resistance
- Dielectric Strength: 500 volts, RS-¼ through RS-1B; 1000 volts RS-2 through RS-10
- Thermal Shock: .5% max. ΔR after MIL-R-26C thermal shock test
- Insulation Resistance: 100 megohms minimum
- Temperature Coefficient: 20 p.p.m. (high values); 30 p.p.m. (intermediate values); 50 p.p.m. (low values). Specific T.C. chart available on request.

RS RELIABILITY STUDY AVAILABLE. Write for a copy as well as for Dale's expanded Catalog "A".

DALE ELECTRONICS, INC.
1304 28th Avenue, Columbus, Nebraska
A subsidiary of THE LIONEL CORPORATION
Also Made and Sold by Dale Electronics Canada, Ltd., Toronto, Ontario, Canada

Circle 98 on Inquiry Card

ELECTRONIC INDUSTRIES
The STATE-OF-THE-ART Magazine for Electronic Engineers

EDITORIAL:

ELECTRONIC MARKETING— MOST NEEDED BREAKTHROUGH

THE DRIVE FOR TECHNOLOGICAL PROGRESS in our industry has obscured a simple fundamental—if nobody needs it, why develop or produce it?

Several years ago, a medium sized company was successful, in competition with some industrial giants, in developing a black box that represented a dramatic engineering design achievement. Impressed with its success in doing what no other company could do, this manufacturer set up to produce in quantity the exotic product for which it had orders for one half dozen units. More than a year later and thousands of dollars poorer, this company discovered that its original order of six units represented the total world market for this unique product.

On the happy side, consider the company which enjoyed a three year lead in silicon transistors. This was no accident. It was deliberately planned. Extensive marketing studies had revealed that the industry was eager to have, and would purchase in large quantities, reliable silicon transistors at a reasonable price. Corporate resources were mobilized fully—research and development, engineering design, production facilities, materials development—for the sole purpose of being first to the market place. This effort paid off handsomely in corporate growth and profitability.

Engineers direct the corporate affairs of the majority of the electronic companies. Yet few engineering schools give more than passing notice to the subject of marketing. Perhaps that is why our industry has concerned itself more with technological progress than with marketing. As a young and dynamic growth industry, we enjoyed many years when the engineer with an idea or new product had little trouble finding customers eager to buy.

Defense requirements are no longer so urgent. Where we had a limited number of talented people and capable organizations, our expanded industry now is loaded with capabilities in technology but short of the marketing skills needed to sell its products.

Marketing is a total concept. It implies an exploration of the needs of customers. What they want, how it should be made, what price they will pay, how many they will buy, and the best way to sell them? Answers to such questions as these are a way of life for successful companies in all industries.

As publishers, we have developed and used the most modern marketing research techniques on our own product—ELECTRONIC INDUSTRIES. We have a major investment in facts and figures on the industry that is available to manufacturers in the form of a Marketing Assistance Program. We have helped many companies find the answers they need to market their products successfully.

There are still far too many companies that have failed to make use either of our facilities or other resources in the marketing area that are available. Manufacturers that have been willing to do their marketing homework are continuing to show growth and profits. Others are complaining about competition, lower volume, and shrinking profits.

We believe that the next important breakthrough for our industry is an awareness that marketing and communication skills are equally as important as technological capabilities.

Bernard F. Osbahr

New from Sprague!

For extreme size reduction and unusual capacitance stability . . .

FILMITE® 'K' POLYCARBONATE FILM CAPACITORS

● New Filmite 'K' Polycarbonate Film Capacitors are *more than 13 times smaller than paper capacitors of equivalent capacitance value and voltage rating!*

● Polycarbonate film dielectric provides exceptionally high capacitance stability over the entire temperature range, due to inherently low coefficient of expansion of polycarbonate film and a dielectric constant which is nearly independent of temperature.

● Filmite 'K' Capacitors exhibit almost no capacitance change with temperature—dramatically better than polyester-film types, they even surpass polystyrene capacitors.

● Low dissipation factor (high *Q*) makes these capacitors extremely desirable where high current capabilities are required, as in SCR commutating capacitor applications.

● Low dielectric absorption (considerably lower than that of many other commonly-used film dielectrics) over a broad frequency/temperature spectrum makes Filmite 'K' Capacitors ideal for timing and integrating.

● Extremely high insulation resistance, especially at higher temperatures. Superior to many other commonly-used film dielectrics.

● Close capacitance tolerances—available to ±0.25%!

● Filmite 'K' Capacitors are excellent for critical applications including tuned circuits, analog and digital computers, precision timing and integrating circuits because of the unusual properties of the polycarbonate film dielectric.

Type 260P *Filmite 'K' Capacitors are metallized, utilizing non-inductive construction. They feature special self-healing characteristics, in the rare event of capacitor dielectric breakdown. Designed for operation at full rated voltage over the temperature range of −55 C to +105 C, these metal-clad capacitors are hermetically-sealed and are available with both standard and weldable wire leads or solder tabs in a variety of mounting styles.*

Types 237P and 238P *Filmite 'K' Capacitors are of high-purity foil construction, and are hermetically sealed in metal cases. Operating temp. range, −55 C to +125 C.*

For complete technical data on Type 260P and on Type 237P and 238P Capacitors, write for Engineering Bulletins 2705 and 2700, respectively, to Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Massachusetts.

SPRAGUE COMPONENTS

CAPACITORS	PULSE TRANSFORMERS	CERAMIC-BASE PRINTED NETWORKS
TRANSISTORS	PIEZOELECTRIC CERAMICS	PACKAGED COMPONENT ASSEMBLIES
RESISTORS	PULSE-FORMING NETWORKS	BOBBIN and TAPE WOUND MAGNETIC CORES
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INTERFERENCE FILTERS	ELECTRIC WAVE FILTERS	FUNCTIONAL DIGITAL CIRCUITS

4SC-4110

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THE MARK OF RELIABILITY

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June 1964, Vol. 23, No. 6

ELECTRONIC INDUSTRIES

The STATE-OF-THE-ART Magazine for Electronic Engineers

6 Reasons Why SPRAGUE is a Major Resistor Supplier

FILMISTOR® PRECISION FILM RESISTORS

metal-film, molded case

Distinct limited temperature coefficients and low tolerances to meet exacting application requirements. Rugged end cap construction for long-term stability and reliability. Superior resistance to humidity and mechanical damage. Surpass MIL-R-10509D requirements. Send for Bulletin 7025B.

deposited-carbon, molded case

Approach precision wirewounds in reliability and stability, yet are smaller in size and have lower self-inductance. Low, controlled temperature coefficient. Dense molded case provides outstanding humidity protection. Send for Bulletin 7000A.

deposited-carbon, conformal coated

Full rated load operation at 70 C with no wattage derating. Assured uprated loads at lower operating temperatures. Ideal for circuitry where small size, humidity resistance, and close tolerance (±1%) are required. Send for Bulletin 7005A.

Circle 61 on Inquiry Card

ACRASIL® PRECISION/POWER WIREWOUND RESISTORS

silicone-encapsulated

Combine the best features of both precision and power wirewound types. Resistance tolerances to ±0.05%. Unusually tough encapsulation protects against shock, vibration, moisture, fungus. Meet MIL-R-26C requirements. Smaller than conventional wirewounds, yet greater in stability. Send for Bulletin 7450.

Circle 62 on Inquiry Card

BLUE JACKET® VITREOUS ENAMEL POWER WIREWOUND RESISTORS

All-welded end cap construction with special vitreous coating for long-term dependability. Axial-lead style for conventional wiring or on printed boards. Tab terminals for higher wattage applications. Meet MIL-R-26C requirements. Send for Bulletins 7400B, 7410D, 7411A.

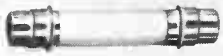
Circle 63 on Inquiry Card

KOOLOHM® CERAMIC-SHELL POWER WIREWOUND RESISTORS

Exclusive ceramic-insulated resistance wire permits "short-proof" multilayer windings for higher resistance values. Standard and non-inductive designs. Non-porous ceramic shell for moisture protection and electrical insulation. Axial-lead, axial-tab, and radial-tab styles. Send for Bulletins 7300B, 7305, 7310.

Circle 64 on Inquiry Card

GLASS-JACKETED POWER WIREWOUND RESISTORS



Ferrule terminals soldered to metallized ends of glass casing for true hermetic seal. Virtually failure-proof, even in extremely corrosive industrial and salt atmosphere. Standard and non-inductive windings. External meter-multiplier types also available. Send for Bulletins 7350, 7420, 7421.

Circle 65 on Inquiry Card

STACKOHM® POWER WIREWOUND RESISTORS

Flat silhouette permits stacking of resistor banks in close quarters. Aluminum thru-bar simplifies mounting and conducts heat from resistance element. Vitreous enamel protective coating. Meet MIL-R-26C performance requirements. Send for Bulletin 7430.

Circle 66 on Inquiry Card

For complete technical data, write for engineering bulletins on the resistors in which you are interested to: Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Massachusetts.

SPRAGUE®
THE MARK OF RELIABILITY

4SR-165-63

New Bridge Design For Safe, Accurate, Easy Measurement of 'Lytic Capacitors

The Sprague Model 1W2A Capacitance Bridge introduces new, improved technical refinements as well as restyling for added attractiveness and ease of operation. Built *by* capacitor engineers *for* capacitor users, it incorporates the best features of bridges used for many years in Sprague laboratories and production facilities.

Precision Measurements over Entire Range from 0 to 120,000 μF

The internal generator of the 1W2A Bridge is a line-driven frequency converter, and detection is obtained from an internal tuned transistor amplifier-null detector, whose sensitivity increases as the balance point is approached. It has provision for 2-terminal, 3-terminal, and 4-terminal capacitance measurements, which are essential for accurate measurement . . . ±1% of reading + 10μμF . . . of medium, low, and high capacitance values, respectively.

No Damage to Capacitors

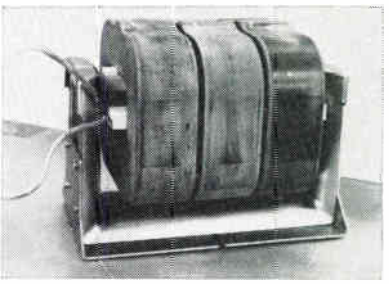
The model 1W2A Capacitance Bridge will not cause degradation or failure in electrolytic or low-voltage ceramic capacitors during test, as is the case in many conventional bridges and test circuits. The 120 cycle A-C voltage, applied to capacitors under test from a built-in source, never exceeds *0.5 volt!* It is usually unnecessary to apply d-c polarizing voltage to electrolytic capacitors because of this safe, low voltage.

Complete Specifications Available

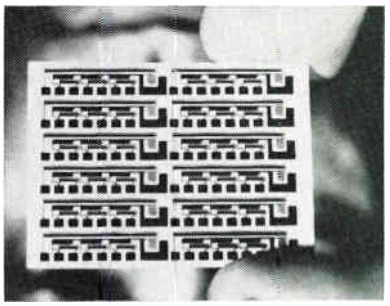
For complete technical data on this precision instrument, write for Engineering Bulletin 90,010A to Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Massachusetts.

4SSP-128-63

Circle 67 on Inquiry Card



Transformers



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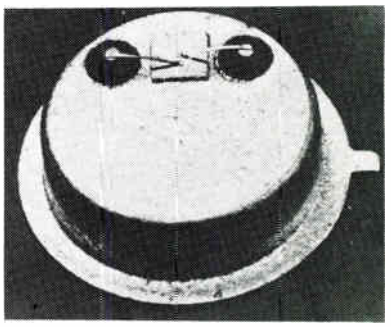

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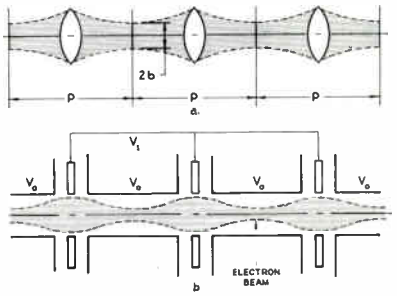
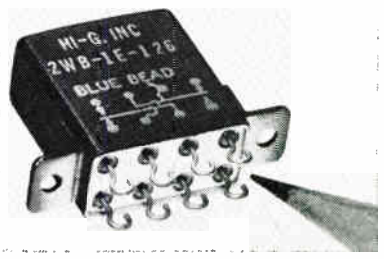


Focusing Klystrons



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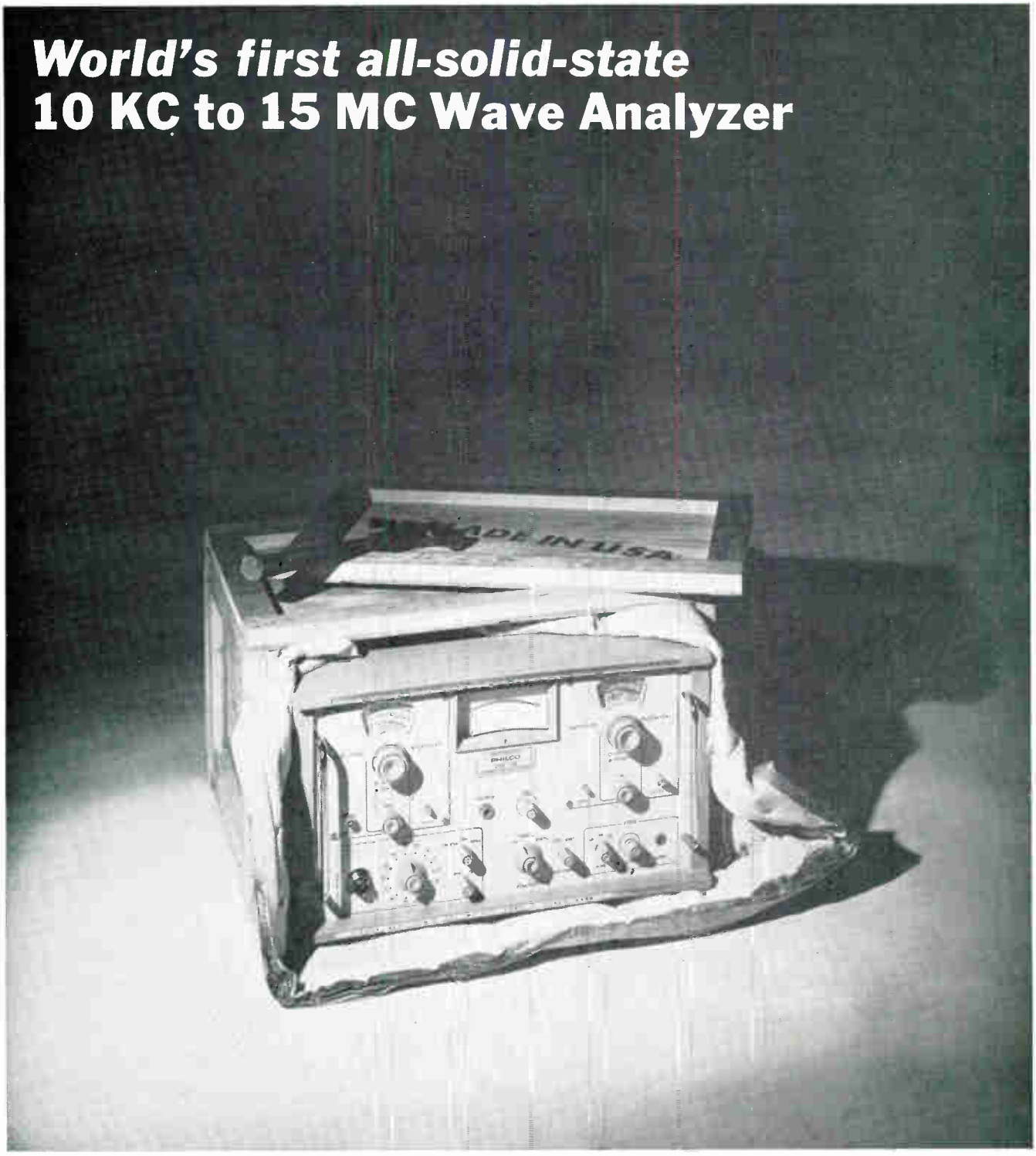
World's first all-solid-state 10 KC to 15 MC Wave Analyzer



Up to now you had to look outside the U.S.A. for a wave analyzer to fit this billing. Except you'd never find an all-solid-state model. Because there weren't any until Sierra's new Model 128A Extended Range Wave Analyzer came along. □ Now you'll be seeing more and more Sierra Wave Analyzers at work in carrier communications terminals, in microwave repeater stations, and in R&D labs. That's because Model 128A's specs, taken as a view of total performance, exceed those of any other wave analyzer made in the world today. You'll find the specs in a newly published product bulletin, available now from Sierra. Or, a word to your Sierra sales representative could produce both the bulletin and a date for a product demonstration.

SIERRA ELECTRONIC DIV.
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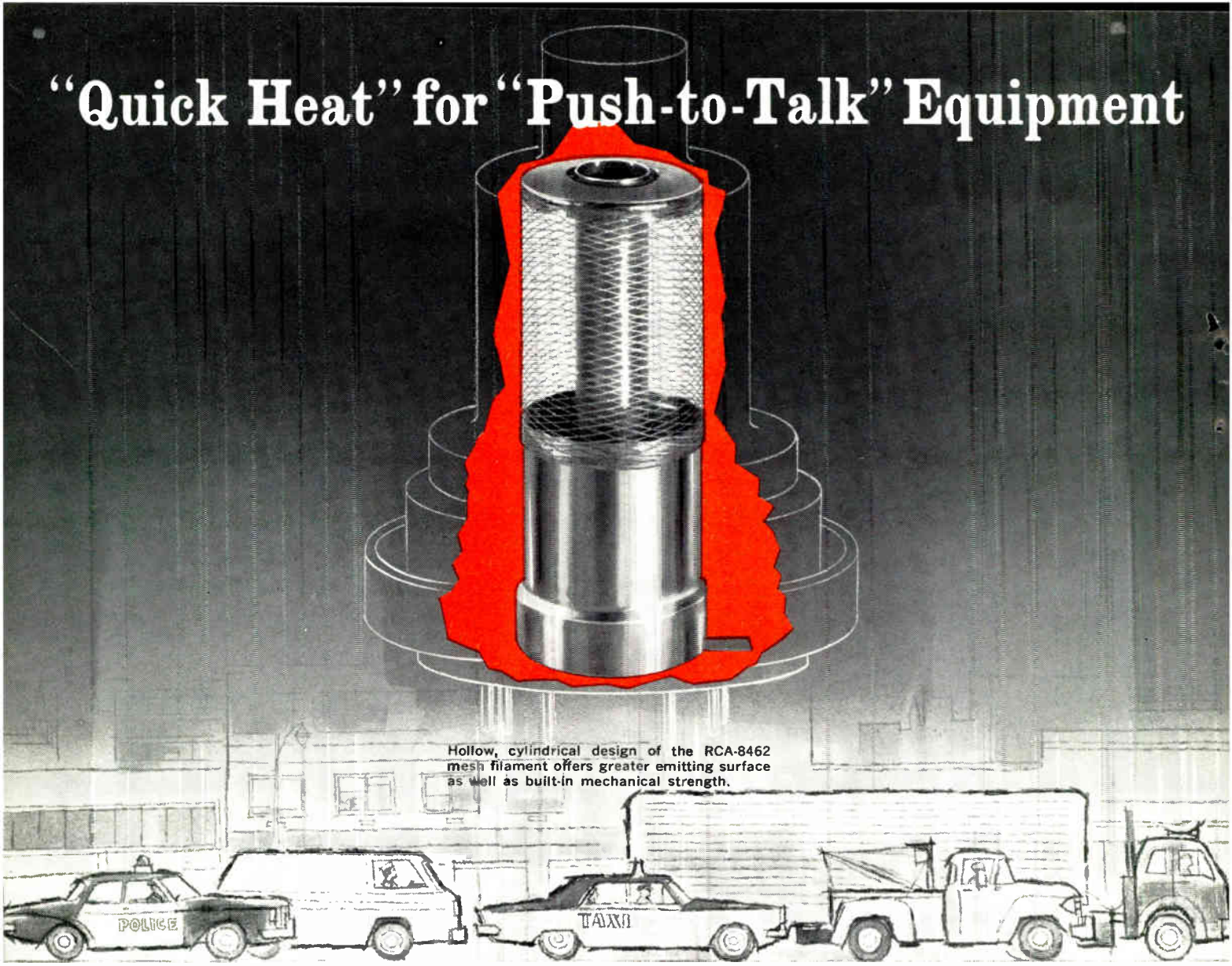
Sierra Electronic Division / 3879 Bohannon Drive / Menlo Park, California

"Quick Heat" for "Push-to-Talk" Equipment



Hollow, cylindrical design of the RCA-8462 mesh filament offers greater emitting surface as well as built-in mechanical strength.

New RCA-8462 with Mesh Filament Achieves 70% of Rated Power Output Within 1 Second

A warm-up time of less than 1 second *without external circuitry* provides the new RCA-8462 conduction-cooled Beam Power Tube with a heating capability so quick that standby power can be eliminated in "push-to-talk" emergency equipment. In a suitably-designed filament over-voltage pulse ("hot-shot") circuit, this ceramic-metal tube achieves warm-up in less than 100 milliseconds.

The thermal capabilities of the mechanically-rugged mesh filament were proved in a 100,000-cycle "hot-shot" test. The only commercially available "Quick-Heat" tube in its frequency-power range, the RCA-8462 is designed for use in inexpensive, 11-pin sockets answering many communications needs.

In CW operation with a plate voltage of only 700 volts, the RCA-8462 provides 110 watts power output at 50 Mc, 105 watts at 175 Mc, and 85 watts at 470 Mc. It can be used as an RF amplifier, oscillator, regulator, distributed amplifier, or linear RF amplifier in both mobile and stationary equipment.

For more information on the RCA-8462 and other RCA tubes with ceramic-metal construction, see your RCA Representative. For technical data, write: Commercial Engineering, Section F-50-DE, RCA Electronic Components and Devices, Harrison, N. J.

AVAILABLE THROUGH YOUR AUTHORIZED RCA INDUSTRIAL TUBE DISTRIBUTOR

RCA The Most Trusted Name in Electronics

ELECTRONIC INDUSTRIES

Advertisers — June 1964

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CLARENCE T. SAKAGUCHI

Some people call our inspectors fuss-budgets

(but Speer customers think they're great)

The man up there in the picture is a member of Speer Carbon's Quality Control and Inspection team. He's checking a resistor lead for solderability – one of many tests that are S.O.P. for Speer fixed carbon resistors.

He's also one big reason why Speer customers are *happy* customers. They know they can rely on Speer electronic components for uniformity and performance – time and time again.

Actually, all of our inspectors are fuss-budgets. They just won't take anything for granted and we're glad. That's why Speer has one quality-assurance employee for every eight employees in production and one quality-assurance engineer for every seventy-five employees in production. And that holds for every manufacturing step ...from raw materials to the finished product.

Mil specs? Speer participates in industry committees that cooperate with military departments in writing them. What's more, our tests don't stop there. This year, 141,912,000 unit life test hours are scheduled for Speer resistors and 40,000,000 for Jeffers coils.

But just to keep the record straight, our inspectors don't deserve all the credit for Speer quality. The folks up and down the line, in all departments, have the same kind of pride in Jeffers' and Speer's performance that our quality-assurance employees have. And we suspect that Speer's multi-million dollar research and development program has something to do with it, too.

SPEER Carbon Co.

SPEER RESISTOR

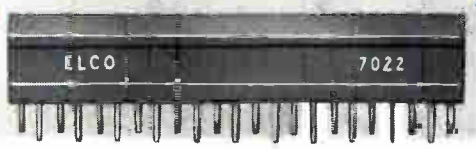
JEFFERS ELECTRONICS

Dept. 476 St. Marys, Pennsylvania 15857
Speer Carbon Co. is a Division of Air Reduction Company, Inc.

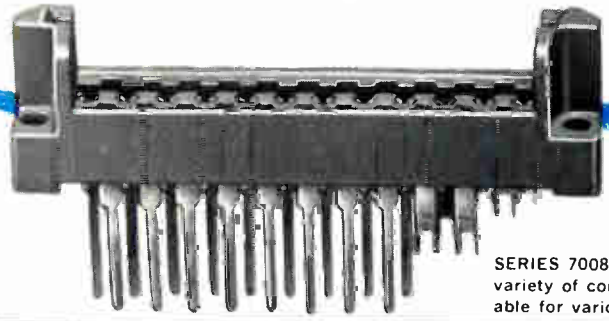
WHY

did SYSTEMS ENGINEERING LABORATORIES select ELCO VARICON* connectors for the system employed to translate Polaris missile telemetry data?

Polaris Data Processor



Series 7022 Plug



SERIES 7008 Receptacle, showing variety of contact terminal ends available for various wiring techniques

- *Series 7021-22 Plugs mate with 7 of our Receptacle Series!*
- *Requires only one hole per contact on module cards!*
- *Assures perfect spacing and perfect mating with Receptacles!*
- *Makes possible simultaneous staking; minimizes card warpage; simplifies circuitry layouts!*
- *Results in higher production efficiency and greater economy!*

"Because," states SEL, of Ft. Lauderdale, Fla., "we needed highest possible reliability. In the matter of connectors, this meant ELCO VARICON® connectors." So SEL selected our Series 7022 card-edge, printed circuit connector plugs, and Series 7008 receptacles, for the data processing system which translates input digital data into output tapes after Polaris test firings. Series 7022, along with Series 7021, is a one-piece, all-molded miniature plug, with upper and lower tier, one-legged ELCO VARICON® contacts. SEL also specifies ELCO VARICON® contacts exclusively for all its NASA, and NASA's prime contractors' data acquisition systems. Why not request ELCO VARICON® connector literature, too, for "highest possible reliability!"

if it's new . . . if it's news . . . it's from . . .

ELCO™ CORPORATION

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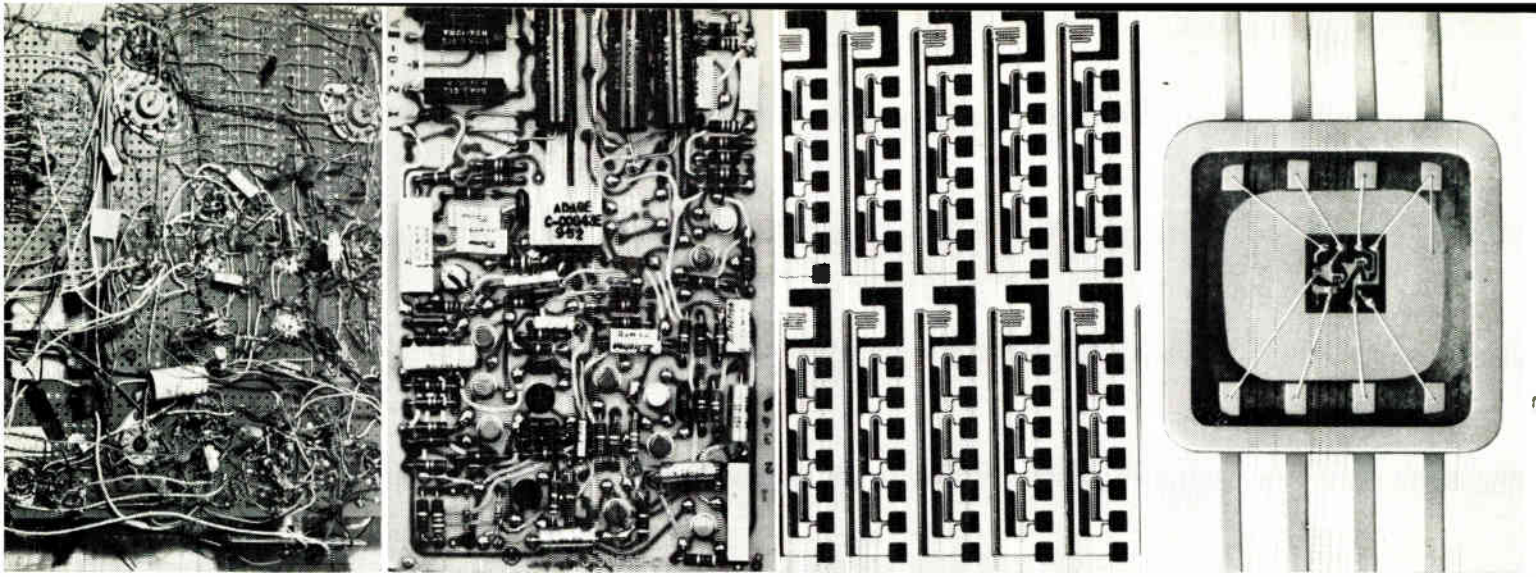


Hand wiring (left) from early radio days, used in first computers, still used in some TV sets, used mostly by amateurs now. Computers sparked development of printed circuits (second left) such as analog to digital conversion module. Desire for smaller and highly sophisticated systems fostered need for microcircuits (second right). Latest in the circuit/component evolution is molecular circuit (right) on a silicon wafer mounted in a flatpack with leads. Flatpack is smaller than a dime.

COMPONENTS: THE STATE-OF-THE-MART

By SIDNEY FELDMAN
Associate Editor
ELECTRONIC INDUSTRIES

Rising microminiature circuit-component sales may hit several billions of dollars yearly by 1970. What of discrete components? Some believe sales will diminish slowly, reaching a low, but profitable plateau. Some suggest that instead of just selling the products they make, firms should concentrate on making products that customers need.

ABOUT EVERY FOURTH DOLLAR spent for electronic products is spent on components. Last year regular components, plus microminiature circuits and components, totaled nearly $4.2 billions in sales by about 2,000 firms. Some sources estimate that discrete and integrated circuits may pass $5 billions by 1967, then continue rising to a possible $6.25 billion by 1970.

Promising yet conflicting trends will confront component makers in those coming years. Active and passive components continue as building blocks and replacement parts for equipment and system. But industry spokesmen say that component makers "have to come to grips with microminiaturization" which threatens to shrink components markets, as well as circuits.

Integrated circuit sales are assumed to hover between a potential $1.5 billion and a possible $750 million market by 1973. That's how Texas Instruments' president Patrick Haggerty pictured the market at IEEE's engineering microelectronics forum last March. He figured microelectronics would help reduce government electronic costs by about 7% by 1973; this particular assumption challenges component makers to compensate for this 7% gap in sales —merely to make up the difference. Then, components makers will have to catch up before sales can really grow.

More optimistic sources look mainly to industrial electronic markets as the fastest growing. Consumer electronic markets supposedly were bypassed by industrial's $2.7 billion billings in 1963, compared to about $2.4 billion in 1962. Yet nearly 25% of these so-called "industrial" sales were made to defense-aerospace contractors.

Some components companies don't make this fine distinction, since they often don't know the ultimate uses of all components they sell. Manufacturers also regard this distinction as "academic," since they insist " a component sold is a component sold." In future, proper marketing definitions will become more important as markets change.

Most component makers report that when they speak glowingly of the "great untapped potential" of industrial electronics, they think chiefly of test and measure equipment, nuclear systems, medical instruments, industrial controls and devices. Market experts

contend that components makers have yet to get closer to equipment makers who, in turn, have yet to get closer to the ultimate users—real and imagined.

Attractive Market

One particularly attractive market for components is among users of industrial controls and process equipment. One estimate is that about $200 million of electronic hardware here represents a mere 10% scratch of total potential. But it remains for components firms to decide whether to accept the challenge of financing and pioneering these markets where electrical, electro-mechanical, and pneumatic devices long have served.

For example, most process control companies don't know how and can't afford to design total systems that "marry" computers to controls. Such industrial processors shift this responsibility to instrument and control makers. Yet these firms often avoid developing new sensors and actuators for such advanced, but small "one of a kind" markets. Instead, economics drives these suppliers to concentrate on components and equipments for big, broad markets.

This commercial market vacuum may be filled by defense-aerospace contractors—if they ever choose to adapt automatic control technology and techniques developed for weapons and aerospace systems. This high-ticket custom components and systems market requires just the high reliability of defense-aerospace markets. Apparently, such industrial systems markets may be left to joint ventures yet to be formed between astute components and computer manufacturers. Some of this work already is being handled by integrated components and computer giants, such as General Electric and Honeywell.

In the cyclical consumer electronic field, total industry sales rose slightly from about $2.4 billion in 1962 to about $2.5 billion in 1963. Sales of black/white TV sets for replacements and new family formations increased to about 6.8 million units in 1963, up from about 6.3 million in 1962. Color TV sales rose from about 400,000 to about 600,000 in 1963 and may sell past 1 million this year. Similarly, auto radio sales kept pace with historically high auto sales, from about 7.2 million sets in 1962 to nearly 8 million in 1963. Home radio set production fell off from about 12 million in 1962 to about 10.3 million in 1963.

'Comfortable' Market

Replacement component sales generally held between $800 and $900 million from 1962 to 1963. This is generally a "comfortable" market which depends upon sales to government, industry, service technicians, hobbyists and amateur repairmen who test electron tubes at the corner drugstore. Components distributors play a growing role here, chiefly supplying original equipment manufacturers as well as R&D laboratories. (*Continued on page* 16)

"We don't know just what percentage of consumer products assembled in the U.S. use foreign-made — chiefly Japanese — electronic parts, from tubes through assemblies," says Frank W. Mansfield, Director of Marketing Research for Sylvania Electric Products.

Sprague Electric Co. had great expectations for military components early in 1963. But "our military component volume fell off $9 million, as compared with 1962, and to less than 25% of our total billings for 1963," reports chief executive officer Robert C. Sprague.

"As a result of tighter government procurement policies, customers are demanding lower costs, tighter schedules, increased reliability and improved performance. Competition is encouraged and we are forced to accept R&D programs on a fixed-price basis," declares Dr. W. H. Christoffers, Manager, Microwave Tube Div., Hughes Aircraft Co.

Patrick Haggerty, Texas Instruments president, figured microelectronics would help reduce government electronic costs by about 7% by 1973. He sees a 1973 market somewhere between $750 million and $1.5 billion.

The Defense Electronics Supply Center, DESC, at Dayton, enables the Defense Department more efficiently to centralize, standardize, and decrease the number of duplicate replacement parts for maintenance. Concurrently, consumer and industrial solid state electronic products are generally lasting longer and requiring less maintenance and fewer replacement parts.

Component makers monitor DOD and NASA developments as bellwethers of future business, depending upon the volume of business they do with these big customers. Sprague Electric Co. had great expectations for military components early in 1963. But "our military component volume fell off $9 million, as compared with 1962, and to less than 25% of our total billings for 1963," reports chief executive officer Robert C. Sprague. P. R. Mallory & Co., in this area, says it seeks "to maintain a proper balance of government business, which presently amounts to 12% of total sales."

Among the hardest hit component makers in 1963 were microwave tube firms serving defense markets. Dr. W. H. Christoffers, manager of Hughes Aircraft Company's Microwave Tube Division, sums up this defense components environment thus:

"As a result of tighter government procurement policies, our customers are demanding lower costs, tighter schedules, increased reliability and improved performance. Competition is encouraged and we are forced to accept research and development programs on a fixed-price basis. We find ourselves in an era where there is continuing emphasis on development, but little production. We should accept this new business picture as a challenge and make the appropriate adjustments in our operation so we can continue to operate profitably and effectively."

Interest in Other Areas

As defense markets shift, there is interest in other microwave component areas. For example, the Air Force Systems Engineering Group at Wright-Patterson Air Force Base, Dayton, is expanding its program to use microcircuit technology to microwave frequencies. In recent months, DOD and NASA funded microminiature sub-systems for Polaris submarines, Appollo, Minuteman guidance, Loran-C receivers, the Army-Navy VAX close-support airplane, the W2F-1 Hawkeye airplane computer, and meteorological satellites, among others.

A commercial microminiature milestone last April was the new System/360 International Business Machines computers using the firm's own multichip logic circuits in flat packages. Here is the third generation of components for electronic computers: tubes in the 1940's, transistors in the 1950's, and microelectronics in the mid-1960's. These tiny circuits foreshadow future component developments. By 1965 these circuits will start cutting into sales of discrete components for computers and data processing equipment. EDP hardware billings grew from about $985 million in 1962 to about $1 billion in 1963.

IBM says that such microcircuits eventually will be produced on in-house fully-automated assembly lines—a feat in itself, when accomplished. Similarly, many components today must be made and packaged for proper use on automated or semi-automated assembly lines. Entire lines of components have been developed especially for use on printed circuit boards. Not only are components used on automated assemblies, but they are being made automatically. Western Electric pioneered the first on-line computer-controlled system to automate production of high reliability deposited carbon resistors. Production is largely for in-house Bell System use and for select defense contractors.

Gradually, according to industrialists, the traditional discrete components field has gone liquid; government prime and major sub-contractors now make components and microcircuits. There's a trend here to joint ventures by primes and components makers. Early in 1963, P. R. Mallory & Co. reported that 21% of the industry's biggest users of components make both components and modules, and 14% make discrete components. This survey also noted that more than 50% of these firms do R&D in components, and all big electronic firms surveyed had their own component evaluation groups. Other surveys show that U. S. electronic industries are approaching the situation in other countries where equipment manufacturers usually make many of the components they utilize.

Want to Widen Horizons

Self-preservation may be leading several components makers into the microcircuits business, while others simply want to widen their horizons. Sprague,

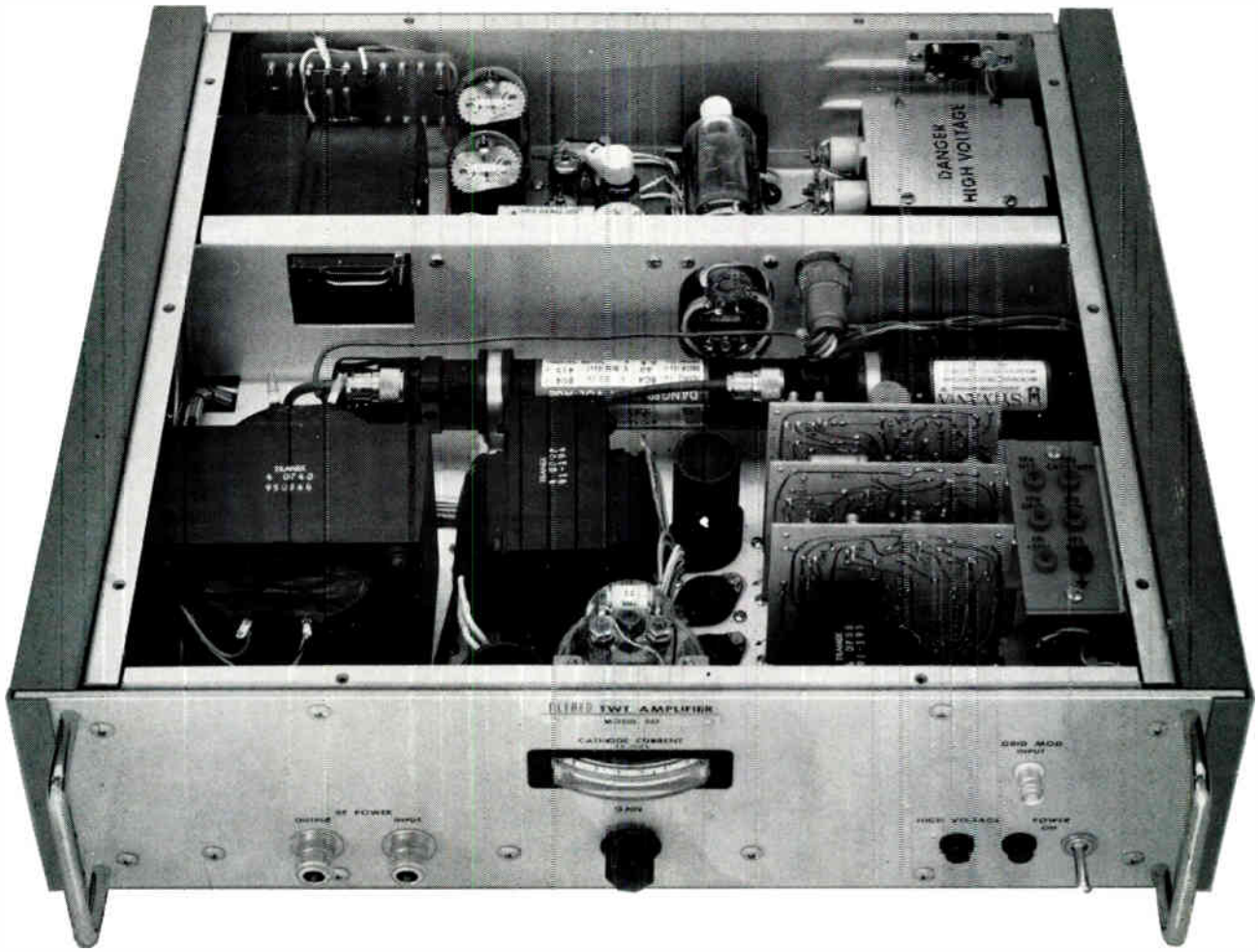
(*Continued on page* 18)

SEMICONDUCTORS

Semiconductors is expected to be our fastest riser in the major component market over the next few years. Total sales for 1964 may reach as high as $605 million, rising through $644 million in 1965, to $677 million in 1966. The semiconductor categories listed in the table are not the complete market.

	1964	1965	1966
	(in millions of dollars)		
Semiconductors—total market	$605	$644	$677
Silicon Diodes & Rectifiers	128	131	135
Germanium Diodes & Rectifiers	33	31	29
Selenium Rectifiers	16	16	15
Zener Diodes	36	38	39
Silicon Transistors	162	171	175
Germanium Transistors	132	120	111

(Figures based on a limited EI survey among 300 leading component manufacturers.)



Sturdy new Alfred microwave amplifiers ■ 1 to 12.4 Gc ■ 1 watt output, 30 db gain ■ 50 db amplitude modulation range ■ gain stable ■ phase stable

Four new Alfred microwave amplifiers are now available to provide you with high gain and uniform response over the whole frequency spectrum. Models 560, 561, 562, and 563 operate from 1 to 2 Gc, 2 to 4 Gc, 4 to 8 Gc and 7 to 12.4 Gc, respectively. All units are ruggedly constructed to meet demanding laboratory or field applications.

Amplitude of the TWT can be continuously controlled over a 50 db range using an external 0 to 10 volt signal. Similar pulse modulation range is available.

Only the Alfred amplifiers provide a gain variation of less than 0.2 db for 105 to 125 volt line variation. Low peak-to-peak ripple provides excellent short term phase stability. Precise voltage regulation, including regulated dc heater supply, insures long term phase and gain stability.

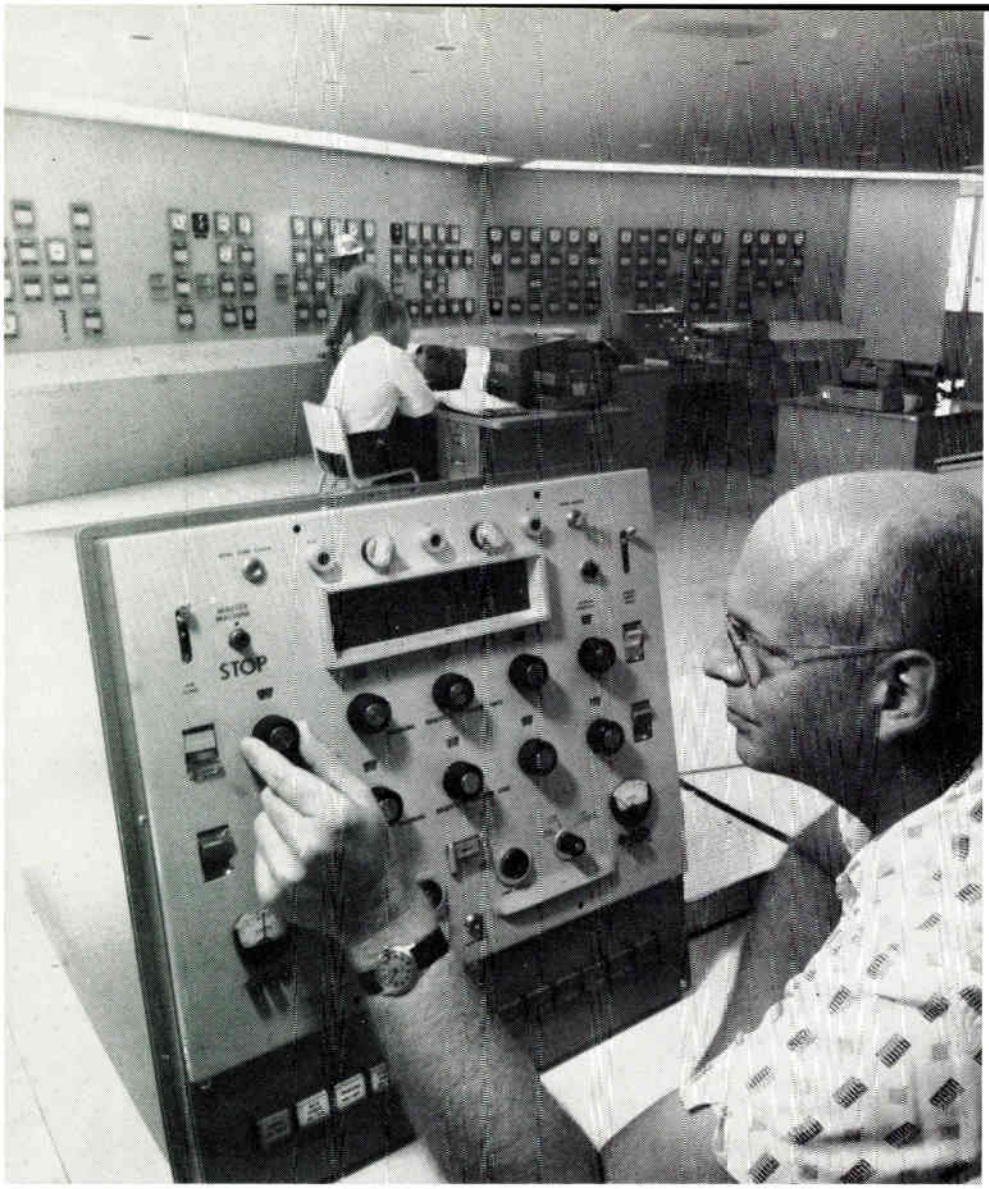
Use of PPM focused TWT's, transistorized circuitry, careful layout, and construction promises reliable long term performance under all kinds of conditions.

BRIEF SPECIFICATIONS

Power Output	1 watt minimum
Gain (at rated power)	30 db (minimum)
Gain Adjustments	0 to 50 db minimum gain reduction
Gain Variation with Line Voltage	0.2 db or less at 1 watt output for 105 to 125 volt line voltage variation
Modulation	Modulation input is direct coupled to permit pulse modulation or continuous control. 10 volts required to cover full 50 db range.
Rise Time	Mocels 560 and 561, less than 4 μsec. Mocels 562 and 563, less than 2 μsec.
Spurious Modulation	At least 45 db below output signal level.
Input Power	115/230 volt, 50/60 cps
Price	Model 560, 1 to 2 Gc: $2150. Model 561, 2 to 4 Gc: $2150. Model 562, 4 to 8 Gc: $2650. Model 563, 7 to 12.4 Gc: $2650.

For complete information or a demonstration, call your Alfred engineering representative or write us at 3176 Porter Drive • Stanford Industrial Park • Palo Alto, Calif. Phone: (415) 326-6496.

ALFRED ELECTRONICS



"One particularly attractive market for components is among users of industrial controls and process equipment. One estimate is that about $200 million of electronic hardware in this market represents a mere 10-percent scratch of total potential."

COMPONENTS (Continued)

for example, develops and fabricates semiconductor materials and devices, thin-films, microcomponents and assemblies. This firm's policy is to hold old customers and cultivate new ones by assisting them in: (a) Selecting optimum combinations of integrated circuitry and discrete components, (b) Evaluating design trade-offs among various approaches to circuit fabrication, and (c) Minimizing the cost of final systems design. Similarly, P. R. Mallory finances its own research on materials, thin-films, solid state components and electro-chemistry.

Virtually all semiconductor manufacturers, including those who never were in the electron tube business, are moving into the microcircuits or integrated circuits field. These firms include Motorola Semiconductor, Fairchild Semiconductor, Transitron, Texas Instruments, among others. Even some companies which were neither in the tube nor transistor business now are heavily in microcircuits—particularly Signetics. At this stage, it remains to be seen which types of microminiature concepts will prevail and how they will be defined, or standardized: discrete components (high density packaging), thin-film circuits (containing simple resistors to cryogenics), semiconductor integrated circuits, and function concepts. Further out along the way, is the ultimate possibility of "growing" computer circuits in highly-packaged bionic units.

Despite this trend, Eric Lidow, president of International Rectifier Corp., has decided to diversify into "black boxes," rather than microcircuits. His firm now makes component lines including silicon rectifiers, regulators, and batteries. IR's new black boxes include an inverter-type power supply, and forthcoming solid state versions of thyratrons and ignitrons. Overcapacity and price-cutting led Mr. Lidow to react against two prime factors affecting component makers: (1) Compared to the rest of the electronic industries, component manufacturers profit more in prosperity — but suffer more during recession, and (2) This situation is repeated cyclically.

More Units, Less Profit

Components companies were selling more units but profiting less, according to the latest statistics of the third quarter of 1963, reported by the Commerce Department's Business and Defense Services Administration. By Spring, 1964, however, this situation seemed to be improving somewhat. Last October, BDSA reported component shipments rose 1.8% in volume, but dropped 6% in value from the second quarter. Defense shipments were off 8.9% and non-defense units were off 5.1%.

BDSA said reduced value of sales characterized "virtually all major categories surveyed except complex components (component packages; integrated circuits, etc.) whose output is growing rapidly because of expanding requirements in miniaturized highly reliable electronic circuitry." BDSA reports indicate, to some extent, that greater use of microcircuits seems to be contributing to overcapacity and oversupply of components—which are driving component prices down.

Pricing is one of the severest problems of the com-

ponents industry. Invariably, as a component market flourishes it attracts an oversupply of top firms as well as loft operators. Such overcrowding ends up by undercutting of prices until there is a company shake-out. Through the years, there has been components cut-throat price-cutting as markets waxed then waned. This originally happened in the electron tube field where about 300 firms are now reduced to a handful. And it has happened more recently in the semiconductor and tantalum capacitor fields.

Concurrently, certain prime and sub-contractors have eased into the components business. What apparently started out as a "make or buy" decision, eventually turned out to be a "make—and sell to the market" decision. Thus, IBM, the major digital computer maker, has a new Industrial Products Division which sells dry reed switches and various other IBM-developed products. Electronic Associates, Inc., the major analog computer maker, has a new line of "miniature, rectangular, precision polystyrene capacitors that meet stringent performance and size requirements." Radiation, Inc., recently spent more than $1 million of its own funds for an in-house plant to make solid state and thin-film microcircuits.

Market Invaders

Good reasons mingle with real reasons for these outsiders invading traditional components markets. Prime and major sub-contractors seek to assure systems reliability and to compensate for shrinking defense and aerospace markets. Radiation, Inc., says it does not want to compete with components and microcircuits makers, but aims to strengthen its systems capability in telemetry and missiles and spacecraft data processing. This firm believes that microcircuits capability will help it win contracts to meet more stringent requirements of high reliability, low weight, small size.

New electronic component reliability specifications recently were developed by Autonetics division of North American Aviation, under U. S. Air Force Ballistics Missile Division contract. The new spec, MIL-R-38100, specifies a supplier's requirements to qualify as a source for high reliability resistors, capacitors, diodes, transistors and parts packaging. Integrated circuitry specifications also are being developed. This program is based upon Autonetics' experience buying high-reliability components for Minuteman missiles.

Some sources differ here, though not specifically with the Minuteman program. The Sarkes Tarzian semiconductor division advertises that "MilSpecs and the Qualified Product List lost their value to the average purchasing agent because they no longer provide an automatic indicator of product quality. Today 50% to 80% of specifications in our commercial customer orders *exceed* MilSpec requirements. Technological improvements take place faster than the military can update MilSpecs."

Defense and aerospace companies fairly strictly have to buy domestic components because of "Buy American" statutes which protects domestic sources. But various components are available in the world component market, particularly from Western Europe and Japan. These countries supply consumer, industrial and replacement parts. Many U. S. component companies have diversified into foreign operations. These firms own foreign plants, are in joint ventures, utilize licensing and cross-licensing, and export and/or import components.

Foreign Imports

Numerous U. S. manufacturers of consumer and industrial electronic products and systems have imported foreign-made components for use in products labeled "Assembled in U. S. A." Last March Tokyo Shibaura Electric Co. Ltd., for example, announced it will provide about $1.1 million worth of silicon diodes for Ford Motor Co. AC automotive motors. In some cases, U. S. firms have minimized foreign competition by stipulating that joint venture or licensed firms could sell components in all countries—except the U. S. A. IBM, for example, will make microcircuits here for its new 360/computers, but IBM's French factory near Paris will make microcircuits for computers to be sold elsewhere in the world.

Despite some outcry in the U. S. against the foreign components invasion, statistics are hard to come by. "We don't know just what percentage of consumer products *assembled* in the U. S. use foreign-made—chiefly Japanese—electronic parts, from tubes through sub-assemblies," says Frank W. Mansfield, of Sylvania Electric Products, who heads AIA's Marketing Services Advisory Committee. Several million dollars worth of components, soldered into circuits, were imported in 1963 as 450,000 TV sets and about 14,000,000 radios.

Foreign components are bought largely on lower

(Continued on page 191)

ELECTRONIC INDUSTRIES
REFERENCE ISSUE
CAPACITORS

CAPACITORS: TODAY AND TOMORROW

Capacitors have made significant strides over the last ten years. The latest improvements and future developments are outlined here. Design and application information are included to aid in the proper use of these new developments.

REQUIREMENTS FOR CAPACITORS have become very stringent in recent years. They are used to filter, tune, couple, block dc, pass ac, shift phase, bypass, feed-thru, compensate, store energy, isolate, suppress noise, start motors, etc. . . . and while doing so, they must frequently be able to withstand such adverse conditions as shock, vibration, salt spray, extremes of temperatures and altitude, humidity and radiation. They must also be small, have minimum weight and be reliable.

Much research work has been carried out during the past decade to develop better manufacturing processes and to uncover new and improved dielectric materials, to enhance capacitor characteristics and reliability. Consequently, many new capacitor types have reached the market. Such a wide choice, however, may make it difficult for the circuit engineer to select *the* correct capacitor for his application. Each capacitor has some characteristics in common with others; yet, each is designed for a specific application where it will excell.

Presented here is an overview of most types of fixed capacitors available today together with peculiar advantages and limitations of each.*

ALUMINUM ELECTROLYTIC CAPACITORS

Electrolytic capacitors provide high capacitance in small volume at a relatively low cost per microfarad-volt. They account for about a third of the total dollar volume expended on capacitors; yet, they collectively amount to only about 10% of the total number of capacitor units manufactured.

Background

The first electrolytic capacitor was made in Germany about 75 years ago. It was first used as a filter element in the 90 v. battery eliminators of the early 1920's. The earliest commercially available electrolytics were "wet" polarized types for vertical mounting. The "dry" electrolytic made its appearance about 1928. Performance was improved with better materials and processing techniques.

During the past ten years many new and important developments have occurred. Better seals assure longer life. A ten-fold increase in volume efficiencies, through improved etching techniques, make for smaller capacitors with equal or improved performance. Leakage characteristics improved a hundred fold.

A recent technological breakthrough in aluminum electrolytics is the availability of units which operate from −55°C to +125°C with voltage ratings to 150 vdc. Heretofore, temperature limits for aluminum electrolytic capacitors were from about −35°C to +85°C.

This advance was accomplished by increased foil purity, improved oxide systems, and newly developed methods of etching that yield higher etch ratios. Other contributing factors were an improvement in capacitor seal design and the development of a unique new electrolyte with a non-aqueous base.

The cost of the new units is about half and weight only about a third of corresponding tantalum foil units; yet, performance characteristics are comparable. Also, they are generally smaller than military grade tantalum foil capacitors of equivalent CV ratings. Aluminum electrolytic capacitors have proven reliable, but temperature requirements of military equipment precluded their use for such applications. Now, they can meet the requirements of military specification, MIL-C-3965.

The mode of failure for both tantalum and aluminum foil electrolytic capacitors is the same and is normally a degradation type of failure. When capacitance falls off, the equivalent series resistance (ESR) and dc leakage current increases. Results of a typical 14,000 hour life test are shown in Fig. 1. This demonstrates unusual stability of capacitance, dissipation factor and leakage current. Such a capacitor has an expected useful life under normal operating conditions of 10 years or more.

How They're Made

Basic to the construction of electrolytic capacitors,

*This is the first of a series and covers electrolytic capacitors. Paper, film, metallized, mica, ceramic and energy storage capacitors, will be covered in subsequent issues.

Fig. 2, is the electrochemical formation of an oxide film on a metal surface. Intimate contact is made with this oxide film by means of another electrical conducting material. The metal on which the oxide film is formed serves as the anode or positive terminal of the capacitor; the oxide film is the dielectric, and the cathode or negative terminal is either a conducting liquid, a gel or a solid material. All present-day electrolytic capacitors are essentially made this way, and the most commonly used basic materials are aluminum and tantalum.

The capacitors described here use an aluminum foil, which may have a smooth or etched surface. The etched surface gives an increase to its surface area resulting in higher capacitance in the same volume. The foil is then electro-chemically treated to form a layer of aluminum oxide on its surface. This oxide film — the dielectric—is extremely thin. When formed on a high purity aluminum foil, it has a dielectric constant between 7 and 10 and an equivalent dielectric strength of 25 million volts per inch. This characteristic of aluminum oxide is used to the fullest, by controlling its thickness from only a few molecules to that required by the capacitor's voltage rating.

The thickness of this oxide coating dielectric is determined by the voltage used to form it. The working voltage of the capacitor is somewhat less than this formation voltage. Thin films result in low voltage, high capacitance units; and thicker films produce higher voltage, lower capacitance units for a given case size.

Following formation of the dielectric, a system of paper spacers is applied to the anode foil. This prevents the possibility of direct shorts between anode and cathode foils that might result because of rough surfaces or jagged edges on either foil. The spacer material also absorbs the electrolyte with which the

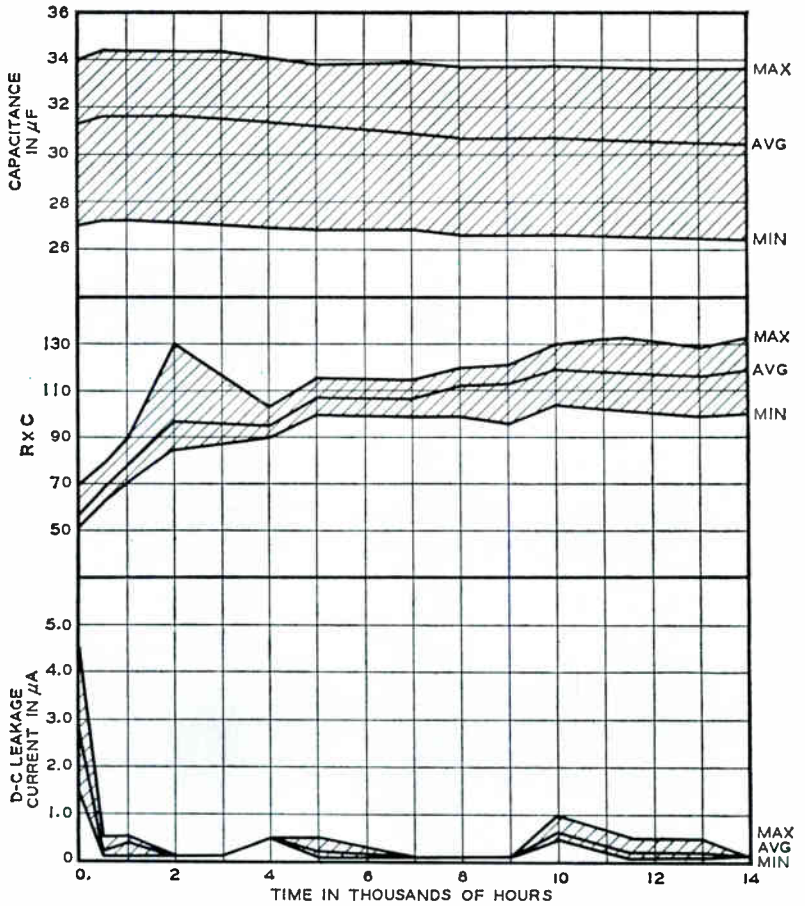


Fig. 1: Typical curves of R x C, capacitance and dc leakage current after life test at 85°C, for 60 volt electrolytic capacitors.

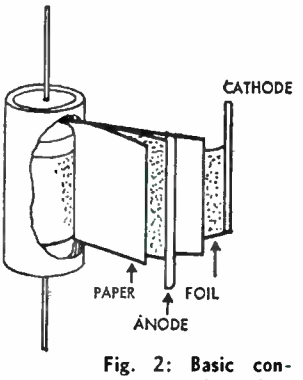
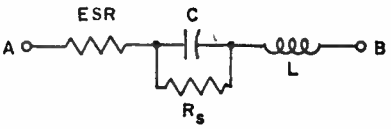


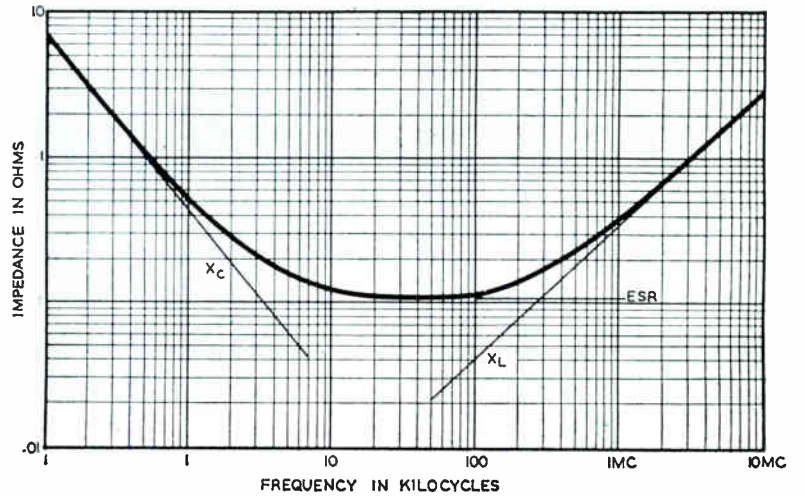
Fig. 2: Basic construction of an electrolytic capacitor.



A, B = capacitor terminals
C = Effective capacitance
R_s = shunt resistance (insulation resistance) through which dc leakage current flows
ESR = equivalent series resistance
L = self inductance of capacitor caused by terminals, electrodes and geometry.

Fig. 3: Simplied equivalent circuit of an electrolytic capacitor.

Fig. 4: A typical curve of impedance as a function of frequency.



By RUDOLF F. GRAF

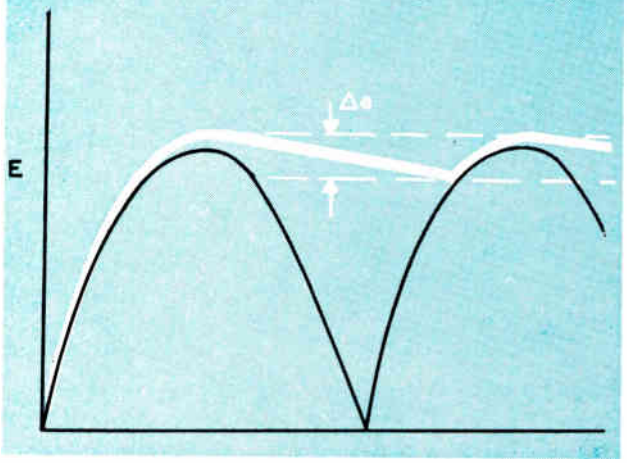
Sprague Electric Co.
North Adams, Mass.

capacitor is impregnated, and thus assures uniform and intimate contact with all of the surface eccentricities of the etched anode foil throughout the life of the capacitor. The cathode foil serves only as an electrical connection to the electrolyte which is in fact the cathode of the electrolytic capacitor.

The foil-spacer-foil is finally rolled into a cylinder, inserted into a suitable container, impregnated and sealed.

The equivalent circuit of an electrolytic capacitor is shown in Fig. 3. The shunt resistance, Rs, in parallel with the effective capacitance, C, accounts for the dc leakage current through the capacitor. The ESR represents energy loss and heating effects within the unit. In an aluminum electrolytic capacitor, this resistance is due mainly to the spacer-electrolyte-oxide system. Generally it varies inversely with temperature. The impedance of a capacitor is frequency dependent, as shown in Fig. 4. The initial

Fig. 5: Full wave rectifier capacitor charge and discharge.



downward slope is a result of the capacitive reactance. The trough (lowest impedance) portion of the curve is almost totally resistive, and the rising upper or higher frequency portion of the curve is due to the capacitor's self-inductance. If the equivalent series resistance were plotted separately, it would show an ESR decrease on the initial downward slope to about 4 KC, and then remain relatively constant throughout the remainder of the frequency range.

The dissipation factor (df) is a measure of the resistive component of the impedance and has a numerical value equal to the ratio of the equivalent series resistance (ESR) to the capacitive reactance (X_c). The design objective is to make this value as close to zero as possible over the operating frequency and temperature range of the capacitor. ESR measurements are practical because most precision capacitance bridges balance both the ESR and capacitance of the unit under test at the same time. This normally results in a direct measurement of ESR.

Leakage current is the dc current which passes through a capacitor when a correctly polarized dc voltage is applied to its terminals. This current is proportional to temperature and becomes increasingly important when capacitors are used at elevated ambients. Imperfections in the oxide dielectric film cause high leakage currents. High leakage currents can also be due to the use of relatively low purity material or to contaminants introduced during the manufacturing process. Leakage current is generally considered to have reached "steady state" conditions after 10 minutes of electrification, and a high continuous level of leakage current normally indicates one of the aforementioned defects.

Only as long as the capacitor is connected with the proper polarity will the current through it be low. If the connections are reversed, the oxide film offers very little resistance; and, the resultant high current, if left unchecked, will cause overheating and self destruction of the capacitor. The low temperature limit on electrolytic capacitors is imposed by the increase in the viscosity and resistivity of the electrolyte, and it is even possible that crystal formation can be encountered at low temperatures. The total amount of heat generated within a capacitor is the sum of that caused by the I^2R losses in the equivalent series resistance, and that caused by the leakage current times the applied voltage.

Application Considerations

For certain ac applications, such as motor starting where a nonpolar electrolytic capacitor is desired, two anodes are used instead of an anode and a cathode and each is formed with an aluminum oxide dielectric film of sufficient thickness to withstand the applied voltages. One foil acts as an anode for one half cycle, the other during the second half cycle. There is no need to observe polarity during installation. These capacitors are effectively two capacitors in series, and, therefore, they will occupy twice the volume of a polarized unit having the same capacitance. Nonpolar capacitors are operated on ac, but the service must be intermittent and brief. A typical maximum operating condition is 20 three-second starting periods per hour, spaced at regular time intervals, so as to prevent overheating. These capacitors cannot be operated continuously at a high ac potential because of their high power factor and the relatively small surface area available for heat dissipation.

Another family of electrolytic capacitors, called semipolar units, has an oxide film formed on the cathode as before; but, this film is not as thick as that formed on the anode. These capacitors are used where the ac ripple voltage is high (such as in a filter application) and where it is necessary to have the cathode capable of withstanding the peak-to-peak voltages of this ripple. If the cathode were not formed, an oxide film would build up so as to reduce the effective capacitance and increase the impedance of the capacitor.

The ac ripple current rating of an electrolytic capacitor is one of the most important factors in

filter applications, because excessive current produces a greater than permissible temperature rise and shortens its life. The maximum permissible RMS ripple current for any capacitor is limited by the temperature within the capacitor and the rate of heat dissipation from the capacitor. It is effected by its equivalent series resistance as well as its physical geometry.

After a capacitor is fully charged, in a full-wave rectifier application, it will discharge into the load as shown in Fig. 5 until the second half cycle comes along. Then the capacitor is recharged again to the peak voltage. The Δe shown in the illustration is equal to the total peak-to-peak ripple voltage. Inspection shows that this is a complex wave which contains many harmonics of the fundamental ripple frequency. It is this ripple that causes the noticeable heating of the capacitor, and it can be mathematically determined. On the other hand, the ripple current through the capacitor can be measured to see if it is within the rating of the specifications. One way to make this measurement is to insert a low impedance thermometer in series with the negative lead. It is very important that the impedance of the meter be small compared with that of the capacitor; otherwise, a great measurement error will result. A thermoammeter is used, since a true RMS reading can thus be obtained on complex waves.

Another way of measuring ripple current is by inserting a very low resistance in series with the negative lead, and measuring the voltage drop across it with a true RMS vacuum tube voltmeter. The current is then equal to the voltage measured divided by the value of the resistor. The resistor value must be small compared with the impedance of the capacitor. A third method, which gives a quick approximation of the ripple current, is to measure the ripple voltage across the capacitor terminals and divide this measurement by the capacitor impedance.

Though the above methods are satisfactory, another way of measuring the heating effect of the capacitor that is often employed involves the insertion of a thermocouple be-

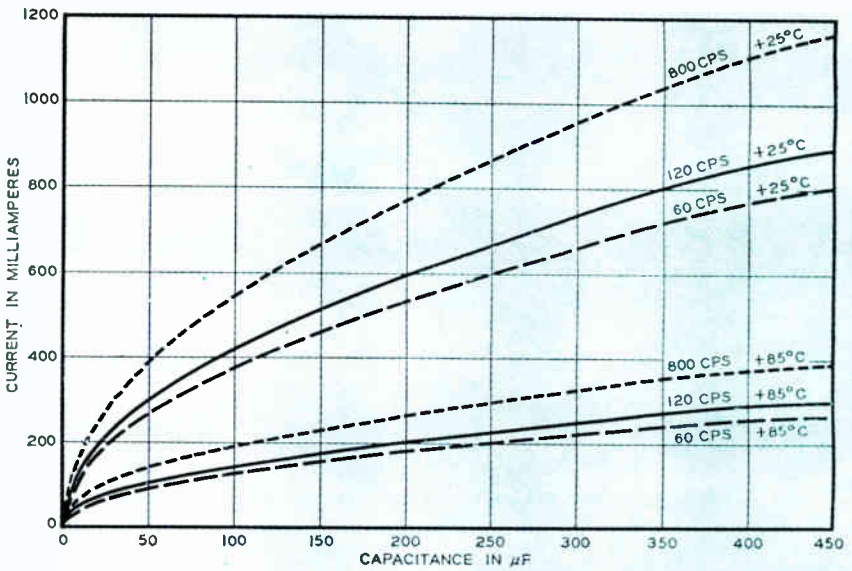


Fig. 6: Maximum ripple current in milliamperes for typical electrolytic capacitor.

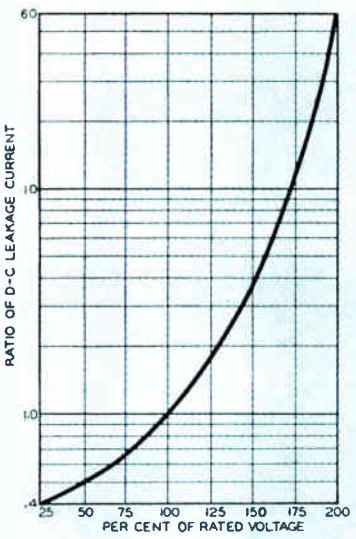


Fig. 7a: Ratio of dc leakage current vs. percent of rated voltage at 25°C for typical foil tantalum capacitors.

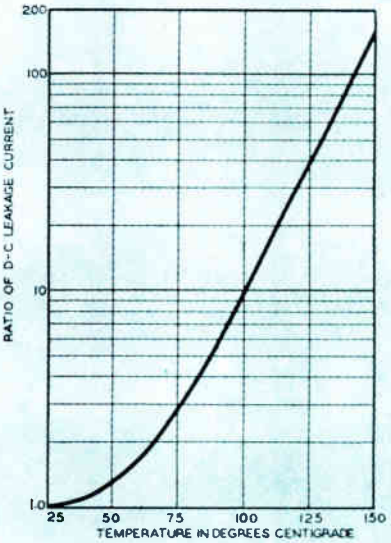


Fig. 7b: Ratio of dc leakage current at rated voltage vs. temperature for typical foil tantalum capacitors.

Fig. 8: Typical liquid-electrolyte sintered-anode tantalum capacitors.

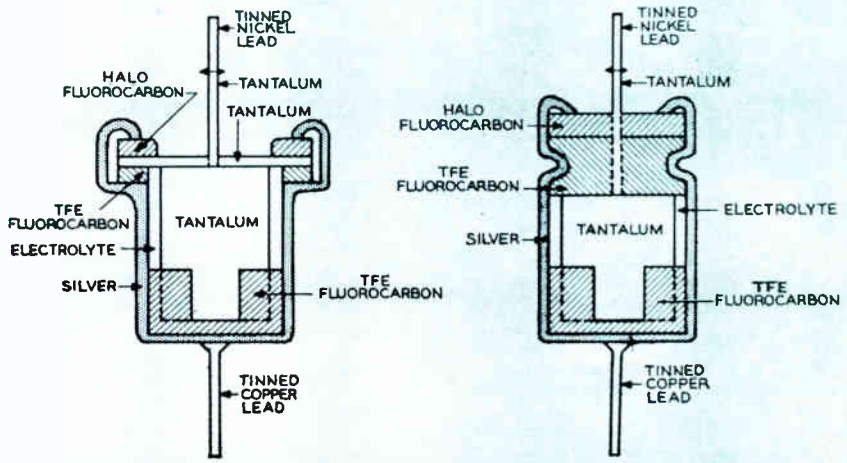


Table 1.
8000 HOUR, 85°C SHELF DATA FOR TYPICAL TANTALUM FOIL CAPACITORS

		HOURS ON TEST				
		0	2000	4000	6000	8000
Capacitor A (2 μf, 150 vdc)	*Capacitance in μf	1.95	2.02	1.94	1.97	1.88
	*Dissipation Factor in %	1.1	1.2	1.4	1.2	1.3
	D-C Leakage Current in μa	0.2	2.0	1.5	1.0	1.2
Capacitor B (100 μf, 75 vdc)	*Capacitance in μf	124.6	120.6	139.0	129.8	121.0
	*Dissipation Factor in %	3.4	3.2	4.7	3.9	3.2
	D-C Leakage Current in μa	30.0	60.0	115.0	60.0	45.0
Capacitor C (12 μf, 25 vdc)	*Capacitance in μf	11.75	11.77	12.40	12.12	12.10
	*Dissipation Factor in %	1.5	1.5	1.7	2.0	2.0
	D-C Leakage Current in μa	0.1	0.1	0.3	0.3	0.1

*Capacitance and Dissipation Factor were measured at 120 CPS.

tween the insulating sleeve and the capacitor can (about half way between the top and the bottom) thereby measuring the heat rise of the capacitor above ambient. For this test to be meaningful, readings should be taken until a condition is reached where two successive readings, taken about 15 minutes apart, show no change in temperature of either the capacitor body or the ambient temperature. A capacitor application may be considered satisfactory if the case temperature does not rise more than about 12°C at a 40°C ambient, or 8°C at a 65°C ambient for an 85°C rated capacitor.

The maximum allowable ripple current at a given temperature and frequency is proportional to the square root of capacitance multiplied by a constant based on rated voltage. Furthermore, increased ripple frequency increases permissible ripple current, while increased operating temperature reduces permissible ripple current. This relationship for a typical capacitor is shown in Fig. 6.

Storage at elevated temperatures without voltage applied gives a very excellent indication of stability of the oxide film and the compatibility of all the materials used in the manufacture of the capacitor. Following a period of at least 24 hours, with no voltage applied and at maximum operating temperature, the leakage current should remain within initially specified limits after a brief period of electrification.

The common misconception that electrolytic capacitors deform their oxide film to a lower voltage when used below their rated voltage, is a carryover from the early days of wet electrolytics which then had a tendency to adjust themselves to the voltage at which they were being used. This is definitely not the case with properly manufactured electrolytic capacitors today. In fact, a lower operating voltage will only result in increased reliability; and, the capacitor can still be used at its full rated voltage if desired. It is known that the recovery time to normal dc leakage current, required after an electrolytic capacitor has been stored for a considerable time at its maximum storage temperature, is a measure of the quality of the capacitor. Therefore, to test capacitor quality it is advisable to subject them, at maximum operating temperature, to various voltages below rated. Following this, the units should be operated at full rated voltage again, at maximum operating temperature, for at least 250 hours. A comparison of dc leakage current, capacitance and dissipation factor after such a test, will quickly indicate which are the well constructed units.

(*Continued on page 26*)

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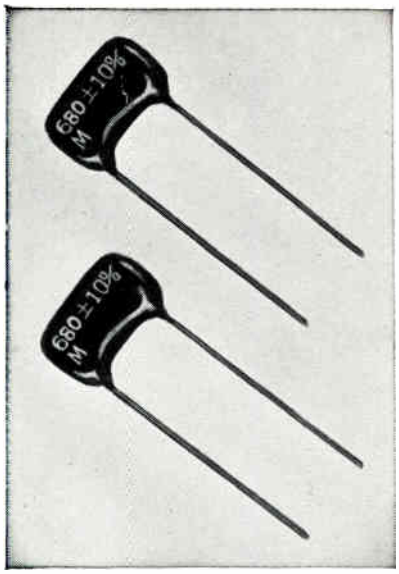
DUR-MICA CAPACITORS TYPE M2DM



Ten thousand EL-MENCO high reliability dipped mica capacitors were put on life test at 85°C with 225% of the rated DC voltage applied—After 26,500,000 actual test unit-hours no failures of any type occurred.

The accumulated 26.5 x 10^6 test unit-hours without any failures can be used to calculate many different failure rates depending upon the confidence level desired. However, we shall explore the meaning of the results at a 90% confidence level.

Assuming no acceleration factor for either temperature or voltage, we have verified a failure rate of less than 0.01% per 1000 hours. (Actually, there is a temperature effect and it has been found that, with the DC voltage stress remaining constant, the life decreases approximately 50% for every 10°C rise in temperature. There is also a voltage effect such that, with the temperature stress remaining constant, the life is inversely proportional to the 8th power of the applied DC voltage.)

Assuming no temperature acceleration factor and assuming the voltage acceleration exponent is such as to yield an acceleration factor as low as 100, we have nevertheless verified a failure rate of less than 0.0001% per 1000 hours.

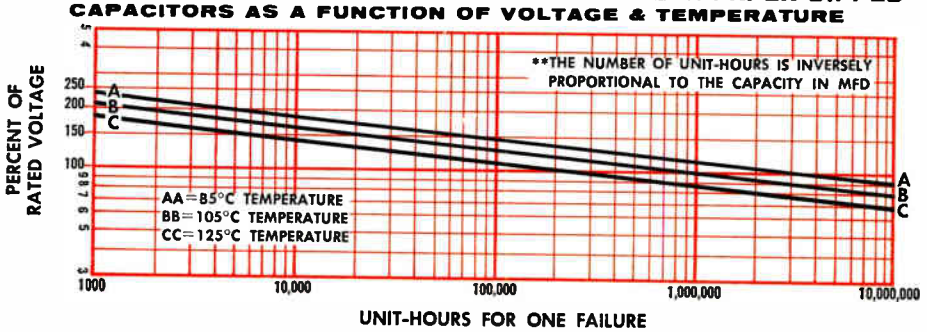
Assuming no temperature acceleration factor and assuming the voltage acceleration factor is on the order of 250 (test results are available to confirm this) we have accumulated sufficient unit-hours to verify a failure rate of less than 0.00004% per 1000 hours!

Note that all the above failure rates are calculated at a 90% confidence level!

Only 1 Failure in 14,336,000 Unit-Hours for 0.1 MFD Capacitors

Life tests have proved that El-Menco Mylar-Paper Dipped Capacitors — tested at 105°C with rated voltage applied—have yielded a failure rate of only 1 per 1,433,600 unit-hours for 1.0 MFD. Since the number of unit-hours of these capacitors is inversely proportional to the capacitance, 0.1 MFD El-Menco Mylar-Paper Dipped Capacitors will yield ONLY 1 FAILURE IN 14,336,000 UNIT-HOURS.

MINIMUM LIFE EXPECTANCY FOR 1.0 MFD MYLAR-PAPER* DIPPED CAPACITORS AS A FUNCTION OF VOLTAGE & TEMPERATURE**



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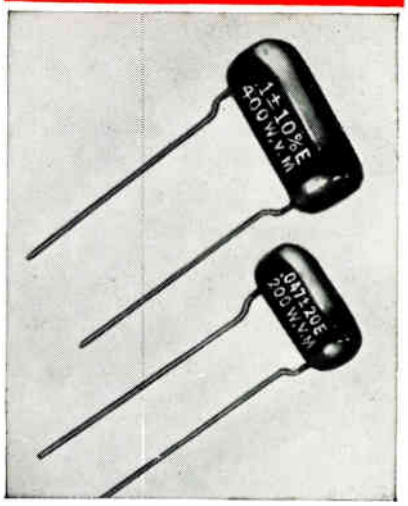
MYLAR-PAPER DIPPED CAPACITORS TYPE MPD



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Though standard life tests at rated voltage and maximum rated temperatures are usually the criterion for determining the quality of an electrolytic capacitor, these two conditions rarely occur simultaneously in practice. Capacitor life expectancy is doubled for each decrease of about 10 degrees in operating temperature. Thus, a capacitor operated at room temperature will have a life expectancy 64 times that of the same capacitor operated at 85°C.

The surge voltage specification of a capacitor determines its ability to withstand high transient voltages which generally occur during the starting up period of equipment. Standard tests generally specify a short on and long off period for an interval of 24 hours or more; and the allowable surge voltage levels are generally from 15 to 30% above the rated voltage of the capacitor. Electrolytic capacitors have a limited over-voltage capability; tests of several times the rated voltage that sometimes are applied to electrostatic capacitors cannot be applied to electrolytic capacitors of any kind.

All polarized electrolytic capacitors, other than those that have one side grounded, characteristically exhibit an indeterminate resistance between the cathode terminal and the metal container. Therefore, the container must be considered at the same potential as the cathode terminal; and there should not be any potential difference between the case and this terminal. If this is not done, the capacitor may be damaged as the result of the current between the cathode terminals and the case.

Electrolytic capacitors are often constructed with pressure sensitive vents to serve as safety valves and to release gas pressure that may be built up in the capacitor if it becomes overloaded or is accidentally connected to reverse polarity. The electrolytic capacitor is essentially an electrochemical device. Hence, the purity and compatibility of all of the material used in its manufacture, as well as tight control over all the manufacturing processes, are of greatest importance.

Failure Modes

Electrolytic capacitors may fail for a number of reasons. One of the main causes of failure is the eventual drying out of the electrolyte. This results in a decrease in capacitance, an increase in dissipation factor, or at worst, an open circuit. Short circuits in electrolytic capacitors have become of minor importance, since potential shorts are generally weeded out during the manufacturing process.

TANTALUM ELECTROLYTIC CAPACITORS

Military and commercial requirements have demanded wider operating temperatures, increased volume efficiency, longer shelf life, higher reliability, uniformity and inertness to generally destructive environmental conditions. Such demands largely account for the rapid development and increased use of tantalum capacitors over the past decade.

Tantalum capacitors can be classified into three groups: the foil, the sintered anode and the solid electrolyte types. Refinements are still taking place in each type. Here presented are the basic characteristics, performance features and latest improvements.

Tantalum Foils

The foil tantalum capacitor has a higher volume efficiency than its aluminum counterpart. Tantalum is more inert than aluminum; therefore, thinner foil (0.0005 in.) can be used without danger of puncture because of local action. Also, tantalum oxide has a dielectric constant almost double that of aluminum oxide. Available in plain or etched foil, both polarized and non-polarized, tantalum foils operate from −55°C and +125°C. At present, plain foil polarized tantalum capacitors can be manufactured in ratings from 3 to 450 vdc. Over their operating temperature range they exhibit the smallest capacitance change of all the foils. Etched foils are currently available to 300 vdc.

By new etching techniques, it is possible to nearly double the capacitance heretofore available in a given case size. The new process produces a much greater effective surface area. Capacitance-voltage products to 42,000 are available. Capacitors rated 2,500 μf at 15 v, 210 μf at 100 v or 45 μf at 250 v, in an axial lead tubular configuration, measure only 0.531 in. diameter by 2¾ in. long. In many cases these axial lead capacitors can be used advantageously to take the place of bulkier, heavier and more expensive rectangular capacitors. In same case size, but for 125°C operation, such ratings as 2500 μf at 10 v, 580 μf at 30 v, 120 μf at 100 v, or 51 μf at 150 v are available.

Tantalum foil capacitors are analagous to aluminum electrolytics, and much of the technological experience and know-how gained for convolutely wound aluminum electrolytic capacitors has been applied to tantalum foil units.

Manufacture of Tantalum Foils

Early in the manufacturing process, tantalum oxide is formed electrochemically by anodizing the tantalum foil. Thickness of the oxide film thus formed depends on the formation voltage and the temperature at which this formation is carried out. The film thickness is about 25A units per volt of formation voltage at 100°C. Increasing formation voltage and temperature increases the thickness.

Anodic connection to the foil is made by welding a tantalum tab to it before the oxide film is formed. The thin foil electrodes are then separated by means of a porous spacer material and rolled to form the conventional convolutely wound cylindrical capacitor section with axial tantalum wires on either end. The

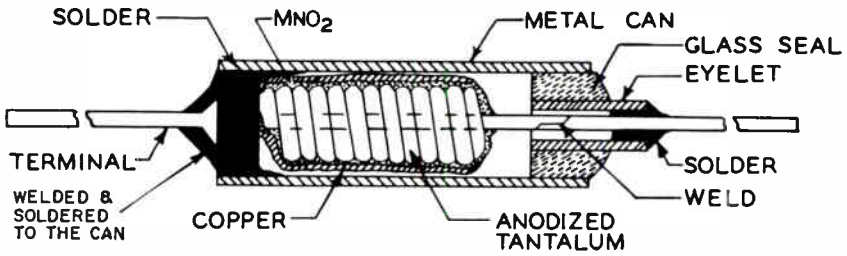


Fig. 9a: Construction of a low capacitance, hermetically-sealed solid tantalum capacitor. The anode is a coil of smooth-surfaced tantalum wire which has been anodized to obtain the dielectric surface film. The type of anode used is only for fractional capacitance values.

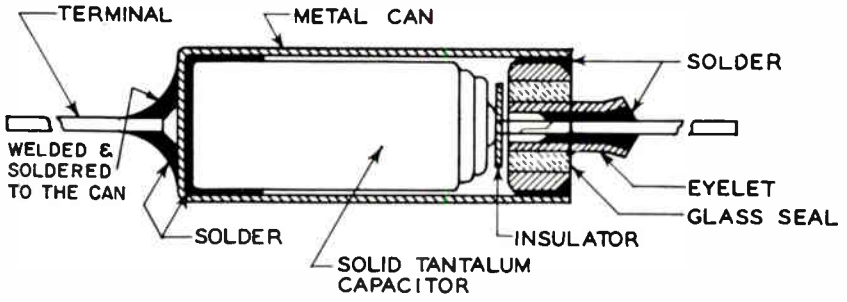


Fig. 9b: A typical porous anode, hermetically-sealed solid tantalum capacitor. The anode is of the sintered tantalum pellet-type which exhibits a large gain in surface area per unit volume. Thus, the resulting capacitor has a large capacitance-to-volume ratio.

section is impregnated with a suitable electrolyte, and the capacitor section is then sealed into a suitable container. Solderable leads are then welded to the tantalum leads.

Foil tantalum capacitors will usually show a decreasing dc leakage current with increased time on voltage. On the other hand, dc leakage current is quite stable even when the capacitor is stored for extended periods of time with no voltage applied. Shelf life data, taken on several 85°C foil capacitors rated at 150, 75 and 25 v, are shown in Table 1. Note that the dc leakage current shows some variation and that the capacitance and dissipation factor show excellent stability even after 8000 hours on the shelf at 85°C.

Leakage current as a function of applied polarizing voltage for 125°C etched-foil capacitors is shown in Fig. 7a. Note that at 50% of rated voltage the dc leakage current is one-half that at full rated voltage. Also, at 150% of rated voltage, the dc leakage current has increased only 3.5 times over that at full rated voltage. The effect of temperature on the leakage current of 125°C foil tantalum capacitors is shown in Fig. 7b. Note that the 125°C leakage current is about 30 times that at room temperature.

Polarized units, with the exception of those with 3 v ratings, are designed with a formed cathode to withstand a reversal of 3 v max. To produce a nonpolar unit, both capacitor electrodes are formed to the same oxide film thickness. One film acts as the insulating medium in one polarity direction, and the other film acts as the insulator in the reverse polarity direction. Such a nonpolar capacitor will withstand equal dc voltage with no deleterious effect in either direction. However, the capacitance of a nonpolar unit is less than the polarized type in a given case size.

The most common operational failure to be expected in foil capacitors is slow degradation brought about by loss of electrolyte through the end seals. This is evidenced by a gradual loss of capacitance, an increase in power factor and a decrease in leakage current. Truly hermetically sealed foil tantalum capacitors using glass-to-metal seals which will not out-gas when in a vacuum or exposed to radiation, should become available in production quantities before the end of 1964.

Foil tantalum capacitors are suitable for ac applications such as phasing of ac motors or tuning of low frequency circuits.

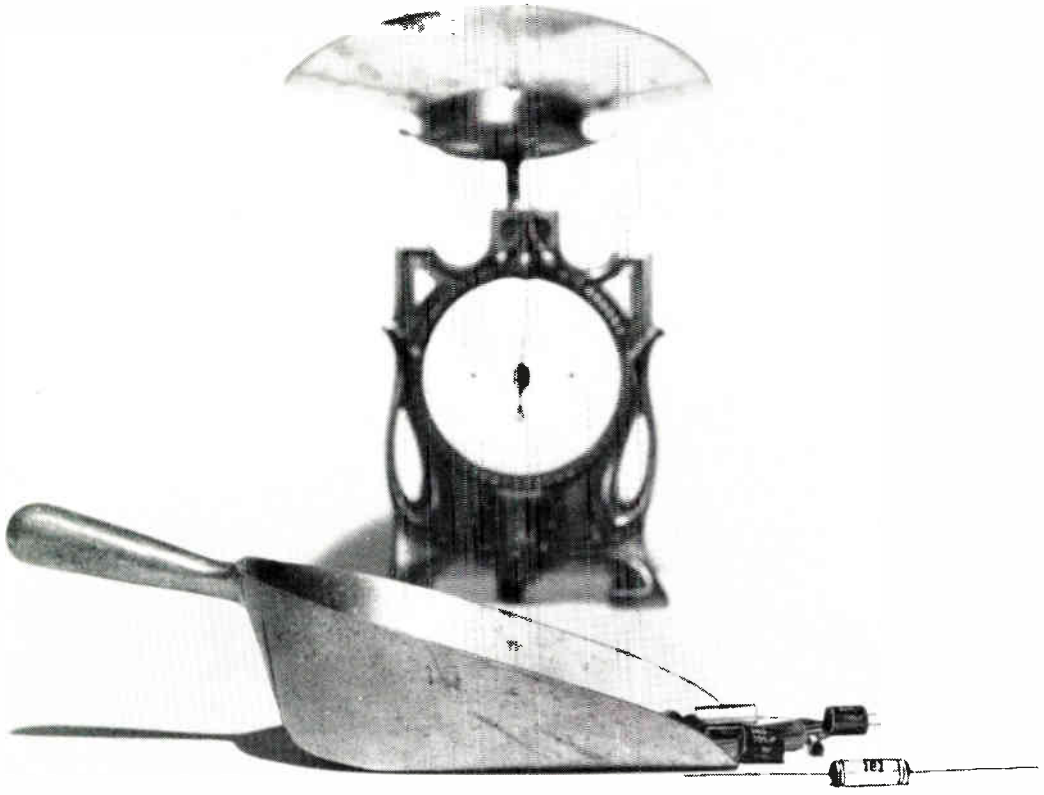
Sintered Anode Tantalums

Sintered-anode-liquid-electrolyte tantalum capacitors have highest capacitance per unit volume, lower rated leakage current, and life unaffected by source impedance. Their low temperature characteristics are better than the foil types, but not as good as the solid tantalum capacitors.

Sintered anode types are made by first pressing powdered tantalum into a pellet together with an organic binder. The pellet is sintered under vacuum to decompose and evaporate the binder. This yields a slug with great mechanical strength and a surface area about 100 times or more that of a solid piece of tantalum having the same outside dimensions. The pellet is then electrochemically formed and sealed in an electrolyte filled fine silver case.

The physical configuration of the sintered anode tantalum unit (Fig. 8) limits this capacitor to polar type. In a variety of mechanical configurations, capacitance ranges from 1.7 to 22,000 μf at 4 to 630 vdc. Operating temperature range of this family of capacitors extends from −55°C to +175°C.

(*Continued on page 29*)



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Limitations

The ability of the sintered anode tantalum capacitor to withstand reverse voltages for any appreciable period of time is poor. In practice, they should not be used in circuits where reversal voltages may be applied. However, short-time reverse voltages usually do little damage. Repeated reversals of currents in excess of rated leakage current will permanently damage liquid-electrolyte tantalum capacitors.

Low Voltage-High Capacitance

Sintered anode capacitors have a larger capacitance loss at low temperature than do higher voltage low capacitance units. By comparison, solid tantalum capacitors have about the same capacitance loss whether they are low or high voltage units.

When properly applied, sintered-anode capacitors customarily fail in the same manner as the foil tantalum units; i.e., there is a gradual degradation of performance which normally results from evaporation of the volatile components in the electrolyte through the end seal of the capacitor. The ability of that seal to contain the electrolyte and thus reduce the rate of weight loss, is a major contributory factor to the extension of the ultimate life of the capacitor.

Aging Characteristics

Shelf aging for appreciable periods lengthens the time during which current in excess of rated leakage current will flow when rated voltage is again applied. Typical sintered-anode wet-electrolyte capacitors, which have been shelf aged one year at room temperature, will drop to rated leakage current at rated voltage in about 10 sec.

New Developments

A recently announced development of considerable importance is the miniature hermetically-sealed tubular sintered-anode tantalum electrolytic capacitor. It employs a gelled-electrolyte and is capable of operation at temperatures to 175°C. Interchangeable in size with MIL Styles CL 64 and CL 65, they are intended for 125°C operation. The electrical characteristics are fully equivalent to those of conventional wet-anode tantalum capacitors, used at temperatures up to 125°C, but the use of a glass-to-metal seal instead of an elastomer seal makes them especially well-suited for use in satellites and other space electronic equipment.

Typical units in this new series have withstood 3000 hour life test at 175°C under vacuum corresponding to space satellite operation, without deterioration. Maximum capacitances available range from 560 μf at 3 v to 28 μf at 63 vdc at 175°C. This is a "dual rated" capacitor, and these working voltages may be doubled for operation at 85°C. This new capacitor is expected to offer a 20 fold increase in life over comparably operated non-hermetically sealed sintered anode capacitors.

Solid Tantalums

The solid-electrolyte tantalum capacitor, Fig. 9, consists of solid inorganic material containing no liquids or other volatile constituents. It uses a solid semiconductor in place of the liquid or semi-liquid electrolytes.

The anode is a porous tantalum pellet, pressed, sintered and formed in a somewhat similar manner as for the wet sintered-anode tantalum capacitor. But after formation, the pellet is impregnated with an aqueous solution of a manganous salt. This salt is then pyrolitically decomposed to yield manganese dioxide, which is the working electrolyte in solid form. A carbon compound is applied over the external layer of manganese dioxide to allow the application of a metallic cathode. The entire system is then sweat-soldered into a metal case and hermetically sealed or otherwise mechanically protected. The use of a completely solid system prevents objectionable escape of electrolyte as a liquid, and greatly extends the life of the capacitor.

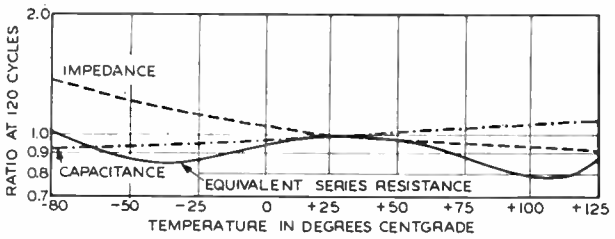


Fig. 10: Typical curves of impedance (Z), capacitance (C), and equivalent series resistance (ESR) with temperature for solid-electrolyte tantalum capacitors.

Solid electrolyte tantalum capacitors are available in polar and nonpolar construction, hermetically sealed, molded, or enclosed in a polyester tube. Capacitance ranges from 4700 pf to 380 μf at voltages from 2 to 125 dc. Operating temperature range is −80°C to +125°C.

Unique Characteristics

Even though the capacitance is relatively high, these units demonstrate an unusual degree of capacitance and dissipation factor stability over a wide temperature range as shown in Fig. 10. The change

(*Continued on page 30*)

FIXED CAPACITORS

Fixed capacitors of all types are seen rising to $364 million in factory sales by the end of 1964. Expected total for 1965 is $377 million. The rise, slow and steady, is characterized by random samples in the table.

	1964	1965	1966
	(in millions of dollars)		
Fixed Capacitors— total market	$364	$377	$391
Electrolytic	121	125	130
Ceramic	44	46	48
Tantalum	76	78	81

(Figures based on a limited EI survey among 300 leading component manufacturers.)

of capacitance indicated by these curves is of the order of 1500 ppm/°C.

Higher capacitance units have a relatively small capacitance change with temperature. Units of 6 v rating may be as low as 300 ppm/°C. The equivalent series resistance does not increase materially at low temperature and remains low over the entire temperature range.

Variation of leakage current with temperature is similar to that for other electrolytic capacitors. Room temperature leakage current increases by a factor of 10 to 30 after capacitors are exposed to 125°C.

Solid tantalum capacitors have been tested for extended periods at elevated temperature with no voltage applied. They have withstood 125°C for thousands of hours with no deleterious effects.

Solid tantalum capacitors charge immediately when voltage is applied, even after being on shelf under no load conditions for extended periods. Liquid-electrolyte tantalum capacitors usually require a finite period in excess of the normal charging time after shelf conditions.

Typical polarized solid tantalum capacitors are capable of withstanding the following maximum peak reverse voltages without harmful effects: 15% of dc rating at 25°C; 10% of dc rating at 55°C; 5% of dc rating at 85°C.

Standard production units have withstood shock of several thousand times gravity. Special units, capable of withstanding 30,000 g, are available.

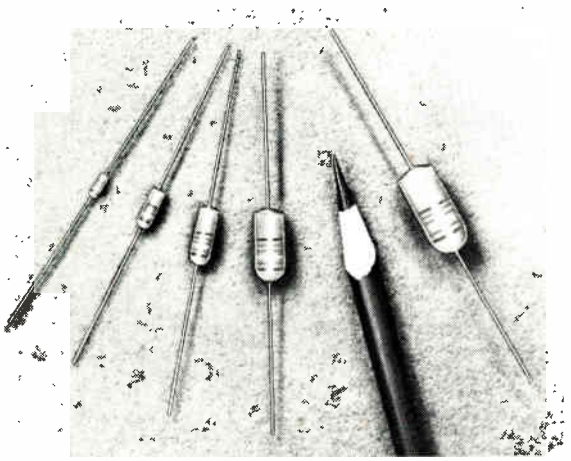
Catastrophic Failure Phenomena

It is well known that voltage and temperature derating reduces the failure rate of capacitors. However, there is another mode of failure peculiar only to solid-electrolyte tantalum capacitors which must also be considered. For some time it has been noted that sudden unexplained catastrophic failures have occurred. This mechanism of failure in solid tantalum capacitors, occurring only in low impedance circuits, is caused by a sudden avalanche of electrons which destroy the capacitor if sufficient power is available from the circuit to which it is connected.

It has also been established that the failure rate will vary with circuit resistance when this resistance is three ohms per volt or less. A decrease in circuit resistance from 3.0 ohms per volt to 0.1 ohm per volt multiplies the failure rate by a factor of about 7.0 at 85°C and by 55 at 125°C.

Because of such sudden breakdowns, it is often to be recommended that the sintered-anode tantalum capacitor, immune to this type of failure, be used in low impedance applications. However, extremely good reliability is attained with solid tantalum capacitors in applications where the circuit impedance is high.

Typical solid tantalum capacitors.



Applications

Solid electrolyte capacitors are available in a variety of mechanical enclosures to fill the requirements for particular applications. Some of these applications include digital computing equipment and industrial electronic devices where cost is of prime importance. They are used for hearing aids and other ultraminiature circuits where space is at a premium. They are employed as feed-through interference suppressors.

Solid tantalum capacitors can be connected back-to-back (cathode to cathode) to produce non-polar units. This can be done within a single metal container by the manufacturer of capacitors or by the user who may connect two polar units in this manner. Such non-polarized capacitors find wide use as phase splitting capacitors for small low-voltage motors, meter phasing circuits, in servo systems, in low frequency tuned circuits, in crossover networks, in bypass applications where high ripple voltages are encountered and in many types of circuits in which there are reversals of polarity greater in magnitude than those which may be applied to a polarized capacitor.

Leakage current of aluminum and tantalum capacitors has been reduced at least 100 fold over the past ten years to a level where it is difficult to measure; and the day may not be far off when leakage current specifications will be supplanted by insulation resistance. For example, a typical 8.2 μf 60 v capacitor is specified as having a maximum leakage current of 0.5μa at 25°C and 2 μa at 85°C. It is interesting to note that this figures out to be equivalent to an insulation resistance of 120 megohms and 30 megohms, respectively. Dissipation factor has improved to where it now is less than 1% and rivalling paper. Capacitance stability is steadily improving.

This improvement in leakage current is noteworthy, since it now offers the opportunity to replace much larger paper capacitors in many applications. Tantalum capacitors are quite suitable for extremely small and stable timing circuit applications.

MEASURING CAPACITOR HEAT RISE

Electrolytic capacitors are being made in smaller and smaller sizes. And, as they shrink, they encounter internal heat problems. Here's how to measure this heat and find the upper limit.

THE DEMAND IS FOR MORE AND MORE CAPACITANCE in smaller and smaller containers with high ripple current ratings. This practice reduces the surface area available for heat dissipation. When a maximum allowable temperature is reached, means must be found to increase the rate of heat transfer.

When the temperature in an electrolytic capacitor cannot be kept to a safe value by natural removal of heat, several possibilities are open to the design engineer.

1. He may provide a better heat-flow path between the capacitor and the region to which the heat is to be transferred.

2. He may resort to forced convection.

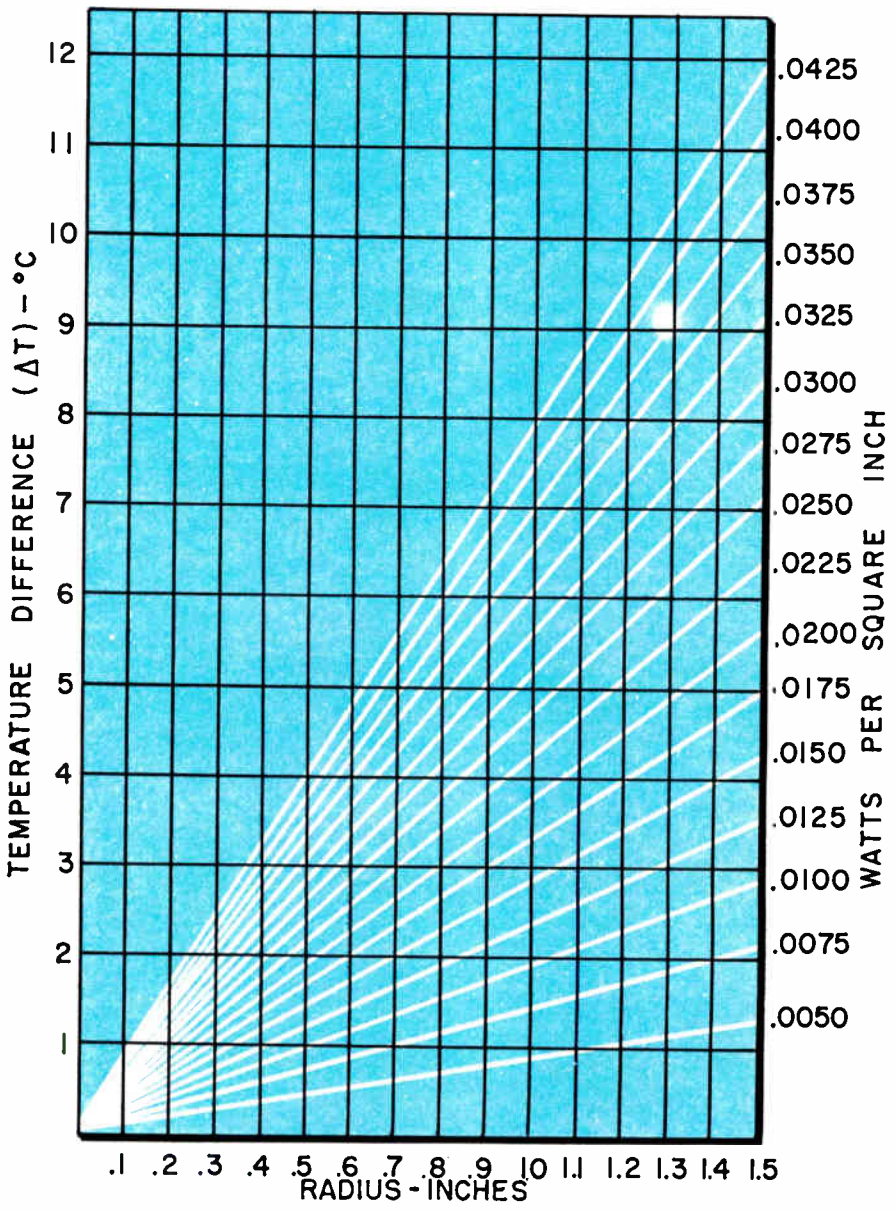
3. He may increase the conducted heat by using a heat sink.

If a heat sink is used, it should be electrically insulated from the chassis, unless the negative terminal of the capacitor is at chassis potential. Initially a capacitor may have a high resistance from the terminals to the container, but the electrolyte tends to decrease this resistance as it saturates the insulator, usually varnish coated paper, between the capacitor and its container.

Method of Measurement

During construction, electrolytic capacitors are wound on a mandrel and therefore a hole about 3/16 in. in diameter extends the length of the capacitor. A thermocouple may be inserted through a small hole drilled in the center of the top and the temperature rise, for a given ripple and leakage current, can be determined. If the internal temperature is not

Fig. 1: The temperature difference versus radius for various levels of internal heat generation due to ripple and leakage currents in electrolytic capacitors.



By EDWARD BOWLING
Project Engineer,
Cornell-Dubilier Electronics,
Div. of Federal Pacific Electric Co.,
Sanford, No. Carolina

allowed to increase over 92°C for a rating of 85°C, a normal life span may be expected.

Ripple current should be applied for about 2 hours, or until two successive measurements, taken 15 minutes apart, show no change in internal temperature.

The temperature difference between the center of the capacitor and the outside of the case is a function of the radius, the internal heat generated due to the ripple and leakage currents, and the surface area.

The power dissipated in a capacitor may be expressed as:

$$Wc = Ir^2 R + I_1 V$$

Where Ir = Ripple current
R = Equivalent series resistance
I_1 = Leakage current
V = Applied dc voltage

A second method which produces results in determining the temperature difference is to use the curves in the Fig. 1.

These curves are based upon the fact that under steady-state conditions, the power dissipated within the capacitor results in a specific temperature differential between the center and the outside surface of the capacitor. This relationship can be represented as:

$$\frac{Wc}{A} = \frac{(0.531)\ (\Delta\ °C)}{r}$$

Where Wc = Power dissipated within the Capacitor.
A = Surface area in square inches.
r = Radius of capacitor in inches.
Δ °C = Temperature difference.

This formula is an empirical condensation of formulas derived from Newton's law of cooling.

The case temperature is easily measured and the internal temperature may then be calculated as shown by the following examples:

EXAMPLE 1: Determine the difference in temperature from the center to the outside of the case of a 1250 MFD., 150 wv capacitor in a 1¾ x 4⅛ in. container. The ripple current is 2 amps at 60 cps and the leakage current is 500 μa. The equivalent series resistance measured at 60 cps is 0.0695 ohm.

SOLUTION: The case area is 27.4 sq. in. The power dissipated is $Wc = (2)^2\ (0.0695) + (0.5 \times 10^{-3})\ (150)$; Wc = 0.353 watts. Therefore, watts/sq. in. = 0.353/27.4 = 0.0129. The radius is 0.875 in. The temperature difference is found to be 2.2°C from the curves.

EXAMPLE 2: If the internal temperature is to be maintained at a maximum value of 80°C, at what temperature must the case be for a 6600 MFD., 75 wv capacitor in a 3 x 4⅛ in container? The ripple current is 4 amps at 60 cps and the leakage current is 1.0 ma. The equivalent series resistance measured at 60 cps is 0.0372 ohms.

SOLUTION: The case area is 52.9 sq. in. The power dissipated is $Wc = (4)^2\ (0.0372) + (1.0 \times 10^{-3})\ (75)$; Wc = 0.670 watts. Therefore, watts/sq. in. = 0.670/52.9 = 0.0127. The radius is 1.5 in. The temperature difference is therefore 3.6°C. The case could be maintained at a temperature of 76.4°C and the internal temperature would not exceed 80°C.

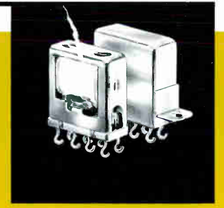
INDUSTRIES, COILS, TRANSFORMERS

Factory sales for transformers, and reactors, including toroids, for 1964 are forecast at $236 million.

The climb will again be slow but steady. Estimates for 1965 average around $242 million, and for 1966 around $248 million.

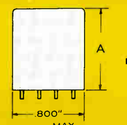
Separate figures for reactors, and various types of transformers are not available. Toroids for 1964 may reach about $30 million.

(Figures based on a limited EI survey among 300 leading component manufacturers.)

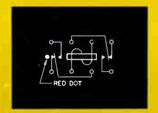


CLARE F & FW MILITARY-TYPE RELAYS

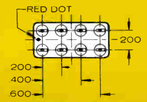
non-polarized
single-side stable
single coil operation



Dimension A:
F—.875" max
FW—.900" max



Shown in unenergized position



Terminal locations F, FW, SF, SFW, One-Coil LF and LFW, and HF Relays

Clare F and FW Relays are standard size crystal can relays, proved capable of handling the most critical design requirements. Developed primarily for military use, they maintain a high degree of reliability with long consistent-performance life under extreme environmental conditions.

These Relays offer high speed, with operate and release time of 5 ms max. They operate at a power of approximately 250 mw. Operated at up to 30 cps, they have a mean mechanical life of 50,000,000 operations. Bifurcated contacts for reliable operation. Gold-plated contact surfaces for consistent, low contact resistance, assuring excellent low level switching, with no sacrifice of reliability under full contact loads.

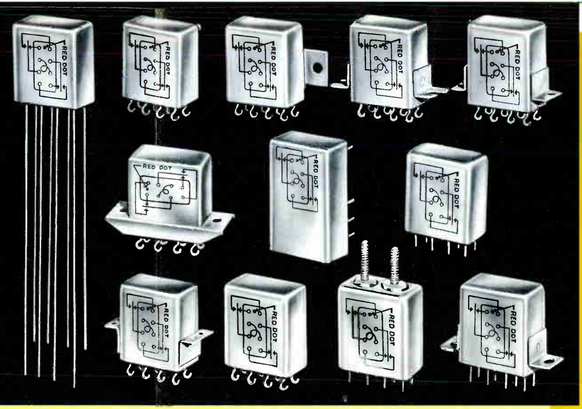
F and FW Relays are available in all popular mounting arrangements (see photo).

F Relays have soldered enclosures; FW Relays have welded enclosures.

TYPICAL TERMINALS AND MOUNTING DESIGNS FOR F, FW, SF, SFW, LF, LFW RELAYS

These Relays provide choice of soldered or welded (W) enclosures.

(Two-coil LF and LFW Relays have 10 terminals—see drawing at right)



CLARE SF & SFW MILITARY-TYPE RELAYS

single-side stable *non-polarized* *single coil operation*

Clare SF and SFW Relays are high-sensitivity versions of the F and FW Relays, identical in dimensions and similar in construction to the F and FW, but capable of operating as low as 40 mw. Four models provide proper sensitivities for a wide variety of applications:

SF-1000/SFW-1000: 40-60 mw
SF-2000/SFW-2000: 61-80 mw
SF-3000/SFW-3000: 81-120 mw
SF-4000/SFW-4000: 121-180 mw

SF Relays have soldered enclosures; SFW Relays have welded enclosures. Circuits, dimensions, mounting arrangements and terminals are same as for F and FW Relays.

CLARE LF & LFW MILITARY-TYPE RELAYS

polarized
single-side stable or bi-stable
single or double coil operation

Clare LF and LFW Relays are magnetic latching relays, similar in external appearance and dimensions to the F and FW Relays.

Two permanent magnets, incorporated in the dynamically balanced armature of the LF and LFW, provide latching forces which hold the contacts in either of the two stable positions.

One-coil LF and LFW Relays operate at approximately 50 mw.

Two-coil LF and LFW Relays operate at approximately 100 mw. They have 10 terminals (see lower drawing at left).

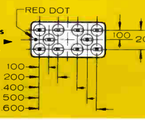
LF Relays have soldered enclosures; LFW Relays have welded enclosures. Dimensions and mounting arrangements are same as for F and FW Relays.

One-Coil LF and LFW Relays

One-Coil LF and LFW Relay terminal locations same as F and FW Relays

Two-Coil LF and LFW Relays

Terminal locations LF and LFW (two-coil) Relays



CLARE HF MILITARY-TYPE RELAY

non-polarized
single-side stable
single coil operation

Shown in unenergized position

Clare HF Relays deliver important features of Clare F Relays—in half size:

Sturdy, simple design . . . plus bifurcated contacts and flexible make and break contacts, which deliver maximum reliability. Gold-plated contact surfaces for consistently low contact resistance, assuring excellent switching at low level or under full contact loads.

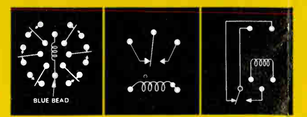
With standard 26.5 vdc coil, the HF Relay has resistance of 1250 ohms, just-operate sensitivity of 160 mw, and power requirement at nominal voltage of only 560 mw. No coil overheating problem, even at overvoltages of 32 vdc.

Dimensions are same as F Relay, except height (.410" max). Mounting arrangements and terminals are same as F Relay.

BA Switch Capsule (encapsulated contacts)

CLARE BA MILITARY-TYPE RELAYS

sealed-in-glass contacts *non-polarized* *single-side stable*



Six-Pole BA Relay

Single-Pole BA Relay

Single-Pole BA Relay Module

Clare BA Relays are designed and built for maximum reliability under extreme shock and vibration. Precise armature balance results in resistance to shock of 125 g at 11 ms and 250 g at 1.5 ms, as well as vibration resistance of 100 g at 5-2500 cps and of 70 g at 2500-4500 cps.

Each BA switch is assembled in a super-clean atmosphere and hermetically sealed in glass under pressure; this glass-encapsulation eliminates possibility of contact contamination from relay environment or relay coil.

Radiation-resistant construction is available on special order.

BA Relays are available in practically every desired configuration, including 6-pole round enclosure (BA6A201), single-pole round enclosure (BA1B201) and single-pole printed circuit board module (BA1C300).

CLARE Military-Type Relays offer the designer every needed relay for military application: standard, sensitive, latching, miniaturized, and special relays for unusual requirements of shock, vibration, and radiation resistance.

IMPORTANT DESIGN CONSIDERATIONS

Versatile contact capability.
Clare Military-Type Relays provide excellent low-level switching without sacrificing reliability under full rated contact loads. Gold-plated contact areas provide consistently low contact resistance. Bifurcated contacts, with high contact pressures and over-travel for proper contact wipe, assure reliable operation at high or low level.

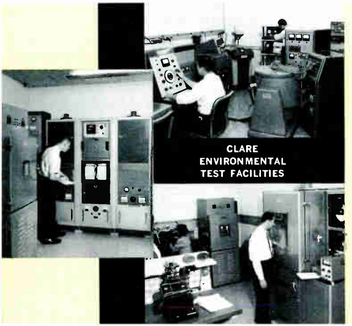
Long mechanical life.
Simple structure (contacts and armature are only moving parts) prevents mechanical breakdown—assures consistent operation over the long life of these relays.

Sensitivity.
Operating characteristics of these relays provide high sensitivity with minimum power requirements, due to accurately-wound high-resistance coils.

Clare Quality.
Clare's Quality Assurance Program utilizes continuous testing in a feed-back program to produce constantly-improving product. Completely documented test results are available to relay users.

	F / FW	One-Coil LF / One-Coil LFW	Two-Coil LF / Two-Coil LFW	SF / SFW	HF	Six-Pole BA	Single-Pole BA
ELECTRICAL CHARACTERISTICS							
Contact Arrangement	2 Form C (dpdt)					6 Form C (6pdt)	1 Form C (spdt)
Contact Rating—High Level	2.0 amp resistive @ 28 vdc; 1.0 amp resistive @ 115 vac; 100,000 miss-free operations monitored at every operation for a maximum drop of 10% of source voltage.					2.0 amp resistive @ 28 vdc. 1,000,000 operations. 1.0 milliamp resistive @ 28 vdc. 40,000,000 operations @ 200 milliohms max contact resistance.	
Contact Rating—Low Level	10μa @ 10 mv. 100,000 miss-free operations monitored at every operation for a maximum drop of .5 mv.						
Contact Resistance—Before Life	50 milliohms max @ 6 v, 100 ma					200 milliohms @ 6 v, 100 ma	
Contact Resistance—After Life	100 milliohms max @ 6 v, 100 ma						
Maximum Operate Time (including bounce)	5.0 ms	8.0 ms	6.0 ms	8.0 ms	5.0 ms	3.5 ms	2.7 ms
Nominal Must-Operate Sensitivity	250 mw	50 mw	100 mw (per coil)	40-180 mw (Note 1)	160 mw	1.2 w	0.6 w
Nominal Operating Voltage	6.3-110 vdc	3.2-110 vdc (continuous duty)	3.2-54 vdc (continuous duty)	6.3-110 vdc	6.3-48 vdc	6.3—110 vdc	
Coil Resistance	35-10,000 ohms	40-9100 ohms	15-4400 ohms (per coil)	35-10,000 ohms	40-2700 ohms	5-3500 ohms	15-7000 ohms
ENVIRONMENTAL CAPABILITIES (Temperature Range: −65°c to +125°c)							
Shock (½ sine wave 11 ± 1 ms pulse)	65 g	100 g		65 g	50 g	Greater than 125 g (250 g for 1.5 ms) (Note 3)	
Vibration	.125″ double amplitude or 20 g (Note 2)	.250″ double amplitude or 20 g (Note 2)		.125″ double amplitude or 15 g (Note 2)	.250″ double amplitude or 20 g (Note 2)	Greater than 100 g to 2500 cps—10 g to 4500 cps (Note 4)	
Linear Acceleration	100 g						

NOTES:
1. SF and SFW Relays are available in four ranges of sensitivity. See detailed description inside this Bulletin.
2. Whichever is less.
3. If hard mounted, Vibration resistance of round-enclosure BA Relays is greater than 100 g through 400 cps. Vibration resistance of printed circuit board module is dependent upon mounting.
4. If hard mounted, Shock resistance of round-enclosure BA Relays is greater than 125 g through 11 ms. Shock resistance of printed circuit board module is dependent upon mounting.



RELIABILITY

Clare's exacting testing procedures prove the reliability of Clare Military-Type Relays, and their ability to meet the rigid specifications of MIL-R-5757D . . . plus the even more stringent requirements of the Clare Quality Assurance Program.

This program assures not only the most reliable relays it is possible to obtain today . . . but a continuously higher norm of reliability from day to day. Clare Relays are tested in general accordance with MIL-R-5757D (par. 4.6.1.4, Group B) . . . then tested to failure. In this way, Clare is able to analyze the cause of final breakdown, even after military requirements have been exceeded—and then take necessary corrective measures (regarding materials, processes or people) to produce ever-increasing reliability.

CLARE QUALITY ASSURANCE PROGRAM

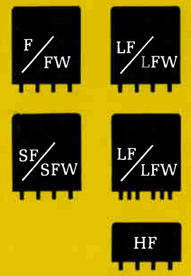
This continuous testing program, with feed-back to product engineering, quality-control and production functions, results in:
(1) Standard production relays of constantly improving reliability.
(2) Reliability data of immediate value to the relay user.

By statistical analysis of test data, Clare produces useful projections of low level life, 2 ampere load life, operate and release voltages, operate and release times, operate bounce, and contact resistance. A number of Clare Relay users find these projections useful in their own Quality Assurance Programs.

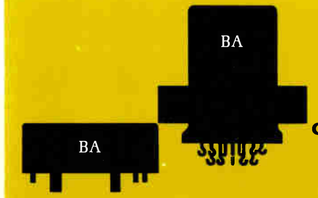
Clare has both the facilities and the desire to participate in customers' high-reliability programs. Clare testing capabilities make it possible to provide individual relay users with special test reports, which may be in accordance with the users' own standards, test methods, and/or reporting procedures.

Reliability Manual 710 explains and reports the Clare Quality Assurance Program, with charts of low level life, 2 ampere load life, operate and release voltages, operate and release times, operate bounce, and contact resistance. It is available to users and prospective users of Clare Military-Type Relays.

Bulletin 700



CLARE MILITARY-TYPE RELAYS



C. P. CLARE & CO.

- proved reliability
- versatile contact capability
- long mechanical life
- high sensitivity
- Clare quality

write for this literature or use indicated Reader Service number

CLARE RELAY	DESCRIPTION	NUMBER
Type F/FW	Design Manual	203
Type SF/SFW	Data Sheet	754
Type LF/LFW	Data Sheet	752
Type HF	Data Sheet	755
Type BA	Data Sheet	753
Clare Quality Assurance Program	Reliability Manual	710

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Tel: 221-9030

Baehr, Greenleaf & Assoc., Inc.
3350 Maplewood Drive
Xenia, Ohio 45385
Tel: 426-5485

Baehr, Greenleaf & Assoc., Inc.
9505 Montgomery Road
Cincinnati, Ohio 45242
Tel: 891-3827

Halgin Sales
5460 Buena Vista
Mission, Kansas 66200
Tel: 722-2441

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1925 Cedar Springs
Dallas, Texas 75201
Tel: 741-4411

Robert E. Nesbitt Co.
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Houston, Texas 77006
Tel: 528-3811

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Tel: 982-7932

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Tel: 787-2510

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Tel: Russell 9-4335

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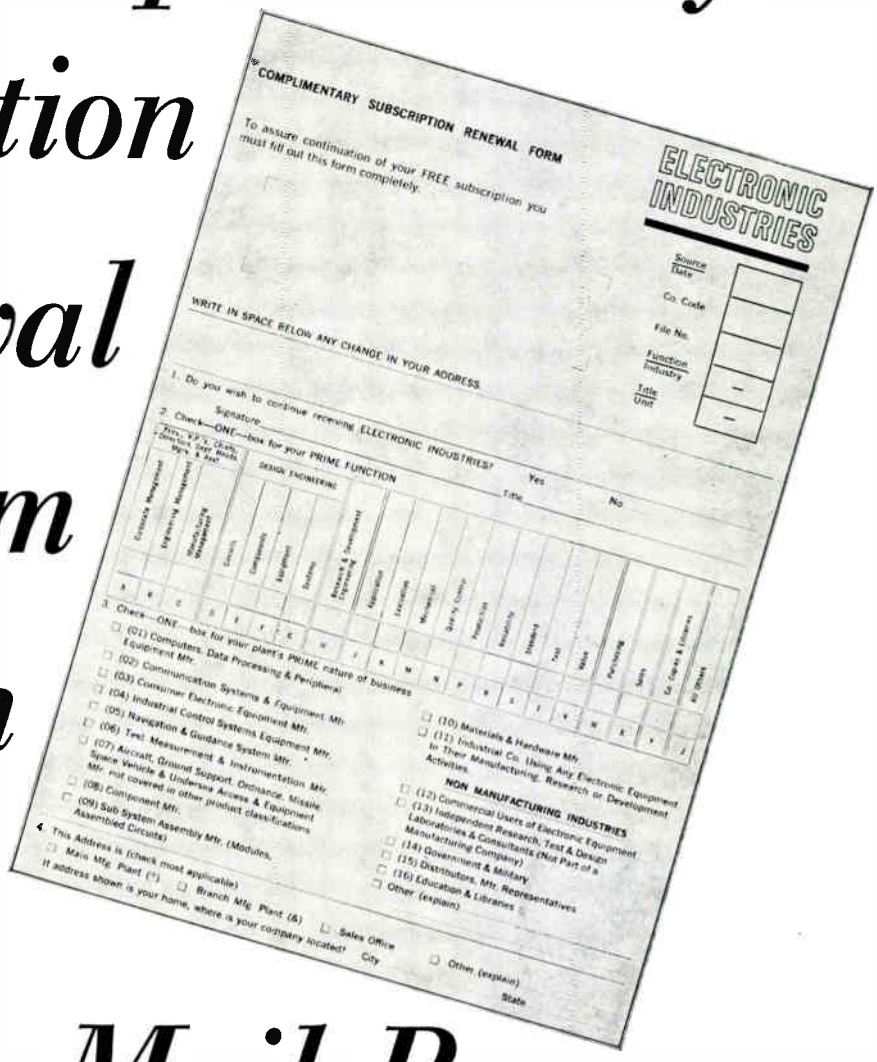

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METAL FILMS' ROLE IN FIXED RESISTORS

Resistors outnumber any other single discrete component by more than 4 to 1. How to select the best fixed resistor, both performance and price-wise, has been a long-standing problem. The latest developments in metal film resistors may eliminate many selection difficulties.

ONE OF THE BIGGEST PROBLEMS facing the specifier and user of resistors is the chaotic assortment of units available and the equally chaotic range of prices at which they have been marketed. To the design engineer, the value analysis engineer and the quality control man, the resistor business has become an increasingly complex and time-consuming operation.

In ratio of usage, resistors outnumber any other single discrete component by almost 4-to-1. The advent of wider integrated circuit usage, coupled with heavy competitive pressures on end item equipment is focusing attention on the fixed resistor. Circuit design engineers are becoming more conscious of price-performance values. They are re-examining traditional choices, such as among carbon composition, film and wirewound types.

All Sizes and Shapes

Resistor manufacturers today make their units in almost every conceivable shape, size, material, temperature coefficient, initial tolerance and life characteristic. An engineer who desires a ½ watt, 10,000 ohm resistor, has many devices available to him, but he may have to search through 40 or 50 pages of specifications, price lists and trick phrasing to find the one unit he needs. For example, he has available to him—if he can ferret it out—a ½ watt, 10,000 ohm resistor made of:

Metal oxides sprayed onto rods;

Glass and metal ground up and baked onto a rod;

Carbon (filament, pellets or film—the latter either deposited or carbon alloyed);

Cermets on a chip;

Wirewound on a bobbin.

There is, of course, even wirewound on wire, and these same ½ watt resistors can be provided on glass rods, ceramic or even precious stone. Costs vary from several dollars each for the 0.1% low temperature coefficient types, down to less than 6 cents each for 2% metallic oxide and carbon films. And between these extremes, the variety of overlap in performance, overlap in maker's claims and overlap in price, confuses the people who buy resistors and increases costs of those who make them.

Three Classifications

Fixed resistors are divided into three basic classifications. These classifications are: "Power" consisting of both film and wirewound types; "General Purpose" consisting of carbon composition, pyrolytic carbon, metal oxide and cermet types; and the "Precision" or "Accurate" consisting of wirewound, metal film, metal oxide and pyrolytic carbon types. Because the usage of "power" type resistors is well defined, this discussion will be limited to "precision" and "general purpose."

To better see what has happened to the price structure, we must look

By WILLIAM E. McLEAN
Vice President,
Research & Engineering
Electra Manufacturing Co.
Independence, Kansas

back. Comparing 1958 with 1962 and then 1964, we see the encroachment of precision units on the price domain of semi-precision resistors.

Carbon composition has held at a steady performance/price level, while carbon film and tin oxide units have dropped from 15 cents to 7 cents to about 6 cents. Metal film, meanwhile, with its inherent extra performance, has had a more spectacular drop from 50 cents to 7 cents, and finally down to meet the price of 5% carbon composition resistors.

Types of Films

Reliability, and, therefore, performance, begins with the design and choice of materials, so it is well at this point to briefly mention the various types of films.

Of the carbon films, deposited carbon resistors are formed by the cracking of hydrocarbon gases at high temperature and atmospheric pressure to deposit a carbon film on a ceramic substrate. These units have a −200 to −500 ppm temperature coefficient. The films are relatively soft and fragile. Finished resistors exhibit a total life excursion after specification stresses and environments of about 3%, based on 10,000 hours load life at 70°C, rated power.

Carbon alloy resistors result from a carbon film deposited on a ceramic substrate by the vacuum deposition of a carbon film from a carbon-bearing liquid, with the addition of the alloying constituents. This film is much tougher than deposited carbon films, and exhibits much greater resistance to damage from abrasion and heat. TC is around −200 to −500 ppm, and, like the deposited carbon units, total specification stresses and environments are about 3% at 10,000 hours load life at 70°C, rated power.

Tin oxide films are created by the exposure of glass or ceramic at high temperature to various compounds of tin in either the liquid or vapor state. There are, however, significant differences between tin oxide on glass substrates and tin oxide films on ceramic substrates. In the case of tin oxide on glass, manufacturers achieve TCR of +200 to +250 ppm, but here, thermal conductivity is less efficient. In the case of tin oxide on ceramic, TCR is greater, but the ability to dissipate power is superior. The glass tin oxide resistor is more susceptible to damage because of cracking or fracturing of the substrate. In both instances, the finished resistors exhibit a total life excursion, after specification stresses and environments, of about 4%. This is based on 10,000 hours load life at 70°C, rated power.

Chemically deposited metal film resistors are prepared by the precipitation of metals onto a ceramic substrate from a solution. They exhibit TCR of ±100 to ±300 ppm. These films, while offering some of the advantages of vacuum evaporated metal film, exhibit less reliability as the result of impurities and film softness.

Vacuum evaporated metal film resistors exhibit the best overall performance of any of the above. The metal film is formed by the deposition of nickel and chromium onto a pure ceramic substrate under high vacuum conditions. The film is formed when the metals reach the diffusion temperature in vacuum. TCR is from 0 ± 25 ppm to 0 ± 150 ppm. The evaporated metal film resistor is noted for its stability and low noise characteristics. Here, total specification stresses and environments are about 2%, based on 10,000 hours load life at 125°C, rated power.

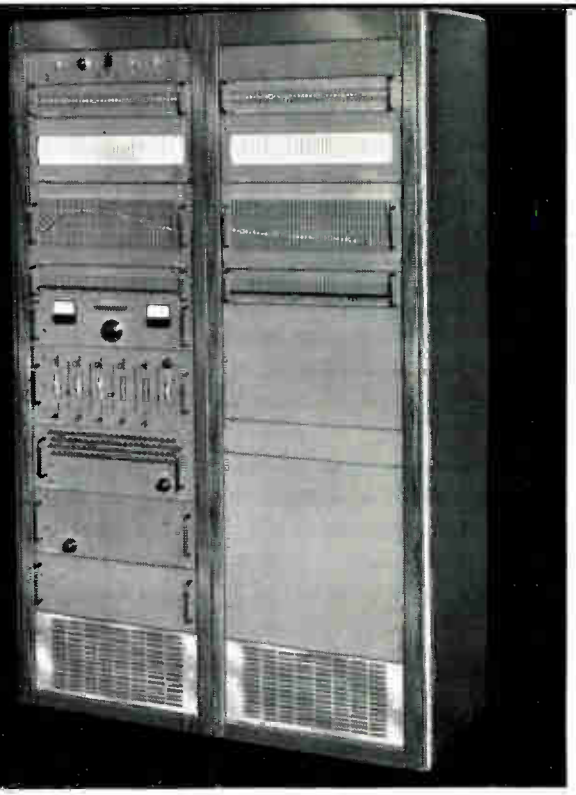
(Continued on following page)

RESISTOR REFERENCE CHART

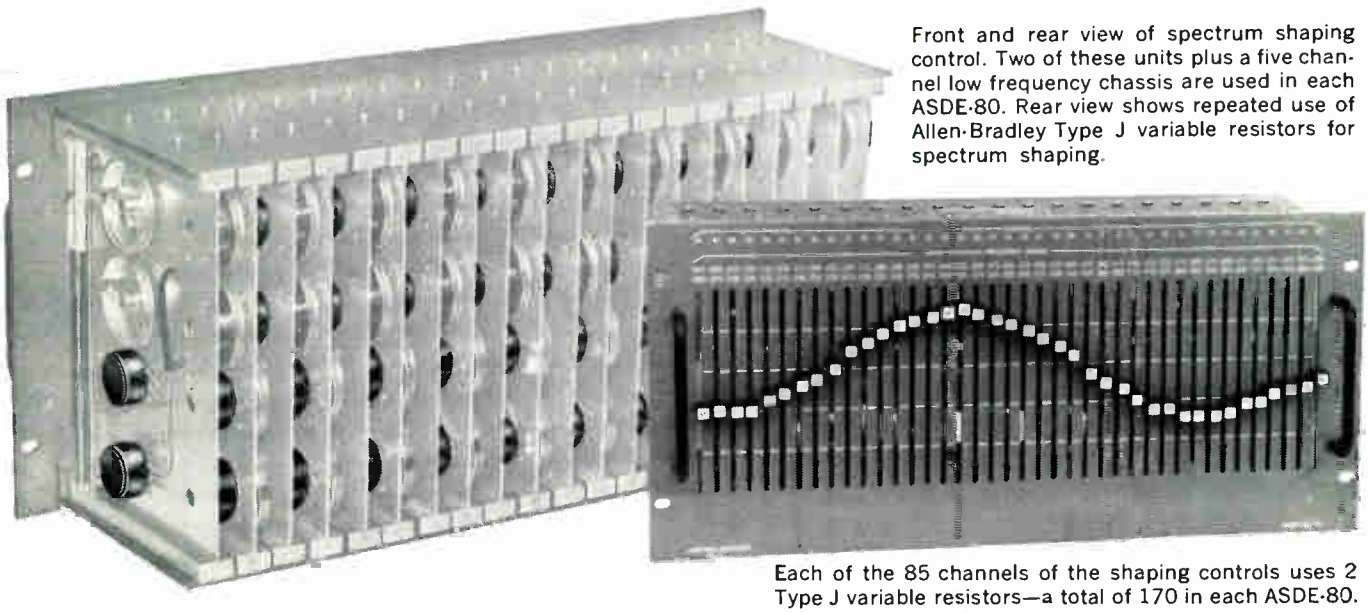
	Carbon Composition (Slug & Film) MIL-R-11 MIL-R-10683	Pyrolytic Carbon MIL-R-10509	Metal Film MIL-R-10509	Metal Oxide MIL-R-22684	Precision Wire Wound MIL-R-93 MIL-R-39005
Resistance Range	2.7Ω – 22 megΩ	10Ω – 10 megΩ	24.9Ω – 2.0 megΩ	10Ω – 1.5 megΩ	.1Ω – 20 megΩ
Tolerance	5 – 20%	± 1%	± .1% – ± 1%	± 2% – ± 5%	0.02 – 1%
T.C. of R (ppm/°C)	± 800 – ± 3000	± 200 – ± 500	± 25 – ± 50	± 200	± 20 – ± 50
Noise	Low	Low	Extremely low	Low	Essentially noise free
Load Life Stability 1000 hrs	± 6% Avg. LL ± 10% Individual ΔR	± 1%	± 0.5%	± 2% – ± 3%	± .5%
Physical Size (Nominal)	0.075 x 0.160 0.312 x 1.312	0.250 x 0.109 2.187 x 0.375	0.250 x 0.109 1.062 x 0.375	0.562 x 0.090 0.688 x 0.318	0.250 x 0.90 0.250 x 2.125
Power Ratings	1/10 w – 2 w	1/10 w – 2 w	1/10 w – 1 w	1/4 w – 2 w	1/8 w – 2.5 w
Voltage Ratings	150 v – 500 v	200 v – 750 v	250 v – 500 v	250 v – 500 v	250 v – 900 v
Operating Temperature	40– 70°C @ full load 110–150°C @ zero load	70°C @ full load 165°C @ zero load	125°C @ full load 175°C @ zero load	70°C @ full load 150°C @ zero load	125°C @ full load 145°C @ zero load

no failure problem

since switching exclusively to Allen-Bradley Type J Variable Resistors

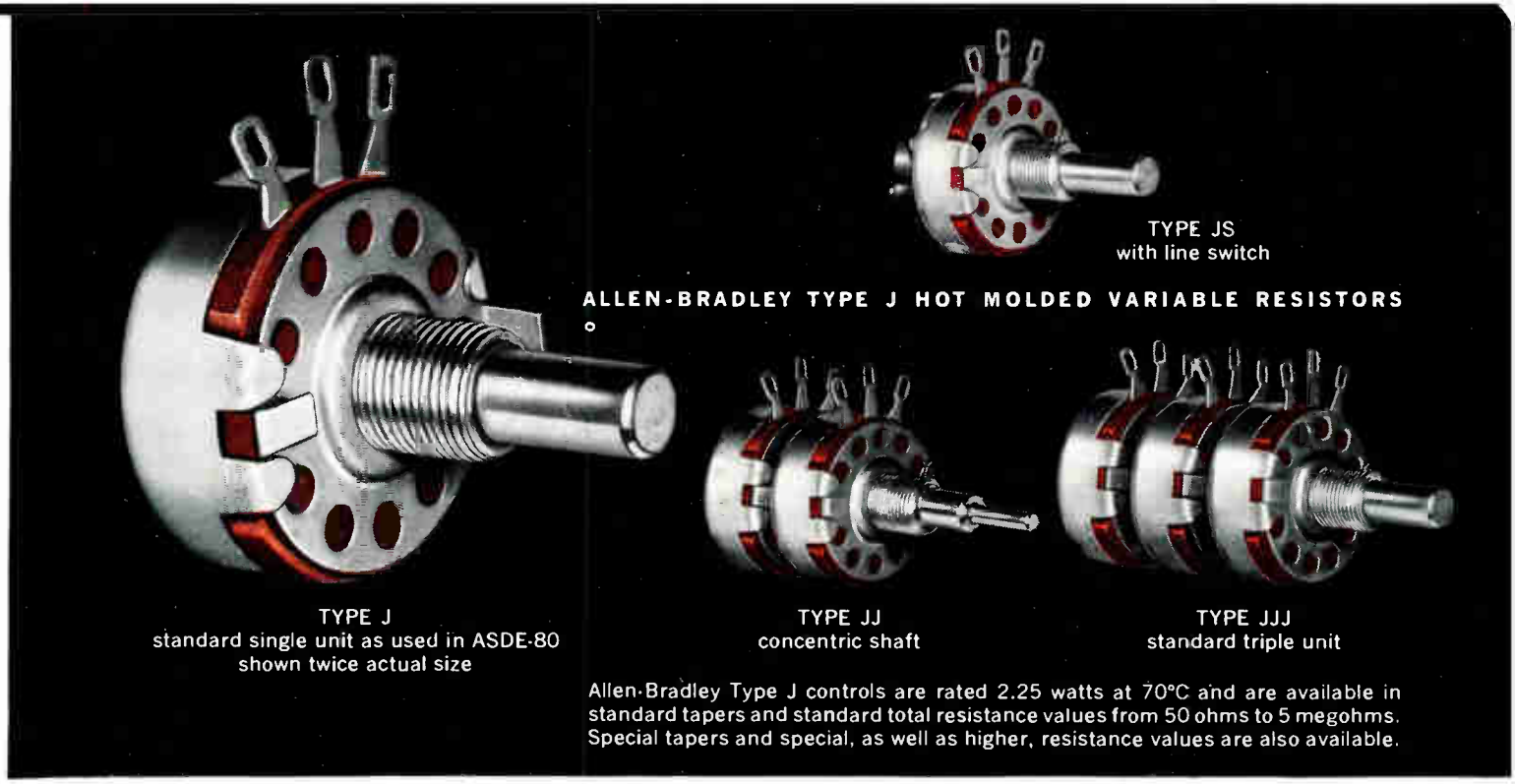


LTV LING ELECTRONICS DIVISION
Ling-Temco-Vought, Inc.
AUTOMATIC DYNAMIC SPECTRAL DENSITY EQUALIZER/ANALYZER



Front and rear view of spectrum shaping control. Two of these units plus a five channel low frequency chassis are used in each ASDE-80. Rear view shows repeated use of Allen-Bradley Type J variable resistors for spectrum shaping.

Each of the 85 channels of the shaping controls uses 2 Type J variable resistors—a total of 170 in each ASDE-80.



Allen-Bradley Type J controls are rated 2.25 watts at 70°C and are available in standard tapers and standard total resistance values from 50 ohms to 5 megohms. Special tapers and special, as well as higher, resistance values are also available.

Since switching to exclusive use of Allen-Bradley Type J *hot molded* variable resistors—shortly after introducing their first equalizers in 1956—LTV Ling Electronics Division has achieved improved performance and reliability.

The superiority of the Type J is the result of an *exclusive* A-B process—the solid resistance element, terminals, faceplate, and threaded bushing are *hot molded* into a single solid structure. Operation is always smooth and free from abrupt changes during adjustment. In addition, the Type J features an exceptionally low noise level when new, and it becomes *even lower with use*. And on accelerated tests, they exceed 100,000 complete rotational cycles with less than 10% resistance change.

Whenever you have a particularly critical application, benefit from the experience of LTV Ling Electronics Division and standardize on Allen-Bradley *hot molded* variable resistors. For more complete details on the Type J variable resistors and other quality electronic components in the A-B line, please send for Publication 6024: Allen-Bradley Co., 102 W. Greenfield Ave., Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

A-B QUALITY

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

Circle 53 on Inquiry Card

FIXED RESISTORS (Concluded)

A critical step in the manufacture of film resistors is the termination, or attachment of leads to the resistive substrate.

One type of lead attachment is the solder termination method, wherein the lead is soldered directly to the body of the resistor. Because the lead is not mechanically fixed to the rod, this has become a poor method of attachment.

In more common usage today is the talon lead attachment, in which the end of the lead is dipped into a conductive cement and inserted into the resistor rod. The major problem here is that force exerted on the lead often results in pressures extreme enough to crack the resistor rod and break the termination.

Several manufacturers, including Electra, have turned to what is called capped construction, because of the superior mechanical strength which results. In this method, a metal cap, with a welded or staked lead, is pressure-fitted onto the resistor rod, resulting in an even distribution of force rather than on a concentrated one as in the other methods. Also, capped leaded resistors are more easily produced than the solder termination or talon leaded type, and with greatly increased mechanical uniformity and predictability.

Data from several military specifications is shown in the table, which compares the major attributes for various types of resistors.

Examples of usage include the accurate wirewound types which are used for extremely close initial tolerances in such applications as bridge and voltage divider circuits as calibrating resistor, etc. But, they are not very good for high frequency uses. Accurate film types have specific application where close initial tolerance, low TCR, high stability and good frequency characteristics are needed. The "Boella Effect" or fall off in resistance with increase in frequency is much less pronounced in film type resistors than in other types (pellet or wirewound).

This effect also decreases with decreasing film thickness, making the metal film types very suitable for high frequency use. The use of close tolerance resistors allows the selection of less critical, and, therefore, lower cost active devices.

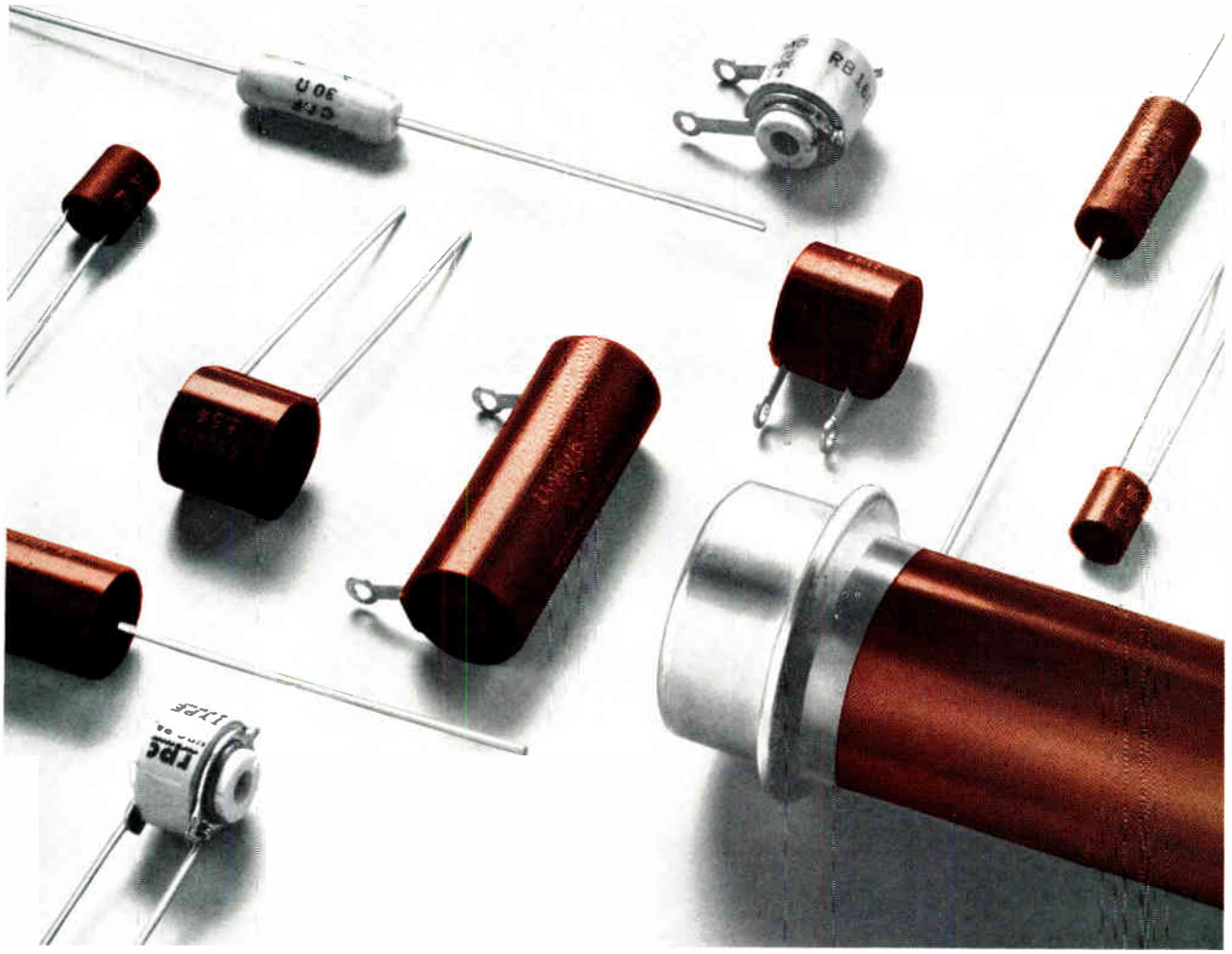
FIXED RESISTORS

Resistors of all fixed types may bring a total of $188 million in factory sales for 1964, followed by an expected steady climb to around $202 million in 1966. Sample categories shown in the following table are only a part of the entire market.

	1964	1965	1966
	(in millions of dollars)		
Fixed Resistors—total market	**$188**	**$197**	**$202**
Composition types	**67**	**67**	**66**
Film	**51**	**56**	**61**
Wire Wound	**55**	**56**	**57**

(Precision wire wound resistors may bring $15 million in total sales for 1964).

(Figures based on a limited EI survey among 300 leading component manufacturers.)



Not a drifter in the bunch

A good thing to know about RPC wire-wound resistors, if you're specifying to tighter tolerances!

Why?

Obviously, with advanced applications calling for greater densities, any reduction in diameter or ohmic tolerance in the resistor results in disproportionate drift.

We engineer wire-wound resistors to maintain maximum stability levels. We *know how* and that's why we *guarantee* drift is kept at specified absolute minimums.

Take the case of a prominent computer manufacturer. We solved his drift problem by engineering a wire-wound resistor which maintains a stability factor of ± 0.0025% over a three year period! Compare this to the 0.01% per year drift in the normally processed wire-wound resistor. And check these additional advantages:

Resistance Tolerance
RPC Standard: ± 1%
RPC Custom: ± 0.5% to ± 0.01%

Temperature Coefficient
RPC Standard: ± 30 PPM/°C
RPC Custom: ± 10 and ± 5 PPM/°C

A.C. Requirements
1 picofarad maximum distributed capacitance

When drift is a consideration in your requirements, a special RPC engineering team is always ready to review your needs and provide resistors that meet your most exact specifications.

Write today for complete information.

rpc

Resistance Products Co.

914 S. 13th Street, Harrisburg, Pennsylvania 17104 ● Phone 717-236-5081

MANUFACTURERS OF QUALITY RESISTORS: *PRECISION WIRE-WOUND, CARBON FILM • RESISTANCE NETWORKS*

NEW TECH DATA

RESISTORS-CAPACITORS

Stripline Resistors

Data is available on two types of stripline resistors for microwave applications. The microwave resistors are for termination and attenuation uses; the bias resistors are for bias control. The microwave resistors values are from 0.9 to 15Ω and 0.1 to 2Ω/sq., can be provided in other sizes. Vishay Instruments, Inc., Malvern, Pa.

Circle 386 on Inquiry Card

Capacitors

This literature describes a line of capacitors, some of which have ribbon leads for welding purposes. Also included are cylindrical style axial leaded capacitors of the diode size. Capacitance range 10 to 10K pf rated at 100vdc up through 150°C. These new products meet or exceed the Mil-C-11015C. King Electronics Inc., 150 Waverly Dr., Pasadena, Calif.

Circle 387 on Inquiry Card

Surge Resistor

A new line of surge resistors designed to withstand large current and voltage surges such as the propagation of atomic blasts or lightning surges is described in a data sheet. They are used with a surge arrester to protect systems from induced electromagnetic current pulses. Some characteristics of a typical Cal-R surge resistor: resistance, 20Ω; current surge, 60a.; dielectric strength, 10kv; resistance stability, ±1.0%; high temp. rating, 125°C; shock 360G, 11msec.; moisture resistance/Mil-E-5272. California Resistor Corp., 1631 Colorado Ave., Santa Monica, Calif.

Circle 388 on Inquiry Card

Metal Film Resistors

Data is available on a new line of precision metal film resistors in a 12-page full-color brochure. Four resistor classes are designed to meet 80 and 90% of all film resistor requirements, from the most precise (0.1%, 25 PPM/°C) down through those which formerly called for carbon film and tin oxide. Technical details and color-coded selection charts are also included. Electra Mfg. Co., Independence, Kans.

Circle 389 on Inquiry Card

Wirewound Resistors

The DAX series of wirewound resistors feature low-cost plus all the characteristics for exceeding the environmental needs of Mil-R-93C. Tolerances are 0.05% for units with value of 20Ω and above. Standard temp. coefficient is 0 ±20 PPM/°C, from −65°C to 150°C. Complete information available from Daven, div. of McGraw Edison Co., Livingston, N. J.

Circle 390 on Inquiry Card

Film Resistors

Bulletin CE-2.12 describes C-style tin oxide film resistors that embody the economy of general purpose units along with electrical stability very close to precision types. The design tolerance for units with 2% purchase tolerance is 5%. Design tolerance is 10% for the 5% units. The design tolerances include purchase tolerance as well as end-of-life max. resistance changes due to temp. coefficients and load life drifting, according to the bulletin. Data on the ¼, ½, 1, and 2w. units, which conform to Mil-R-22684 (Navy), is available from Corning Glass Works, Bradford, Pa.

Circle 391 on Inquiry Card

Precision Resistors

This 21-page catalog contains data on a line of wirewound and carbon-film resistors, and resistance networks. General information and engineering data are included. Also given is a price schedule. Resistance Products Co., 914 S. 13th St., Harrisburg, Pa.

Circle 392 on Inquiry Card

Capacitor Catalog

This 40-page catalog describes ceramic capacitors. Included with full specs. are disk, transistor plate, tubular, feed-thru and stand-off capacitors. Hi-Q Div., Aerovox Corp., Olean, N. Y.

Circle 393 on Inquiry Card

Capacitors

Bulletin GET-2989 describes the computer-grade alumalytic® capacitors. They are available in 8 standard case sizes with ratings to 165,000μf and a voltage range of 3 to 450v. The bulletin contains a general description, performance characteristics, life test performance, dimensions, performance curves, and tables. General Electric, Capacitor Dept., Irmo, S. C.

Circle 394 on Inquiry Card

Ceramic Capacitors

Bulletin H-15 describes the miniature sq. CK-15 series capacitors. They are rated at 50 vdc over a temp. range from −55°C to +125°C. Capacitance values are from 1200 to 10,000μμf in tolerances of ±10% and ±20%. Gulton Industries, Technical Publications, 212 Durham Ave., Metuchen, N. J.

Circle 395 on Inquiry Card

Computer Capacitors

Bulletin 2236 describes the type 500 capacitor, designed to provide greater capacitance/case size and to operate normally at 85°C with ripple applied. Graphs, charts and illustrations are used throughout the 12-page bulletin. Sangamo Electric Co., Springfield, Ill.

Circle 396 on Inquiry Card

Tantalum Capacitors

Data sheet TSD-2-64 describes a series of cost-and-space-saving polar, epoxy dip-coated solid-electrolyte tantalum capacitors with full-rated dc voltage. The new units are available in 5 case sizes; operating temp. is −55° to +85°C. Capacitances range from 0.82μf to 250μf. U. S. Semcor, 3540 W. Osborn Rd., Phoenix, Ariz.

Circle 397 on Inquiry Card

Miniature Capacitors

The Kemet Z-Series capacitors exhibit extremely low dc leakage current, low dissipation factor, and good capacitance stability with respect to freq. and temp. The capacitors are designed for continuous operation over the temp. range from −80°C to +125°C. Capacitance values range from 0.047 to 18μf, with working voltages from 6 to 50v. @ 80°C. More data available from Union Carbide Corp., Linde Div., 270 Park Ave., New York, N. Y.

Circle 398 on Inquiry Card

Ceramic Capacitors

Data on a new cordwood-size capacitor of molded ceramic, the MC-70, is now available. Ratings are from 10 to 20,000pf. It is in a uniform molded case and is ideally suited to automatic insertion in printed circuits. Dimensions of the capacitor are 0.260 in. max. length by 0.100 in. max. dia., with axial leads at least 1½ in. long. Aerovox Corp., Distributor Div., New Bedford, Mass.

Circle 399 on Inquiry Card

Capacitor Report

This test report gives data on performance of glass-dielectric capacitors in space environments. The report states that the CYFR capacitors in the 15-step sequential test program withstood the severe environmental stresses of simulated space conditions without significant effect on performance. Capacitance change was less than 0.5% or 0.5pf, dissipation factor was less than 0.0006, insulation resistance was greater than 1 million megohms temp. coefficient of capacitance was within limits of + 140 ± 25 ppm/°C, and capacitance drift was less than 0.1% or 0.1 pf. Corning Glass Works, Public Relations Dept., Corning, N. Y.

Circle 400 on Inquiry Card

Miniature Capacitor

Unique advantages to the circuit designer, who uses printed-wiring boards, may be realized by using the Type 190D oblong solid Tantalex capacitors described in Bulletin 3531. These capacitors have a constant height of 0.350 in. max., regardless of rating, so that they fit in with all normal printed-wiring board spacing which use multiple stacks of boards. Likewise, a constant width of 0.375 in. makes for neat and economical layout of boards. Complete tech. details are available upon letterhead request to the Technical Literature Service, Sprague Electric Co., 233 Marshall St., North Adams, Mass.

Circle 401 on Inquiry Card

Capacitor Catalog

This 8-page catalog covers Miniature Alumalytic® capacitors. The literature specifies a line of 109 different capacitors ranging from 1 to 560 μf and 3 to 150 v. The units are offered in 8 case sizes, with axial leads or for printed circuit-board mounting. They are especially suited for low voltage electronic applications such as bypassing capacitors or for filtering and coupling. The catalog gives application information, application and life-test curves, electrical characteristics, and dimensions. Semiconductor Specialists, Inc., 5700 W. North Ave., Chicago, Ill.

Circle 402 on Inquiry Card

Capacitor Catalog

Bulletin 42-1849 describes trimmer capacitors for Mil-C-81A uses. The catalog contains detailed specs. on Types 825 and 828 rotary-trimmer capacitors. The 10 capacity ranges of single trimmers and 9 duals, covering 4 temp. coefficient tolerances, are described. Centralab, The Electronics Div. of Globe-Union Inc., P. O. Box 591, Milwaukee, Wisc.

Circle 403 on Inquiry Card

Tantalum Capacitors

This brochure describes a range of thixotropic tantalum capacitors. The RL capacitor line, described in the booklet, comprises 78 standard units. The capacitors feature low electrical leakage, positive seal, high surge ratings, weldable lead wires, and high reliability. The units are surge rated at 150% of working voltage for extra safety factor; with a background of 10 meg unit hrs. of life testing, they have established a failure rate of 0.1%/thousand hrs. @ 125°C at full voltage. ITT, 320 Park Ave., New York 22, N. Y.

Circle 404 on Inquiry Card

Ceramic Capacitors

Bulletin H-13 describes a line of miniature sq. packaged capacitors. The CK-16 series capacitors are rated at 50wvdc in temp. range −55°C to +125°C. These capacitors exceed the applicable spec. set forth in Mil-C-11015C. Capacitance values range from 12K to 100K μμf in tolerances of ±10% and ±20%. Gulton Industries, Technical, Technical Publications, 212 Durham Ave., Metuchen, N. J.

Circle 405 on Inquiry Card

Ceramic Capacitors

This brochure provides complete data on a line of micro-miniature ceramic capacitors. Literature covers microminiature pellet ceramic capacitors with values from 22 pf to 0.1 mfd at 50 wvdc. These pellet capacitors are available with a wide variety of form factors and termination methods including ribbon or wire leads, disc terminations, or without termination for direct connection. Also covered are microminiature axial lead ceramic capacitors with resin dip coats or molded epoxy cases. Values are from 47 pf to 1 mfd with ratings of 50 wvdc and 200 wvdc. The Scionics Corp., 8900 Winnetka Ave., Northbridge, Calif.

Circle 406 on Inquiry Card

Capacitor Catalog

Catalog C-64, 40 pages, describes over 400 standard precision piston trimmer capacitors. Electrical and physical details are given. JFD Electronics Corp., 15th Ave. at 62nd St., Brooklyn 19, N. Y.

Circle 407 on Inquiry Card

Filter Application Chart

This Filter Guideline Application Wall Chart is in 2 colors and measures 22 x 17 in. It is unique in that it displays in one viewing the inter-relationships between applications and filter types and characteristics. Terminations and mountings are listed in detail. Cornell-Dubilier Electronics, 50 Paris St., Newark 1, N. J.

Circle 408 on Inquiry Card

Metallized Capacitors

Catalog 51-6343, "51 Series Hermetically Sealed Combination Metallized Capacitors," covers a line of miniaturized units designed for use in airborne and transistorized equipment. In the 100vdc rating, substantially decreased sizes/unit capacitance have been achieved without sacrifice of operational characteristics. Additional ratings in the 51 Series, such as 200, 300, 400 and 600v. capacitors are also covered. Characteristics such as insulation resistance, dissipation factor, capacitance change, moisture resistance, and other related qualities are given. Gudeman Co. of Calif., Inc., 7473 Avenue 304, Visalia, Calif.

Circle 409 on Inquiry Card

Gains are being made in achieving higher power handling, size reduction, higher operating frequencies, and higher temperature capabilities. New materials and techniques are the main factors.

ACHIEVEMENTS AND TRENDS IN TRANSFORMERS

By REUBEN LEE
Consulting Engineer
Westinghouse Electric Corp.
Baltimore, Md.

COMMON CLASSIFICATIONS OF TRANSFORMERS and inductors go under the headings of power, pulse and audio. As we shall see, these classifications often overlap, but will serve here as a starting point for discussion. The progress of transformers depends on new developments in materials, chiefly core material and insulation. Silicon steel is still the work-horse of core materials. It is used in the form of punched laminations for the common power frequencies of 50 and 60 CPS. Where the weight and size are important, recourse is to grain-oriented silicon steel, which is laminated by wrapping tape of appropriate thickness on a mandrel.

In uses where weight must be kept very small, higher frequencies are used. In addition to the common aircraft frequency of 400 CPS, still higher frequencies are coming into use. Since high frequency alternators have design problems, a common practice is to use dc power and solid-state inverters with saturating transformers to produce frequencies of 1000 CPS and upwards. Cores for such transformers are made of thin tape, from 0.5 to 2 mils thick. The core is driven into saturation in both directions, so that the core must be force-cooled. Square wave outputs are produced, with waveforms similar to those in pulse transformers, which will be mentioned later.

One of the recent core material developments is doubly oriented silicon steel, which provides the square loop properties needed for inverters. A trade-name under which this material is manufactured is Cubex. It can be rolled in thin gauge tape of high permeability.

Insulation

Most transformers are still insulated with 105°C insulation for cost reasons. When no-load to full-load regulation must be kept small, the transformer operates within the 105°C limit, so that this insulation is adequate. In hotter environments or where regulation limits are wide, 130°C or 155°C insulation classes are used. These generally take the form of epoxy or polyester wire and impregnating resins. Where still higher operating temperatures (180 to 220°C) are permitted, silicone insulation has been used. Silicones have serious mechanical problems. A recent development is the appearance of aromatic polymers which are used as wire enamel, impregnating varnish and layer paper. These materials are mechanically strong and offer superior electric strength at these high temperatures. For applications where they can be used they offer great promise. Fig. 1 is plot of life vs. temperature for paper of this sort. Weight reduction of 50% can be achieved by using such insulation in place of Kraft paper and oleoresinous varnish.

As long as the exploration of space was geared to manned aircraft, there was a search for insulation operating at higher and higher temperatures. With the shift of emphasis to satellites, work on such high temperature insulation was temporarily halted, because temperatures in satellites may average 70°C, and the present need is mostly for reliable insulation in such ambients.

Recently there has been another burst of activity in the high temperature range, extending up to 2000°C. Such insulation is necessarily inorganic, and has the disadvantage of porosity. Where the insulation must operate under the conditions of high voltage and a humid atmosphere, such insulation would be inadequate because it would permit moisture to enter and soak the insulation. Also, it would be subject to voltage breakdown by corona formation. The most reliable safeguard against both of these conditions is solventless im-

pregnating resin. Work is going forward on development of such resins for use with the aromatic polymers. These show promise of drastically reducing size in space and surface uses. Much interest is being shown in evaluation and test of insulation under such conditions.

The advantages of insulating oil at high voltages are well-known. However, oil has several disadvantages, among them flammability, limiting operating temperature, and added weight. Much work has been done on the replacement of oil by gaseous insulation, chiefly fluorocarbons and sulphur hexafluoride. To function properly in such media, careful attention must be paid to reduction of electric strength concentration by proper shaping of electrodes. Also associated with this development is the use of coils cast in resin. Fig. 3 shows a core and coil assembly for voltages of 30 to 50 KV, with sharp corners on the core mitigated through the use of rounded shields. In the exploded view the coil at the right is the low voltage primary, which is mounted directly on the core and acts as a rounded shield in itself. Incentives constantly arise for eliminating heavy components, and this applies particularly to the inductor of a power supply filter, which often may be eliminated in solid state rectifiers.

Pulse Transformers

Noteworthy reduction in size of pulse transformers have been made by bias or resetting the core to negative saturation. This possibility has been known for some time, but the chief obstacle was cooling means. Referring to Fig. 2, the difference in flux density swing in a reset core compared to a non-reset core is plainly evident. Since core loss depends upon the area of the B-H loop, it is evident that better cooling means must be used for reset cores. This is done readily in fluorocarbon liquids which boil at low temperatures. As the liquid boils it carries the heat to the top of the container as steam, condenses and returns to the pool of liquid, giving up the heat of vaporization during the process. This gives an increase of about 10:1 in cooling efficiency.

The chief disadvantages of such cooling are the heavy weight of the liquid and a necessity for vapor seals. These liquids are used sparingly, and sometimes are sprayed on to the coil

(*Continued on following page*)

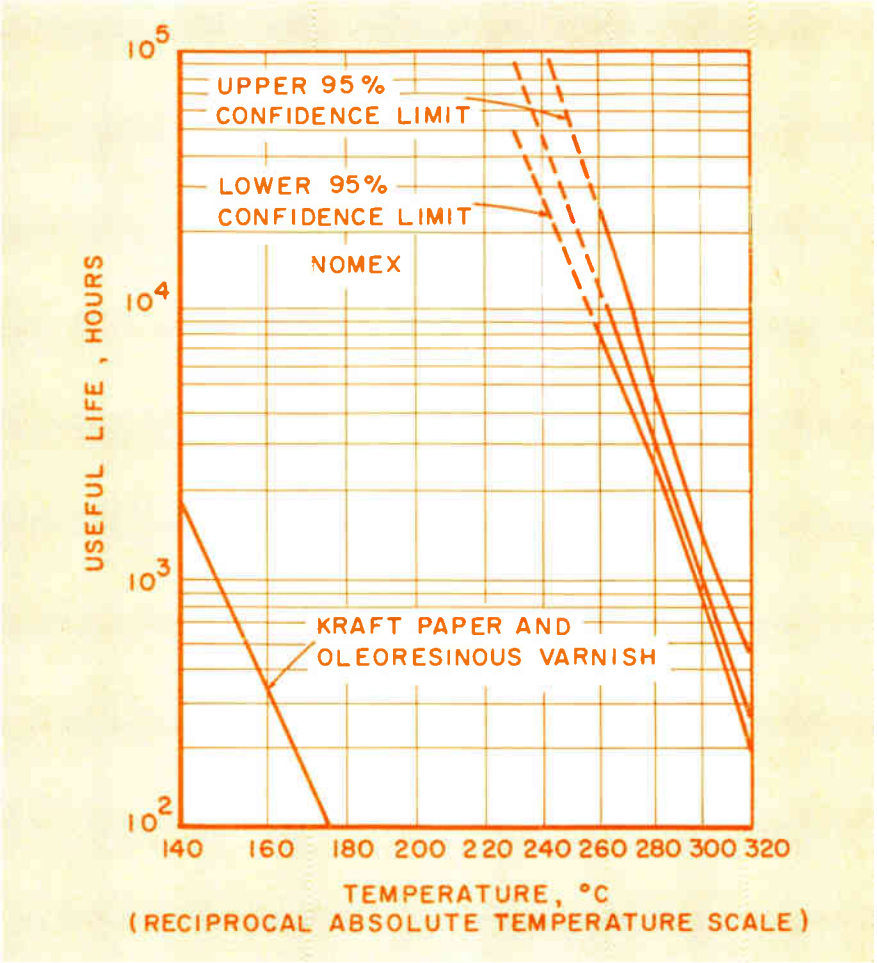
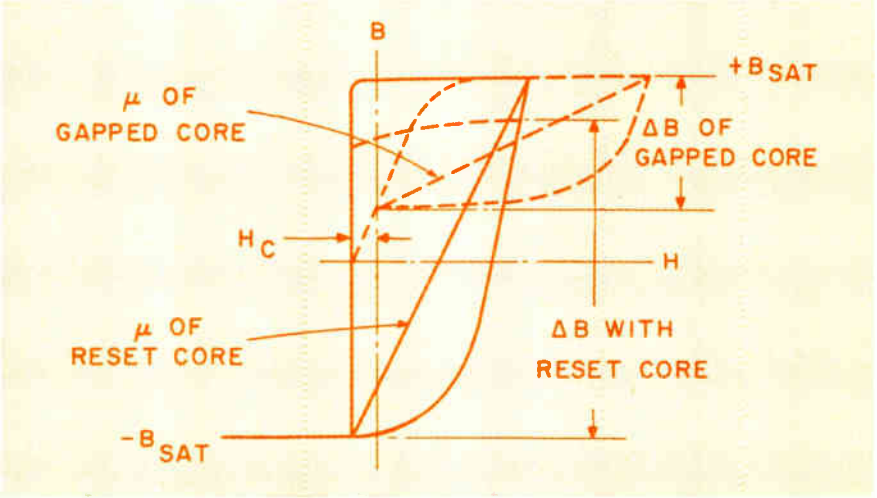


Fig. 1: The useful life of Nomex™ paper is compared with treated Kraft paper.

Fig. 2: Pulse transformer core B-H loops with and without resetting are illustrated.



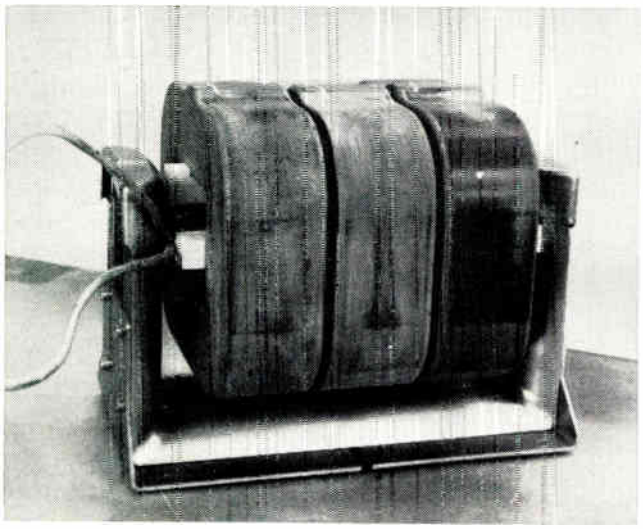


Fig. 3a: Assembled high voltage transformer handles 30-50 kv.

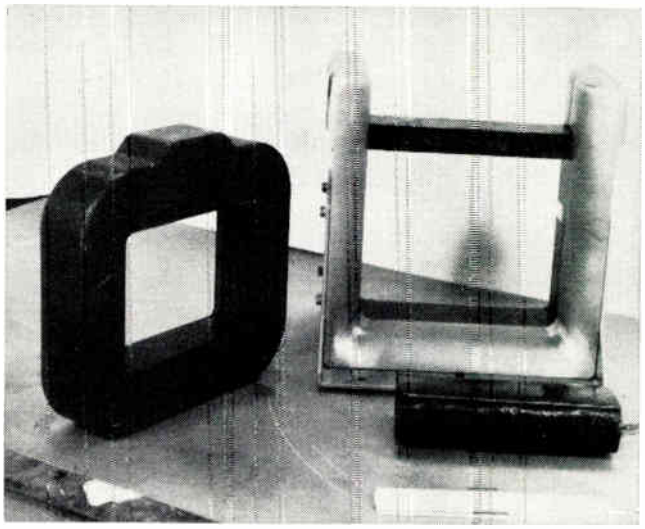


Fig. 3b: High voltage coils and core of Fig. 3a before assembly.

TRANSFORMERS (Continued)

or cores. Permeability of a reset core is usually higher than in a non-reset core (which must have an air gap) as seen in Fig. 2, and this results in better pulse shape.

The need for artificial cooling is less in small pulse transformers, where the ratio of surface area to volume is greater. Computer size pulse transformers used to drive memory matrices almost never need cooling. Such transformers usually have ferrite cores where flux density swing is small.

Frequency Range Transformers

This classification is used rather than the word audio, because the upper frequency limit has long since exceeded the audio range. High frequency transformers, extending in upper frequency limit to hundreds of megacycles have been constructed with ferrite cores, and so have high Q inductors for tuning antennas and tank circuits. The upper operating frequency of such a device is determined largely by its dimensions, so that it's much easier to design a transformer for high frequencies with a milliwatt rating than it is to design one for several kilowatts.

The kind of ferrites used in high frequency transformers and inductors depends on the frequency range. With continual development work, new ferrites become available and make possible new performance. Sometimes the application of transformers at these high frequencies demands a revision of either design, application or measuring technique. One instance in which all three of these steps were taken is shown in Fig. 4. This is a photograph of a large balun (balanced to unbalanced circuit) operating from 2 to 30 MC at 70 ohms unbalanced to 600 ohms balanced and a CW rating of 70 KW. The operating frequency range could not be achieved at this power level with the usual transformer winding arrangements. Instead, cables with their distributed properties were used, and ferrite cores provided the necessary frequency range.

To measure the degree of balance achieved in this unit, it was necessary to use the measuring circuit shown in Fig. 5. Here the normally grounded r-f generator and vacuum tube voltmeter are employed, with particular attention to keeping the circuit balanced while the switch was operated during measurement.

Miniaturization

Because inductive components are heavier than other kinds there is continual pressure to make them smaller or eliminate them completely. The situation is most acute in integrated circuits. Where there are as many as 50 circuits on a 1 in. diameter wafer, an inductor of even miniature, dimensions appears to be incompatibly huge, and where high Q is required it is intolerably so. Several attempts to eliminate conventional inductors have been made by means of inductive diodes or by semiconductor circuits with feedback, analogous to reactance tubes, as recently pointed out by Newell. But, such efforts have disadvantages. The stage is set here for a real engineering breakthrough, and we may expect intense development activity in inductor miniaturization in the near future.

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2. Ray E. Lee, "Three Phase Power Supplies Using Capacitor Input Filters," AIEE Conf. Paper 62-288.
3. J. H. McWhirter, N. C. Foster, D. Berg and C. F. Hofmann, "Cast-Resin Power Transformers." *Westinghouse Engineer*, Jan. 1963.
4. F. V. Kadri, "Telstar Satellite Component Reliability," IEEE Conf. Paper 63-1150.
5. W. E. Newell, "The Frustrating Problem of Inductors in Integrated Circuits," *Electronics*, March 13, 1964.

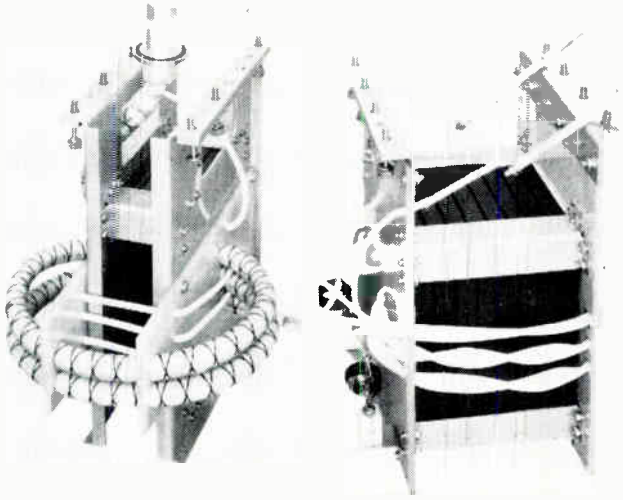


Fig. 4: Wideband high-power balun cores and coils operate from 2 to 30 mc. Coil on left is 70 ohms unbalanced and the other coil is 600 ohms balanced. CW rating is 70 kw.

Fig. 5: Circuit for measuring balance and response in unbalanced to balanced transformer.

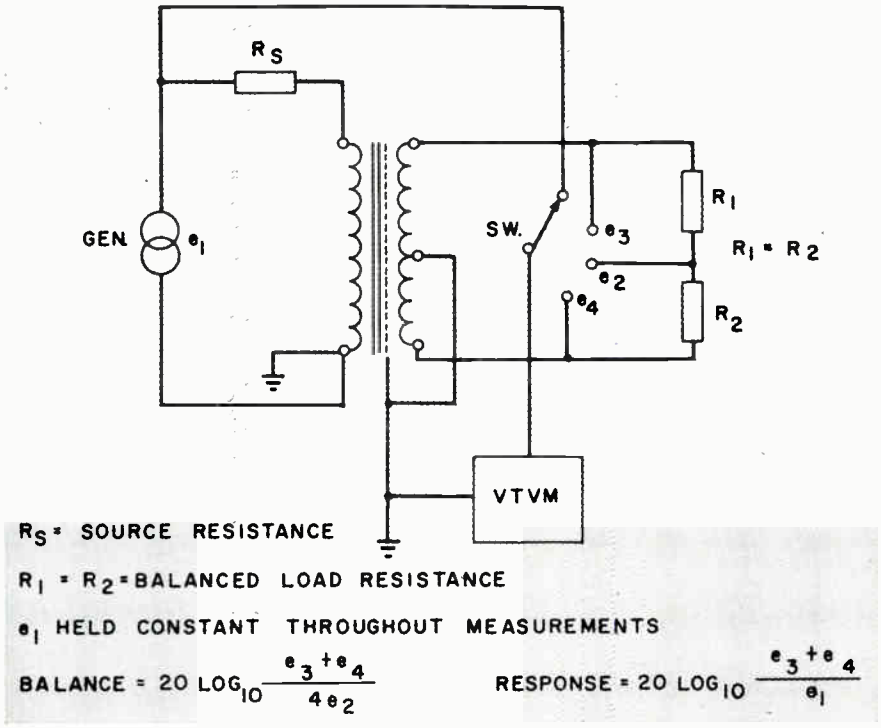
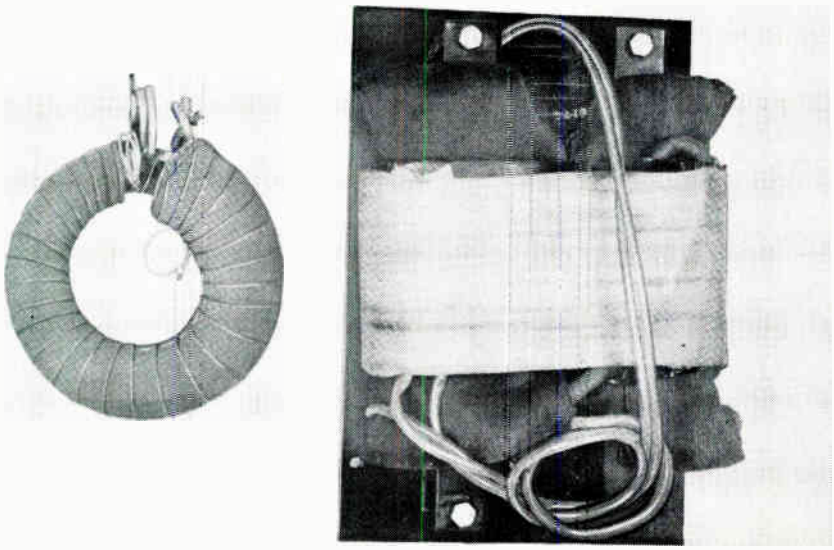
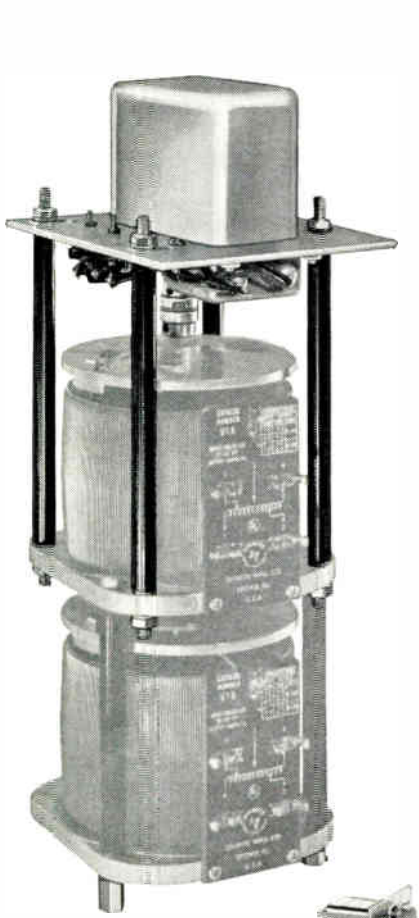
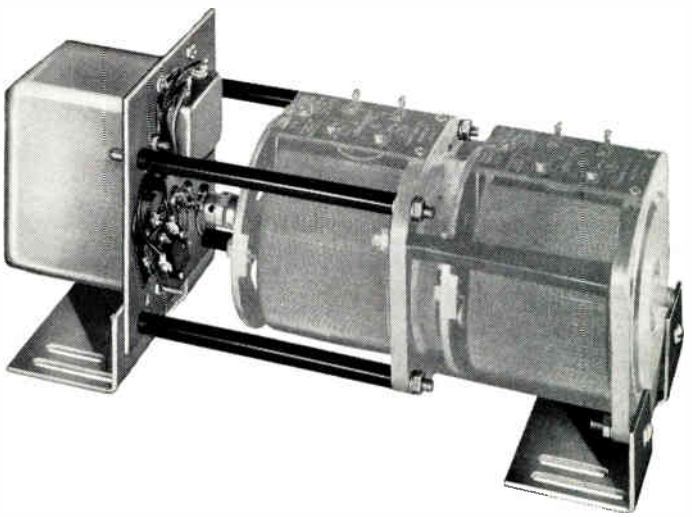


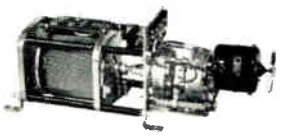
Fig. 6: Size comparison of reset toroid and non-reset, gapped-core pulse transformers.

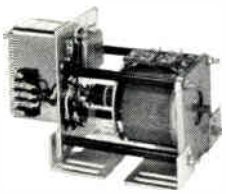


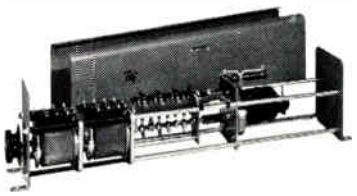


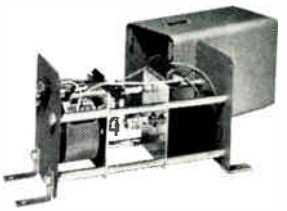


motorized variable transformers in big variety









Shown above is a sampling of the many motorized variable transformers produced for Ohmite customers.

Some are extremely complex, involving many components to arrive at a multiple control function. Others are relatively simple combinations. All, however, contain that irreplaceable ingredient of Ohmite quality.

Fast Service on Popular Models

Complete motor subassemblies, transformers, parts, cases, and hardware are stocked for the most called for combinations. Many orders for these units are shipped within a matter of days. But even the more complex types are speeded up because of the pre-engineered solutions in Ohmite files.

Large Transformer Selection

In transformers, you choose from models covering 1.75 to 25 amps. Transformers include: optional overvoltage units; no overvoltage types; hi-amps, lo-volts models for transistorized circuits; ganged transformers; and multitap units among others. These can be further modified with all kinds of mechanical and electrical variations.

Want to "Motorize-It-Yourself?"

If you already possess Ohmite VT4, VT8, or VT20 transformers and would like to motorize them yourself, order Ohmite Motor Modules from stock. They attach in less than 15 minutes. Modules contain low-inertia motor, coupling, cams, and limit switches plus all hardware.

For Ohmite VT4 and VT8 transformers there is a choice of 4, 8, 16, 30, and 45-second traverse speeds; for Ohmite VT20 transformers, 5, 10, 30, and 52 seconds. (*Write for Bulletin 501.*)

Send a description of your requirements to the factory for a prompt quotation.

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NEW TECH DATA

INDUCTORS/TRANSFORMERS

Step-Down Transformer

The Micronia MC-218A Input Resistance Transformer for dc VTVMs is a 10:1 dc step-down unit. It reflects its secondary load 100 times enlarged at its primary terminals. The unit reduces VTVM measuring sensitivity by 10:1 but increases VTVM input resistance 100 times, exclusive of the transformer's losses which are 10,000-20,000 meg. Voltage transformation errors are —0.15% with a 10 meg meter load, and —0.02% with a 100 meg meter load. Complete specs. available from Micronia Corp., 26 Valley Rd., Port Washington, N. Y.

Circle 346 on Inquiry Card

Circuit Design Data

This 16-page, color booklet contains engineering data in easy-to-read graph and chart form as well as photos of many unique transformers and their major uses. A section is devoted to providing engineers with helpful circuit-design data. In addition, 180 transformers are listed and described. Sterling Transformer Corp., 510 Driggs Ave., Brooklyn, N. Y.

Circle 347 on Inquiry Card

Transformers

Bulletin G-1003 contains data on a line of Hertner general-purpose, 60-cycle, single-phase transformers in all standard voltages and ratings from ¼ KVA through 2 KVA. It describes the total insulation system of the transformers, rated NEMA class B (60°C rise). Kearfott Div., General Precision, Inc., 12690 Elmwood Ave., N.W., Cleveland, Ohio.

Circle 348 on Inquiry Card

Winding Machines Catalog

Comprehensive 64-page, 2-color catalog No. 65 contains illustrations and exhaustive technical data on a complete line of coil winding machines, tensions, counters, high speed tailstocks, accessories and optional equipment as well as a page of winding formulas. Geo. Stevens Mfg. Co., Inc., 6001 No. Keystone Ave., Chicago, Ill.

Circle 349 on Inquiry Card

Micro Inductors

Catalog section G(a) describes a line of transistor-size micro inductors. The tiny units have Q's exceeding 30 at 20KC and 120 at 200KC. They meet Mil-T-27A, Grade 4, Class R. They may be inserted by hand or machine. Other features include: insulation resistance of 10K megohms minimum at 100vdc; dielectric strength of 100v. RMS; amb. temp. range of —55°C to +85°C; inductance change with temp. of ±2% over range of —20°C to +85°C. Collins Radio Co., 19700 San Joaquin Rd., Newport Beach, Calif.

Circle 350 on Inquiry Card

Transformer Theory

A comprehensive bulletin on the theory and application of linear variable differential transformers is available. The bulletin describes these displacement transformers as versatile electro-mechanical transducers for instrumentation, includes numerous illustrations, diagrams, and tables. Also a chart is available for selecting the proper transformer for use with Atcotran demodulators, relay controllers, and receivers. Bulletin 6234 is available from Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle 351 on Inquiry Card

Chopper Transformers

A new line of miniaturized, hermetically-sealed chopper input transformers is designed to efficiently transfer 30 to 500 CPS transducer or thermal-couple signals to instrument amplifiers at signal level ranges from 0.5μv to 0.5v. Features of transformer series include 90db magnetic shielding, low microphonism and accurate center taps. The units are designed to meet the requirements of Mil-T-27B, Grade 4, Class R, Life X. Data available from Microtran Co., 145 E. Mineola Ave., Valley Stream, N. Y.

Circle 352 on Inquiry Card

Test Kit

Data is available on a complete ceramic-engineered coil system for ultra-high temp. service. The CS-1200 allows low-cost investigating and testing of wound coils in all foreseeable operating conditions encountered by an end product. Kit parts include magnet wire encapsulant, and phase insulation. Each is matched in a system capable of efficient functioning at temps. from 500° to 1200°F. Anaconda Wire and Cable Co., 2590 E. Devon Ave., Des Plaines, Ill.

Circle 353 on Inquiry Card

Transformers

Special voltage regulating transformers which operate in the 15 va to 5 kva (50, 60, 400 CPS) are described in bulletins CVT-100 and T-101. Photos, specs., and operating principles are given. Central Transformer Co., 900 W. Jackson Blvd., Chicago 7, Ill.

Circle 354 on Inquiry Card

Variable Transformer

Adjust-A-Volt variable transformers of the 2500 series, designed to meet a great variety of military and commercial applications for manual or motorized operation, are described in this 8-page catalog. The units operate on either 120 or 240v., 50/60 cycles; output is 3.5kva. The 2500 series is available as an uncased unit for easy panel mounting with a 4-hole sq. aluminum base. Staco, Inc., Standard Electrical Products Div., Dayton, Ohio.

Circle 355 on Inquiry Card

NEW TECH DATA

INDUCTORS

Filament Transformer

This current-limiting transformer controls current to the filament on high-power transmitting tubes operating in the kw to megawatt ranges. It has multi-tapped inputs and operates at an output of 12v., 300a. Specs. available from United Transformer Corp., 150 Varick St., New York 13, N. Y.

Circle 321 on Inquiry Card

Transistor Transformer

This toroidal transistor transformer is part of a new line of TTTs for use in dc-dc and dc-ac power supplies. These epoxy-molded triple Ts exceed Mil-T-27A, grade 5, class R requirements. They give reduced noise level, increased efficiency, increased life expectancy and reliability, all of this with appreciable reduction in size. Normal operating freqs. are in the range between 1500 CPS to 5KC. Specially designed units can also be obtained with operating freqs. up to 10KC. Additional information available from Bundy Electronics Corp., 44 Fadem Rd., Springfield, N. J.

Circle 322 on Inquiry Card

Transformers

Data is available on a line of shielded wide-range output transformers for use with low-profile high-fidelity amplifiers. Eight models ranging from 3300 to 8KΩ primary impedance are for use with Williamson circuits, single-ended and push-pull operation. Freq. response for each is ±2db from 20 CPS-2°KC, with secondary impedances of 4, 8, and 16Ω. Triad Distributor Div., 305 N. Briant St., Huntington, Ind.

Circle 323 on Inquiry Card

Differential Transformer

Bulletin AA402 describes a unique, economical, high-output differential transformer which operates at 6 v./60 CPS. The new instrument can be adapted to monitor and/or control pressure, acceleration, load, and, in general, any phenomenon characterized by a corresponding physical displacement. The transformer finds wide application in both military and industrial servo systems as a relatively simple and inexpensive remote displacement or deflection indicator or controller. It requires no electronic oscillator or mechanical alternator. Gulton Industries, 212 Durham Ave., Metuchen, N. J.

Circle 324 on Inquiry Card

R-F Chokes

A line of molded, magnetically-shielded, miniature r-f chokes ranging from 0.1μh to 10mh are described in this literature. They have less than 2% coupling. J. W. Miller Co., 5917 S. Main St., Los Angeles, Calif.

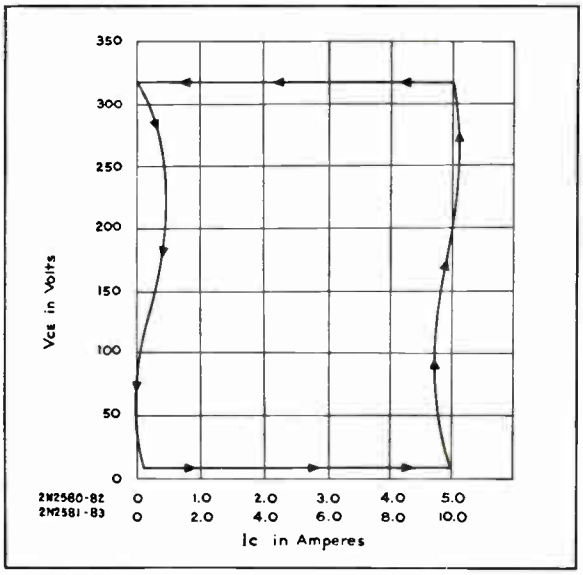
Circle 325 on Inquiry Card

HERE'S A SWITCH

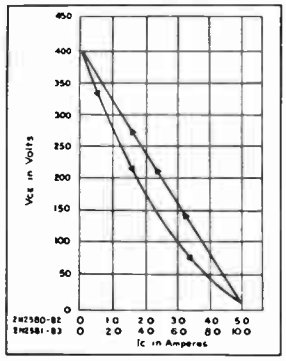
1500 watts inductive
2000 watts resistive

Delco's silicon 2N2580 series

Switch ultrahigh voltages at peak power levels with Delco Radio's family of silicon transistors —2N2580, 2N2581, 2N2582, 2N2583.

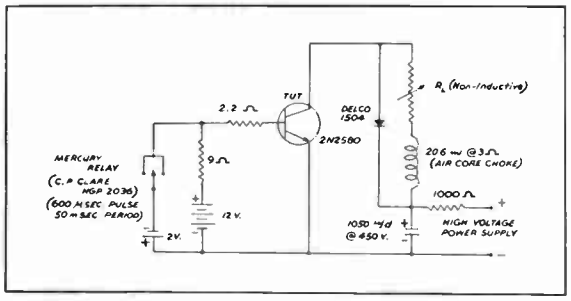


Typical inductive switching curve



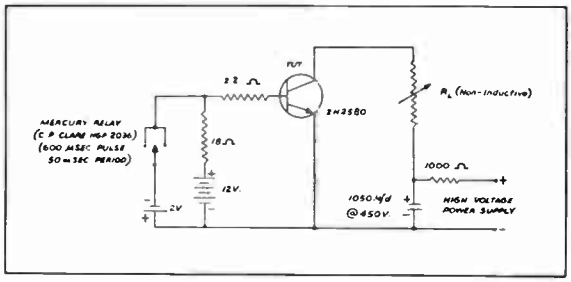
Typical resistive switching curve

Each transistor features a maximum sustaining voltage (VCE sus.) of 325V, and has VCBO, VCEX and VCEO ratings of either 400 or 500 volts in either of two gain ranges.



Test circuit—inductive load

Inductive or resistive loads can be switched at full rated collector current (up to 10 amperes) within the 325-volt safe operating area —with freedom from secondary breakdown.



Test circuit—resistive load

All 2N2580 series transistors are available now at new reduced prices. For complete data, contact your Delco Radio semiconductor distributor or any of the sales offices listed below.

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MUrdock 7-3770
AREA CODE 201

Palo Alto, California
201 Town & Country Village
DAvenport 6-0365
AREA CODE 415

Syracuse, New York
1054 James Street
GRanite 2-2668
AREA CODE 315

Detroit, Michigan
57 Harper Avenue
TRinity 3-6560
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ELECTRONIC INDUSTRIES
REFERENCE ISSUE
SEMI-CONDUCTORS

INTEGRATED CIRCUITS TODAY AND TOMORROW

A number of significant approaches are being followed in the area of integrated circuits. While industry waits for one approach to achieve a dominant position, each is finding certain unique applications for which it is best suited. This may well be the pattern of development in integrated circuits for many years to come.

By DR. C. LESTER HOGAN
Vice President, General Manager, Semiconductor Products Div. Motorola, Inc.

IN AN INDUSTRY AS DYNAMIC AND FAST-MOVING as the electronic industry, it is always hard and often dangerous to look beyond present technology and predict the effects of new developments on tomorrow's products. This is particularly true with integrated circuits; technical breakthroughs have succeeded each other at such a fantastic rate that new developments are being discarded in favor of still newer developments even before they have been put to actual use.

It is possible, however, to take a close look at today's capabilities, combine these with the latest laboratory techniques, and project their combined impact on the industry over the next few years.

Total acceptance of integrated circuits by the industry is predicated on our ability to manufacture such devices with performance and price advantages, as well as other features predicted for integrated circuits over the past several years.

To achieve these advantages, a number of techniques have been developed and are in somewhat common use. Among these are the *thin-film* approach, the *semiconductor* approach, comprising silicon monolithic circuits and hybrid (multichip) devices, the *magnetic element* technique, and *magnetic and superconducting thin-f'm* technologies.

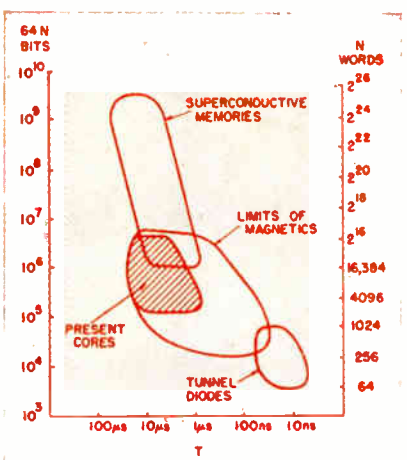

Fig. 1 — Limits of speed and storage capacity of magnetic, superconductive and tunnel-diode memories in thin-film technology (RCA Laboratories, Princeton, N.J.).

The last two approaches, although they have received much notice for a number of years, appear to be restricted to a limited number of applications. *Magnetic elements*, for example, made of multi-aperture ferrite cores with the proper number of windings, can provide most logic functions. These circuits can be made at very low cost and probably have a reliability exceeding all other integrated circuits.

However, they are very large and extremely slow when compared with semiconductor circuits. In addition, they must be driven by transistors. As long as such additional devices are required it is more convenient and less expensive to build the entire circuit on a silicon substrate.

Promise for Logical Functions

Magnetic and superconducting thin-films offer some promise for logical functions, but the present state of development limits them to computer memory applications. In this area, thin magnetic films promise storage capacity as great as 10 million bits, with cycle times on the order of 100 nanoseconds, Figure 1.

Superconducting thin-films promise memories with capacity greater than 1 billion bits, with

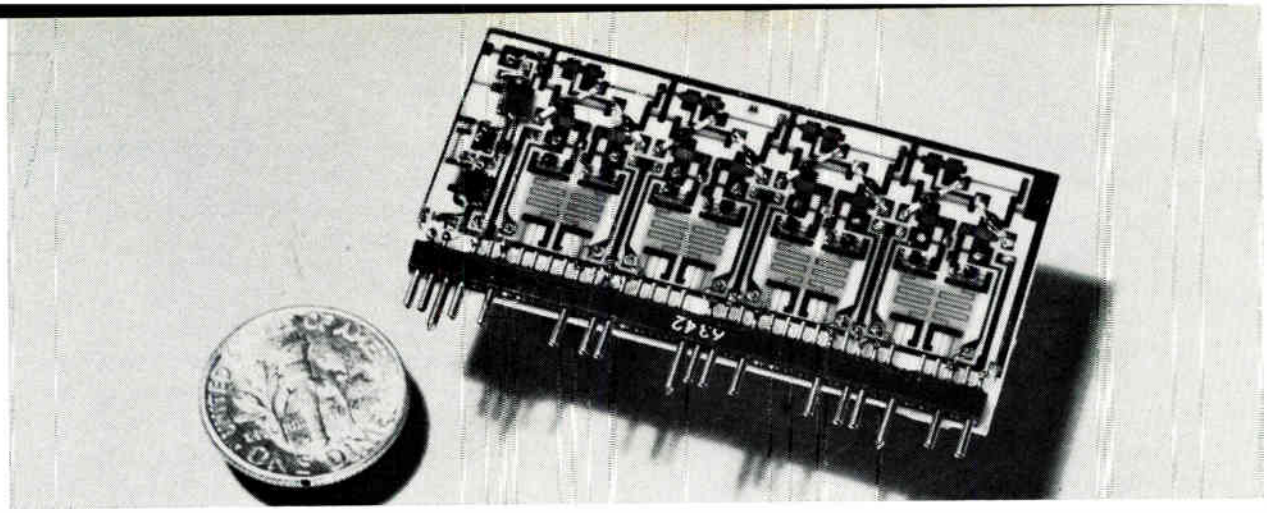

Fig. 2—Example of 16 to 1 digital divider with discrete active elements attached to passive patterns on a ceramic substrate.

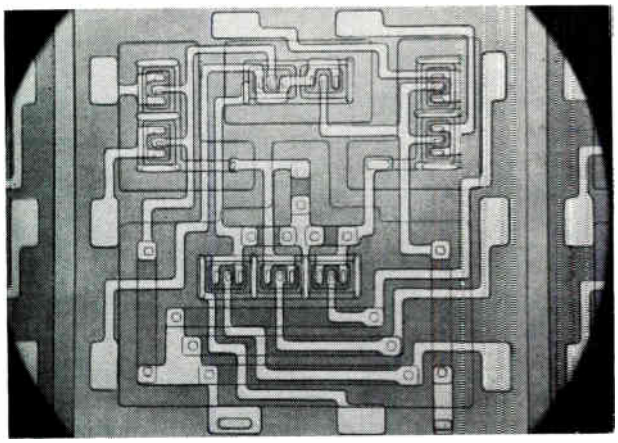

Fig. 3—Greatly enlarged view of current - mode half - adder for computer applications. These circuits are made by semiconductor techniques using epitaxial and diffusion processes on substrates.

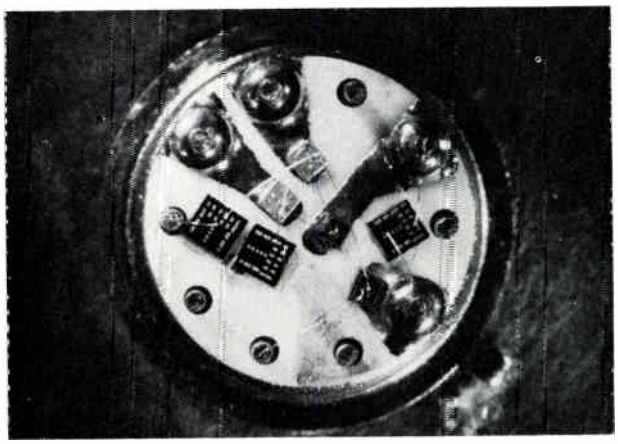

Fig. 4—Hybrid (multichip) technique uses component chips, diffused or thin - film, fastened to ceramic substrate, and interconnected by combination of metallized patterns and wire bonds.

cycle times as fast as one microsecond. In this application, such films appear to have no peers, but for general circuit use they do not promise the performance, cost and size advantage of either the silicon monolithic circuit or the general thin-film circuit. Thus, for general-purpose use, the semiconductor and thin-film techniques present the only practical approaches at this time.

Before delving into performance characteristics and economics of these integrated circuit approaches, let's define the various types of structures evolving from these techniques, and mention their basic features and limitations. The conventional thin-film circuit, Figure 2, consists of a passive substrate, either glass or ceramic, on which interconnecting pattern and passive elements (resistors, capacitors) are deposited as thin metallic films.

Active elements (transistors, diodes) are added to these thin-film patterns in discrete form, either by conventional soldering methods or by the "flip-chip" method. With the flip-chip technique, three metal balls are attached to the transistor chip, contacting the emitter, base and collector regions.

When this transistor is flipped over on the basic metallized substrate, the three metal balls are made to contact three previously tinned land regions on the substrate. After heating, the solder from these tinned regions flows around the metal balls, making both mechanical and electrical connections to the transistor.

The dimensions of the basic substrate of a thin-film circuit are normally on the order of ½" by ½", which is quite large in comparison with the dimensions of a monolithic silicon integrated circuit. Moreover, the material costs and the fabrication processes are relatively expensive. However, the range of component values is considerably greater and component tolerances are tighter.

Material, Labor Costs Lower

The basic monolithic silicon integrated circuit, Figure 3, is made by a series of sequential photo resist and diffusion steps. By this means, upwards of 400 individual circuits can be processed simultaneously on a single silicon wafer approximately 1" in diameter. Hence, material and labor costs in preparing such circuits can be kept lower than with any other known process, provided such circuits are produced in large quantities with reasonable yields.

In comparison with thin-film circuits, the range of component values and tolerances in diffused monolithic circuits are more restricted. Whereas the performance of thin-film circuits can equal that of conventional discrete-component circuits, the performance of diffused monolithic silicon circuits is some-

what limited at both the high- and low-frequency ends of the design spectrum.

A third technology that has very recently entered the production phase combines the advantages of both the thin-film and silicon monolithic circuits. Known as a *"compatible"* technology, this technique utilizes the silicon substrate of a monolithic circuit for the diffusion of active elements. Resistors are deposited on top of the silicon dioxide passivating layer which completely covers the active circuits, and interconnections between active and resistive elements are made through holes etched in the oxide layer at the appropriate points. Capacitors normally are formed using the silicon substrate as one plate, the silicon dioxide as the dielectric, and aluminum metallization, used for interconnecting purposes, as the second plate.

More Expensive to Make

Compatible circuits require more processing steps than a monolithic silicon circuit and are somewhat more expensive to fabricate. Circuit design flexibility is enhanced, however, due to greater range of passive component values.

A fourth technology, the *hybrid* (multichip) technique, Figure 4, utilizes individual component chips, either diffused or thin-film, fastened to a ceramic substrate and interconnected by a combination of metallized patterns and wire bonds. Such devices, in all respects, can outperform discrete component circuits. In spite of their superior performance, however, the primary application for such devices is in special circuits whose complexity and/or performance is so demanding that the technology does not permit their reduction to monolithic form. They are applied also where integrated circuits are required in such small quantities that one cannot afford the mask charges for monolithic circuit fabrication.

Although it is safe to predict a continuing market for hybrid devices, this approach cannot offer the low-cost advantage of monolithic circuits for large-quantity (1000 or more identical circuits) requirements. Hybrid techniques are generally considered as the best way of achieving complex circuit functions when required in relatively low volume.

A primary limitation to high-speed, high-frequency performance of monolithic silicon integrated circuits to date is imposed by the diode-isolation process that has become a standard of the industry. With this technique, the elements diffused into a silicon chip are isolated from each other by means of p-n junctions which, in use, are reverse biased to present very large impedances at low frequencies. At high frequencies, however, the elements are effectively coupled by the so-called parasitic capacitances of these p-n junctions.

This coupling becomes extremely important at very high frequencies and, hence, degrades the performance of digital circuits appreciably when the switching time is in the range of a few nanoseconds. In addition, this capacitance has made it extremely difficult to build good linear circuits.

Received Much Attention

This problem has received much attention from our industry recently in an effort to improve the performance of monolithic circuits. At Motorola, a solution to the problem has been found and we are now building essentially parasitic-free monolithic silicon integrated circuits in our pilot line operation. This solution is in the form of a new fabrication process which is trademarked EPIC.

It is quite significant that the parasitic problem has been solved in such a way that these new circuits are made by exactly the same techniques of epitaxial growth, oxidation, photo masking, etching and diffusion as before. However, the cross-section of the wafer Figure 5, in the EPIC process includes an insulating layer that separates each integrated component from the silicon substrate that supports it. The extra processing to obtain this insulating layer will add about a half a cent to the cost of the finished integrated circuit when the process is in full scale production. This insulating layer can be made so thick that the effective capacitance is reduced to zero.

We have made measurements on hundreds of circuits produced in this way and find already that the circuits are as fast as their hybrid circuit counterparts which do not suffer from the parasitic problem. The table shows typical data taken on two monolithic MECL OR-NOR gates.

	STANDARD MONOLITHIC	HYBRID	EPIC MONOLITHIC
t_D	6 ns	4.6 ns	5 ns
t_R	8 ns	4.5 ns	4.7 ns
t_F	9 ns	5.2 ns	5.2 ns

Fan out of 1
Fan in of 3
C_S (test jig) = 13 pf.
Nor output.

The first set of data was taken on today's standard product which was constructed by conventional monolithic techniques. The second set of data was taken on a MECL OR-NOR gate made by this new EPIC process. Even at this early stage of development, it will be noted that the rise and fall times have been almost cut in half and the propagation delay has been reduced by about 20%.

As a result of this new technique it is possible to ignore all arguments against monolithic silicon integrated circuits that are based on the contention that thin-film circuits can provide superior high-frequency performance due to parasite-free construction. Moreover, enough EPIC devices have been manufactured and tested to permit a prediction that they will be in widespread commercial use within a year.

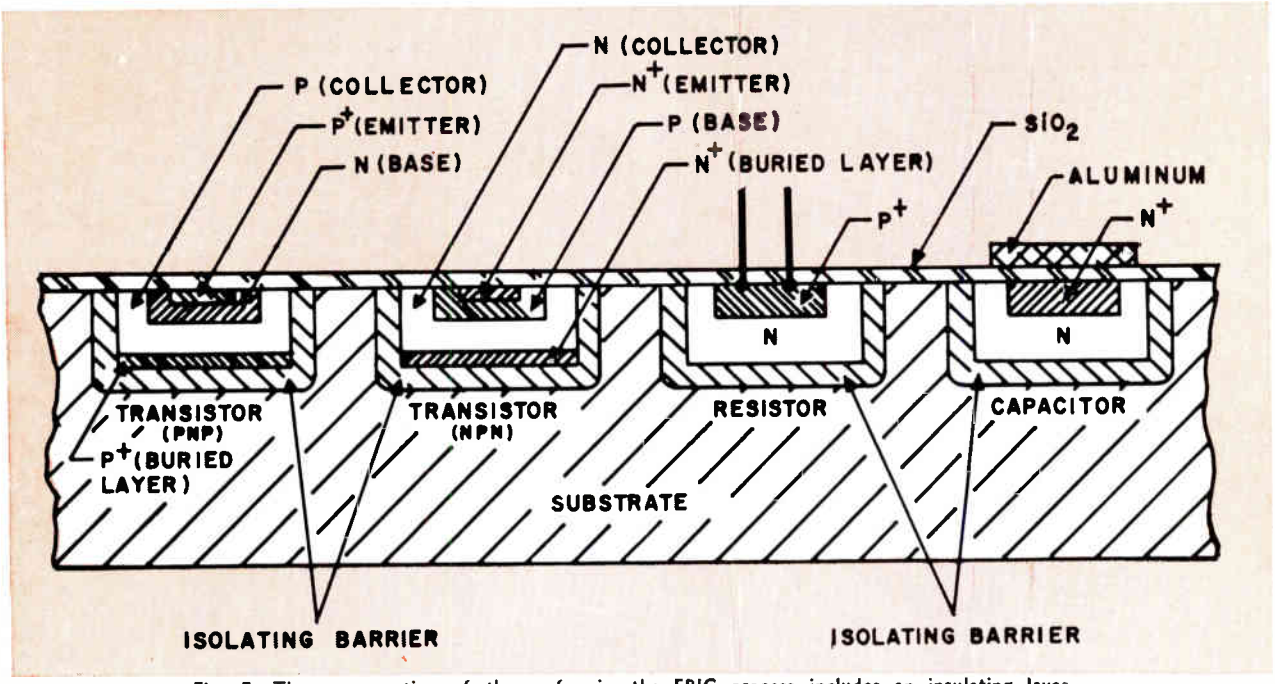

Fig. 5—The cross-section of the wafer in the EPIC process includes an insulating layer that separates each integrated component from the silicon substrate that supports it.

Use of Mono-Silicon Rising

While both thin-film and monolithic silicon circuits have their special fields of applications, it appears that monolithic silicon will have the edge in digital circuits through cost alone. With this technology, circuits of a high order of complexity can be constructed today on a 50 mil x 50 mil silicon chip and, as stated earlier, hundreds of circuits can be built simultaneously on silicon wafers approximately 1" in diameter.

The cost to carry a wafer through all steps of diffusion and metallization, provided it is run at moderately high volume and at 100% yield, is approximately $10.00 per wafer, including normal overhead. If a one inch square wafer can be adequately processed, then each wafer will contain 400 individual circuits at a cost, before packaging, of 2½¢ each, at a 100% yield. If one contemplates an ultimate yield as low as 50%, the finished silicon monolithic integrated circuit before packaging will be approximately 5¢.

Even without any major technical breakthroughs, however, it is certain that over the next three years we shall steadily improve the resolution with which we can build such circuits. An indication of what has already been achieved in the R & D laboratories is the diagram of one bit of a two phase shift register, Figure 6, that has been placed successfully on a die only 70 mils square. Again, assuming a 50% yield, this entire circuit, consisting of 33 transistors, 2 diodes, and 24 resistors, eventually could be built for less than 10¢.

A reasonable projection of what might be achieved in a few years is illustrated by the JK flip-flop circuit in Figure 7. This circuit contains 14 transistors, 10 resistors and 2 capacitors. This has already been placed on a 70 mil square die, and while one might question the goal of placing this on a 25 mil square die by 1967, there can be little question that this circuit will be placed on a 30 mil square die by 1966. Again, at a 50% yield, one can calculate that at reasonably high volume before packaging, this circuit would cost less than two cents to process, including overhead.

Cost, Size, Yield Related

Basically, the cost of producing a silicon monolithic integrated circuit or a silicon transistor is related to die size and to yield. In both cases one cannot talk about die sizes much less than twenty mils square because the difficulty in handling and the subsequent alignment during packaging and lead attachment mitigates against smaller die sizes. Thus, if we build transistors rather than integrated circuits on a one-inch wafer, and if the ultimate die size is 20 mils square, the cost of each transistor is in excess of one cent, as compared to a complete JK flip-flop cost of three cents. (All of these costs, of course, refer to a device before lead attachment and packaging.)

From this example, it is obvious that thin-film circuits which require the construction and attachment of individual transistors to a circuit can never achieve the low cost of the monolithic silicon approach to integrated circuits, providing the yield to an integrated circuit specification is comparable to a yield to a set of specifications for building a transistor.

Intuitively, it might seem that integrated circuit yields per wafer will never be as high as present-day transistor yield;

(*Continued on page 63*)

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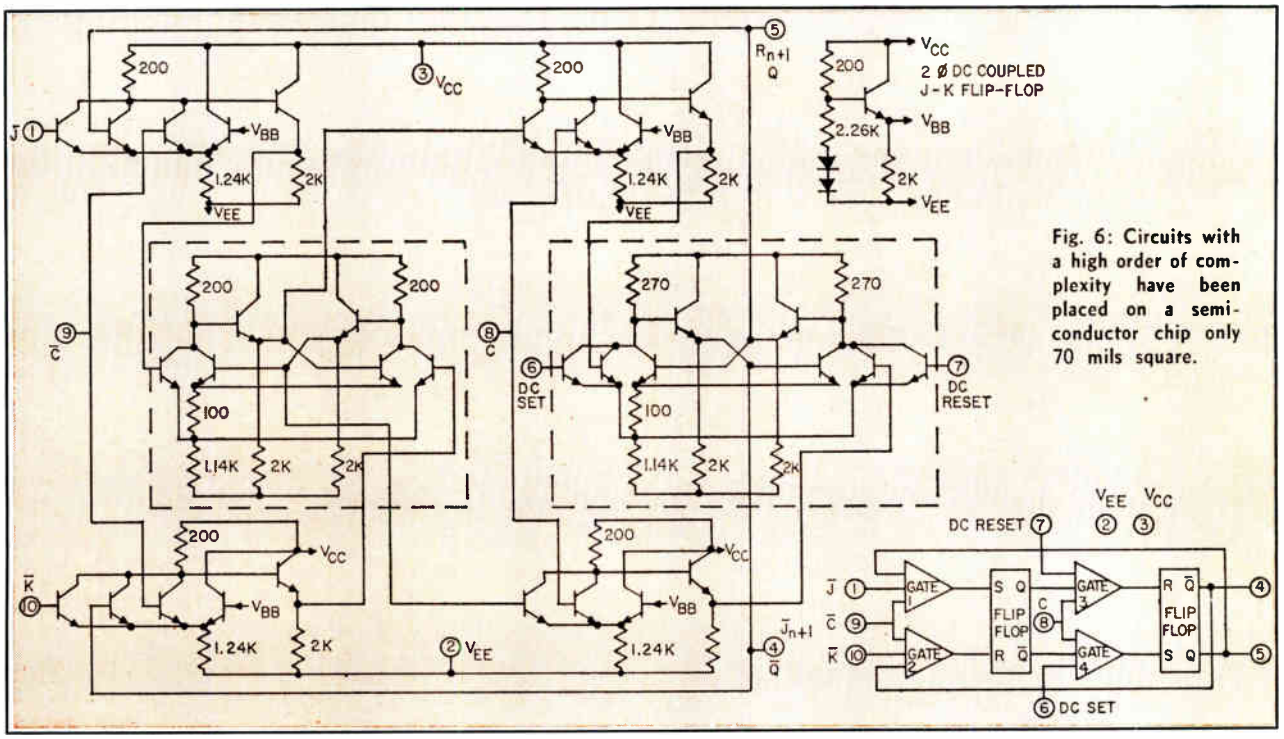


Fig. 6: Circuits with a high order of complexity have been placed on a semiconductor chip only 70 mils square.

1. Because integrated circuits are larger than individual transistors and yield fewer devices per wafer, and

2. Because many transistors whose electrical parameters vary from the design center can be sold to a different set of specifications whereas integrated circuits that vary widely from the initial specifications may not be saleable.

These arguments, however, do not tell the whole story. A transistor is often specified to such tight limits, on a large number of parameters that the yield to a complete set of specifications is relatively low. For example, when a device is selected to such conflicting requirements as high breakdown voltage, low saturation resistance, high current gain, low storage time, etc., it becomes necessary to select successively from 20 or more distribution curves. Even if the line yield to each tightly specified parameter is as high as 90%, the resulting yield to all specifications would be only approximately 12%.

Need Not Have Low Yield

Such a state of affairs need not occur in integrated circuits. The circuit designer is really concerned with blackbox specifications concerning circuit performance and not with detailed characteristics of the individual components within the circuit. In a loose sense, if the integrated circuit functions at all, it usually meets all the specifications placed on it, once one has learned how to make it using the proper mask design, the proper processing steps, and the proper resistivity of the starting wafers.

To indicate what has been achieved, Figure 8 shows the circuit diagram of a 120 mc r. f. amplifier which has been reduced to a monolithic silicon integrated circuit. Several hundred of these circuits have been built with an actual yield of 90%, where yield is measured in terms of the d. c. operating levels and gain vs. frequency of the amplifier, as shown. In comparison with transistor data sheets, these specifications are relatively short and simple. Yet, in general, it is believed that these are the kind of specifications that might become realistic when we are dealing with circuits instead of individual devices.

A vast amount of data accumulated on standard Motorola integrated circuit lines and standard Motorola transistor lines indicates that the yield on the standard integrated circuit line is roughly the same as the yield of the very critical transistors that are now produced. Hence, it seems reasonable to assume that monolithic silicon integrated circuit yields and transistor yields are comparable, for comparable size dies.

The above discussion might lead one to believe that monolithic silicon integrated circuits would eventually take over, with no future for thin-film elements. Such is definitely not the case. In the first place, diffused resistors have such a large temperature coefficient, and the problem of maintaining mechanical tolerances on such small dimensions is so large, that one cannot expect to build them with tolerances less than 20% with any reasonable yield. Thus, critical circuits which require closer control of resistance must, of necessity, be made by thin film or other techniques. (*Continued on page* 64)

Have Very Low Q's

Capacitors that are made by using diffused p-n junctions have very low Q's, are voltage sensitive, are polar, and can be subjected only to relatively low voltage. For these reasons, most capacitors, even when used on monolithic silicon circuits, usually use the thermally grown SiO_2 or other glass as a dielectric rather than using the junction capacitance.

The most important limitation of silicon substrate capacitors, however, is the cost. Using thermally grown SiO_2 as the dielectric, one can obtain capacitance values of approximately 0.25 pf/mil^2. Again, considering a $10.00, one-inch wafer, it is evident that a capacitor built on a silicon substrate would cost about .008 cents per picofarad at 50% yield. Practically, therefore, capacitors placed on silicon substrates must be limited to rather small values.

For comparison, we can calculate the cost of a thin-film capacitor using pyrolitically deposited boroaluminosilicate glass as the dielectric as follows:

Substrate ½" x ½"	$0.12
Al interconnect	0.04
Boroaluminosilicate	0.02
Al counterelectrode	0.04
	$0.22

If one assumes a 90% yield on this process, one arrives at a cost of 24 cents. Again, if the capacitor covered the entire area, the capacitance value would be 0.1 pf, or a cost of 2.4 x 10^{-4} cents per pf. Thus, it costs about thirty times as much to make a capacitor on a silicon substrate as on an insulating substrate using thin-film techniques.

Obviously, then, completely passive circuits requiring large values of capacitance and resistance, and requiring no transistors and diodes, will be cheaper to construct on insulating substrates, and the passive components so constructed can be built to closer tolerances than on silicon substrate. In spite of the calculation above, we limit this statement to circuits requiring large capacitors and resistors because if the required values are small, such that they will fit on a 50 mil silicon chip, it will probably be cheaper to build on silicon because it is difficult to get ceramic substrate this small.

A Complex Problem

The exact situation, as to when you would put passive components on silicon and when you would put them on an insulating substrate and attach the silicon active elements to them, is a complex problem involving the actual size of the finished circuit and the cost of the attachment procedure. However, to a first approximation, it can be said that if the passive components require an area that is trivial compared with the area required for the transistors and diodes, then you can almost get them for free if you place them on the silicon substrate. And, certainly the interconnection problem cannot be simpler than when all components in a circuit are formed on one single substrate.

When the area required for the passive components is greater than the area required for the active components, then packaging and interconnecting techniques will determine whether it is cheaper to put the passive components on the silicon substrate or to form them separately on an insulating substrate and attach the active parts of the circuit to them.

The technique one should use for forming integrated circuits, and the ultimate cost, will depend in a large measure on the final packaging and interconnection technique used. An an example, if one is to attach discrete transistors or partially integrated circuits to a substrate containing interconnections and passive components, the break-even point depends on the complexity and cost of the attachment process.

Also, when it is possible to build so much circuit complexity in a small chip of silicon only 50 mils on a side, it seems a dreadful waste of space to hermetically package these circuits separately, since the individual packages take up so much space.

Much Work Being Done

Much work is now being done on packaging techniques and there is little doubt that within a year or two integrated circuit packages will not just contain

(*Continued on page 67*)

Fig. 7: J K Flip-Flop circuit already available commercially on single 70 mil square substrate; it has 14 transistors, 10 resistors, 2 capacitors. It may become a 30 mil square by 1966.

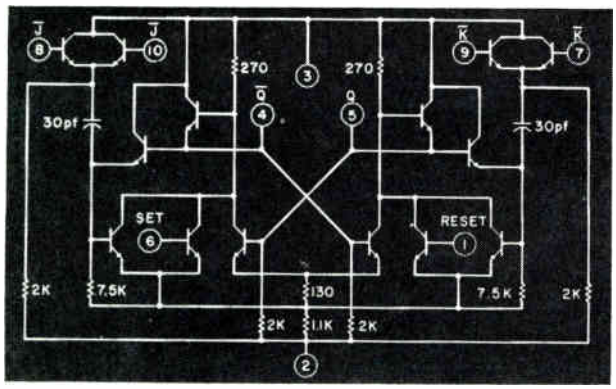
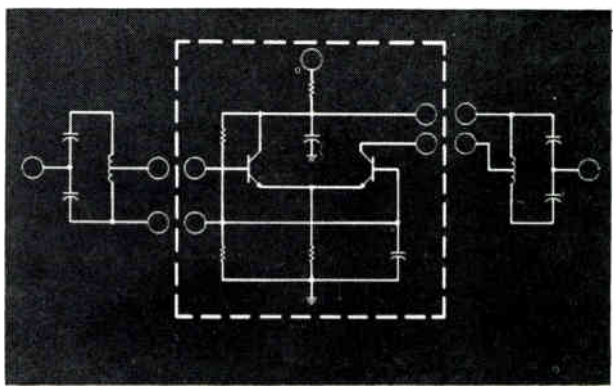


Fig. 8: Circuit of 120 mc r-f amplifier reduced to a monolithic silicon integrated circuit. Several hundred have been built with 90% yield in terms of dc levels and gain vs freq.



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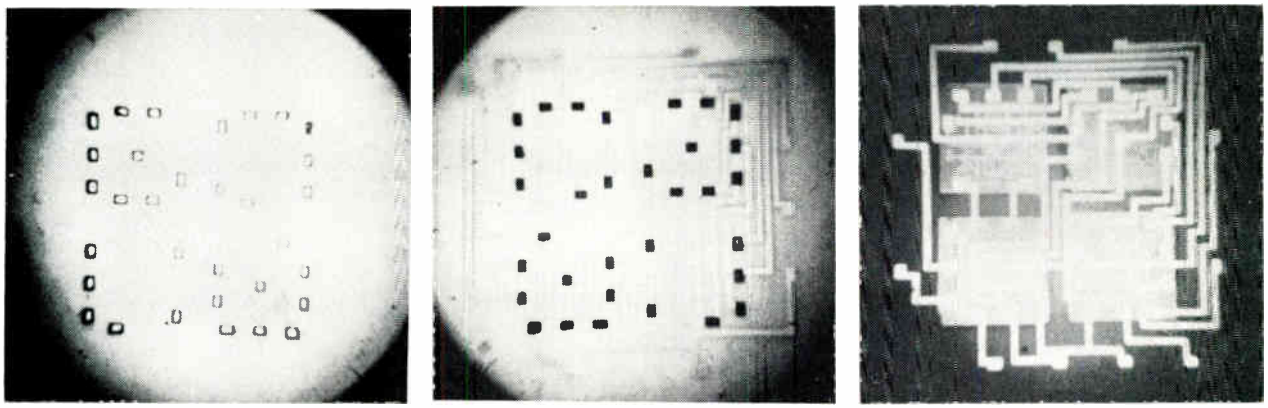

Fig. 9: Packaging concept that combines thin-film and semiconductor technologies; (a) bonding pads are deposited on glass substrate; (b) thin-film components and interconnections are deposited on same substrate; (c) semiconductor circuits are bonded, face down, to bonding islands.

INTEGRATED CIRCUITS (Concluded)

flip-flops, logic gates, or half-adders, but will contain collections of these circuits to produce functional items.

At first, the complexity will be kept rather low so that individual packages will contain elements like shift registers or binary or decade counters.

Figure 9 shows a technique that promises the ability to combine the best features of monolithic silicon with the best features of thin-film technology. First, 9a, a group of aluminum bonding islands are placed on a glass substrate by photo resist techniques. These islands are on the order of a mil thick so that the silicon chips attached to them will be held up off the substrate. Next, 9b, thin-film components and interconnections are deposited on the glass substrate. Finally, 9c, monolithic silicon circuits are flipped over onto the bonding islands and an aluminum-aluminum bond is made; bonding in this case two half-adders and two flip-flops to the thin-film substrate to form one bit of a two phase shift register.

Other packaging techniques are being developed very assiduously in our industry to take advantage of the extremely small size of the silicon die that contains the basic integrated circuitry by combining many dice in one hermetic package. It is obviously too early to say which of the various techniques offer the greatest potential, but an example of what can be done is illustrated in Figure 10. Illustration (a) shows an exploded view of a six-layer printed circuit board that will ultimately hold 16 silicon chips. The board illustrated has two signal planes and four voltage-supply planes. After these boards are assembled with their individual silicon chips, they are stacked very much like the old "tinkertoy" project using vertical pins to make the interconnections between boards as illustrated in (b). Using this technique, a full parallel-parallel adder with look-ahead logic has recently been assembled at Motorola in a one-inch cube.

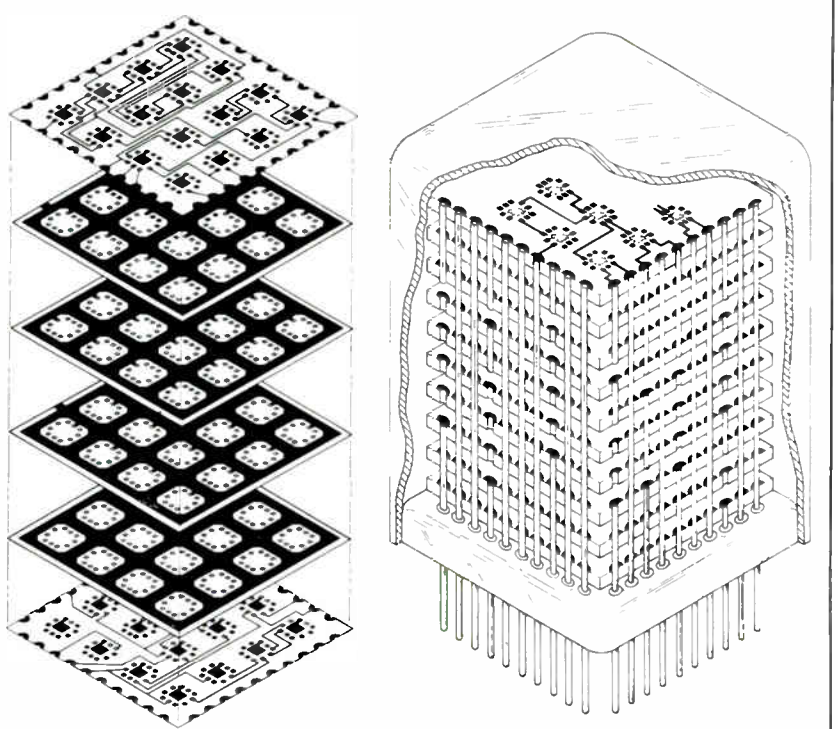

Fig. 10: High density digital integrated circuits packaging technique. (a) multilayer board accommodates 16 complete I/C dice; (b) a number of boards are assembled and interconnected before final packaging.

Certainly, some technique similar to one of the foregoing illustrations must be developed in order to allow us to take full advantage of the size of present-day integrated circuits.

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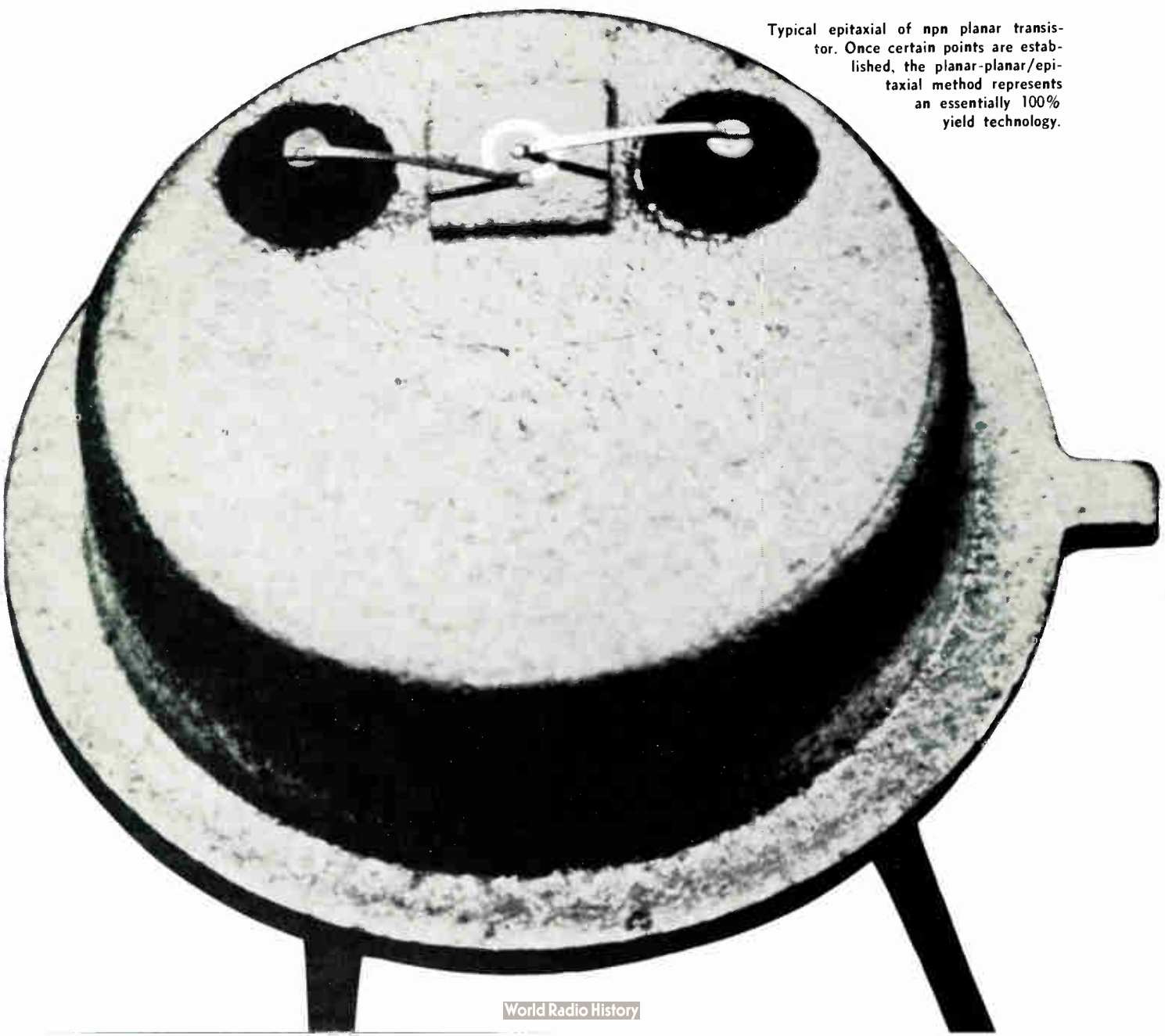


Typical epitaxial of npn planar transistor. Once certain points are established, the planar-planar/epitaxial method represents an essentially 100% yield technology.

of a few degrees above absolute zero, rectify and control megawatts of ac power for motors, etc. Often several circuit functions, such as logic gating and binary addition, can be integrated into a single device smaller than a postage stamp.

First Experiments

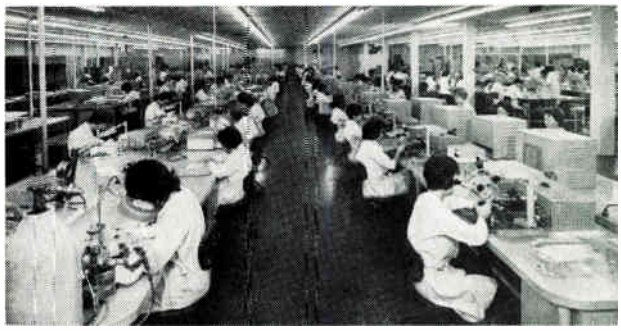
The first experiments of significance to an understanding of semiconductors took place in the 19th century. They consisted of measuring the Hall coefficients of various materials. A magnetic field was applied at right angles to a bar of material carrying a current. Electrodes applied to the specimen perpendicular to both the current flow and the magnetic field showed that a potential, called the Hall voltage, was developed between the electrodes. Magnitude of the voltage differed with different materials and even with different specimens of the same material. Some materials even showed a Hall voltage of polarity opposite to that expected from the model of current flow based on the motion of electrons. In fact, it seemed necessary to assume that current was carried by the motion of positively charged particles. These experiments when recalled in the 40's, led to the two carrier (hole and electron) theory of rectification which was basic to the development of junction semiconductor devices.

Early in the 20th century, it was found that certain minerals, when probed with a stiff wire whisker, showed unsymmetrical, non-linear current-voltage relationships. When theory was first developed to try to explain this, it predicted the opposite sign of rectification to that actually observed. It is also interesting to note that a patent was issued in 1930 to a J. E. Llienfeld which appears to describe a rude but workable npn transistor using copper sulfide as the semiconductor material (U. S. Patent 1 745 175)[1]. It was not until the 50's that devices were made by Leo Esaki, which showed the sign of rectification predicted by early theory.

Intensive work on point contact devices was done during World War II since it was found that they gave better S/N ratios, when used as mixers in radar receivers, than did vacuum tubes.

Shortly after the war, transistor action was first observed and recognized by the Nobel Prize winning team of Bardeen, Brattain and Shockley. This discovery occurred during probing experiments on germanium surfaces. These experiments were done to better understand the behavior of point contact rectifiers.

Rapidly following was the development by W.



Shockley of the theory of p-n junction diodes and transistors. Almost immediately, such devices were built whose behavior was essentially that predicted by the two carrier theory of rectification, i.e., that both holes (positive carriers) and electrons (negative carriers) are of significance in understanding p-n junction behavior.

Technology of Materials

This rapid progress in both theory and experiment needed a correspondingly speedy breakthrough in the technology of materials, i.e., in the growth of perfect single crystals of germanium (Ge) and silicon (Si) with electrically significant impurity content controlled to fractions of a part per billion. Three methods were evolved for such crystal growth: the Czochralsky Method, where a single crystal seed is pulled out of a crucible containing the molten semiconductor through a temperature gradient; the Pfann Method, where a molten zone is passed from the end of horizontal seed through a polycrystalline billet in a quartz boat; and the Keck technique where, by a combination of surface tension and electromagnetic levitation, a molten zone is passed vertically from a seed crystal through an initially polycrystalline bar which is not in contact with any crucible boat or other container.

By variations of these methods single crystals of GeSi alloys, of gallium arsenide, indium phosphide, etc., can be grown. These materials are also semiconductors, all having individual properties.

Another method for growing single crystal semiconductors was evolved in the late 50's. This is the epitaxial method, where layers of controllable thickness and impurity content are grown onto single crystal substrates. This is done by high temperature decomposition of gaseous compounds of the basic semiconductor such as $SiCL_4$ on the clean Si surface. Small amounts of impurities are provided by the introduction of a low level of vapor pressure of an impurity compound such as PCl_3 to give n-type conduction, or BCl_3 to give p-type conduction. This method is basic to the manufacture of high power and/or high frequency devices. It is also useful in the manufacture of integrated circuits.

As a result of these rapid steps in material technology, many new semiconductor devices were quick-

By DR. DELBERT M. VAN WINKLE,
Vice President & Technical Director,
Continental Device Corp.,
Hawthorne, Calif.

[1]Bottom, Virgil E., "Invention of the Solid-State Amplifier," *Physics Today*, Feb. 1964, pp. 24-26.

ly developed. These included Ge and Si rectifiers, transistors, field effect transistors (FET's), controlled rectifiers and switches, parametric amplifiers, varactor frequency multipliers and tunnel diodes. A few years later, integrated circuits, in which many circuit elements and interconnections were made on a single chip of Si, were shown to be feasible. It was also recently shown that lasers could be made of compound semiconductor p-n junctions.

Device Technology

Device technology, which began with point contacts, went through grown, alloy and diffused junction formation stages. It finally reached the stage of multiple diffused, photolithographically controlled planar structures with internal device interconnections made as part of the manufacturing processing.

Most of these developments were made at Bell Telephone Co. Laboratories. Many useful ideas and inventions have also come from other sources such as G. E., Motorola, Texas Instruments, the Diamond Ordnance Fuse Laboratories, Fairchild, Sylvania, Hughes and Raytheon. Esaki's work at Sony Corp. was unique. Other smaller companies have made contributions, but these have primarily been in the area of improved production methods.

Semiconductor devices such as transistors are now made by either the alloying or the planar method. Ge planar units are made by means of evaporated Si dioxide layers, since Ge dioxide is a friable white powder which will not serve to selectively mask the diffusion of impurities.

The planar method is very powerful and permits structures and geometries as complicated as anything one may draw to scale on paper. When combined with the capability of growing layers on the semiconductor material of controllable thickness and impurity content (epitaxy) much can be done. One can make anything from a simple switching transistor to r-f power transistors, FET's (including the insulated gate field effect types) to complex logic circuits.

The planar method depends technically on two points:

(1) Certain electrically important impurities, such as phosphorus, arsenic and boron will not diffuse through a Si dioxide surface layer as rapidly as they will diffuse into Si itself.

(2) It is possible by means of a photographic method to produce replicas on Si, its oxide, or metal coating, any pattern which can be produced on a photographic plate.

Once these two points are established, it is clear that the planar-planar/epitaxial technology is fundamentally a 100% yield technology and hence will continue to play a big role in future semiconductor device manufacturing processes.

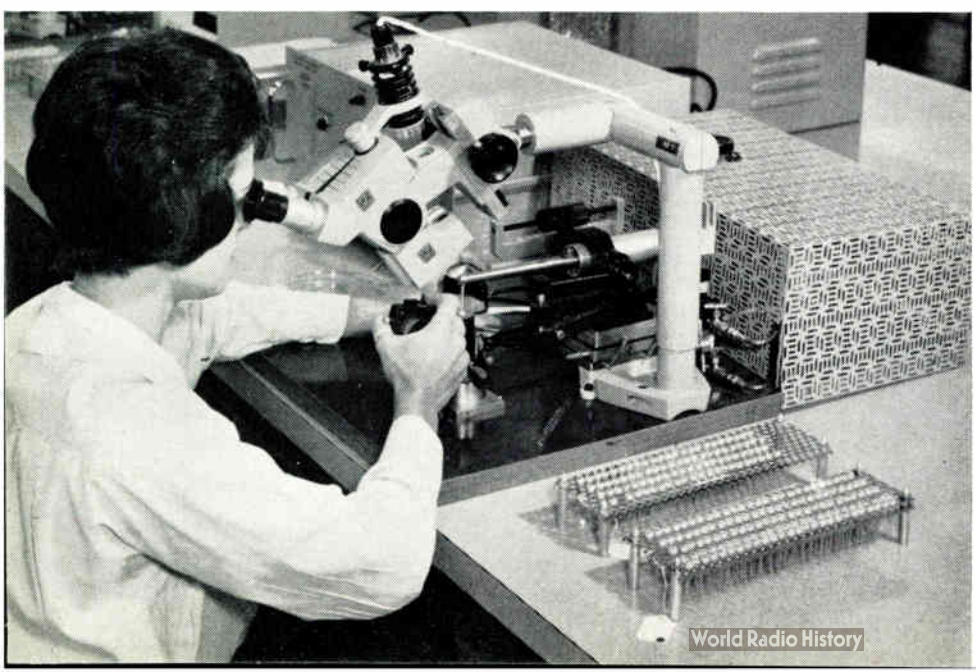
Deviations in the process yield from 100% that are not due to mechanical scrap in the assembly operation are merely a measure of process errors which can be eliminated. An example of this might be inadequate protection of the semiconductor wafer against dust at critical parts of the operation.

Elimination of mechanical assembly line scrap is also a straightforward problem in mechanical and industrial engineering. That is, provided all the material in the device assembly is in chemical and metallurgical equilibrium and reasonable account is taken of differences in thermal coefficients of expansion in the materials used.

Problems in Si device technology that must be solved are, therefore, those associated with the reduction of assembly costs and improvement in the assembly area. These must be solved to improve mechanical reliability and reduce labor input in the assembly area.

Since the planar process is inherently one which gives high yields, it can be expected that any device which can be made by this method will eventually be quite cheap. In particular, the cost of a finished perfect die can be expected to approach zero, except perhaps in the case of very high power devices or quite complicated integrated circuits. Main elements of the remainder of the manufacturing cost can then be analyzed as (1) Cost of package parts, (2) cost of attaching the die to the header, (3) cost of attaching internal leads between the device and the external terminals and (4) test cost.

Parts costs are rapidly decreasing as certain package setups become more standardized. On such high volume, the parts manufacture is getting closer to the raw material costs.

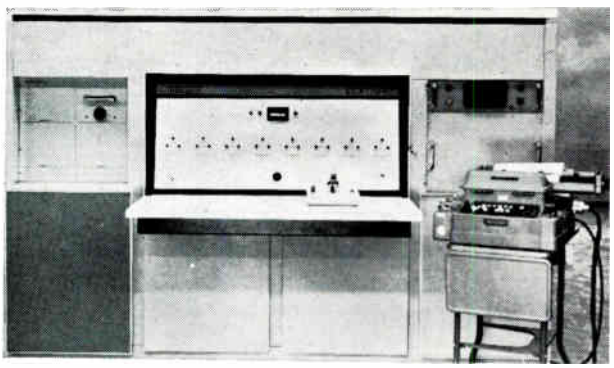


Worker pictured here is performing a transistor "lead binding" operation.

Assembly costs will continue to drop and product mechanical quality will continue to improve as better tooling is developed and installed.

Test costs have already been sharply cut by automatic test equipment. Sequential Component Automatic Test (SCAT) specialized equipment reduces testing costs to a minimum. Such equipment can perform many sequential tests on the component. Also, if needed, it can convert the data into a form that can be placed on magnetic tape, punched cards, etc.

Of all of the devices listed—transistors, rectifiers and diodes, voltage regulators, FET's, controlled rectifiers and switches, tunnel diodes, parametric amplifiers, high power frequency multipliers, integrated circuits, it appears that all but the tunnel diode and low voltage regulators eventually will be made by, or are now being made by, oxide masking and diffusion technology.



Introduction of automatic test equipment such as the Sequential Component Automatic Test system (SCAT-24) has cut semiconductor test costs. It can perform a variety of tests.

Possibly the cheapest of audio Ge transistors will continue to be made by alloying methods. But, even here, the economics may reverse within the next few years.

The tunnel diode and low voltage regulators appear to need alloying technology because of the special need of a very abrupt p-n junction.

This is because the thickness of the transition region from the heavily doped p-region into the heavily doped n-region determines the probability of an electron tunneling from the bottom of the conduction band to the top of the valence band. It is not now clear to what extent tunnel diodes will come into extensive usage. There are three major reasons for this uncertainty:

(1) The tunnel diode is completely bilateral. There is no isolation between input and output circuits. This presents a serious problem to a circuit designer who is using the tunnel diode for anything but an oscillator or a switch.

(2) The tunnel diode is a negative resistance device. Traditionally, circuit designs (as in the vacuum tube tetrode oscillator) using negative resistance effects have been marginal since small parameter shifts can cause a large change in the device operating point.

(3) The tunnel diode is inconvenient in that it must operate into low impedance external circuitry. Making transmission lines with characteristic impedance of only a few ohms is quite difficult.

Use of compound semiconductors can be predicted to be small in extent since these materials have severe disadvantages in transistor or diode uses that are inherent in the physics of the materials. Certain specialized uses may be found for some of these compounds, (eg. magnetic compasses or solid state lasers) but this will probably not be on a large scale.

It is expected that Si will increasingly replace Ge in most, if not all, of those uses in which low price is an essential. This is because the planar technology is inherently cheaper and better with Si than with Ge. Hence, for over the high volume, low cost, "entertainment" market, the greater inherent reliability of Si devices coupled with prices rapidly approaching Ge device prices will tend to push the Ge devices off the market.

The last significant scientific gain needed in Si devices is a better understanding of the Si surface. This permits more control in those parameters such as noise and low current gain stability (particularly in Si pnp structures) which appear to be controlled by the surface. Such an improved understanding and control will also lead to much improvement in insulated gate field effect devices whose operation is closely tied to the detailed electrical "structure" of the surface.

Metal—metal oxide semiconductors such as have been produced by Hewlett-Packard Associates can be confidently predicted to play an increasing role in very fast switching diode needs.

Industry Growth

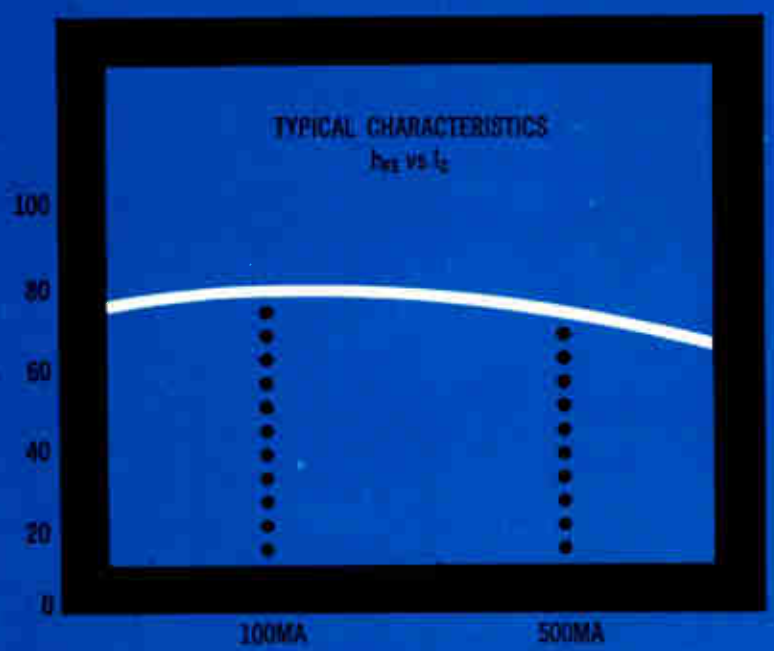
The dramatic growth of the semiconductor industry within the last 10 years is evident to all. The tremendous improvements in reliability, process control and parts handling methods that have been developed to support this growth are not so evident but, are still very significant. It is the improvement of the quality base, rather than the quantity base, that constitutes the really significant change in the state-of-the-art of the semiconductor field of the last few years. New uses and improvement of device characteristics will continue to be made because even today it is a rare device that achieves the theoretical capability of the basic semiconducting material from which it is made. The progressive companies will keep their engineering targets focused on the true potential of the semiconducting material. They will direct their management efforts toward achieving a well balanced, competitive organization that places equal emphasis on manufacturing efficiency, accounting, sales and service. Any company that does not show equal strength in the areas of engineering, manufacturing, management and sales cannot survive the competitive future in the semiconductor components field.

● **A REPRINT of this article is available from ELECTRONIC INDUSTRIES Reader Service Department**

Silicon NPN

SYLVANIA BROADENS THE RANGE OF FROM 100MA TO 500MA AT

100MA



Only with Sylvania

NPN core drivers do you get linear beta between 100 and 500ma. Imagine how important this can be in high current switching, or other instances where you have sudden changes in current. With their unique "double-H" construction these core drivers span their functional range with a stability unlike any other transistors. Look at the high degree of beta linearity and uniformity, as indicated in the graph. In the typical samples tested the curve is almost flat over a wide functional range.

Saturation Voltage is low.

V_{CE} (sat) typ. 0.25V @ I_C = 150ma, I_B = 15ma
V_{CE} (sat) typ. 0.5V @ I_C = 500ma, I_B = 50ma
V_{BE} (sat) typ. 0.85V @ 150ma, I_B = 15ma

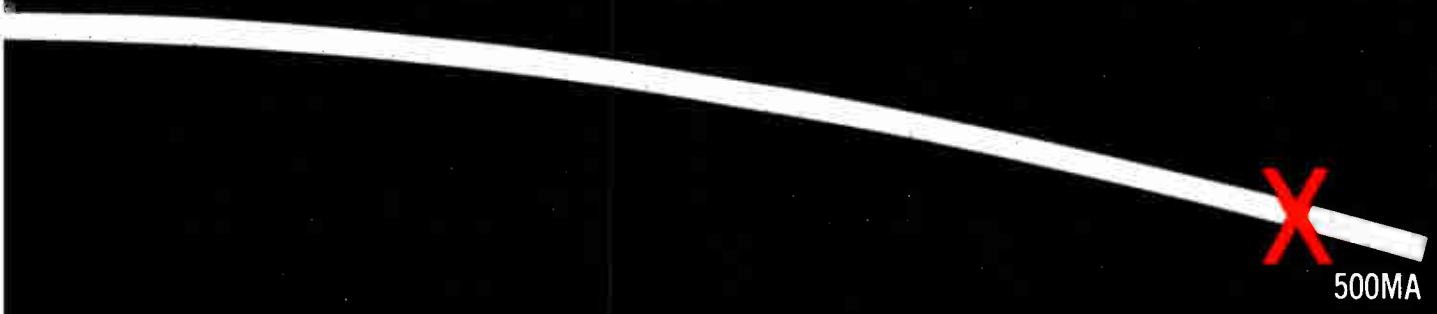
Junction Construction	TO-5	TO-18	TO-51
(double-H)	2N1959A		2N1959A/51
	2N2410		2N2410/51
(single-H)	2N2217	2N2220	2N2217/51
	2N2218	2N2221	2N2218/51
	2N2219	2N2222	2N2219/51
	2N2537	2N2539	2N2537/51
	2N2538	2N2540	2N2538/51
	2N2297		2N2297/51

Packaging

Sylvania's NPN core drivers are the only ones available in three packages—the popular TO-5, TO-18, and TO-51. Packaging for both the H and Double-H units are shown at the left.

Core Drivers

FLAT BETA IN SILICON NPN CORE DRIVERS LOWER SATURATION VOLTAGES



Uniformity

of characteristics is found from transistor to transistor.

Combination

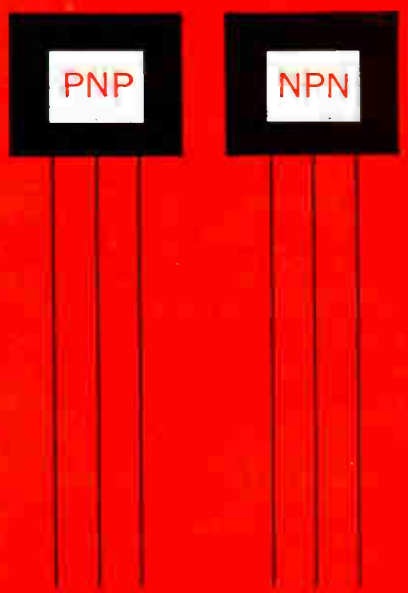
of important features is designed into these epitaxial units—high latching voltage, low storage time and flat beta characteristics.

LV_{CEO} (35 typ.) : t_s (25 N_{SEC} typ.) : h_{FE} (65 typ. @ 150ma, V_{CE} 10V)

Complementary pairs

are now available. Because of their highly compatible characteristics (including the remarkably flat betas in both types), Sylvania's NPN and PNP core drivers work ideally in combination.

The characteristics you want in a core driver, whether NPN or PNP, are combined in Sylvania's line of silicon epitaxial planar core drivers. And remember that they're plague-free—thanks to aluminum wire bonding. Reliability, high performance and versatility are assured. A Sylvania sales engineer is ready to give you more complete information. Call him or write Semiconductor Division, Sylvania Electric Products Inc., Woburn, Mass.



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NEW CAPABILITIES IN: ELECTRONIC TUBES • SEMICONDUCTORS
MICROWAVE DEVICES • SPECIAL COMPONENTS • DISPLAY DEVICES

Circle 74 on Inquiry Card

NEW TECH DATA

SEMICONDUCTORS

Zener Diodes

Data is available on 10w. zener diodes, designated, 1N2970 through 1N3015, including ±20%, ±10% and ±5% versions. All units are checked for thermal impedance, assuring sound back contact structure. The positive front contact is formed by metallurgically bonding the whisker to the crystal. Both standard and reverse polarity types are available. TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif.

Circle 293 on Inquiry Card

Turn-Off Rectifier

Bi-stable latching-switch action for uses in which turn-off as well as turn-on gate action is desired can be achieved with the silicon pnpn gate turn-off rectifiers. Max. gate current required to fire the Type 3GCR devices is 50madc. Gate turn-off current varies from 100ma to 300ma, depending on circuit requirements. Semiconductor Div., Sarkes Tarzian, Inc., 415 N. College, Bloomington, Ind.

Circle 294 on Inquiry Card

Tunnel Diodes

Bulletin L-1055 describes a series of gallium-arsenide and germanium tunnel diodes. Designated series 1300 for Ge and 1700 for GaAs, these tunnel diodes are designed and characterized for high-speed, low-level switching uses. The units feature typical switching speeds of 0.3nsec. Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N. J.

Circle 295 on Inquiry Card

FET Reliability Report

A 2 million unit-hr. reliability report on field-effect transistors is contained in this 16-page booklet. The report contains data on device selection, product conditioning, test conditions and procedures, and failure definitions. Histograms are supplied. Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif.

Circle 296 on Inquiry Card

VHF-UHF Transistors

New data sheets give specs. and describe new VHF-UHF silicon-planar epitaxial npn transistors, including the 2N2217, through 2N2222 and 2N2846, 2N2848. The units are free of "purple plague"—the high temp. storage problem. This is eliminated by aluminum-to-aluminum bonding. Aluminum alloy lead wires are used in bonding to the aluminum base and emitter contact areas. Use of a new configuration results in excellent h-f response up to 400MC, improved Beta linearity, and greater reliability because of larger bonding areas. The new units are called BELL (Bendix Epitaxial Little Leaf) transistors. Bendix Semiconductor Div., The Bendix Corp., Holmdel, N. J.

Circle 297 on Inquiry Card

Photomixer Diodes

This data sheet describes the Series L4500 photomixing and photodetecting devices to be used in communication systems. The diodes have a storage temp. of 100°C; an operating temp. of 85°C; and a forward current of 10 ma. Other specs. and photos are given. Philco Corp., Lansdale Div., Lansdale, Pa.

Circle 298 on Inquiry Card

Core Testing Note

Magnetic Testing Application Note, No. 1 shows a circuit which will improve current waveforms in core testing systems using current drivers connected in parallel. A brief consideration of the theory is also included. Digital Equipment Corp., 146 Main St., Maynard, Mass.

Circle 299 on Inquiry Card

Field-Effect Transistors

A 2,000,000 unit-hour reliability report has been published on the 2N2606 through 2N2609 field-effect transistors. The report includes a number of charts and graphs on life test conditions and readout conditions. Siliconix Inc., 1140 W. Evelyn Ave., Sunnyvale, Calif.

Circle 300 on Inquiry Card

Microcircuits Data

New data on microcircuits—dual 2 input gate, dual 3 input gate, 4 input gate, 5 input gate and full shift register elements—is available. Included in this 8-page folder are 3 DTL NAND/NOR units and data on 10 industrial type integrated circuits suited to computer and control systems use. Amelco Semiconductor, 1300 Terra Bella Ave., Mt. View, Calif.

Circle 301 on Inquiry Card

Transistors

Data is available on the 2N327B, 28B, and 29B epitaxial-junction pnp silicon transistor. They have an I_{cbo} and I_{ebo} of 1ma. max. Power dissipation is 400mv. Collector capacitance is 9pfd, and alpha cutoff range from 2 - 5MC. Crystalonics, Inc., 147 Sherman St., Cambridge 40, Mass.

Circle 302 on Inquiry Card

Rectifier Bulletin

Bulletin G-1000, a "Designer's Guide," details a standard line of silicon rectifiers, selenium rectifiers, assemblies and engineering capabilities. The bulletin illustrates each product series, and offers a quick reference to each category. It also contains information on current and voltage ratings, dimensions and configurations. Electronic Devices, Inc., 21 Gray Oaks Ave., Yonkers, N. Y.

Circle 303 on Inquiry Card

PNP Transistors

Types 2N2357-59 are a series of Diffused Alloy Power (DAP®) transistors designed for efficient high-current, high-speed switching. The diffused base gives very low input resistance and high-cutoff freq. while maintaining high breakdown voltage. The units can switch 4500w. in μsec. More data available from Bendix Semiconductor Div., Holmdel, N. J.

Circle 304 on Inquiry Card

Memory Core

Data is available on a 20-mil coincident-current memory core that has high-drive and fast-switching characteristics. The new core is intended for use in coincident-current memories in the 1μsec. speed class. Typical specs. at 25°C are 850/425ma drive pulse; 0.4μsec. drive width; 0.18 μsec. switching time, 50mv amplitude for 1, 6mv amplitude for 0. Electronic Memories, Inc., 12621 Chadron Ave., Hawthorne, Calif.

Circle 305 on Inquiry Card

Semiconductor Test Brochure

A new brochure describing a wide line of automatic semiconductor test and measure equipment in the industry is now available. It describes 8 high-speed, high-volume testers designed to serve both semiconductor users and manufacturers. The equipment tests transistors, diodes and integrated circuits to meet the high reliability needs of today's military and space programs. Fairchild Semiconductor Instrumentation, 844 Charleston Rd., Palo Alto, Calif.

Circle 306 on Inquiry Card

Choppers

Four models of Photocom solid-state choppers are available in this data. They can be driven at any external freq. from 1 CPS to 3KC. Turn on and off time is 2msec. or less. James Electronics, Inc., 4050 N. Rockwell St., Chicago, Ill.

Circle 307 on Inquiry Card

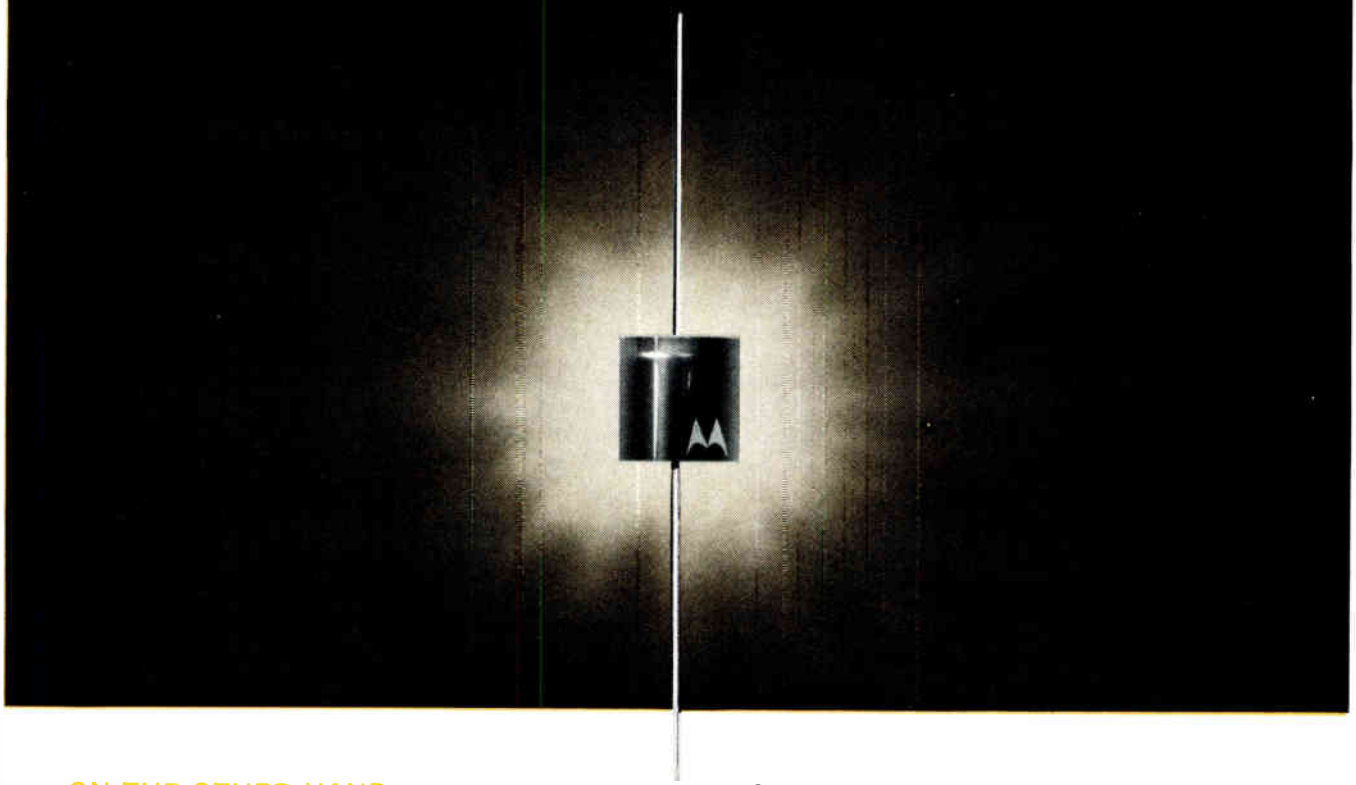
Power-Transistors Protector

New circuit resistive elements that provide dc stabilization, circuit balance and 2-way overload protection in power transistor circuits are announced in bulletin A-16. The circuit elements, called Barretters, have a positive temp. coefficient of resistivity and are located in series with transistor emitters. They prevent thermal runaway in power transistors by offsetting any increase in transistor collector current by a corresponding increase in the internal resistance of the Barretters. The bulletin includes a typical application circuit. Dimensional diagrams, performance curves, and complete specs. are also given. Tung-Sol Electric Inc., One Summer Ave., Newark 4, N. J.

Circle 308 on Inquiry Card

4 customers bought 24 of these during the past year

(It's a 49.6 Volt Motorola Temperature Compensated Zener Diode)



ON THE OTHER HAND . . .

. . . thousands of satisfied customers bought millions of other Motorola zener diodes during the same period. And in every voltage from 2.4 to 200 V. This reveals two important things about us:

1. We can meet virtually any zener diode requirement you may have (including 49.6V units).

2. We pay as much attention to your order for a "small demand" device as we do to your order for one of our "fast movers."

In fact, we maintain the largest inventoried zener line in the industry — literally, there's well over 3 million devices on the shelf (at the factory, and in your local Motorola distributor's warehouse). We keep the inventory that big so we can ship what you want, when you want it.

One more point — at Motorola we're dead serious about an ingredient called "Quality." It's a no-extra-cost ingredient you buy, and need, and get from Motorola, for sure.

FREE ZENER DIODE SELECTOR
Send today for your free copy of this easy-to-use profile of the largest inventoried zener diode line anywhere.

MOTOROLA Semiconductor Products Inc.

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WITH ITS NOISE FIGURE OF 3 db AT 100 mc AND 7.5 db AT 800 mc... WITH ITS POWER GAIN OF 11.5 db AT 800 mc, AND WITH ITS FEEDBACK CAPACITANCE OF 0.2 pf... NOTHING CAN TOUCH THE NEW AMPEREX 2N3399 FOR PERFORMANCE, FOR AVAILABILITY, AND FOR PRICE

AMPEREX 2N3399 SIGNIFICANT CHARACTERISTICS

PARAMETER	VALUE	CONDITIONS
Noise Figure	3 db typ.	$I_E = 1.75$ ma, $V_{CB} = -10$ V. $R_S = 120\Omega$, f = 100 Mc
Noise Figure	7.5 db typ; 9 db max.	$I_E = 1.5$ ma, $V_{CB} = -12$ V. $R_S = 60\Omega$, f = 800 Mc
Power Gain	8.2 db. min. 11.5 db typ.	$I_E = 1.5$, $V_{CB} = -12$ V. f = 800 Mc
C_{re}	0.2 pf typ.	$I_E = 0$, $V_{CB} = -10$ V.
f_T	600 Mc typ.	$I_c = -1.5$ ma $V_{CE} = -12$ V.
		Germanium Mesa, TO-18 Case, 4-Leads

Ideally suited for both VHF and UHF applications including mobile receivers, FM radios, TV tuner RF amplifiers, antenna booster amplifiers and wide band IF amplifiers. The 2N3399 is immediately available in unlimited production quantities. For additional data and applications engineering assistance, write: Amperex Electronic Corporation, Semiconductor and Receiving Tube Division, Hicksville, L. I., New York 11802.

Amperex®

IN CANADA: PHILIPS ELECTRON DEVICES LTD., TORONTO 18, ONT.

Circle 76 on Inquiry Card

NEW TECH DATA

SEMICONDUCTORS

Step-Recovery Diodes

This data sheet describes step-recovery diodes 0112 - 0114. These units are epitaxial, diffused - junction, surface - passivated, silicon devices with abrupt junctions. When conducting in a forward direction it stores a charge. When the voltage polarity is revised, it conducts for a brief period. The data sheet contains specs., characteristic curves, schematics, and scope-trace photos. HP Associates, 620 Page Mill Rd., Palo Alto, Calif.

Circle 250 on Inquiry Card

Nanowatt Transistor

The type 2N3058 (TO-46) high-gain pnp silicon transistor has a typical Beta of 100 at 1na of base current. Collector cut-off current is 0.1na max., and Beta limits are guaranteed at collector currents of 10, 1 and 0.1μa. Additional data available from Crystalonics, Inc., 147 Sherman St., Cambridge, Mass.

Circle 251 on Inquiry Card

High-Amp SCR

Data is available on an 18a. SCR with a surge current of 250a. The device represents an improvement in surge current rating of 67% over standard devices. The new series spans the PRV range from 25 to 500v. and has a minimum critical rate of rise of forward voltage of 200v/μsec. for the 25 through 300v. devices, and 100v. for the 400 and 500v. types. Reverse leakage of the devices, 2N681A through 2N689A, is also lower, with a max. of 1ma full cycle average leakage current across the entire range of voltage ratings. International Rectifier Corp., 233 Kansas St., El Segundo, Calif.

Circle 252 on Inquiry Card

Diode Catalog

Bulletin 122-264, 20 pages, describes nearly 500 zener-diode types and variations. The catalog details on a line from micro zener diodes through ½w. and 1w. to 10w. types. In addition to the extensive tabulations, several pages are devoted to technical data, application curves and dimension information. TRW Semiconductors Inc., 14520 Aviation Blvd., Lawndale, Calif.

Circle 253 on Inquiry Card

Logic Module

Data is available on a complete silicon logic module family which performs with an exceptionally high degree of reliability over extreme temp. ranges. These 3-dimensional potted modules are designed and manufactured in rigid quality control standards which exceed military specs. Operating freq., 2MC; operating temp. range, −55°C to +125°C. Electronic Modules Corp., 1949 Greenspring Dr., Timonium, Md.

Circle 254 on Inquiry Card

Silicon Rectifiers

Bulletin 104 offers full operating characteristics applicable to miniature, flangeless silicon rectifiers. Available in several types, they possess equal or better electrical ratings than larger top-hat types. Features include high power in miniature package, glass-to-metal hermetic seals, axial leads, currents to la., voltate to 1200v. Edal Industries, Inc., 4 Short Beach Rd., East Haven 12, Conn.

Circle 255 on Inquiry Card

Semiconductor Catalog

This 24-page condensed catalog which contains specs. for transistors, FETs, diodes, SCRs, special products, and integrated micro-circuits as well as microwave products, including solid-state sources and varactor diodes, and instrumentation products, both automatic test equipment and system modules. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif.

Circle 256 on Inquiry Card

Digital Magnetics Brochure

A 10-page, 3-color brochure entitled, "Digital Magnetics" is available. The booklet highlights the past, present and future of magnetic techniques as they relate to commercial, military and aerospace equipment. It features research and development capabilities and illustrates basic magnetic building blocks and typical digital magnetic systems. Di/An Controls, Inc., 944 Dorchester Ave., Boston, Mass.

Circle 257 on Inquiry Card

Semiconductor Reliability

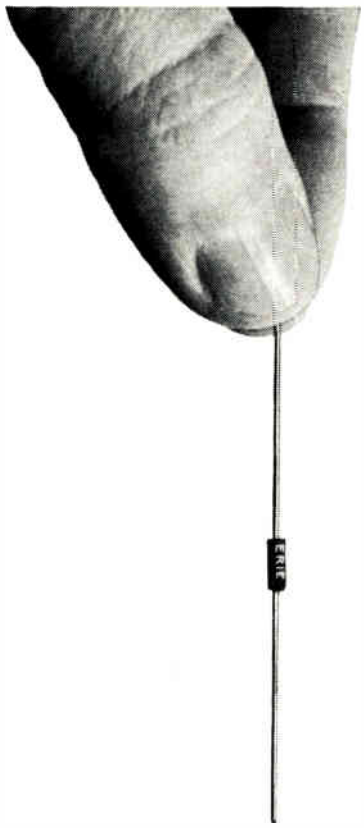
Reliability bulletin #204, "Reliability Notes on Constant Acceleration of Semiconductor Diodes and Rectifiers" is available. It should be an aid to engineers dealing with high-reliability specs. Erie Technological Products, Inc., 644 W. 12th St., Erie, Pa.

Circle 258 on Inquiry Card

Microcircuit Production

Brochure C-2 provides complete technical data on facilities and capabilities for packaging and producing microcircuits. Detailed attention is paid to the "clean room" production of welded subminiature modules, cermet thin-film networks, and integrated active-passive hybrid circuitry. A separate fold-out section contains photographs and descriptions of circuit modules currently available for military and commercial use, including the 19-component ladder-type welded module. The brochure also offers information on microcircuit end-uses, as well as details of the circuit packaging, quality assurance, and quality control programs. El-Pac Co., Inc., 800 E. Main St., Norristown, Pa.

Circle 259 on Inquiry Card



NOW!

MINIATURIZED ENCAPSULATED RECTIFIER

. . .100% reliability? . . . . . at 750ma . . . . . and SMALL!!!

There's a good chance! *Not one* rectifier has ever been returned to Erie out of hundreds of thousands shipped. In 1000-hour tests for parametric and catastrophic failures, production samples of this new molded silicon rectifier showed a *reliability* rate that meets or exceeds the standard military test requirements. Tests included operational life testing, temperature cycling, surge testing, shock, vibration, constant acceleration, lead fatigue and tension, and solderability tests on the heavy, soft silver leads.

Now rated at 750ma., 100 to 1000 PIV. Improved construction gives high forward conductance, low leakage currents, and extremely low thermal resistance. These rectifiers can safely pass large surge currents frequently developed in power supply circuitry.

Truly a miniature (only .090" x .250"), Erie's encapsulated silicon rectifier is a major achievement in electronic packaging . . . highly resistant to parametric degradation from moisture absorption and molecular diffusion.

Tip your top hats and flip your flanges! Write Larry Scalise, Mgr. Customer Engineering, for Reliability Bulletin #205 . . . or call your authorized Erie distributor or Erie regional sales office for specifications, evaluation samples, and production quantities.

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ERIE

644 West 12th Street
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FORMERLY ERIE RESISTOR CORPORATION

WHERE IMAGINATION CREATES VALUE IN ELECTRONICS

NEW TECH DATA

SEMICONDUCTORS

Circuit Designers Guide

A brochure entitled, "Voltage-Variable Capacitor Guide for Communications Circuit Designers," 12 pages is available. It reviews the theory and characteristics of the voltage-variable capacitance diode and discusses design considerations for using these diodes in electronic tuning applications. The discussion is confined to small signal applications, but much of the information is applicable to large signal applications, such as freq. multipliers and parametric amplifiers. The guide contains schematics, characteristic curves, and equations. Special Products Operation, Lansdale Div., Philco Corp., Lansdale, Pa.

Circle 260 on Inquiry Card

Core Memory Brochure

Bulletin contains a detailed description of the new VersaLOGIC 2μsec. and 5μsec. core-memory systems. Includes block diagrams, timing charts, and operational, environmental and physical specs. It explains a new design concept that integrates the memory into an overall system design. Control Associates, Inc., 1590 Monrovia Ave., Newport Beach, Calif.

Circle 261 on Inquiry Card

Low-Noise Gates

The D-Series NAND-NOR logic gates assure approx. 2v. noise rejection. The output of every gate is clamped to provide a low impedance-to-noise when the gate is cut off. Complete details available from Abacus, Inc., 1718 21st St., Santa Monica, Calif.

Circle 262 on Inquiry Card

Solid-State Products

This product catalog describes a line of zener diodes, diffused silicon rectifiers, fast-recovery rectifiers, stacks and bridges. The catalog contains photos, characteristic tables and curves, and schematics. Unitrode Transistor Products, Inc., 214 Calvary St., Waltham, Mass.

Circle 263 on Inquiry Card

Avalanche Rectifiers

Data is available on a line of 1, 6, and 12a. controlled avalanche silicon rectifiers. The product line includes the 1a. Type FA in 400, 600, and 800v. PIV ratings, and the 6a. Series HA 3 and 12a. Series ST2A, both offering 100 to 600 PIV. The units are made from low resistivity, low radial gradient silicon with controlled lattice dislocation. Extremely high transient over-voltages can be withstood, since the units are capable of dissipating the same power in the reverse as in the forward direction. Dielectric breakdown is eliminated. Complete specs., performance characteristics, and test circuits are given. Semiconductor Div., Sarkes Tarzian, Inc., 415 N. College, Bloomington, Ind.

Circle 264 on Inquiry Card

Transistor Device

This short-form catalog describes a complete line of transistor devices. It includes an expanded list of dual output, midget and unregulated power supply modules. The units are guaranteed for 3 yrs. of continuous operation. Ferrotran Electronics Co. Inc., 693 Broadway, New York 12, N. Y.

Circle 265 on Inquiry Card

Controlled Rectifier

The series 72REB60 thru 130 controlled rectifiers withstand a high critical rate-of-rise of forward voltage (dV/dt) of 200v/μsec. The new semiconductor is a high voltage (up to 1300v. prv) epitaxial 70a. (110a rms) unit exhibiting bulk avalanche characteristics. This series, a device that will overcome problems arising from rapid increases of anode-to-cathode voltages. Also the bulky filtering circuits that were used to protect the system from steeply rising voltages are eliminated or at least reduced in size. Additional data available from International Rectifier Corp., 233 Kansas St., El Segundo, Calif.

Circle 266 on Inquiry Card

NEW TECH DATA

SEMICONDUCTORS

SCR

Data sheets describe 2 new silicon-controlled rectifiers rated @ 1000v. and 1200v., PRV. Two series are designated NL-510 and NL-511. Both are rated at 7a. dc and 11a. RMS. The NL-510 has a low PRV to permit a reduction in costs by using a series diode. NL-511 has a PRV equal to peak forward breakover volts. Photos, charts, and specs. are also included. National Electronics, Inc., subs. of Eitel-McCullough, Inc., Geneva, Ill.

Circle 267 on Inquiry Card

Logic Module Catalog

This catalog presents the D-series silicon and germanium digital modules, available in speeds to 10MC, which feature extensive noise rejection techniques not usually available in one family of circuits. Also described is the A-series, containing a variety of analog modules, compatible with the D-series, for building D/A and A/D converters. Mounting hardware, power supplies, and other accessories are described, and prices of all of the products are included. Abacus Inc., 1718-21st St., Santa Monica, Calif.

Circle 268 on Inquiry Card

Gallium-Arsenide Diodes

Bulletin PD-364 describes the Type 7000 diffused gallium-arsenide emission diodes. The diodes, when biased in the forward direction, emit infrared radiation in a narrow spectral band centered at approx. 0.9 microns. It is designed for high conversion efficiency, and is packaged in a standard TO-18 enclosure with flat glass window. Electrical characteristics and curves are included. Micro State Electronics Corp., 152 Floral Ave., Murray Hill, N. J.

Circle 269 on Inquiry Card

Semiconductor Reliability

Reliability bulletin #204, "Reliability Notes on Constant Acceleration of Semiconductor Diodes and Rectifiers" is available. It should be an aid to engineers dealing with high-reliability specs. Erie Technological Products, Inc., 644 W. 12th St., Erie, Pa.

Circle 270 on Inquiry Card

Logic-Elements Catalog

This 28-page, 2-color catalog describes a line of 3MC and 10MC germanium and silicon NAND logic elements. It provides detailed on logic cards available with either germanium or silicon semiconductors, and with operational rates from dc to 3MC, or dc to 10MC. Also included in the catalog is data on power supplies, mounting hardware and accessories, including card trays, pull handles, card extenders and wire kits. Intercontinental Instruments Inc., 123 Gazza Blvd., Farmingdale, N. Y.

Circle 271 on Inquiry Card

NEW TECH DATA

ELECTRONIC INDUSTRIES

REFERENCE ISSUE

ELECTRON TUBES

Low AM/PM TWT

Data is available on a microwave link traveling-wave tube with low AM/PM conversion. The N1055 covers the 5.8 - 7.2 GC band with a 10w. output. AM/PM conversion is 1°/db with a noise figure of 25db. Data on this tube, developed by English Electric Valve Co., may be obtained from Calvert Electronics Inc., 220 E. 23rd St., New York, N. Y.

Circle 277 on Inquiry Card

CRT Magnetic Shields

Data Sheet 168 pictures and gives helpful technical data on the construction and applications of new sectionalized Netic and Co-Netic magnetic shields for large dual or single-gun cathode-ray tubes. Magnetic Shield Div., Perfection Mica Co., 1322 N. Elston Ave., Chicago, Ill.

Circle 278 on Inquiry Card

Magnetrons

Data is available on 2 voltage-tunable magnetrons with nearly 3 times the power output and 50% greater efficiency than previously available VTM's. Types ZM-6046 and ZM-6047 have average power outputs exceeding 90w. across the bandwidths from 2600 to 2900MC and from 2900 to 3200MC. Tube Dept., General Electric Co., Owensboro, Ky.

Circle 279 on Inquiry Card

Tube Catalogs

A group of condensed catalogs describing lines of electron tubes is available. The 4 booklets give type numbers and electrical characteristics for display storage tubes, hydrogen thyratrons, power tubes, microwave tubes, and other types. ITT Corp., 320 Park Ave., New York 22, N. Y.

Circle 280 on Inquiry Card

Tube Applications Notes

Two new sets of Tonotron direct-view storage tube application notes are available. One combines #91-19A-5 and #91-19A-13, "Operation of Tonotron and Multi-Mode Tonotron Tubes," while the second (#91-19A-6) is entitled, "Storage Tube Operating and Handling Precautions." Vacuum Tube Products Div., 2020 Oceanside Blvd., Oceanside, Calif.

Circle 281 on Inquiry Card

Microwave Digest

This 32-page product digit contains photos, specs., and a description on a line of magnetrons, BWOs, klystrons, ESF klystrons, TWTs, switch tubes, display devices, and CRTs. Equipment and accessories are also included. Litton Industries, Electron Tube Div., San Carlos, Calif.

Circle 282 on Inquiry Card

Flashtube Manual

This manual describes the characteristics of xenon, neon, and argon helical and straight flash lamps. Special sections are devoted to circuit design, parameters of ac and battery high voltage power supplies and stroboscopic equipment design. Amglo Corp., 4325-33 No. Ravenswood Ave., Chicago 13, Ill.

Circle 283 on Inquiry Card

Traveling-Wave Tube

Type SYT-4353A is a 20-w TWT designed primarily for radar augmenter applications. It offers you outstanding electrical performance—20 w. CW from 5GC to 11GC—in a package 9.4 in. long, 1 in. in dia., and weighing 2 lbs. It is fully ruggedized to military specs. for airborne environments. Data is available from Sylvania Electric Prods., Inc., Electronic Tube Mktg., Seneca Falls, N. Y.

Circle 284 on Inquiry Card

Cathode-Ray Tube

The D13-26 is a tight-tolerance, 5 in. mesh tube usable to over 100MC with a sensitivity of 2.5v./cm. This state-of-the-art sensitivity and bandwidth has been achieved in an 18.4 in. envelope, making this tube ideal for use in h-f transistorized display systems. The tube has a 5 in. flat face, post acceleration voltage of 15kv, a 6 x 10 cm scan, and a spot size of 0.023 in. @ 25μa beam current. Amperex Electronic Corp., Tube Div., Hicksville, L. I., N. Y.

Circle 285 on Inquiry Card

Microwave Tube Catalog

This 36-page catalog lists unclassified microwave tubes, display devices and tube-related equipment. These include pulse and CW magnetrons, crossed field amplifiers, M-type backward wave oscillators, pulse and CW klystrons, electrostatically focused klystrons, millimeter wave tubes, TWTs, beam switching tubes, cathode ray tubes, fiber optic tubes, and related equipment. Litton Industries, Electron Tube Div., San Carlos, Calif.

Circle 286 on Inquiry Card

S-Band TWT

Data is available on a new series of S-band pulse TWT designed for airborne or missile use in electronic counter measure equipment. These metal - ceramic, broadband amplifiers are PPM focused, have a duty factor of 2%, and weigh 9 lbs. All 5 tubes in the series are cooled by 75 cfm of forced air, and heater voltage on each tube is 6.3v ±10%. Eitel-McCullough, Inc., 301 Industrial Way, San Carlos, Calif.

Circle 287 on Inquiry Card

100-Watt CW TWT's

A new brochure, "100-w. CW Traveling-Wave Tube," contains the first available applications information for TWT's operating at high CW power levels. As the brochure points out, 100-w. CW TWT's are available in various ranges from 1 to 11 GC and in bands, L, S, C, and X. All tubes provide 30 db saturation gain, and all are PPM-focused and air-cooled. Operating characteristics and features are described fully. Sylvania Electric Products Inc., Electronic Tube Mktg., Seneca Falls, N. Y.

Circle 288 on Inquiry Card

Beam Power Tube

This product bulletin provides complete data on a new type of r-f beam power transmitting tube which operates to 600MC. The type 6907 tube and its applications are described in detail with full electrical and mechanical data charts, and complete outline and basing drawings. Tung Sol Electric Inc., One Summer Ave., Newark 4, N. J.

Circle 289 on Inquiry Card

Power Tetrodes

A special application report covering 4X150/250 series forced air-cooled UHF power tetrodes has been issued. The 60-page report includes voltage and current graphs and charts, schematics for suggested circuits uses with photos showing actual configurations. Standard Telephones and Cables, Ltd., Special Valve Sales Dept., Brixham Rd., Paignton, Devon, England.

Circle 290 on Inquiry Card

Counter Tubes

This brochure outlines the design characteristics, operating requirements and typical applications of counter tubes. The brochure describes the 2 basic types of counter tubes, low speed with operating freq. of 0-4K pps and the high-speed tubes with operating ranges from 0-100K pps. Detailed descriptions of the tubes, operating principles and requirements, as well as circuit designs and typical circuit diagrams are included. Sylvania Electric Products Inc., 1100 Main St., Buffalo, N. Y.

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TCR 53	200
TCR 56	400

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Type	Minimum forward and reverse breakover voltage
TCR 70	50
TCR 71	100
TCR 73	200
TCR 76	400

TURN-OFF TRANSWITCH TCR 80 SERIES Features: Maximum forward and reverse leakage current @ rated voltage of 10μa @ 25°C and 250μa @ 125°C. Minimum turn-off beta of 10 @ 2.0 amps Ic.

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TCR 81	100
TCR 83	200
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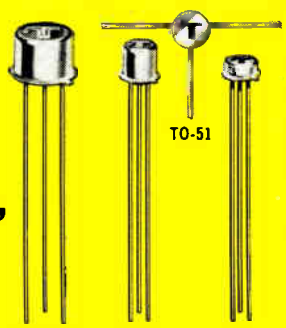

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Gives you complete specifications and details on the broadest line of planar silicon controlled rectifiers available today. A must for your files. Write today: SCR FILE Transitron, Wakefield, Mass.

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Circle 80 on Inquiry Card

MINIMIZING ELECTRON TUBE HUM

Decisions by tube designers can have a serious effect on circuit performance. Designing tubes for low hum often means a series of compromises which should be understood by the circuit designer. This subject is treated in detail in this authoritative article.

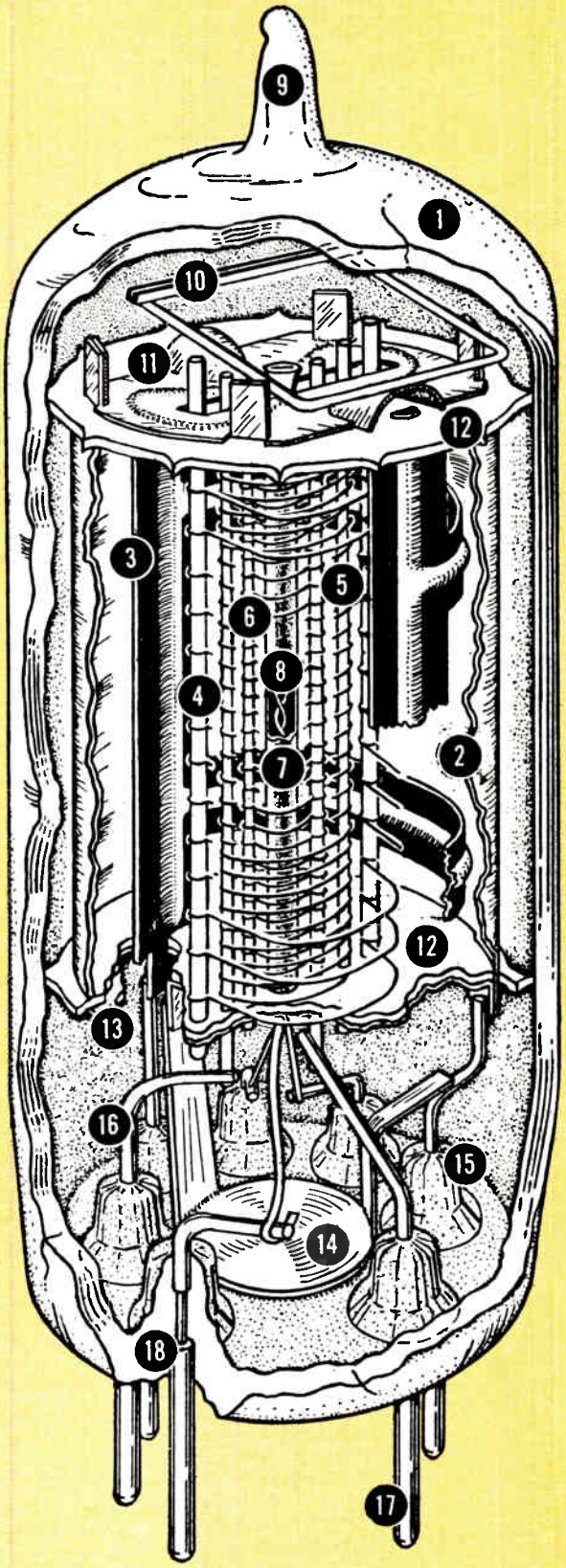
By WAYNE AUSTIN,
Radio Corporation of America,
Electron Tube Division,
Harrison, N. J.

HUM IS COMMONLY DEFINED as an undesired low-pitched tone in the output of audio-frequency equipment supplied by an ac power source. Although the causes of hum can be generally traced to improperly designed circuits and poor circuit layouts, electron tubes can also be a major source of hum in audio uses. Basically, the reasons for electron-tube hum are either internal effects caused by the heater current on the tube electrodes, or external effects caused by the ac power supply. Because the external effects can be readily eliminated by tube shielding, this article discusses only design considerations for the reduction of hum caused by conditions within the tube.

Inductive Hum

Inductive hum is caused by inductive coupling between the heater and heater wires and the critical electrodes of the tube. Poor heater-wire dress, lack of heater-wire shielding, and other stray magnetic fields are the primary sources of inductive hum. The loop formed by the input circuit to the control grid and cathode generates an induced voltage; the current in the heater wires and heater-stem leads provide the magnetic field. As a result, control-grid-to-cathode voltage of the heater-supply frequency is amplified in the tube. For this reason, some reference must be given to the magnitude of generated hum. Because all hum sources are not equally amplified, the hum magnitude is given an equivalent control-grid signal reference. Because electrodes other than the control grid and cathode do not generally amplify inductive hum, hum referred to the control grid for the non-amplifying electrodes is usually insignificant and does not merit attention.

(*Continued on page* 84)



Structure of a miniature tube shows (1) glass envelope, (2) internal shield, (3) plate, (4) suppressor grid, (5) screen grid, (6) control grid, (7) cathode, (8) heater, (9) exhaust tip, (10) getter, (11) spacer shield header, (12) insulating spacer, (13) spacer shield, (14) inter-pin shield, (15) glass button-stem seal, (16) lead wire, (17) base pin and (18) the glass-to-metal-seal.

The induced voltage (Egk) between the control grid and cathode can be visualized from Fig. 1a. Fig. 1b shows a rectangular loop in the vicinity of the heater wires in which alternating current flows. For a determination of the magnitude of inductive hum, the following assumptions are made: (1) The heater wires are infinitely long and produce a larger value of E_{gk} than that determined with finite segments of heater wire. (2) The permeability value chosen is that of free space even though various materials in the vicinity of the tube distort the magnetic field. (3) Placing the rectangular loop in the same plane as the heater wires is only one of a number of possible configurations. (4) Wire sizes are very small compared to the distance between wires.

An x, y rectangular coordinate system is then chosen with the y axis as one of the heater wires and the x axis as the bottom of the loop. The value of the H-field at any point p for an infinitely long wire carrying a current I is given by

$$H = \frac{I}{2\pi r} \cdot \quad (1)$$

In this equation, r is the perpendicular distance to the point p. If $\mu = 4\pi \times 10^{-7}$ henries/meter, the flux density per unit area for the y-axis heater wire is

$$B = \mu H = \mu \frac{I}{2\pi x} \quad (2)$$

Flux density for both heater wires is

$$B' = \mu \frac{I}{2\pi (x - a)} - \mu \frac{I}{2\pi x} \quad (3)$$

For a differential area, dA, the flux is expressed as

$$d\phi = B' \, d\, A \quad (4)$$

The total flux in the rectangular loop is

$$\phi = \int_{\text{area}} B' \, d\, A = \frac{\mu I d}{2\pi} \left[ln \left(\frac{c - a}{b - a} \right) \frac{b}{c} \right] \quad (5)$$

By use of Faraday's Law and for an assumed value of current, the induced voltage is

$$E_{ok} = - \frac{d\phi}{dt} \cdot \quad (6)$$

$I = I_m \sin \omega t$, where $\omega = 2\pi$ (f of the power supply)

Therefore,

$$E_{ok} = \mu f d I_m \left[ln \left(\frac{c - a}{b - a} \right) \frac{b}{c} \right] \sin \left(\omega t - \frac{\pi}{2} \right) \quad (7)$$

Example:

$f = 60$ cps; $b = 2a = 0.8$ cm; $c = d = 5.0$ cm;

$I_m = 1.414$ (300) ma.

$$\therefore E_{ok} = (1.414)\ (0.55 \times 10^{-6}) \sin \left(377\, t - \frac{\pi}{2} \right) .$$

As shown in Eq. 7, the induced loop voltage is 90° out of phase with the heater current. In the example above, the RMS voltage induced in the control-grid-and-cathode loop is 0.55 μv. Because audio preamplifiers may have a noise factor many times this value[1], inductive hum coupling in the tube input circuit is relatively small for a 60 cps frequency. As indicated in Eq. 7, the frequency should be kept as low as possible because the induced voltage is dependent on the time rate of change of flux. If the heater-supply current has an irregular waveform high in harmonic content, a high-resultant induced voltage may be produced on the grid. For this reason, the current waveform should not have a "stepped" or "spiked" shape. Because the induced-voltage value is also proportional to the heater current, I_m should be kept as small as possible by choosing tubes with low values of heater-current. These tubes should be placed at the lowest current point in a parallel heater arrangement. (It will be shown later, however, that the use of tubes with high heater voltage and low heater current is not the best way to achieve over-all low hum).

The most effective way to achieve low inductive hum is to keep the control-grid-to-cathode loop well removed from the heater wires and as small as possible. Twisting of the heater wires also reduces the magnetic field. Although it is impossible under normal conditions to place the loop in a field-free area, rearrangement of the circuit layout can be effective if magnetic hum is a problem.[2]

Electrostatic Hum

Electrostatic hum is caused by capacitance between the heater and electrodes. As with inductive hum, the area of most critical coupling is usually either the cathode or control-grid electrode, because they amplify the electrostatic hum. Since the cathode impedance is often one or more magnitudes lower than that of the control-grid, and because it is usually bypassed for the fundamental hum frequency, the control-grid coupling generally presents the greatest problem (except when a cathode follower is used in a low-signal-level pre-amplifier stage).

For all tube types, the heater-to-cathode capacitance (C_{hk}) is much larger than the heater-to-control-grid capacitance (C_{hg}). The cathode sleeve acts as an electrostatic shield and reduces C_{hg} to primarily that caused by the stem leads. The value of C_{hg} depends upon the basing arrangement. The control-grid pins are placed as far from the heater pins as possible to reduce all impedance couplings between the heater and control grid, and thus make C_{hg} much smaller than C_{hk}.

Before a quantitative analysis of electrostatic hum can be performed, a basic circuit design must be established because the heater ground point is not fixed for all circuits. In Figs. 2a, 2b, and 2c are three common arrangements often used. (For this discussion, the diagrams do not include positive biasing of the heater, which is normally used to reduce hum caused by heater-cathode leakage). The heater is not considered one element, because the effective heater ground point may be arbitrarily chosen. The heater-to-electrode capacitance is mainly that be-

(*Continued on page 86*)

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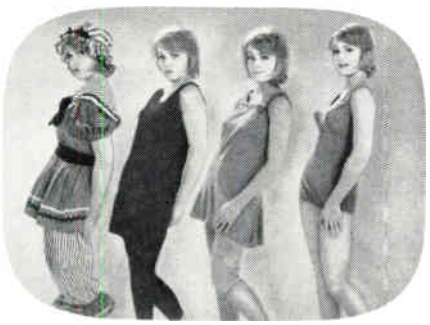

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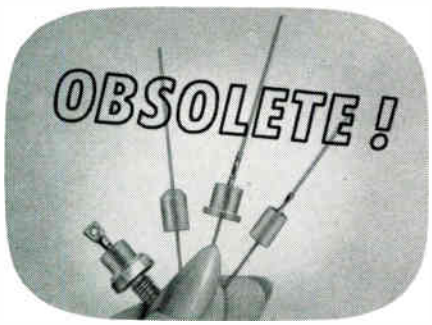

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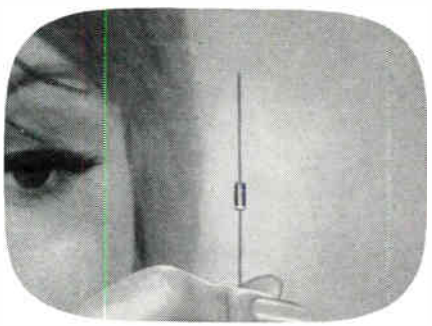

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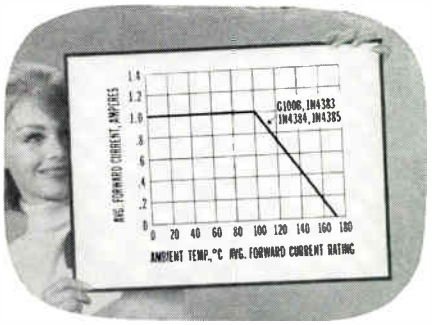

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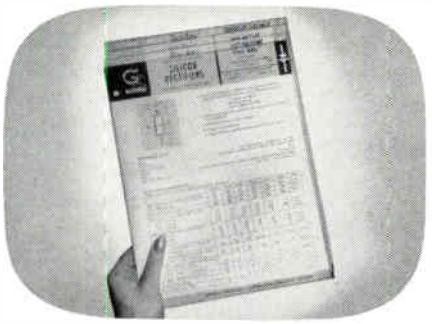

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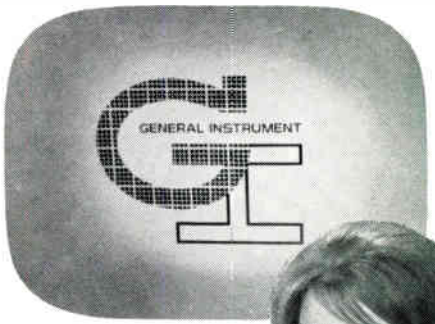

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HUM IN ELECTRON TUBES (Continued)

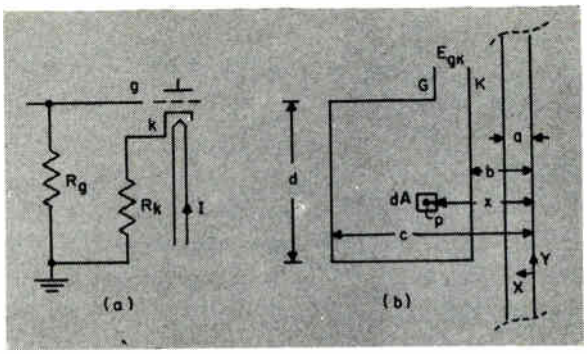


Fig. 1: Diagrams at the right are (a) Control grid - to - cathode loop, and (b) The geometrical configuration for calculating Egk.

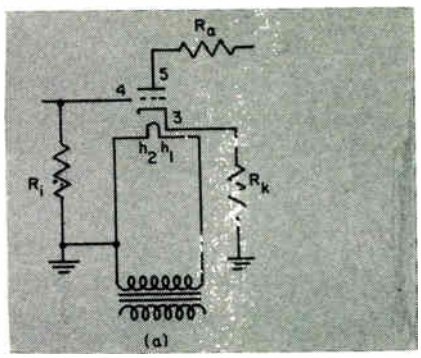


Fig. 2: Common heater-circuit designs. (center)

tween the heater-stem leads and the other electrodes and their respective stem leads, and is not distributed over the length of the heater. Accordingly the circuits of Fig. 2 can be represented by the equivalent circuits shown in Fig. 3. In these diagrams C_{h1g} and C_{h2g} represent the capacitances between the heater legs and the control grid. The circuit shown in Fig. 3c is not calculated, because it is evident that a bridge is formed in which R_i is the null branch.[3] Further mention of this bridge will be made under considerations for insulation hum. Electrostatic hum may be nulled out by adjustment of the potentiometer. If leakage effects are neglected, the voltage E_{i4} appearing at the control grid because of electrostatic hum is:

3a. $$E_i'_4 = \left(j \frac{\omega R_i C_{h1g}}{1 + j \omega R_i C_{h1g}}\right) E_f \approx j \omega R_i C_{h1g} E_f \quad (8)$$

3b. $$E_i''_4 = \left[j \frac{\omega R_i (C_{h1g} - C_{h2g})}{1 + j \omega R_i (C_{h1g} + C_{h2g})}\right] \frac{E_f}{2}$$

$$\approx j \omega R_i (C_{h1g} - C_{h2g}) \frac{E_f}{2} \quad (9)$$

3c. $E_i'''_4 = 0$ (null condition) (10)

where:

j = A phasor showing +90° phase shift

$\omega = 2\pi f$, where f is power supply frequency

Therefore:

$$E_i'_4 \gg E_i''_4 \geq E_i'''_4 = 0. \quad (11)$$

By substituting R_k for R_i, Eq. 8 through 11 may also be used to analyze the electrostatic hum caused by the heater-to-cathode capacitance.

Electrostatic hum, due to heater-to-plate capacitance, is negligible in nearly all tube amplifier stages. To calculate it, the circuits of Fig. 3 still apply except that the plate-to-ground resistance is effectively the plate-load resistance (Ra) in parallel with the effective plate resistance (R_p).[4] To refer the plate hum voltage, E_{a5}, to grid, $E_{i4} = E_{a5}/A$ where A is the voltage gain of the tube amplifier. For example, the equation for Fig. 2a is:

$$E_{a5} \approx \frac{j \omega R_a R_p C_{h1g} E_f}{A (R_a + R_p)}. \quad (12)$$

For all cases considered, the electrostatic hum produces a hum phased 90° from the applied heater voltage. The hum output is proportional to the frequency, the resistance value to ground for the electrode, and the applied heater voltage. The most effective way to keep the electrostatic hum small is to use a low-frequency heater supply. A low heater voltage would also be desirable; but, for a given heater power a larger heater current would be needed, thus increasing the inductive hum.

The analysis for circuit 2a, which has a much larger electrostatic-hum coupling than circuits 2b or 2c is as follows:

Assume that $C_{h1g} = 1 \times 10^{-12}$ farads
$f = 60$ cps
$R_i = 39$ K ohms
$E_f = 6.3$ v

From the above, $E_i 4$ approximately equals $j\, 1 \times 10^{-6}$ v. or 1μv of hum referred to the control grid.

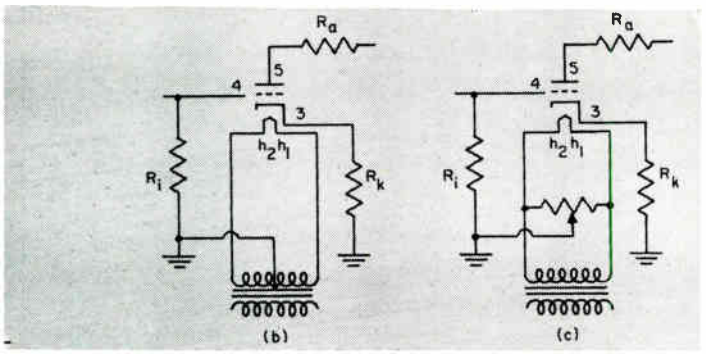
Insulation Hum

Of all sources of hum in electron tubes, insulation hum is considered the most troublesome. Caused by leakage paths between the heater and the tube electrodes, the effects of insulation hum may vary from negligible to a total short-circuit of the heater-to-electrode path. One of the principal causes of insulation hum is the formation of a conductive film[5] on the insulation of the electron-tube. This film can be produced during the assembly, activation, or use of the tube, and is caused by a transfer of particles within the tube. Because this film can be formed by a number of different processes (sublimation, gas sorption, vapor deposition, electron bombardment, diffusion, permeation, or electrolysis[6]), it is difficult to control. Conductivity of the film varies extremely and depends upon such factors as electrode geometry, choice of materials, material process history, parts fabrication, tube assembly, and the final integrated process of the tube.

In addition to these conductive films, impurities and contamination in or on the insulating parts contribute to hum. The degree and type of contamination influence the magnitude of insulation resistance. Although contaminates can be introduced through environmental conditions, impurities exist by degree in any type of insulating material. Further, the properties of an insulator are such that there is some degree of conduction even without impurities.

Heater-Electrode Leakage

Although hum can be caused by leakage between the heater and all the electrodes, heater-cathode leakage is by far the most serious problem. Because of the unique and extensive mechanism of heater-cathode leakage, its properties are discussed separately from the other types of insulation hum.



The paths of leakage from the heater to the control grid and plate are assumed to exist external to the distributed length of the heater. Because the heater does not contact the insulating mica directly in a cathode-type tube, mica leakage does not contribute to hum, although it can produce other types of noise. Major paths of leakage from the heater to the control grid and plate are: (1) the bulb area between the stem leads; (2) thermionic emission from exposed parts of the heater-wire; (3) ion transfer through the residual gases in the tube; and (4) leakage in the bakelite base of octal tubes.

Because high-vacuum electron tubes are factory-tested for gas, the ion transfer from the heater to the control grid and plate may be considered negligible. Ion transfer can become objectionable in the heater-cathode area where gas sorption exists because of the high temperatures.

The heater-to-electrode emission is pronounced in the heater-cathode region but exists to a much lesser degree from the heater to the control grid and plate, because only a small portion of the heater below the cathode is exposed to the stem leads of the control grid and plate. The heater wire is exposed at the welds to the stem leads. Also, bending of the heater sometimes occurs during welding and can break the heater-wire insulation. Flaws in the insulation coating also expose the heater wire. As a result, these exposures provide an escape for thermionic emission from the heater to the electrodes. Because the tungsten or tungsten-alloy wire of the heater is a poor emitter, the emission hum from the heater wire is highly distorted. The hum wave-shape and magnitude are affected by changes in the hum-balancing potentiometer and heater biasing, and is in phase with the heater voltage.

For purposes of analysis, the resistance between the heater and electrodes is assumed linear, otherwise an analysis would have little meaning because non-linear characteristics may be erratic from tube to tube. (This circuit analysis can also be applied to the calculation of heater cathode leakage.) The analysis is further complicated because insulation-resistance values are not readily available or easily measured. For this reason, the numerical magnitude of insulation hum cannot be determined although it

(Continued on page 88)

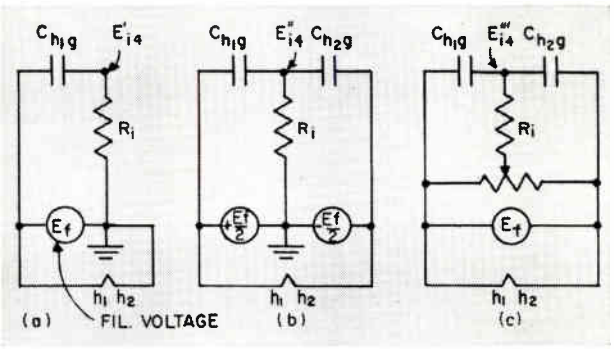


Fig. 3: These schematic diagrams (above) show the equivalent common heater-circuit designs for electrostatic hum analysis.

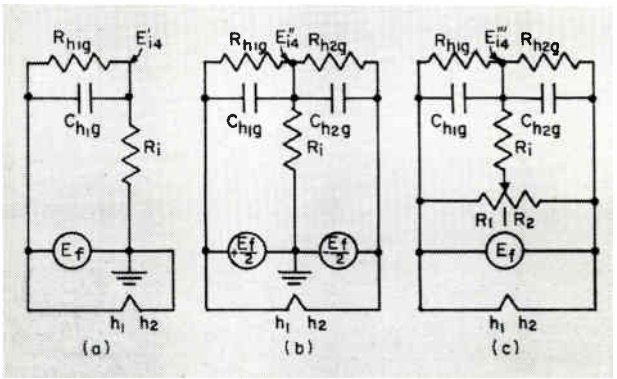


Fig. 4: Diagrams show equivalent common heater-circuit designs for heater - electrode leakage and electrostatic hum analysis.

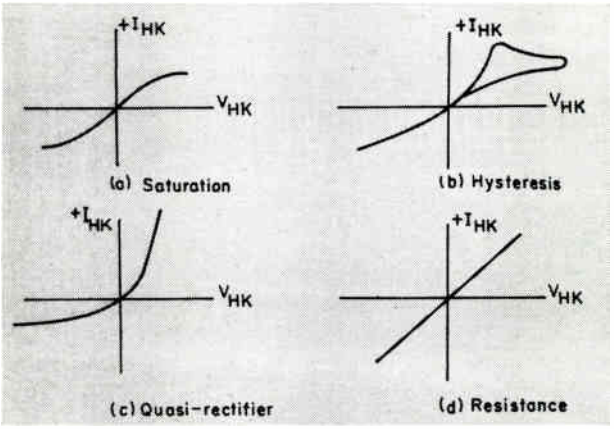
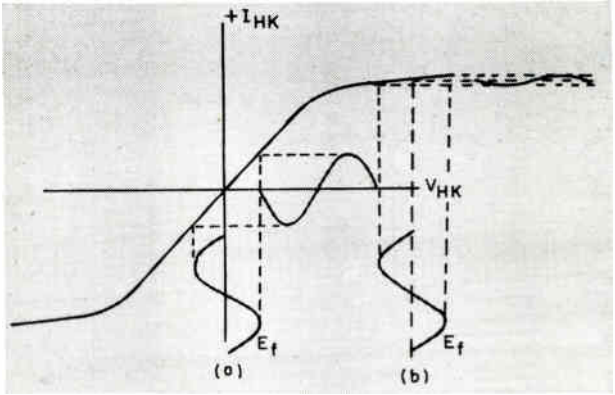


Fig. 5: Heater-cathode leakage characteristics.

Fig. 6: Heater-cathode leakage characteristics. In (a) there is no positive bias between heater and cathode and in (b) there is positive bias applied between the heater and the cathode.



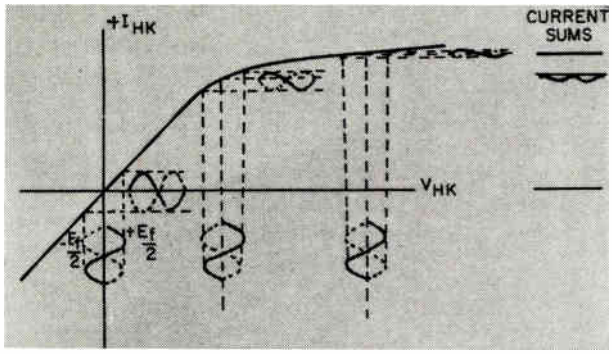


Fig. 7: AC voltage grounding of heater-supply center tap (right).

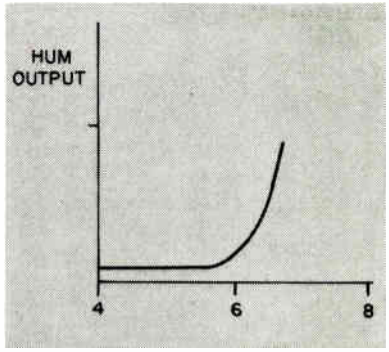


Fig. 8: Hum as a function of ac heater voltage for a 6.3 v. heater-type tube (far right).

HUM IN ELECTRON TUBES (Cont'd)

is possible to make comparisons of the common heater-circuit designs.

During the analysis of electrostatic hum, the assumption was made that insulation hum was negligible. To a large extent, this analysis was academic and only showed that electrostatic hum was small and easily reduced in magnitude. To consider insulation hum separately from electrostatic hum would not be practical because tube capacitances are rigidly fixed.

The following analysis includes heater-to-electrode capacitances and insulation resistances to illustrate the practical aspects of the heater-circuit designs. Equivalent circuits for the common-heater configurations shown in Fig. 2 are illustrated in Fig. 4. In the diagrams, C_{h1g} and C_{h2g} and R_{h1g} and R_{h2g} represent the capacitances and resistances, respectively, between the heater legs and the control grid. The voltage, because of both electrostatic and insulation hum, is computed as follows:

$$4a.\quad E_i'_4 = \frac{R_i\,(1 + j\,\omega\,R_{h1g}\,C_{h1g})\,E_f}{R_{h1g} + R_i\,(1 + j\,\omega\,R_{h1g}\,C_{h1g})} \qquad (13)$$

$$4b.\quad E_i''_4 = \frac{R_i[R_{h2g} - R_{h1g} + j\,\omega\,R_{h1g}\,R_{h2g}(C_{h1g} - C_{h2g})]\frac{E_f}{2}}{R_{h1g}\,R_{h2g} + R_i\,[R_{h1g} + R_{h2g} + j\,\omega\,R_{h1g}\,R_{h2g}\,(C_{h1g} + C_{h2g})]} \qquad (14)$$

$$4c.\quad \text{Let } R_{h1g} \text{ in parallel with } C_{h1g} = Z_{h1g}$$
$$\text{Let } R_{h2g} \text{ in parallel with } C_{h2g} = Z_{h2g} \qquad (15)$$

$$\text{The condition of balance is then } \frac{Z_{h1g}}{Z_{h2g}} = \frac{R_1}{R_2} \qquad (16)$$

In Eq. 16, $R1$ and $R2$ are the resistance values from the center tap to each end of the hum-balance pot. By proper substitution of variables, these equations also apply to the electrostatic and insulation hum at the cathode. Because the analysis for both electrostatic hum and insulation hum at the plate is similar to that for electrostatic hum alone, it is not included in this discussion. For example, the equation for circuit 2a is

$$E_{is} = \frac{R_{eq}\,(1 + j\,\omega\,C_{h1g}\,R_{h1g})\,E_f}{A\,[R_{h1g} + R_{eq}\,(1 + j\,\omega\,R_{h1g}\,C_{h1g})]}$$

where $R_{eq} = \dfrac{R_d\,R_p}{R_d + R_p}$.

For the circuits shown in Fig. 2, a hum-balance pot has the greatest effect in reducing hum. A center-tapped heater winding is also effective. Admittedly, the circuit shown in Fig. 2a is a poor way to minimize hum, but it is certainly better than a floating-heater circuit which assumes a high ac potential because of leakage and stray capacitance in and near the power transformer.

Equations 13 to 16 indicate that the heater-supply voltage and frequency should be kept as low as possible. In Eq. 15, Z_{h1g} and Z_{h2g} should be equal in phase to obtain a null condition. If they are not, the electrostatic and insulation hum can still be reduced, but the reduction will depend on the degree of unbalance. To reduce electrostatic and insulation hum to zero in Eq. 14, it is necessary that R_{h1g} equal R_{h2g} and C_{h1g} equal C_{h2g}.

As previously mentioned, heater-to-cathode leakage is by far the most objectionable source of hum, with heater-to-control grid leakage next, and heater-to-plate leakage least critical of the three. Although the order of severity cited is the usual one in commonly applied circuits, any one of the three can become more pronounced in irregular uses. An increase in resistance to ground from electrodes also increases the electrostatic and insulation hum at the electrodes (except for a perfect null, which is a practically non-existent condition). For this reason, it is desirable to use low values of electrode resistances.

Heater-Cathode Leakage

All factors that contribute to insulation hum also contribute to heater-cathode insulation hum. In addition, the close spacings and high temperature of the heater-cathode system produce an insulation problem that is, at present, still unsolved.

The heater-cathode system is composed primarily of a nickel-cathode sleeve, a tungsten-heater wire, and an alumina insulation coated on the heater wire. Alumina is a crystalline form of aluminum oxide and in its pure form is an excellent insulator. Under the severe operating conditions of an electron tube (particularly in the heater-cathode system), the alumina becomes degraded. This degradation causes the following types of heater-cathode leakage: (1) thermionic emission of electrons and ions from either the heater or the nickel-cathode, (2) conductivity through the alumina or over its sur-

face, and (3) electrical contact phenomena at the alumina-nickel or alumina-tungsten interfaces.[7] These sources of heater-cathode leakage may be studied in part by closely examining heater - cathode leakage characteristics. Voltage-versus-current curves for four characteristics of heater-cathode leakage are shown in Fig. 5.[8] Because any combination of the saturation, hysteresis, quasi-rectifier, or resistance characteristics can exist for a particular tube, it is evident that the heater-cathode voltage-versus-current curve can be quite erratic.

As previously stated, positive bias is often used to reduce insulation hum caused by heater-cathode leakage. Effectiveness of this bias when applied to the saturation - leakage curve is illustrated in Fig. 6. As shown, when an ac heater voltage is applied, one terminal of the heater grounded, and the heater at the same potential as the cathode, significant cathode-leakage current is present. By comparison, when a positive-bias voltage is placed on the ac heater voltage (part b of Fig. 6), a much smaller leakage current is conducted to the cathode.

Although the application of a positive bias to a saturation characteristic is desirable, the quasi-rectifier characteristic needs negative - bias voltage for best results. The resistance characteristic would not be greatly improved by the use of either positive- or negative-bias voltage. The hysteresis characteristic yields good results if the positive-bias voltage is well beyond the peaked portion of the hysteresis loop. For this reason, as much as +80 v. is recommended for best results.[9]

Advantages of grounding the heater - supply transformer center tap are illustrated in Fig. 7. The heater-pin voltages are opposite in phase and equal in magnitude. As shown, heater - cathode insulation hum may be reduced to zero over any linear portion of the leakage curve, because the two out-of-phase components cancel each other. When the heater-cathode bias voltage approaches the curved portion of the

(*Continued on next page*)

characteristic, the hum is still greatly reduced; but, it is high in second harmonic content. Because of the irregular nature of the heater-cathode leakage curve, the chances of operating over a near-linear portion of the leakage curve are improved by positive heater-cathode bias voltage.

Heater-cathode leakage may also be reduced by decreasing the ac heater voltage, which increases rapidly when the heater voltage rises above the recommended design value. But, because the cathode temperature must be at or near the value determined by the proper heater voltage for stable emission over the life of the tube, it is not recommended that the heater voltage be reduced for an improvement in heater-cathode insulation hum.

Insulation hum, as a function of heater-cathode leakage, is illustrated in Fig. 8. A 6.3 v. heater is varied from 4.0 to 8.0 v. on the horizontal scale; the vertical scale shows the resultant hum as referred to the control grid. The lower portion of the curve is relatively flat; and, therefore, this would rule out electrostatic and inductive hum as the causes for hum increase. Actually, the sharp rise is the result of the rapid decrease in heater-cathode insulation resistance caused by the increased heater temperature. If the heater temperature is reduced, insulation hum caused by heater-cathode leakage reduces to a relatively low value below 6.3 v.

Because the thermal emissivity of a white body is very low compared to that of a dark or black body, darkening of the white alumina heater reduces its operating temperature. The improved radiation of the "dark heater" lengthens tube life, enhances stability, and reduces heater-cathode leakage.

Magnetic Hum

Magnetic hum within electron tubes is caused primarily by the magnetic field of the heater coils or folds. The magnetic field of the heater element, because of the narrow space within the cathode sleeve, is quite close to the stream of electrons emitted by the cathode. Because the temperature of the heater-cathode system at operating conditions is well above the curie point for nickel, the nickel-cathode material is no longer an effective magnetic shield. As a result, the magnetic field produces hum at the plate electrode by modulating the cathode current density. This modulation has the same effect as a change in control-grid-to-plate spacing. The magnetic field also produced additional hum by deflecting the electrons and varying their rate of arrival at the plate. In pentodes, the variation of the plate-to-screen-grid current by deflection may also cause magnetic hum.

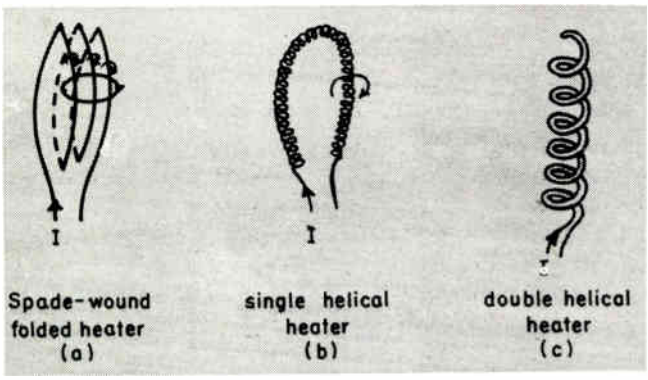


Fig. 9: Principal types of heater configurations.

The spade-wound folded-heater, Fig. 9a, although uniformly wound, may assume a random form when placed in the cathode. The single-helical, Fig. 9b, and double-helical types, Fig. 9c, are also uniformly wound but retain their shape more effectively. The shape of each type, however, may change as the tube reaches operating temperature. Also, permanent changes may occur as the tube is cycled during its life. Even with these changes, the coiled heaters have lower magnetic hum than the spade-wound heater.

Of the three types, the double-helical heater is considered the most effective, because its closely adjacent strands cause almost total cancellation of the magnetic field. The spade-wound heater produces a strong magnetic field in the vicinity of the cathode because of the number of folds in the winding. In addition, the random position of the spade-wound heater produces a wide distribution of magnetic hum. In comparison, the single-helical heater has only one fold and produces a lower magnetic field in the vicinity of the cathode. The closely wound coils of this-type heater prevent the magnetic field from being directed through the cathode. With a spade-wound folded-heater, the magnetic hum may be as much as 25 μv. By the use of the double-helical heater, magnetic hum may be reduced as much as one order of magnitude.[10]

The characteristics of magnetic hum are nonuniform in that the magnetic-hum frequency may be either the fundamental or second harmonic, or a mixture of both. The heater current and the shape of the heater are sole factors that can cause magnetic hum. Accordingly, because both factors are a part of the tube design, magnetic hum can only be reduced by the choice of the proper tube type for a given use.

Photoelectric Hum

Although photoelectric hum is caused by an external effect, it is discussed here because normal tube shielding does not protect against it. In normal tube uses, photoelectric hum rarely presents a problem. This type of hum is primarily caused by varying intensity light that is in close proximity to the tube, or by fluorescent light that has the same frequency as the heater supply. The hum can be caused by light striking film deposits, such as the getter flash on the tube mica. With a 60 cps light source, the light intensity varies at the rate of 120 cps. As a

(Continued on page 224)

HIGH-TEMPERATURE WIRE AND CABLE

This state-of-the-art treatment of high-temperature wire and cable includes discussions on conductors, insulating materials, fillers and enamels. New developments and future needs are also discussed. Areas of concern are covered and predictions made.

ELECTRONIC INDUSTRIES

REFERENCE ISSUE

WIRE AND CABLE

ALMOST ALL ELECTRONIC PROJECTS use wire and cable. For many uses it must withstand high temperatures.

What is high-temperature wire and cable? A broad definition is that it includes wire and cable capable of continuous operation at temperatures greater than 300° F. This is not an arbitrary basis, but would be considered a minimum standard.

In discussing state of the wire and cable art with respect to high-temperature product, the most significant factor is the broad acceptance, today, of fluorocarbon insulation for high-temperature use.

Fluorocarbons

Polyvinylchloride (PVC) and polyethylene (PE), and other lower-temperature materials had been standard for wire and cable. But, in the past two or three years, fluorocarbons have been widely favored.

Two of the most commonly used fluorocarbons are tetrafluoroethylene (TFE) and fluorinated ethylene propylene (FEP).

Both have outstanding resistance to chemicals and good electrical properties. These properties include the lowest dielectric constant of any known solid insulation. They also have temperature capabilities which range from low cryogenic to 260° C. for TFE and 200° C. for FEP. Neither is affected by moisture, and both are almost unaffected by ultraviolet radiation.

The most common method of use is: both TFE and FEP may be extruded, and may be wrapped as tape on appropriate conductors. For special uses, both materials may be applied as dispersion coating.

Our company recently announced an extruded Teflon FEP wire which is nearly as thin as magnet wire and takes full advantage of the fluorocarbon properties cited above. Called "Ultra-Thin" (trade mark applied for), it has been developed for uses needing smaller, lighter lead wire in sub-miniature wall thickness, including aerospace and other instrumentation, and computer and logic circuits.

Silicone Rubber

Silicone rubber insulation also figures prominently in high-temperature constructions. This material is commonly accepted as insulation at 300° F. and above. It is particularly desirable because of its ability to withstand low temperature, assure flexibility, and offer both radiation and corona resistance.

Because of these properties and advantages, it has become especially important in nuclear cables, shipboard cables, and specialty control cables, including both aerial and underwater uses.

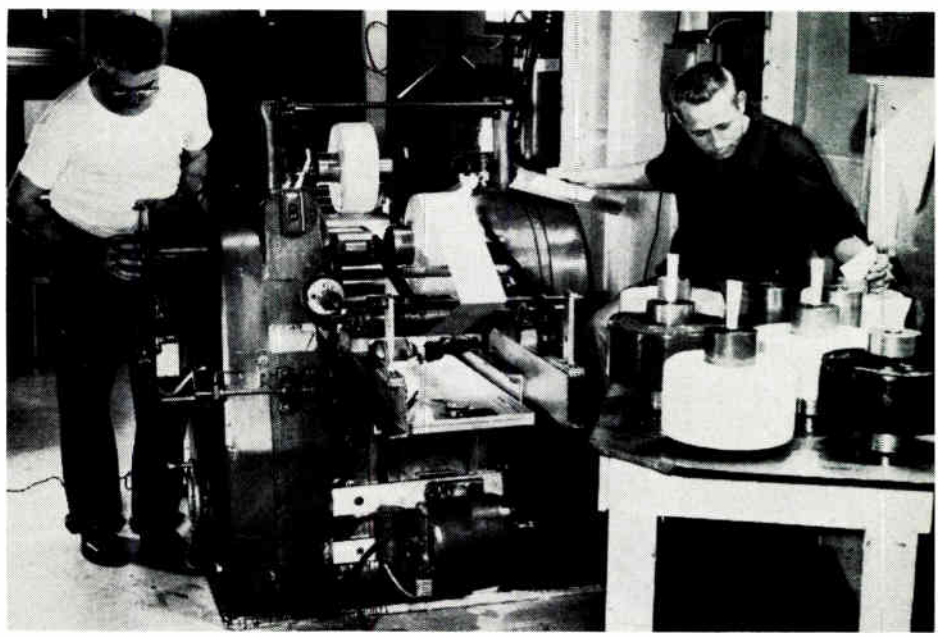
Inorganic Materials

Glass, ceramic and other inorganic materials have attained increasing importance in recent years. This is because of the need to operate in temperature environments beyond those for which fluoros are suitable and practicable.

Our organization has recently produced a high-temperature product

(*Continued on page 92*)

Manufacturing Teflon tape for high-temperature wire and cable.



By DAVID BINCH,
Manager-Engineering,
Haveg/Super-Temperature Wires, Inc.,
Winooski, Vt.

WIRE AND CABLE (Continued)

trade marked "Pyrad-1000". It is a highly flexible wire and cable which has both high-temperature resistance and resistance to the vacuum and radiation need of space during operation at 1,000° F. Requiring a minimum of weight and space, it has no bulky tubing-type jackets and is versatile both in construction and in use.

Pyrad 1000 and other inorganically-insulated wire and cable have an increasing place of importance because of the need to operate in temperature environments well beyond those for which fluoros are capable.

Such products are generally used in conjunction with more specialized and exacting conductor materials, including molybdenum, and nickel-plated silver. Present state of the art is such that use of these materials has made available cable which can operate at 1,000° F. continuously close to aircraft engines and also on missile test sites.

The use of glass, ceramics and similar materials has also produced some highly specialized cables which can operate satisfactorily at temperatures up to 2,000° F.

Fillers

Another area that has a direct bearing on high-temperature wire and cable performance concerns fillers. Although granting that these are not a "materials category," as such they can extend the properties of insulations previously mentioned here. Thus they have become increasingly important in the search for products that can withstand higher and higher temperatures. These fillers would include glass, asbestos and other mineral materials.

Major areas of use would be those needing increased mechanical resistance, together with the temperature ratings previously discussed (300° F. +).

Enamels

Let's continue on factors affecting the state of the high-temperature wire and cable art. It should be noted that polyimide enamels, such as duPont's "Pyre-ML," were initially

introduced as a magnet wire coating. A significant insulation concept has, however, been developed wherein the enamel is applied over a base insulation, generally a fluorocarbon, to increase the mechanical properties without adding bulky filler material.

Once again, a new and successful example of such a use of polyimide enamel coating is found in our Durad-T (Teflon TFE) and Durad-F (FEP) insulated wire, both new developments.

More recently, polyimide has been introduced in film form — duPont's H-Film — and this provides a material which can be handled on normal wrapping equipment. H-Film for high-temperature wire and cable use is available in both 100% polyimide form and also in a laminated form combined with FEP film. The latter provides a means of heat-sealing the laminate.

WIRE AND CABLE

Wire and cable of all types for electronic purposes, naturally, will continue to be big business for the industry. Total wire sales for 1964 are forecast at around $256 million, rising through $267 million in 1965 and to $278 million in 1966. Of these totals, cables, especially co-axial, will continue to amount to about 16 to 17% of the total wire market.

	1964	1965	1966
	(in millions of Dollars)		
Total Wire and Cable	$256	$267	$278
Cable (including co-axial)	52	56	60

(Figures based on a limited EI survey among 300 leading component manufacturers.)

The resultant material's toughness, and its good electrical properties, make it ideal for aerospace needs and other uses where space and weight are at a premium.

Problems and Requirements

Challenges to high-temperature wire and cable designers and makers are not at an end despite recent advances that have been made. Higher and higher temperature needs and capabilities are demanded of wire and cable, and today the goal is already about 4,000° F.—in continuous operation—for conductors and insulation. Any material, and it must also be flexible, will soon have to meet that goal. Ceramic materials could do the job now—but flexibility would be sacrificed.

The major criteria for conductors are that they have a low temperature

(*Continued on page* 95)

MATERIAL USED FOR LEADWIRE INSULATION & TUBING
(E–excellent G–good F–fair P–poor)

Generic name	Tetrafluoroethylene	Fluorinated Ethylene Profrylene	Silicone Rubber
Trade name	Teflon	FEP-100	—
Compatibility with potting	F	F	G
Radiation resistance	P	P	E
Dielectric strength (v/mil)	600	500–600	50–100
Moisture absorption	<0.01%	<0.01%	0.5–5.0
Chemical properties: Resists what?	Acids, Alkalies, Solvents	Acids, Alkalies, Solvents	Acids, Alcohols, Keytones
Susceptible to what?	—	—	Alkalies, Promatic Solvents
Fungus resistance	E	E	E
Heat distortion temp.	250°F (66 psi)	—	Slight
Max. recommended operation temp.	260°C	200°C	200°C
Flammability	E	E	G
Flexibility	E	E	E
Abrasion resistance	F	F	P
Cut-through resistance	F	F	G
Corona resistance	P	P	E
Low temp. brittle point	Not Determined	Not Determined	−100°F
Suitability for marking	G	G	G
Applicable specs. (Mil)	MIL-W-16878D	MIL-W-16878D	MIL-W-16878D
Check here if heat-shrinkable	X	—	—
For uses requiring	High Temp. Operation	High Temp. Operation	High Temp. Operation

ENAMELS

Generic Name	Polyimide
Trade name	Pyre-ML
Compatibility with waxes and other winding materials	G
Compatibility with potting compounds	E
Chemical properties: Resists what?	Oils, Fuels, Hydrocarbon Solvents
Susceptible to what?	Strong Acids & Alkalies
Dielectric strength (v/mil)	500
Fungus resistance	V.G.
Heat distortion temp.	300°C
Max. recommended operating temp.	250°C
Flammability	G
Abrasion resistance	V.G.
Cut-through resistance	V.G.
Corona resistance	Not Determined
Class (AIEE)	—
Trade name of wire on which enamel is used	Durad
Applicable spec. (Mil)	MIL-W-1583C, MIL-W-22759
For uses requiring	Abrasion Resistance and High Temperature. Good Radiation Resistance.

TUBING, JACKETING AND SLEEVING USING REINFORCING FIBERS

Name of impregnant or primary dielectric	Tef-Impregnated Fiberglass
Generic name of fiber	Fiberglass
Trade name of fiber	Fluorglas
Tensile strength of fiber	200–220,000
Moisture absorption of combination	0–0.3% Surface
Recommended operating temp. of combination	260°C
Flammability of combination	Will Not Burn
Dielectric strength of combination	Up to 2800 Volts
Flexibility	Excellent
Trade name of tubing	—
Applicable specs. (Mil)	MIL-Y-1140
Suitability for marking	Good
Chemical properties– Resists what?	Most Acids, Alkalis
Susceptible to what?	—

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Every electronic and electrical wire you need—from the finest drawn magnet wire to the most complex multi-conductor cables.

There is a Belden wire or cable in every insulation and shielding to meet your application and design needs. Here is just part of this complete line. Available from stock. Ask your Belden electronics distributor for complete line information or write for catalog. Request also a copy of A Buyers' Guide to Specifing Electrical Wire and Cable.

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1. **Basic Manufacturer**—Belden draws its own wire—compounds its own insulations for complete quality control.
2. **Research and Testing**—All Belden wire and cable are laboratory tested to guarantee insulation and conductor efficiency. Lab test data available.
3. **Design and Engineering Service**—Belden has a completely staffed design and engineering department to help customers meet unusual wire application or design requirements.

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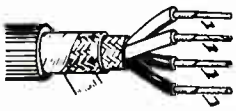
Cathode Ray Tube Lead


Miniaturized Cables


Magnet Wire

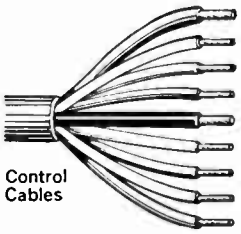

Automation Cable


Miniature Microphone Cables


Shielded Power Supply Cables—Rubber or Vinyl


Grid Wires


Language Lab Cables


Control Cables


60 KV D.C. High Voltage Cable

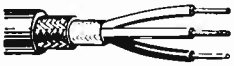
Miniature Coaxial Cables


Plastic Microphone Cables


Multi-Conductor Cables


TV Distribution Cables


RG/U Transmission Line Cables

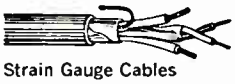

Shielded Interconnecting Cables


Low Impedance Lines


Multiple Pair Individually Shielded RF Cables

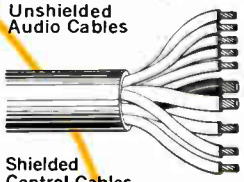

3-Conductor Power Cords


Unshielded Audio Cables


Strain Gauge Cables


Call System Cables


Test Prod Wires

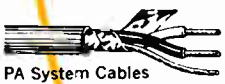

Shielded Control Cables

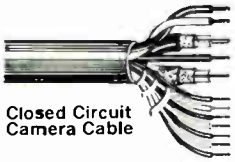

Broadcast Audio Cables


2 & 3 Conductor Extension Cords


Rubber Microphone Cables


Coiled Test Prod Wire


PA System Cables


Closed Circuit Camera Cable


Sound & Alarm System Cables


Hook-Up Wires


Mil-Spec Wires


Duplex Wires


RG/U Cables


75-Ohm Video Cable


Power Supply Cordage


Lamp Cordage


Teflon* Hook-Up Wires

Shielded Cables

Color, Studio, Camera Cables

Coiled Cords

Multiple Pair Cables

Miniature Audio Cables

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Multiple Pair Individually Shielded Audio and Data Cables

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8-1-4

WIRE AND CABLE (Concluded)

coefficient of resistance, and that they have conductivity as close to copper as possible.

Conductors will also have to meet space environments such as high radiation levels and high vacuum environments.

Insulation will undoubtedly be inorganic, and will have to withstand environments similar to those encountered by conductors. They will also have to have "reasonable" electrical properties, so that size will not be a prohibitive factor. This aspect also applies to the matter of weight in wire and cable.

A prime criterion will be that the manufacturing process involved must allow for the production of wire and cable at costs which meet economic considerations.

The Future

Closely akin to the search for higher temperature conductors and insulation is the quest for moisture barriers and/or impregnants which will also function at these elevated temperatures.

It may be questioned why a moisture barrier or impregnant is needed at these high temperatures when obviously no moisture will be present. But this involves another factor. Storage needs and temperature cycling, however, may dictate the need for such protection.

A major continuing area of investigation probably will be the need for further size and weight reduction of wire and cable. This may be achieved by further miniaturization of conductors and insulation by such developments as "Ultra-Thin." Then again, it may be necessary to develop entirely new design methods, such as the trend toward integrated circuits.

It may be argued that the integrated circuit approach does not properly belong in a discussion of wire and cable futures. But, if a wire manufacturer will think of himself as a maker of "interconnecting methods," then it becomes vital that he keep abreast of developments in the area of integrated circuitry.

The Challenge

Improvement of outer space properties of wire and cable call for meeting such problems as low outgassing and high radiation resistance.

Another area of concern is the need to develop new manufacturing processes using available materials—including fluorocarbon uses by fluidized bed methods.

Still another problem will be the development of new test methods to permit faster and more comprehensive testing, and the possibility of testing parameters that are not now measurable.

In summary, looking ahead to inevitable challenges for the industry, manufacturers must broaden their customer bases—especially to take advantage of serving commercial users of their products. This will, undoubtedly, be done by pointing out technical advantages to be achieved by use of these materials and products. These advantages will certainly outweigh any possible price disadvantage.

NEW TECH DATA

WIRE & CABLE

Delay Lines

The Picolines offer impedances from 50 to 200Ω. Delays from 10 to 200nsec. in any desired value can be furnished. Rise time depends upon the delay/in. supplied and overall delay line length, or roughly a 10 to 1 delay-to-rise-time ratio. Complete details available from JFD Electronics Corp., 15th Ave. at 62nd St., Brooklyn, N. Y.

Circle 272 on Inquiry Card

Resistance Wire

A new resistance wire for the resistor and potentiometer industry is described in detail in this circular. The new product is Moleculoy® with Hi Mol insulation. The circular explains that Moleculoy insulated with Hi Mol enamel withstands temps. up to 250°C for long duration and up to 450° for short periods of operation. General properties, characteristics and advantages are fully covered. Molecu-Wire Corp., Eatontown-Freehold Pike, Scobeyville, N. J.

Circle 273 on Inquiry Card

Superconducting Wire

Cryostrand is a superconducting wire for cryogenic uses which uses a novel conductor configuration of niobium-tin. It allows the design of superconducting magnets smaller than any heretofore possible. Current-carrying capacity and critical field is 200 plus kilogauss. Critical temp. is 18°K. General Electric, Construction Industries Div., Bridgeport, Conn.

Circle 274 on Inquiry Card

Thermocouple Cable

Complete specs. are available on a new type of thermocouple extension wire cable that provides 4 different ISA extension wire calibrations in a single flexible cable slightly over ¼ in. dia. One new Multiloy™ cable contains the extension wires for matching the 4 most common thermocouple wire calibrations, thus eliminating the need for carrying more than 1 reel of extension wire in inventory. Each cable contains 5 different thermocouple alloy wires in an aluminum-Mylar electrostatic shield. Dekoron Div., Samuel Moore & Co., Mantua, Ohio.

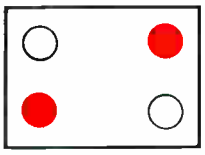
Circle 275 on Inquiry Card

Wire and Cable Catalog

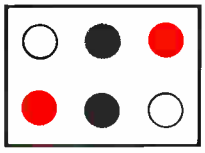
Catalog, No. W-4, contains 52 pages detailing more than 7000 items available from stock, including 2 pages of coaxial cable manufactured to military specs. Also illustrated and described are many new wire and cable items, including control and instrumentation cable, flat ribbon cable, unshielded control cable, and U.L. hook-up wire. This catalog, plus a comprehensive 16-page coaxial-cable catalog and a 24-page tubing catalog, is available from Alpha Wire Corp., 180 Varick St., New York, N. Y.

Circle 276 on Inquiry Card

MOST 4-LAMP, 2-COLOR ILLUMINATED PUSH-BUTTON SWITCHES ARE THIS SIZE:

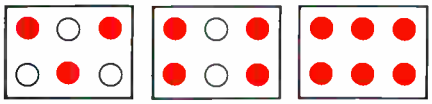


NEW IEE LUMI-SWITCH® IS JUST AS SMALL:

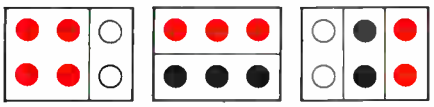


BUT ONLY LUMI-SWITCH GIVES YOU 6 LAMPS, 3 COLORS!

Lumi-Switch gives you 3 colors with 2-lamp-per color reliability. Or, you can get these color/lamp combinations:

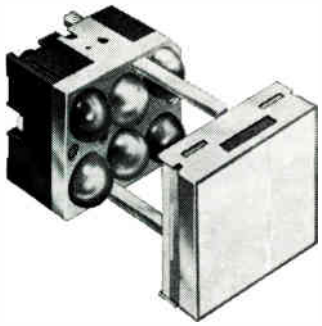


You also have horizontal and vertical split-face options like these:



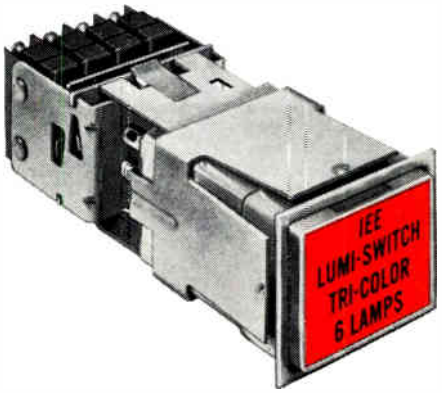
The big advantage of Lumi-Switch's small size (besides saving space) is the fact that it fits existing panel cutouts made for 4-lamp push-button switches. Though Lumi-Switch is only 0.965" H x 1.205" W, it offers more display screen (0.75" H x 0.98" W) for your message than units of comparable size: up to 5 full lines with characters up to .12" high.

To pack 6 standard MS T-1¾ midget flange-base lamps into a space where only 4 lamps normally fit, we eliminated the center switch shaft found in conventional illuminated push-button switches.



This, in turn, permits proximity grouping of lamps for other advantages: bright, even light and color distribution, completely free of hot spots.

For easy replacement of lamps, the lamp/screen assembly (shown above) pulls out from the front. No twist action or tools involved. A safety mechanism prevents switch from being activated accidentally during re-insertion of assembly. Another safety protects against pop-out up to 50 G's.



EASY TO MOUNT; EASY TO WIRE

You insert the entire unit, including retainer frame, from the front through cutout in panel. Two integral screws inside the housing are tightened, also from the front, to draw mounting sleeve against back of panel. For easy wiring of lamp terminals, switch module snaps off; after wiring, module is locked in place by positive latch that prevents accidental disengagement.

FOR DEDICATED BUTTON PUSHERS, A FEW MORE FEATURES:

- Lumi-Switch push button travels independently of lamp housing; lamps remain stationary for longer life.
- In 3 color applications, exceeds 100 foot lamberts in brightness. Even brighter in 2 colors (3 lamps per color).
- Accepts MS silicone rubber color boots. IEE "Hi-Temp" molded plastic color caps also available in matched sets.
- Legends may be engraved and filled or on film mounted behind screen.
- May be ordered with any switch module up to 4PDT, momentary contact, alternate action, and with holding coil.
- Optional features include positive drip-proofing, vertical and horizontal separator barriers, and a transparent face guard that prevents accidental switch actuation. An elliptical mask insert helps identify switch units when mounted with non-switch indicators in same panel.
- 6-lamp Lumi-Switch is priced at $18.75, with decreasing scale for quantity. Price includes basic unit, color boots, standard 2PDT switch. An identical 4-lamp unit is available at $14.35.

We are anxious to send you all sorts of information about Lumi-Switch. We'll even include material on our readouts. All we need is your inquiry.

INDUSTRIAL ELECTRONIC ENGINEERS, INC.

5528 Vineland Avenue, North Hollywood, California
Phone: (213) 877-1144 • TWX: (213) 769-1636
Representatives in Principal Cities ©1964 IEE

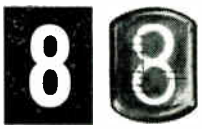
SOME COMMON SENSE OBSERVATIONS ON READABILITY OF READOUTS

As you may know, we build more rear-projection, single-plane readouts than anyone. Here's a cut-away of a typical IEE unit:

One of the main reasons our readouts are so much in demand (especially by end-users): "IEE readouts are the most readable readouts made."

Why they're so readable is no secret. Here's a comparison with another popular readout, the gas ionization tube:

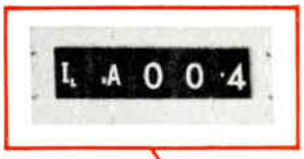
- IEE characters are bigger, thicker, bolder.
- IEE makes the presentation in a single plane; only the message that's "on" is visible.



- IEE projects the message against a dark surrounding area. This makes for strong visual contrast, essential for good legibility.
- IEE readouts are bright (up to 90 foot lamberts). And, because they are rear projectors, they are free of glare. A lot more relaxing to the eye than the glare of a direct light source. There *is* such a thing as being too bright for comfort. Our readouts can also be dimmed for greater eye comfort when used in dark surroundings.

These are some of the reasons IEE readouts are the most readable. But that's only as it should be. After all, what's a readout for if not for optimum readability?

DIGITAL TRANSISTOR/DIODE TESTER BY FAIRCHILD; VISUAL TRANSLATION BY IEE



For economical digitally-programmed volume inspection of solid state devices, it's the Fairchild Series 500... a real sophisticated sort of thing. And, right in the center of things, you can see an assembly of IEE Series 10 rear-projection readouts. The operator can see them too. Sharp and clear, and from wide angles. Even in brightest light. IEE readouts make their presentation in a single plane, there's no visual hash. We're glad Fairchild uses IEE readouts. Bet the operator is glad too.

VARIABLE RESISTORS

Complete Line. Whatever you need, CTS has it or can make it to your Exact Requirement. CTS' world-wide sales organization will help solve your variable resistor problems.

APPLICATION	SIZE (Diameter)	POWER RATING (Watts)	RESISTANCE (ohms)	CTS SERIES	DATA SHEET
COMPOSITION VARIABLE RESISTORS					
Commercial	15/16"	1/4 to 1	200Ω—10 Meg.	45	Cat1000
Commercial	3/4"	2/10 to 3/10	200Ω—7.5 Meg.	70	1100
Commercial	5/8"	2/10 to 1/4	200Ω—2.5 Meg.	200	1200
Commercial	Side by Side	1/4 to 1/3	250Ω—10 Meg.	X52-53	2700
Commercial	2"	2	5K—50 Meg.	HVC	1600
MIL-R-94B, Style RV5	3/4"	1/2	100Ω—2.5 Meg.	65	2400
MIL-R-94B, Style RV2	15/16"	1	100Ω—5 Meg.	90	2300
WIREWOUND VARIABLE RESISTORS					
Commercial	1-17/32"	4	3Ω—25K	25	2001
Commercial	1-17/64"	2	3Ω—15K	252	1901
Commercial	1-1/4"	2	1Ω—50K	2W	1800
Commercial	15/16"	5	1Ω—25K	AW	2100
Commercial	3/4"	1.5 to 3	1/2Ω—10K	110	1700
Commercial	3/4"	2 to 3	1/2Ω—10K	115	1750
MIL-R-19, Style RA30	1-17/32"	4	3Ω—25K	25	2000
MIL-R-19, Style RA20	1-17/64"	2	3Ω—15K	252	1900
MIL-R-19, Style RA20	1-1/4"	2	3Ω—15K	WP	2200
CARBON CERAMIC VARIABLE RESISTORS					
MIL-R-94B, Style RV6	1/2	3/4	100Ω—2.5 Meg.	300	2450
MIL-R-94B, Style RV4	1-1/16"	3	250Ω—1 Meg.	320	1400
Commercial	Side by Side	1/4	500Ω—5 Meg.	151-54	1500
Industrial	1-1/16"	1/4	250Ω—2.5 Meg.	321	1401
CERMET* VARIABLE RESISTORS					
Ind. or MIL, Style RV4	1-3/64"	3	100Ω—5 Meg.	400	Cermet Cat.
Ind. or MIL, Style RV5	3/4"	1-1/2	100Ω—5 Meg.	500	Cermet Cat.
Ind. or MIL, Style RV6	1/2"	3/4	100Ω—5 Meg.	600	Cermet Cat.

*Meets or exceeds MIL-R-94B and MIL-R-23285 (Navy)

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Ceradot—Solid cermet, .050" dia. x .030" long or as required, 1/10 watt, 50Ω-100K, with or without leads. Request Cermet catalog.

TRIMMER—POTENTIOMETERS

APPLICATION	SIZE (Diameter)	POWER RATING (Watts)	RESISTANCE (ohms)	CTS SERIES	DATA SHEET
COMPOSITION TRIMMER RESISTORS					
Commercial	19/32"	1/8	250Ω—2.5 Meg.	201	1201
Commercial	7/16x5/16x1/2"	1/8	250Ω—2.5 Meg.	220	2500
Commercial	9/32"	1/10	100Ω—10 Meg.	M-250	1300
MIL-R-22097, Style RJ11	1-1/4x.295x.350"	1/4	100Ω—1 Meg.	140	2600
WIREWOUND TRIMMER RESISTORS					
Industrial & Military	1/2"	1	50Ω—20K	350	5500
CERMET TRIMMER RESISTORS					
MIL-R-22097, Style RJ22	1/2" Sq.	1	100Ω—1 Meg.	170	Cermet Cat.
MIL-R-22097, Style RJ11	1-1/4x.295x.335"	1	100Ω—1 Meg.	180	Cermet Cat.
Industrial & Military	11/32"	1/8	100Ω—500K	385	8050
Industrial & Military	3/8"	1/4	100Ω—500K	660	8400

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CHOOSING RELAYS OR SOLID-STATE SWITCHING

Neither the electromechanical relay nor the solid-state switch is the panacea for switching problems. Each has its own advantages. This article presents the pros and cons of each, and gives the various parameters to be considered in design application of a switching device.

ELECTRONIC INDUSTRIES
REFERENCE ISSUE
ELECTRO-MECHANICAL COMPONENTS

THERE ARE MANY TYPES OF ELECTROMECHANICAL RELAYS which are electrically and mechanically interchangeable. Solid-state switches, relatively new in the field, are finding uses which cannot normally be filled by standard electromechanical relays. These two devices, however, are not necessarily interchangeable, and neither has a complete advantage over the other. The choice of device depends on the use.

This article presents the various parameters which must be considered in design application of a switching device, and offers comments on these parameters as they pertain to relays or solid-state switching units. Following the comments, a table is given as a quick reference guide to those parameters which are best handled by either the relay or the solid-state switch.

RELIABILITY. Reliability is usually the most important attribute which must be considered for any use. It depends not so much on the individual device used, but on how well suited the component is to the circuit requirements. It is therefore design reliability which is of prime importance; this takes into account all the parameters of the switching device and evaluates them against the requirements of the circuit design.

Relay reliability is considered on the basis of the relay as a single component, whether it be single-pole or six-pole. The solid-state switch, on the other hand, is considered as a system, and the composite reliability figures on the individual components must be considered. When computing theoretical reliability, use the actual stresses which the use will impose upon the device, rather than their rated values. This is particularly true in terms of the environmental stresses which will be imposed. For example, a change in temperature yields a totally different reliability figure for both relays and solid-state switches.

Consideration must also be given to use in terms of the necessary functions that the device must perform. A relay reliability figure changes little if it is a two-pole or a four-pole device, assuming everything else is equal. On the other hand, a solid-state switch used for a four-pole application has considerably more components than a two-pole device, and its reliability is seriously affected. There are instances where only a single-pole relay is required, and a two-pole relay is used simply because it is available and no money is saved by ordering a single-pole unit. However, if the use only requires a single-pole function, possibly even limited to a normally open or a normally closed contact, the saving in reliability by using solid-state components is apparent.

COST. For a particular use the relay generally costs less than a solid-state device. A simple switching application may be accomplished by a single transistor, but the cost is not merely the component. The cost of the required associated parts and power sources must also be considered. For example, a solid-state device requires auxiliary power, which may or may not be readily available. Also, any simple solid-state switch requires additional components other than the switch device itself.

Multiple-pole functions increase the cost of the solid-state switch rapidly, and this factor must be weighed against the other desired parameters before a decision can be made by the user.

VERSATILITY. Versatility must be reviewed from the economy standpoint since purchase of large quantities of a given device results in a lower unit cost. The solid-state switch is generally designed for the particular use and drives a given load; the relay, on the other hand, handles a variety of loads. The solid-state switch must be designed specifically to handle an ac or a dc output; a relay can carry low-level currents to rated loads, either ac or dc, without a component change. The relays, therefore,

(*Continued on page* 101)

By JOHN A. PFINGSTEN
Hi-G Incorporated,
Windsor Locks, Conn.

Be a wow!

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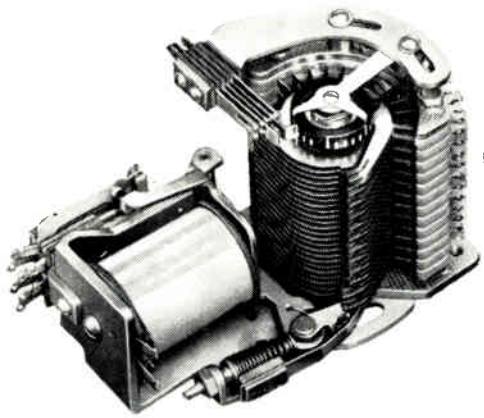
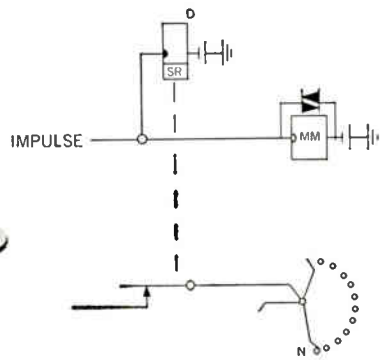
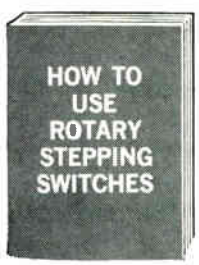




A rotary stepping switch is a natural for simple, straightforward, economical selection. It should be, because that's what it was designed to do. The above circuit, operating under control of a telephone dial (not shown), shows how a wiper disconnect can be utilized during stepping, to avoid energizing circuits wiped over. If **you** have a problem in selecting, let us help you do a wow of a job.

Ask the men who wrote the book! Let us show you how rotary stepping switches can save you time, money and space in the design of your selection circuits. For striking success, ask for your personal copy of "How to Use Rotary Stepping Switches," our new 160-page book. Just contact the AE representative in your area, or write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois 60164.

Wow's Handbook



AUTOMATIC ELECTRIC

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have the advantage of being applicable to many general-purpose use, whereas the solid-state switching must be designed for the specific application in each instance.

CONTACT CAPABILITIES. For a resistive load, either device is satisfactory provided it operates within a normal rating of the unit. However, very few uses have pure resistive loads.

Inductive loads have circuit transients which may or may not be measurable. In any case, it is good practice to protect any contact application against inductive-load transients. A relay operates without protection under reduced ratings. Even if unexpected transients occur, relay operation is generally not impaired. A solid-state device, however, must be protected against any inductive-load transients that exceed the breakdown voltage of the solid-state switching device. If transient appears that exceeds this voltage, a solid-state device is destroyed.

Relays operate satisfactorily after a contact *overload* provided it is not too severe. Contact overloads for relays are generally at 2 to 4 times the normal rated load for the device. On the other hand, static switches cannot accept severe overloads for very long periods, since the switching mechanism will be destroyed.

There is no *bounce* characteristic in a solid-state device. Relays, however, exhibit bounce in the order of 250μsec. to several msec. The bounce characteristic depends upon the type of relay, its adjustment, and the application. Since the contact current to be switched severely affects the bounce, care must be taken that the relay specification reflects the actual load to be used when measuring bounce characteristics. For example, a relay switching 50μa has a severe bounce characteristic as compared to the same relay switching 2 amps. This is due to the higher current sustaining an arc across a pair of physically separated contacts much longer than a lower current, thus allowing conduction to occur where bounce normally appears at low-level current.

Contact *resistance*, or forward voltage drop, is important to the circuit designer from the standpoint of loss in circuit voltage that can be tolerated. It is important to the component because current passing through a resistance causes damaging heat. The contact resistance characteristic of a relay is superior to a solid-state device for most uses particularly when low-level currents are considered.

The relay is superior to the solid-state devices for *low-level operations*. Inherently, the contact resistance of a relay can be made very low. Solid-state devices have a voltage drop in the area of 200mv to 1v., depending upon the device. This value may exceed the open circuit voltage available for most low-level applications. Relay applications are often practical in the microamp and microvolt region. Both relays and solid-state devices exhibit better resistance characteristics at higher temperature.

A solid-state switch retains its initial operational characteristics within relatively narrow limits so long as it is used within its ratings. The relay exhibits changes in its various parameters, including pull-in, drop-out, contact resistance, etc., with life. This is due to the normal *erosion and wear* on other component parts of the relay. These characteristics must be compensated for in any design using a relay.

SENSITIVITY. If low power consumption is required for the signal circuit, the solid-state device is superior since relays are limited to milliwatts of input. A solid-state switch can readily operate in the millivolt range with microwatts input. A disadvantage of the solid-state device is that it requires auxiliary power other than the signal circuit.

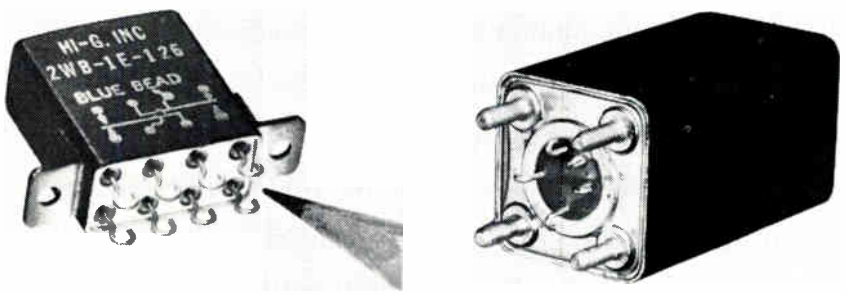
OPERATING SPEED. For operating speed solid-state devices are superior to relays because they operate in microseconds while relays require milliseconds. This is also true of the release times required for both devices.

TRANSIENTS. Transient may occur on the input circuitry either in a positive or negative direction. Any solid-state device requires protection against these transients to avoid total malfunction and possible destruction. Relays are relatively immune to short transients, and do not cause accidental contact switching since the transients are usually of shorter duration than the relay reaction time.

INPUT OVERLOAD. Generally, a relay can withstand a prolonged input overload of 15 or 20% over the nominal coil voltage to a possible several hundred percent capability, depending upon the relay type used. Solid-state devices accept a wide range of input voltage, thus allowing superior overload characteristics.

ISOLATION. Isolation, in terms of dielectric strength and insulation resistance, must be considered for

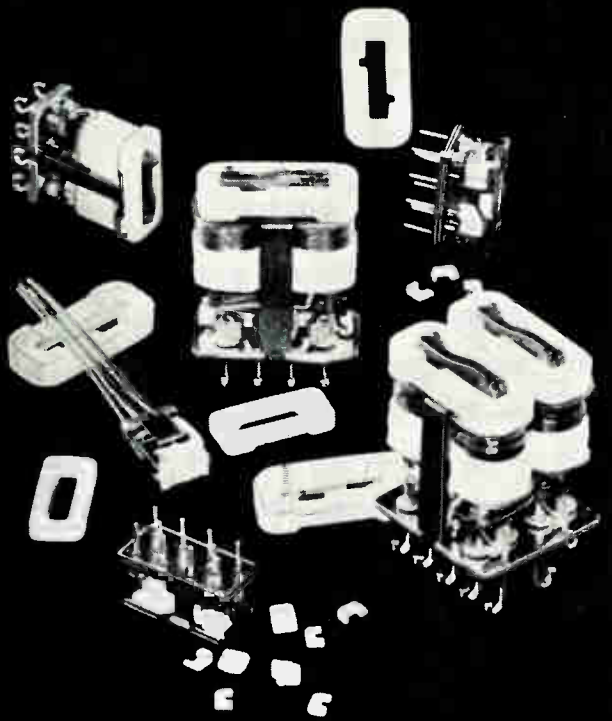
(*Continued on page* 103)



The electromechanical relay (l) and solid-state switch have distinct advantages. In choosing one for a particular switching operation, the designer must consider factors of reliability, cost, and environmental operating conditions for efficient operation.

What good is a getter?

Babcock uses them to increase relay reliability.



Exclusive Babcock Design Feature Provides Lower Contact Resistance & Longer Relay Life

Contact contamination from vaporization is one of the major causes of erratic performance and eventual failure of hermetically sealed relays. After extensive investigation Babcock Relays, in conjunction with Corning Glass Works, has developed an activated getter from Corning's Vycor brand porous glass. During operation, the activated getters prevent relay contacts from being fouled by contaminants emitted at elevated temperatures.

Babcock has subjected relays using Vycor getters to hundreds of thousands of operations at loads varying in excess of 200G's for 11 milliseconds and vibration at 35G's, 3-5,000 cps. It has been determined that up to 99% of organic contaminants remaining after production degassing are adsorbed by the dessicant. Conclusive life testing at 125°C has proven that contact erosion and contamination accumulation on all vital areas within hermetically sealed relays has been substantially reduced. Consistently lower contact resistance is also exhibited due to the reduction in contamination.

The end result provides Babcock relays with increased performance and efficiency, higher temperature application, and longer, more reliable life.

Babcock reliability rated relays featuring Vycor getters include:

BR-5—Transistor-sized dry circuit to one amp

BR-13—Microminiature, all-welded for dry circuit to 3 amp

BR-17—Half-size magnetic latching for dry circuit to 2 amp operation. Also available as non-latching model.

BR-14—Subminiature 4 PDT available in 10, 7.5 and 5 amp

BR-19—Subminiature all-welded 10 amp relay. BR-20 magnetic latching version also available.

Send for complete catalog.

BABCOCK RELAYS

A DIVISION OF BABCOCK ELECTRONICS CORPORATION
3501 HARBOR BLVD., COSTA MESA, CALIF. • 546-2711

RELAYS OR SWITCHES (Concluded)

all uses, since it is desirable to have excellent isolation between the driving signal and the switching contact. Electromechanical relays are excellent under these conditions. A solid-state device requires an isolation transformer or other means of coupling the input to output in order to obtain the required isolation. Unfortuntely, such methods affect the other operating characteristics of the solid-state device, particularly in the area of operating speed. Isolation of the open contact is also a strict requirement of many circuits. The relay is superior in this regard, since a physical opening yields many thousands of megohms isolation. With solid-state devices, a backward leakage effectively reduces this isolation.

TEMPERATURE. Mil. Specs. calls for an operating temperature of −65° to +125°C. Relays and solid-state switches are affected in several areas due to the temperature extremes. The temperature co-efficient of copper causes the operating power and voltage characteristics of a relay to vary over the temperature range. This may be compensated for, to some extent, by properly selecting coil, power, pull-in voltage, and nominal operating voltage. However, the problem does not end here for the relay operating speed, bounce and life characteristics are affected by temperature change. The contact current-carrying capability of a relay is reduced at high temperature, though virtually all relay specifications indicate the rated load at the maximum temperature.

The solid-state device does not have a severe change in its input operating characteristics, though care must be taken to select the proper output switching device which can perform over the required temperature range. It is also necessary to insure that the heat can be dissipated at high temperatures. The reduction in current-switching capability of a solid-state device is severe when going from room temperature to high temperature; thus derating curves should be carefully consulted.

Applications requiring higher temperatures than 125°C are more complex with solid-state devices due to the rapid component derating and lack of available high-temperature semiconductors. Relays can be designed for temperatures to 200°C or more.

VIBRATION AND SHOCK. Solid-state devices are generally superior in the area of vibration and shock, since they can withstand vibrations as high as 100G and an operating shock of 250 G or more. Though relays are available which can withstand 50 or 100G vibration, they are rare and most applications are limited to 20 or 30G vibration. Uses involving high shock requirement such as MIL-S-901C depend entirely upon the mechanical design of either device, which can be easily designed to withstand this level of shock.

RADIATION. Materials are available for relay use which are relatively resistant to nuclear *radiation*. Solid-state switching devices, however, use a wide variety of materials. This presents a problem for the solid-state switch designer who must design the device to be radiation resistant.

LIFE. The solid-state switching device is superior to the relay in both hours of operation and the number of operations. The relay has a life of 100,000 operations; solid-state devices, on the other hand, can perform tens of millions of operations without problem.

CONCLUSION. The following table serves as a quick reference guide to whether a relay or a solid-state switch is more desirable for the parameter under consideration.

ELECTRO-MECHANICAL RELAY VS SOLID-STATE SWITCH

	Relay	Switch
Reliability	X	X
Cost	X	—
Size	X	—
Versatility	X	—
Contact Capabilities		
Resistive Load	X	X
Inductive Load	X	—
Overload	X	—
Bounce	—	X
Resistance	X	—
Low Level Operation	X	—
Contamination & Wear	—	X
Sensitivity	—	X
Operate Speed	—	X
Transients	X	—
Input Overload	—	X
Isolation	X	X
Temperature	X	—
Vibration & Shock	—	X
Nuclear Radiation	X	—
Life	—	X

"X" indicates the device considered to be superior.

The important parameters to be considered when designing a circuit using a switching device have been considered on the basis of the effect they will have on the circuit. It is often desirable to use both relays and solid-state switching components side by side in a particular design, thus taking advantage of the best features of each. When selecting switching components for a particular use, it is wise to consult specialists in the manufacture of relays and solid-state switches who can offer design and manufacturing experience to yield an improved, less costly product.

• A REPRINT of ANY ARTICLE in this issue is available from ELECTRONIC INDUSTRIES Reader Service Department.

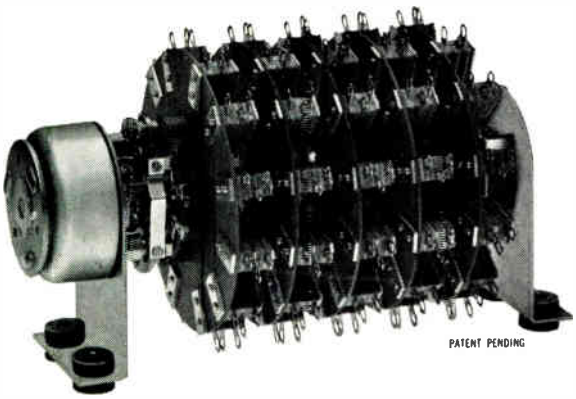
ELECTROMECHANICAL COMPONENTS—RELAYS

Relays of most types for electronic applications are also on a continuous and gradual rise in annual sales. Average total relay sales for 1964 are estimated at $201 million, increasing at something less than 5% a year to $219 million in 1966. Leader, of course is still electromagnetic relays, including rotary, plunger and solenoid types.

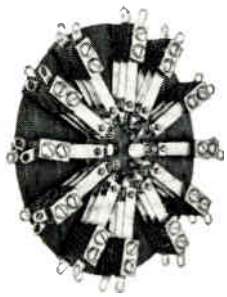
	1964	1965	1966
	(in millions of dollars)		
Total Market (electronic uses)	$201	$210	$219
Electromagnetic	104	108	112
Mercury-Wetted	10	11	11
Dry Reed	11	12	13
Crystal Can	26	29	32

Totals of sample relay categories listed above do not constitute the entire relay market.

(Figures based on a limited EI survey among 300 leading component manufacturers.)



New stepping switch makes/breaks 5 amp circuits; has life expectancy of 25 million steps



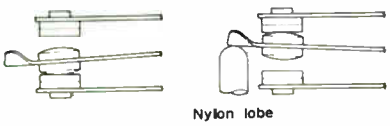
Each deck has 12 stations. Each station can have two 2-position, relay-type contacts, a total of 24 switching operations per deck.

This new stepping switch is built to perform a complex switching job, switch high current, and to make 25 million steps without maintenance or adjustment. It does the job in a compact package. It does not require auxiliary relays to switch 5 amp loads.

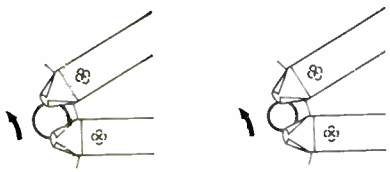
Relay-type 2-position contacts are stacked up 12 or 24 circuits per deck, providing an almost unlimited variety of switching patterns. Decks can be designed for your specific switching program.

In addition to long life and high switching capacity, the switch has exceptional control versatility. Any of the standard Ledex control principles for sequence stepping or automatic selective control can be used.

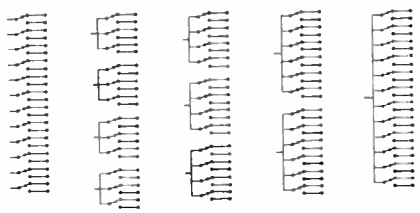
Write for Bulletin B-364 today. Or, let us know by mail or phone (513-224-9891) about your application. We'd like to tailor a switch to meet your requirements.



Each circuit station has two contacts, one normally open and one normally closed... the equivalent of a 1P2T relay. Single contact stations are available either normally open or normally closed. Nylon lobe operates switch.



Adjacent stations can make before break or break before make, depending on the programing required.



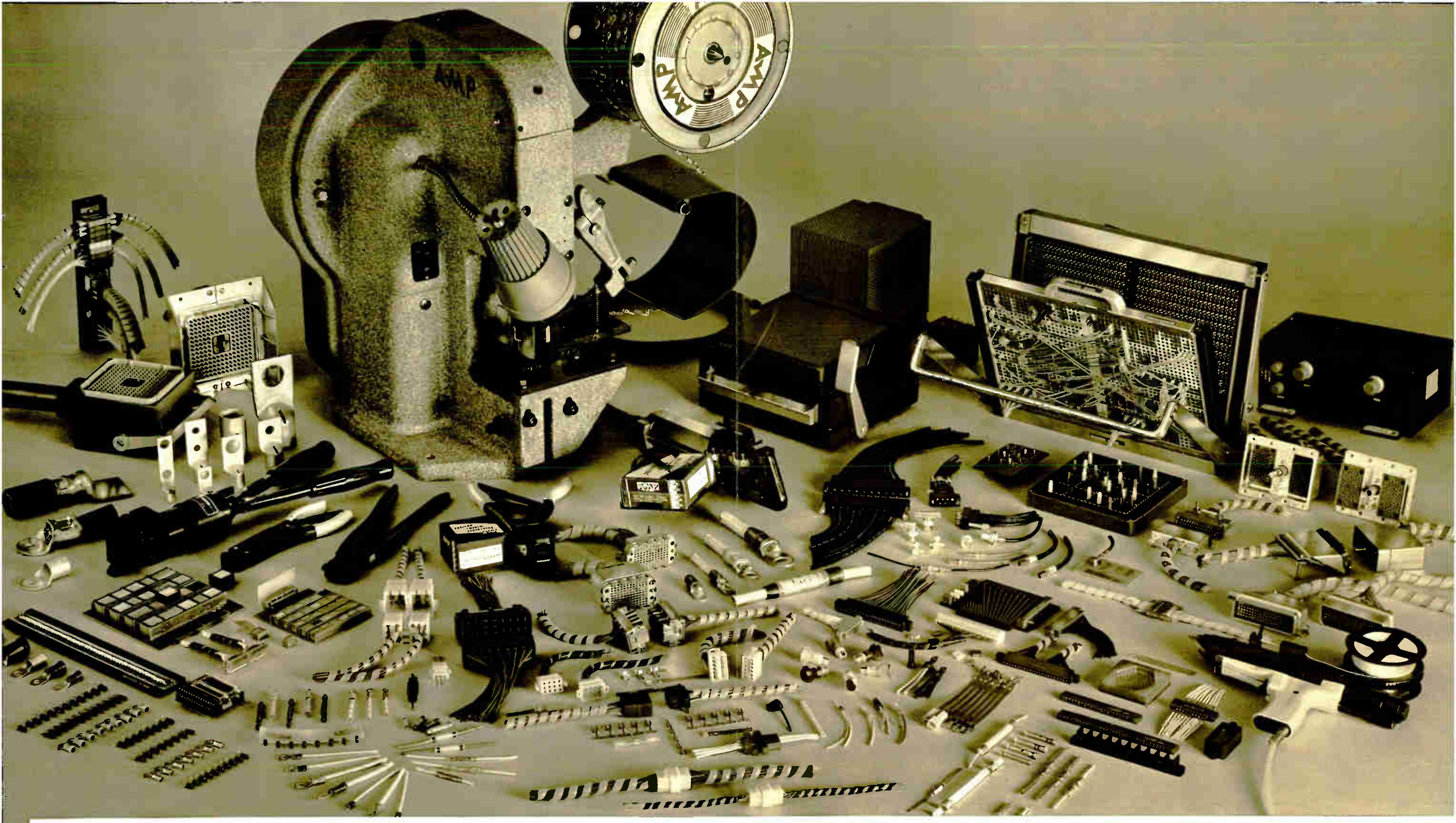
Multiple circuits can be programed by placement of lobes and by connecting the contacts in series or parallel. A few of the standard combinations possible are 144P2T, 48P3T, 36P4T, 24P6T and 12P12T.

Specifications:

contact rating (make-break)	5 amps at 115VAC or 10 amps at 28VDC
contact dielectric strength	1000 VRMS
contact resistance	20 milliohms, nominal
drive voltages available	6 to 300VDC, 115 or 230VAC
operating temperature range	−20°C to +80°C
life expectancy	25,000,000 steps

LEDEX

Ledex Inc.
123 Webster Street, Dayton, Ohio 45402
Designers & Manufacturers
Electronic and Electro-Mechanical Components
& Remote Control Switching Systems



In all this, there's a common denominator . . . proven research, testing, development and the cumulative engineering know-how that assures continuous improvement of product and technique to satisfy the growing electrical/electronic requirements of our time.

No matter what your need may be from basic solderless terminals to advanced electronic subassemblies, it makes good sense to consider the leader . . . first!

Solderless terminals and splices • special environmental terminals and splices • taper technique • pin and socket • printed circuit • general purpose and coaxial connectors • capacitors • power supplies • pulse indicators • patchcord programming systems and devices • pinboards • card readers • magnetic memory-logic devices • solderless clip-type point-to-point wiring terminals and application tooling • matched hand application tooling • automatic application machinery

AMP
INCORPORATED
Harrisburg, Pennsylvania

INDUSTRIAL SALES DIVISION

A-MP★ products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • Mexico • West Germany

★ Trademark of AMP Incorporated

1882

As far back as 1882 patents were issued for primitive solderless wire terminations. These crude designs presented a number of problems—some of them almost insurmountable. But year by year gradual improvements were instrumented. However, it was not until AMP Incorporated came upon the scene sixty years later that industry began to recognize the full value of improved solderless terminations—in both products and techniques.

AMP developed the matched tool and terminal concept that completely changed the industry. Today AMP is also an acknowledged leader in the design and manufacture of multiple connectors, coaxial cable and shielded wire connections, programming systems, power supplies and other transformer and capacitor products, printed circuit products and other allied components required by the expanding needs of our time.

So great is this product diversification, that AMP has established world-wide penetration into every electrical/electronic area known to man—appliance, aircraft, missile, communications, power, automotive, maritime, military and commercial.

Everything from AMP's design improvements, automated tooling for increased production facilities and electro-mechanical advantages of product emphasizes the quality control that began with their solderless termination technique. That thoroughness is maintained in the manufacture of all their other products.

This concentration on engineering skill, product development and modern procedures led to more than 15,000 different A-MP★ items, covered by over 4,300 patents issued or pending here and abroad, designed to further fulfill evergrowing electrical/electronic requirements.

AMP
INCORPORATED

MATCHED TOOL AND TERMINAL CONCEPT

A-MP application tools are designed to create a carefully controlled and predetermined pressure-crimp for each terminal type, wire size range and specific wiring requirement. To accomplish this union of wire and terminal into one homogeneous mass, tool and terminal are exactly matched so that the utmost degree of control and accuracy is a characteristic of each pressure-crimped connection. The result is a strong, positive termination with a tensile strength almost equal to that of the wire itself, and an electrical and mechanical connection superior to and more reliable than those made by any other wire terminating method.

"F" CRIMP

CONFINED "C" CRIMP

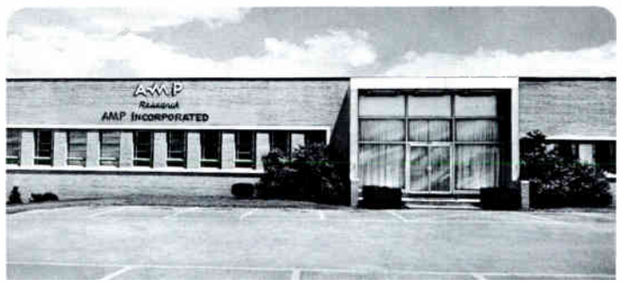
INSULATION PIERCING CRIMP

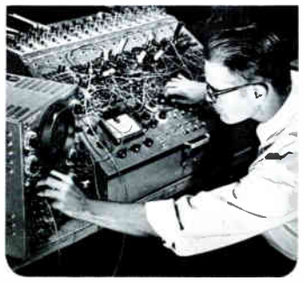
"W" CRIMP

RESEARCH AND DEVELOPMENT

The story of AMP's growth and leadership can, in large part, be attributed to substantial and continuous efforts directed toward product improvement and development through the company's research and testing facilities. Here a large staff of scientists and skilled technicians contribute toward the creation of superior products and techniques to assure the finest quality and maximum reliability in the performance of today's newest and most advanced electrical/electronic equipment. Among their achievements are special plating processes to increase product efficiency and life expectancy, special studies in the effects of environment, including radiation on metals, insulating materials and other related circuits components.

With such experienced personnel and ample facilities available, we welcome opportunities to work on special projects requiring the creation of functionalized products that fulfill unusual requirements of every type. It is this inquiring philosophy that enables us to lead the field in the development of newer, better and more efficient products.





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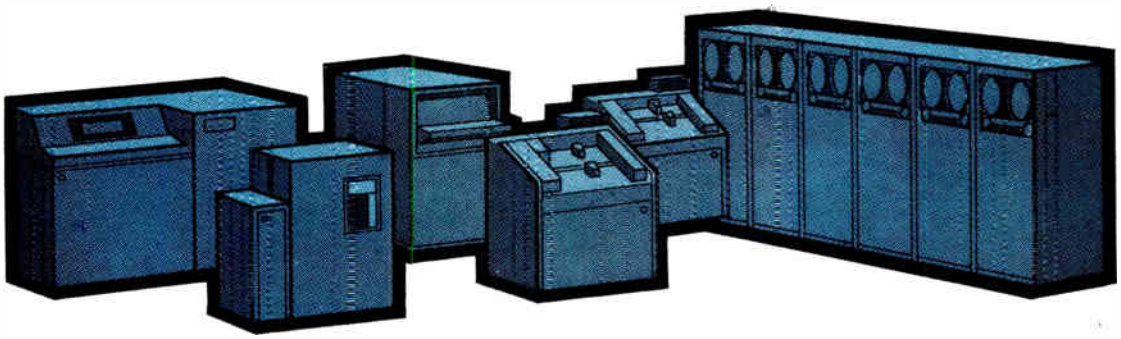
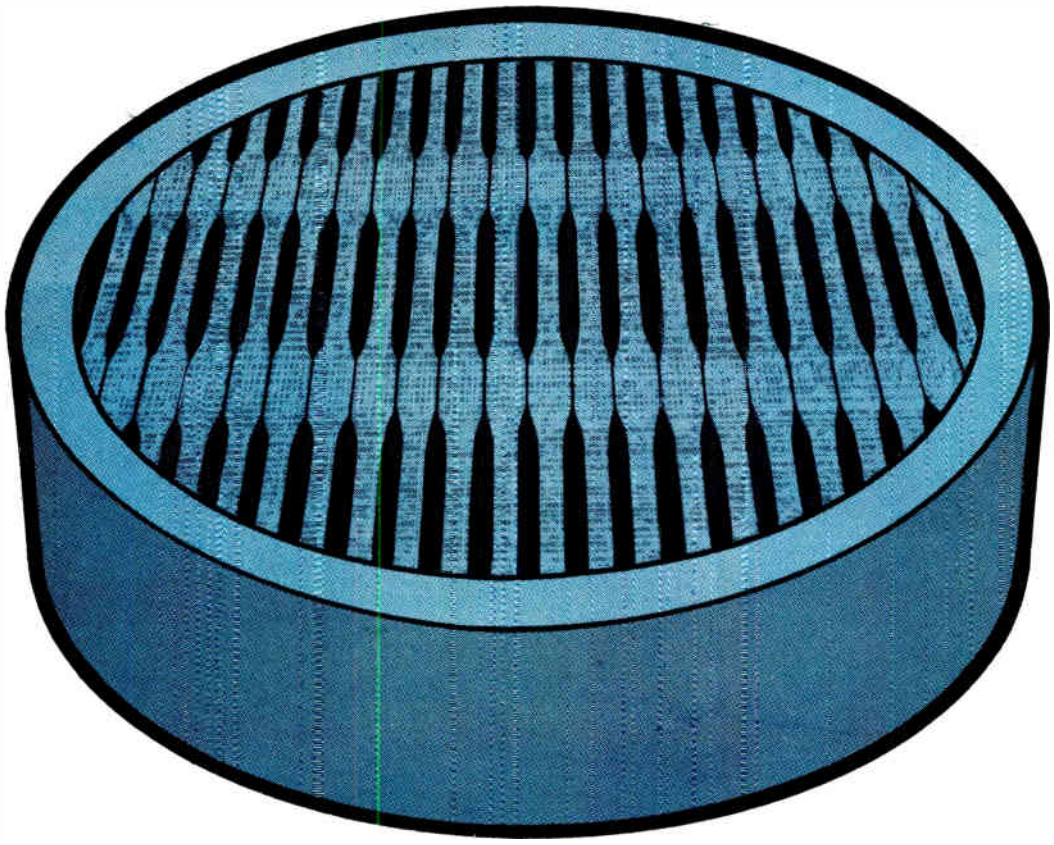
F-5-4—73M—PP—5-64 Printed in U.S.A.



IF YOU DON'T LIKE TO COMPROMISE ON ELECTRONIC COMPONENTS



SELECT AN UNCOMPROMISING FILTER

It doesn't take much to discombobulate the most carefully conceived and manufactured electronic units. A couple of ten-micron dust particles floating around in a computer can butcher astrophysical equations as surely as a monkey wrench. That's why it's a good idea to talk to an Air-Maze engineer about the right kind of air filter. Round or rectangular, oil-wetted or dry, with or without RF shielding, he will show you how to make the filter an integral part of the unit. He's got the filter that allows proper cooling without compromising the reliability of the system. For more detailed information, write or call Rockwell-Standard Corporation, Air-Maze Division, Cleveland 28, Ohio.

ROCKWELL R STANDARD®

AIR-MAZE FILTERS ARE PRODUCED BY ROCKWELL-STANDARD CORPORATION

A NEW PLUS FACTOR IN RELAYS

PHILLIPS-ADVANCE = Phillips Control Company + Elgin Advance (two names long synonymous with the highest standards of relay reliability). The recent consolidation of PHILLIPS and ADVANCE adds up to numerous plus-factors of real importance to all relay users—broader range of relay types and sizes + expanded research and development + increased plant facilities + new production economies + greater number of skilled personnel + faster service thru broader distribution. For prompt attention to every relay requirement, contact the PHILLIPS-ADVANCE representative in your area.

phillips advance control co.
Joliet · Illinois

NEW TECH DATA

ELECTROMECHANICAL

Rectilinear Potentiometer

Data is available on a rectilinear potentiometer which gives reliable performance in extreme environments. In tests the electromechanical measuring device operated perfectly at temps. from −65° to +302°F. In instrumentation and control systems, the lightweight unit accurately indicates by electrical output the mechanical position of a valve. The pot has a self-aligning shaft. The shaft disengages should the system push it past the mechanical stops, thus preventing damage. The 4 coils, instead of the usual 1, can be mounted on each assembly. ITT General Controls Inc., Glendale, Calif.

Circle 421 on Inquiry Card

Blower Application

Bulletin C-10 describes simplified procedures for determining cooling requirements for electronic systems based on heat dissipation and back pressure. Also described are characteristics of various blower types. Globe Industries, Inc., 1784 Stanley Ave., Dayton, Ohio.

Circle 422 on Inquiry Card

Pushbutton Switches

Data Sheet 224 describes the new 2N Series of lighted pushbutton switches which feature relamping without tools. The series has 3 basic modular units which assemble by snapping together Switch units attach to clips on the housing. There is a choice between 1, 2, 3 and 4-pole DT and 2-circuit double-break contact arrangements. Micro Switch, Freeport, Ill.

Circle 423 on Inquiry Card

Variable Capacitors

Data is available on 54 different voltage-variable capacitors which provide the circuit engineer with a broad range of max. reverse voltage, capacitance ratio and Q. The devices include 12 EIA types. The high-Q series has special applications in such critical control circuits as automatic freq. control, electronic tuning, freq. modulation, and signal seeking, as well as controlled filters and controlled attenuators. Computer Diode Corp., 250 Garibaldi Ave., Lodi, N. J.

Circle 424 on Inquiry Card

Latching Relays

This catalog sheet describes the Type LS magnetic latching relay, which maintains either of its 2 positions without power consumption and needs only a short duration pulse to change positions. Data on coil voltages, schematic diagram, complete electrical and mechanical specs., outlines of all case and header styles, and complete ordering information are included. Branson Corp., 41 S. Jefferson Rd., Whippany, N. J.

Circle 425 on Inquiry Card

Time-Delay Relay

Model 632 is a plug-in electronic time-delay relay suitable for many automatic and semi-automatic uses. It provides interval operation under control of foot switch, limit switch or other contact closure. Timer uses cold-cathode tubes in a patented circuit and needs no warm-up. Power can be connected continuously. Timing is adjustable over ranges from 0.02 to 300 sec. Repeatability is ±1% or ±5%. Recycling is instantaneous. Data available from G. C. Wilson and Co., P. O. Box 5437, Huntington, W. Va.

Circle 426 on Inquiry Card

Rotary Relay

Data Sheet No. 9 contains complete specs. for Type 2X rotary relay, which measures 0.5 x 0.4 x 0.2 in., has 0.1 in. grid terminal spacing, and is designed primarily for signal switching with other printed-circuit board components. Couch Ordnance, Inc., 3 Arlington St., N. Quincy 71, Mass.

Circle 427 on Inquiry Card

Microwatt Sensitive Relay

This transistorized amplifier relay, series 162, combines the advantage of solid-state sensitivity with an electromagnetic relay into a single unit. This relay functions on power sensitivities as low as 10μw. The use of an electro-magnetic relay as the switching device permits complete contact isolation and very low contact resistance. It is non-latching and available in contact arrangements up to 4 Form C. Contact capacities are 5a. at 29vdc or 115vac. Additional data available from General Automatic Corp., 7 Sherman Ave., Jersey City, N. J.

Circle 428 on Inquiry Card

Switch/Relay Guide

This practical and easy-to-use application guide is for reed switch and reed relay users. For a given application, the design engineer can select from the load selector a few recommended reed switch types. From this selection, the designer can open to the switch selector section and match his own physical and electrical characteristic needs. Hamlin, Inc., Lake Mills, Wisc.

Circle 429 on Inquiry Card

High-Amp. Relay

Data is available on the Series T relay which features 10 a. contact rating and reduced size. This new relay is designed to meet the requirements of high reliability applications and all applicable portions of MIL-R-5757D. Contacts are rated at 10 a. resistive, 30 VDC or 115 V, 400 cps. Life at rated contact load is 100,000 operations. Coils are available to 9K ohms and sensitivity is 500 mw. Hi-G, Inc., Rt. 75 and Spring St., Windsor Locks, Conn.

Circle 430 on Inquiry Card

Precision Potentiometers

Complete electrical and mechanical specs. for the new standard slimline series infinite resolution precision potentiometers are given in a condensed catalog. Included are standard resistance values and linearities available in 6 standard dia., which feature 0.2 in. thickness for each additional cup. Made to MIL or industrial specs., the potentiometers are available with linear or nonlinear outputs in a variety of configurations. Markite Corp., 155 Waverly Place, New York, N. Y.

Circle 431 on Inquiry Card

Potentiometer Test Report

This 4-page test report describes the ¼ in. Mechatrim - type HT250-2 miniature trimmer potentiometer. The report describes the tests that were performed in accordance with the Mil Spec. for non-wirewound trimmer. It demonstrates the extreme setting stability, low-temp. coefficient of resistance and h-f characteristics of these units. In addition, the report contains enlarged cutaway views with descriptive text. Mechatrol Div., 1200 Prospect Ave., Westbury, L. I.

Circle 432 on Inquiry Card

Wirewound Potentiometers

Model 3307 is a low-cost, single-turn potentiometer specifically designed for industrial and commercial uses. It measures 5/16 in. in dia. by 3/16 in. Resistance range, 50 to 20,000 Ω; Power Rating, 0.5 w. at 70°C. Data available from Bourns, Inc., Trimpot Div., 1200 Columbia Ave., Riverside, Calif.

Circle 433 on Inquiry Card

PB Switch Catalogs

A file of catalogs dealing with momentary contact type subminiature pushbutton switches is available. Included in the file are catalogs on subminiature illuminated PB switches and matching indicator lights. Series M, V, and P switches are included. Dialight Corp., 60 Stewart Ave., Brooklyn, N. Y.

Circle 434 on Inquiry Card

Motor Speed Control

Data is available on a motor speed control which provides good speed regulation with extreme on-the-job reliability. Feedback-type control has a 20:1 speed range which may be precisely selected with fingertip control. Solid-state SCR circuitry assures dependable performance and long life on the most rugged applications. It has an automatic circuit breaker for overload protection and a manual reset pushbutton. This control is for 115v., 60 cycle ac input 115vdc shunt-wound 1/15th and 1/8th hp motors. Minarik Electric Co., 224 E. Third St., Los Angeles 13, Calif.

Circle 435 on Inquiry Card

NEW TECH DATA

ELECTROMECHANICAL

Subminiature Switches

Data Sheet 180b describes the 10a. capacity subminiature 41SM series switches. These switches are the answer for uses requiring a small switch with a substantial ac electrical rating. They are Underwriters' Laboratories listed at 10a. - 1.4 hp, 125 or 250vac. They have an SPDT contact arrangement and feature fine silver contacts. Micro Switch, Freeport, Ill.

Circle 416 on Inquiry Card

Servo-Amplifier

The Series B 400 cycle magnetic servo-amplifier delivers a phase reversible voltage of 115v. to each motor with 1ma dc current into either of the control windings. It is internally biased to approx. half of the full output voltage value across each phase. This results in a 50% decrease of required standby power as compared to a single-phase servo-motor driver. The servo-amplifier is compatible to all types of servo systems. Operating temp. range from $-55°C$ to $+85°C$; storage temp., $-55°C$ to $+105°C$. Complete specs. are available from Military and Computer Electronics Corp., 900 NE 13th St., Ft. Lauderdale, Fla.

Circle 417 on Inquiry Card

Relay Socket

Data is available on micro-miniature relay socket designed to accept Type AR 6-pole crystal can size relay. Operating temp. range of $-65°C$ to $+125°C$; current rating 3a.; dielectric strength @ 1500v. RMS between terminals or terminals and ground. Branson Corp., 41 S. Jefferson Rd., Whippany, N. J.

Circle 418 on Inquiry Card

Potentiometric Switch

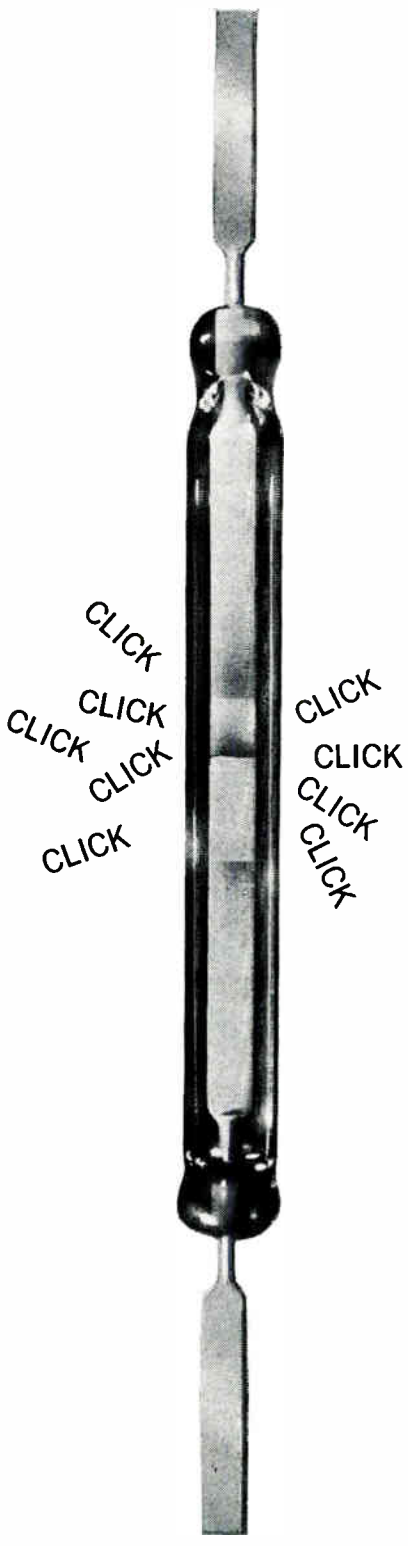
Type 559 adjustable potentiometric switch permits any potentiometer to be used as an adjustable switch. The unit operates on 115v. 60 cycles and accepts an input from any 750 to 15KΩ potentiometer. Repeatability of $\pm 0.15\%$, drift of less than $\pm 0.1\%$ over 24 hrs., and life of greater than 1¼ million cycles with the rated switching current of 10a. are performance features. Colvin Instruments, 9621 Coors Rd., N.W., Albuquerque, N. Mexico.

Circle 419 on Inquiry Card

Reed Relay

This glass reed relay, Series 3002, offers 3000 standard combinations of switch, pole, coil and construction features. This complete line includes 1 through 5 pole switching, coil voltages up to 120 vdc and a fast replacement of reed switches without having to remove relay from its PCB mounting. Typical life is 20 x 10^6 operations at max. ratings. For additional information contact Wheelock Signals, Inc., 273 Branchport Ave., Long Branch, N. J.

Circle 420 on Inquiry Card



2,799,999,996

2,799,999,997

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This is where we last checked

twenty G-E reed switches that were on extended life tests. They were part of a statistical sample pulled from one of our regular production runs. Normally, we don't life test this far. Usual production test limits are 20.7 million cycles. But we wanted to dramatize the excellent long-life characteristics of standard G-E reed switches operating on light to dry circuit loads (i.e., low current).

Dramatize we did! Even though the load on our twenty switches is low (1.5 μa and 1.5 VDC @ 400 CPS), so is the failure rate—*zero!* Here, however, are some more results obtained under our normal full load production life-test conditions:

G-E type 1DR04 Test Conditions: 20.7x10^6 on-off cycles @ 60 operations per second; 90 amp-turns peak; 25 VDC; 0.16 amp current.
Failure Rate: 0.074% per million operations.

G-E type 2DR50 Test Conditions: 20.7x10^6 on-off cycles @ 60 operations per second; 190 amp-turns peak; 125 VDC; 0.40 amp current.
Failure Rate: 0.051% per million operations.

G-E type 2DR15 Test Conditions: 20.7x10^6 on-off cycles @ 60 operations per second; 190 amp-turns peak; 50 VDC; 0.30 amp current.
Failure Rate: 0.069% per million operations.

We challenge any other switch to match these failure rates under the same load and cycling conditions. In fact, G-E reed switches will give you consistently lower failure rates than those of any other manufacturer. The reason stems from over 30 years' experience in metal-glass sealing techniques and from industry's best quality assurance program (every switch you buy has run a gauntlet of 14 electrical and mechanical tests including pull-in operate, drop-out release, high-voltage, and leakage).

Why don't you send for the free folder that gives life data and specifications on our full line of reed switches: General Electric Tube Department, Owensboro, Kentucky. You'll see why those twenty will probably still be going strong at

3,000,000,000

3,000,000,001

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 94 on Inquiry Card

NEW TECH DATA

ELECTROMECHANICAL

Relay Chart

Pick-A-Relay chart simplifies the selection of stock relays according to coil voltage; contact arrangement; and mounting details. On the reverse side of this chart is a complete listing of all standard variations which can be supplied without additional tooling charges or long production delays. Kurman Electric Co., 191 Newel St., Brooklyn 22, N. Y.

Circle 410 on Inquiry Card

Relay Bulletin

Reed relays and mercury-watted contact relays are described in a comprehensive bulletin. Complete technical data, illustrations and mounting information are given. The bulletin includes 40 stock part numbers covering varied packages including printed-circuit and octal plug-in units. Magnecraft Electric Co., 5577 N. Lynch Ave., Chicago, Ill.

Circle 412 on Inquiry Card

Resonant Reed Relay

Data is available on a miniaturized, 4-channel resonant reed relay, RD7. The device switches multiple circuits remotely by audio signal command. The reeds can be tuned to provide over 50 separate control freqs. within 150 to 700 cps range. It requires 15mw normal drive level. Bramco Controls Div., Ledex Inc., College and South Sts., Piqua, Ohio.

Circle 414 on Inquiry Card

Sealed Relay

This grid-spaced micro-miniature relay requires 80 to 90% less power than other hermetically-sealed crystal-can relays. The unit, all-welded construction, including enclosure to header seal, needs only 40 mw for DP units and 25mw for the SP version. Amb. temp. range is −65°C to +125°C; weight is 0.95 oz. max., not including brackets or studs. Min. rated life of 100,000 operations at rated load or 10 million mechanical operations. Operating, 10msec. max., including bounce; release time, 5msec. which also includes bounce. General Electric Co., 392 S. Stratford Rd., Winston-Salem, N. C.

Circle 411 on Inquiry Card

AC Potentiometer

The model 6R1 single-turn Vernistat® ac potentiometer is for use in high-performance servos, analog computers, and navigation systems. It is ideally suited for high accuracy uses wherever mechanical rotation is limited to 360°. The potentiometer features a quadrature of 0.1mv/v., an input impedance of 10KΩ @ 30v., and an output impedance of 100Ω. This provides an input/output impedance ratio of 100. Absolute linearity is ±0.1%. A data sheet providing complete electrical and mechanical specs. is available from Electronic Products Div., Perkin-Elmer Corp., Norwalk, Conn.

Circle 413 on Inquiry Card

Magnetic Circuit Breakers

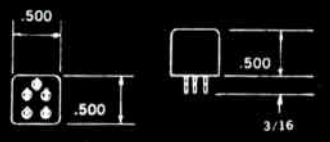
These circuit-breakers offer simultaneous 3-pole operation. If overload occurs in any 1 pole, all 3 open simultaneously. The circuit breakers are connected internally as well as externally. It has a slide-type internal connecting mechanism for high repeatability and trip-free operation. Other special features include a precision latching mechanism, individual calibration, toggle actuation, and long contact life. Computer manufacturers and the aerospace industry will find them useful. Additional data available from Wood Electric Corp., 244 Broad St., Lynn, Mass.

Circle 415 on Inquiry Card

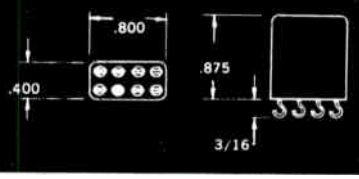
think reliability—
specify Hi-G

IN RELAYS The broadest selection of crystal can and half-size crystal can relays, including high current capacity units. All units have following environmental characteristics per Military Specification MIL-R-5757D. Temperature Range, —65°C to +125°C; Vibration, 20G to 2000 CPS; Shock, 50G for 11 MS; Sealing, 80,000 feet; Dielectric Strength, 1000 VRMS; Life, 100,000 operations.

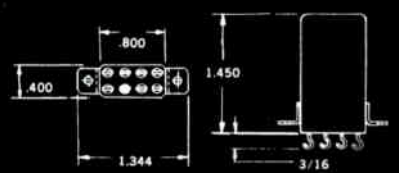
SERIES C
POLE 1 PDT
RATING 1 Amp.
SENSITIVITY 150 MW



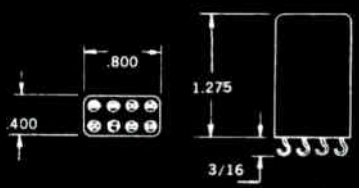
SERIES B
POLE 2 PDT
RATING 2 Amp.
SENSITIVITY 250 MW



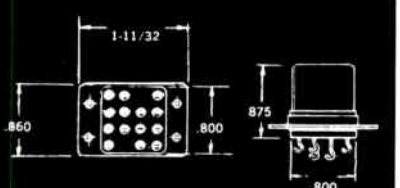
SERIES ABC
POLE 2 PDT
RATING 2 Amp.
SENSITIVITY 12 MW



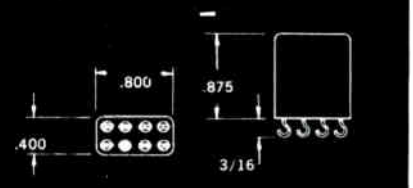
SERIES BC
POLE 2 PDT
RATING 2 Amp.
SENSITIVITY 40 MW



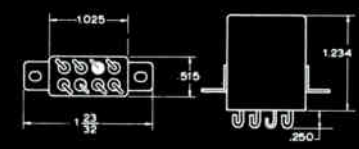
SERIES 4B
POLE 4 PDT
RATING 2 Amp.
SENSITIVITY 400 MW



SERIES BK
POLE 1 or 2 PDT
RATING 2 Amp.
SENSITIVITY 40 MW

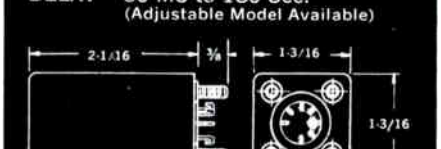


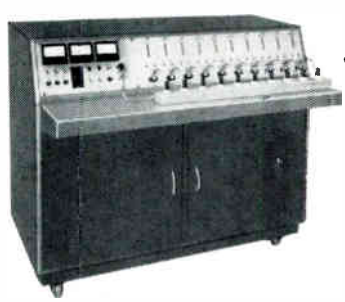
SERIES T
POLE 2 PDT
RATING 10 Amp.
SENSITIVITY 500 MW



SERIES H AND HA
POLE 2 PDT
RATING 2 Amp. (H); 4 Amp. (HA)
SENSITIVITY 250 MW (H)
300 MW (HA)

IN TIME DELAYS
TYPES 115 VAC 400 CPS 18-31 VDC
POLE Up to 4 PDT
RATING 2 Amp. Thru 4 Amp.
DELAY 50 MS to 180 Sec.
(Adjustable Model Available)





...IN AUTOMATIC CONTACT TESTING

The Hi-G MISS TESTER is a completely integrated dry circuit test system which provides fully automatic actuation, resistance limit measurement and indication for critical testing of relays, switches, or other contact devices.

FOR YOUR DESIGN FILE

Complete technical information in the form of catalogs or data sheets is available on all of the units illustrated.

Hi-G INC.

SPRING STREET & ROUTE 75
WINDSOR LOCKS, CONN.

BALANCED relays ROTARY

World's largest selection of adjustment potentiometers

BOURNS TRIMPOT® POTENTIOMETERS

More engineers specify Bourns TRIMPOT Potentiometers because:

TRIMPOT Potentiometer line is complete:
Bourns offers you the largest selection of adjustment potentiometers...33 standard models—4 terminal types—3 mounting styles.

TRIMPOT Potentiometers are small:
Space-saving size and choice of shapes permit the installation of up to 17 units (and sometimes even more) in one square inch of panel area.

TRIMPOT Potentiometers are accurate:
Screw-driver adjustment gives as much as 9000° of rotation ...you can make and repeat the finest adjustments.

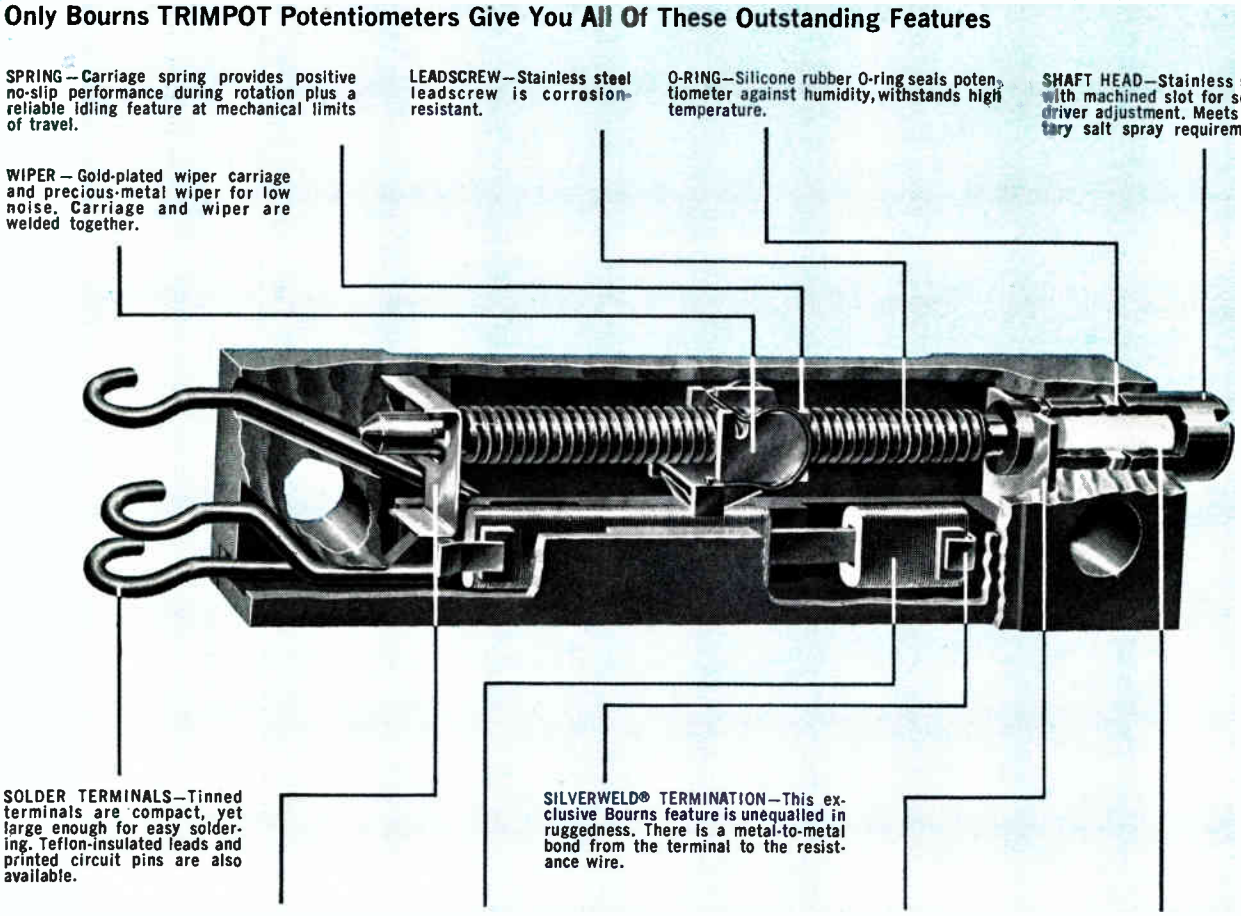
TRIMPOT Potentiometers are stable:
Adjustment shaft is self-locking...settings are virtually immune to acceleration, vibration and shock.

TRIMPOT Potentiometers are fully tested:
All units are 100% inspected before shipment and are checked by Bourns' exclusive Reliability Assurance Program to assure you of reliable performance.

TRIMPOT Potentiometers are proven:
They are backed by over 17 years of engineering know-how and have been specified and used in more military, industrial or commercial equipment than any other leadscrew potentiometer in the world!

REMEMBER—IF IT'S TRIMPOT, IT'S BOURNS

Only Bourns TRIMPOT Potentiometers Give You All Of These Outstanding Features



This cutaway of Model 224 shows the typical high quality to be found in all Bourns TRIMPOT potentiometers, although some features may vary from model to model.

...longest record of reliability

TRIMPOT® POTENTIOMETERS—UNSEALED

General-Purpose Wirewound Model 200. Max. temp. 105° C / L, S, P terminals / 0.50 watt at 70°C / 10 ohms to 100K.

General-Purpose RESISTON® Carbon Element Model 215. Max. temp. 125°C / L, S, P terminals / 0.25 watt at 50°C / 20K to 1 Meg.

High-Temperature Wirewound Model 260. Max. temp. 175°C / L, S, P terminals / 1.0 watt at 70°C / 10 ohms to 100K.

TRIMPOT POTENTIOMETERS—HUMIDITY PROOF

General-Purpose RESISTON Carbon Element Model 235. Max. temp. 135°C / L, S, P terminals / 0.25 watt at 50°C / 20K to 1 Meg.

General-Purpose Wirewound Model 236. Max. temp. 135°C / L, S, P terminals / 0.8 watt at 70°C / 10 ohms to 100K.

Micro-Miniature High-Temperature Wirewound Model 3000. Max. temp. 175°C / P terminals / 0.5 watt at 70°C / 50 ohms to 20K.

Micro-Miniature High-Temperature RESISTON Carbon Element Model 3001. Max. temp. 150°C / P terminals / 0.20 watt at 70°C / 20K to 1 Meg.

Sub-Miniature High-Temperature Wirewound Model 220. Max. temp. 175°C / L, W terminals / 1.0 watt at 70°C / 10 ohms to 30K / Mil-Spec style RT10 and meets MIL-R-27208A.

High-Temperature Wirewound Model 224. Max. temp. 175°C / L, S, P terminals / 1.0 watt at 70°C / 10 ohms to 100K / Mil-Spec style RT12 and meets MIL-R-27208A.

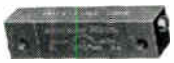
Ultra-Reliable High-Temperature Wirewound Model 224-500. Max. temp. 150°C / L, P terminals / 0.5 watt at 70°C / 100 ohms to 20K. Performance and reliability statistically verified to customer.

High-Temperature, High-Resistance RESISTON Carbon Element Model 3051. Max. temp. 150°C / L, S, P terminals / 0.25 watt at 50°C / 20K to 1 Meg / Mil-Spec style RJ11 and meets MIL-22097B.

High-Temperature High-Resistance PALIRIUM® Film Element Model 3052. Max. temp. 175°C / L, P terminals / 1.0 watt at 70°C / 10K to 1 Meg.

High-Temperature, Low-Resistance PALIRIUM Element Model 3053. Max. temp. 175°C / L, P terminals / 0.5 watt at 70°C / 2 ohms to 100 ohms.

High-Temperature Wirewound Model 3010. Max. temp. 175°C / L, P terminals / 1.0 watt at 70°C / 10 ohms to 100K / Mil-Spec style RT11 and meets MIL-R-27208A.



High-Temperature RESISTON Carbon Element Model 3011. Max. temp. 150°C / L, P terminals / 0.25 watt at 50°C / 20K to 1 Meg / Mil-Spec style RJ11 and meets MIL-R-22097B.

High-Temperature High-Resistance PALIRIUM Element Model 3012. Max. temp. 175°C / L, P terminals / 1.0 watt at 70°C / 10K to 1 Meg.

⅜"-Square Wirewound Model 3280. Max. temp. 175°C / L, P, W terminals / 1.0 watt at 70°C / 10 ohms to 50K.

⅜"-Square RESISTON Carbon Element Model 3281. Max. temp. 150°C / L, P, W terminals / 0.5 watt at 50°C / 20K to 1 Meg.

½"-Square, High-Temperature Wirewound Model 3250. Max. temp. 175°C / L, P, W terminals / 1.0 watt at 70°C / 10 ohms to 50K / Mil-Spec style RT22 and meets MIL-27208A.

½"-Square High-Temperature RESISTON Carbon Element Model 3251. Max. temp. 150°C / L, P, W terminals / 0.50 watt at 50°C / 20K to 1 Meg / Mil-Spec style RJ22 and meets MIL-R-22097B.

BOURNS® SINGLE-TURN POTENTIOMETERS

⅜"-Diameter Micro-Miniature High-Temperature Humidity-Proof Wirewound Model 3300. Max. temp. 175°C / P, S terminals / 0.5 watt at 70°C / 50 ohms to 20K.

⅜"-Diameter Micro-Miniature High-Temperature Humidity-Proof RESISTON Carbon Element Model 3301. Max. temp. 150°C / P, S terminals / 0.25 watt at 70°C / 10K to 1 Meg.

Sub-Miniature Wirewound Model 3367. Max. temp. 105°C / P, S terminals / 0.5 watt at 70°C / 10 ohms to 20K / meets steady-state humidity.

Sub-Miniature RESISTON Carbon Element Model 3368. Max. temp. 105°C / P, S terminals / 0.25 watt at 50°C / 20K to 1 Meg / meets steady-state humidity.

LOW-COST COMMERCIAL POTENTIOMETERS

Wirewound TRIMIT® Potentiometers Models 271, 273, 275. Max. temp. 85°C / L, S, P terminals / 0.5 watt at 25°C / 50 ohms to 20K.

RESISTALOY® Carbon Element TRIMIT Models 272, 274, 276. Max. temp. 85°C / L, S, P terminals / 0.2 watt at 25°C / 20K to 1 Meg.

Wirewound E-Z-TRIM® Potentiometer Model 3067. Max. temp. 85°C / S, P terminals / 0.5 watt at 25°C / 100 ohms to 20K / Priced under $1 in production quantities.

Carbon Element E-Z-TRIM Potentiometer Model 3068. Max. temp. 85°C / S, P terminals / 0.2 watt at 25°C / 20K to 1 Meg.

SPECIAL-PURPOSE POTENTIOMETERS

High-Power (2 watts) High-Temperature Wirewound Model 207. Max. temp. 175°C / L terminals / 2 watts at 50°C / 100 ohms to 100K. As Rheostat Model 208, available 100K to 200K.

High-Power (5 watts) Humidity-Proof Wirewound Model 3020. Max. temp. 200°C / L terminals / 5.0 watts at 25°C / 100 ohms to 50K.

Dual-Element Wirewound TWIN-POT® Potentiometer Model 209. Max. temp. 135°C / L terminals / 0.50 watt (each element) at 70°C / 10 ohms to 50K.

15 watts, High-Temperature Wirewound Model 3030. Max. temp. 265°C / L terminals / 15 watts at 25°C / 10 ohms to 10K.

Radiation-Resistant, High-Temperature Wirewound Model 3040. Max. temp. 350°C / W terminals / 5.0 watts at 70°C / 500 ohms to 20K.

PANEL-MOUNTED POTENTIOMETERS

Most models are available with panel mounting. Unique design permits quick factory assembly to "on-the-shelf" units. In addition, mounting screws, brackets and clip brackets are available from factory or distributor stocks to meet almost any mounting requirement.

KEY TO TERMINAL TYPES

L=Insulated stranded leads

S=Solder lugs (includes panel-mounting bushing on Models 3367S, 3368S, 3300S and 3301S only)

P=Printed-circuit pins

W=Uninsulated wires (edge-mounting 3250, 3251, 3280 and 3281).

Write **TODAY** for detailed specifications on any model in the large BOURNS® Potentiometer and TRIMPOT® Potentiometer line **AND** the name of your local stocking distributor.

TRIMPOT® *means* BOURNS, BOURNS *means* quality, so remember—don't MIL-SPEC-ulate . . . SPECify BOURNS.

TRIMPOT is a registered trademark of Bourns, Inc.

BOURNS

BOURNS, INC., TRIMPOT DIVISION
1200 COLUMBIA AVE., RIVERSIDE, CALIF.
PHONE 684-1700 • TWX: 714-682 9582
CABLE: BOURNSINC.

MANUFACTURER: TRIMPOT® & PRECISION POTENTIOMETERS, RELAYS; TRANSDUCERS FOR PRESSURE, POSITION, ACCELERATION. PLANTS: RIVERSIDE, CALIFORNIA; AMES, IOWA; TORONTO, CANADA

NEW TECH DATA

ROTARY COMPONENTS

Induction Motors

Curves for temp. rise and speed vs. torque are shown for Type S, 2-pole shaded-pole induction motors of 1/85th to 1/400th hp. in Bulletin SA-40. Of special interest is a chart of temp. equilibrium at various load points from 1 to 5 oz.-in. for each of 5 models covering the power range from 1/85th to 1/400th hp. This allows the designer to predetermine temp. rise under given load conditions. Heinze Electric Co., Lowell, Mass.

Circle 356 on Inquiry Card

Brushless Generators

Bulletin GET-3137, 16 pages, provides technical data on generator set that has no brushes, slip rings, or commutators. The 3 components of the set—brushless generator, brushless exciter, and silicon-controlled-rectifier voltage regulator—are described and illustrated. Circuit diagrams of the SCR voltage regulator are included. Charts and equations are provided to help estimate generator voltage dips and recovery voltage. General Electric Co., Schenectady 5, N. Y.

Circle 357 on Inquiry Card

Synchronous Motor

This literature describes a heavy duty synchronous motor, type PC series, that is instantly reversible, with a start-stop capability of 10msec. It is available from 40 in. oz. to 120 in. oz. The motor runs continously with clutch and brake controlled by switching actuator only. Literature includes all specs. on a positive clutch that starts the output shaft within 10msec., and a brake that will stop output shaft within 1/10° at 1 rpm or within 6° at 60 RPM. Speeds are available from ½ rpm to 360 RPM. Hurst Mfg. Co., Princeton, Ind.

Circle 358 on Inquiry Card

Induction Motors

Bulletin #164A presents new line of permanent split capacitor ac induction motors and gear motors. Small, powerful ac motors are available with single and double gear reduction in 14 models, providing output shaft speeds from 1.3 to 287 rpm. Bulletin gives photos, dimensional diagrams, performance charts and complete specs. Carter Motor Co., 2760A W. George St., Chicago, Ill.

Circle 359 on Inquiry Card

AC Motor Design Guide

Bulletin B-10 describes miniature ac induction and hysteresis synchronous motors, their use, and performance characteristics. Useful information is provided to guide the designer in specifying ac motors. Globe Industries, Inc., 1784 Stanley Ave., Dayton, Ohio.

Circle 360 on Inquiry Card

SAVE $2.00* PER RELAY AND GET EXTRA CONVENIENCE TOO!

WIRE THIS

This precision-built socket starts you off to a savings of nearly $2.00* per installed LS telephone-type relay when you specify our relay-socket-cover combination instead of a similar relay with factory-wired, octal-type plug. Also (1) you have the convenience of a plug-in component, and (2) you can use a relay having more contacts than octal-type plugs will accommodate.

Two sizes of sockets are available. The 16-pin smaller one (1.39" x 1.71") accepts relays with contact arrangements from 1 Form C to 4 Form C. The larger 28-pin one (1.39" x 2.11") will take relays with contact arrangements up to 8 Form C. Each size socket has four coil terminals for single or dual coil relays.

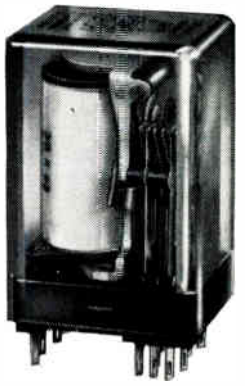
**Approximate. Based on single lot price. Savings depend on contact arrangements.*

PLUG RELAY IN

Plug the LS into the socket . . . just as you would a vacuum tube. The relay's tab terminals mate snuggly with the socket, will hold the relay in place under normal conditions. When the relay is mounted horizontally, or when vibration is a problem, two banana plugs or two machine screws may be used.

A choice of cadmium or gold plated socket terminals is available . . . and the pierced solder terminals are designed also for AMP-78 taper tab connectors.

SLIP ON DUST COVER



The transparent, high impact, high temperature resistant dust cover fits over the socket nearly flush with the chassis. Covers as well as sockets of either size may be purchased separately. With socket and cover, the LS relay is designated the LSP . . . a sparkling addition to this series of reliable telephone type relays.

Here is a neat, modern, cost-reducing approach to using the reliable, versatile LS relay. Better send for complete information today.

LS SERIES ENGINEERING DATA

GENERAL

Description: Medium coil telephone type relay with bifurcated contacts.

Time Values:

AC: Operate: 3 to 15 milliseconds. Release: 3 to 15 milliseconds.

DC: Operate: 5 to 50 milliseconds. Release: 5 to 140 milliseconds.

Precise time values depend upon coil power and contact arrangement.

Operate and release time delay slugs and fixed or adjustable residuals are available for DC relays.

Expected Life: 100,000,000 mechanical operations minimum.

Contacts: 100,000 operations minimum at rated load.

Temperature Range: −55°C to +85°C standard (+105°C available on special order).

Weight: Approximately 3¼ ozs. (open).

CONTACTS:

Arrangements: AC: Up to 12 springs (6 per stack-4 movables). DC: Up to 24 springs (12 per stack).

Material: ⅛" dia. twin palladium is standard for bifurcated contact arms. Gold-alloy, other contact materials, and single contacts are available for specific applications.

Rating: AC: 4 amps @ 115 volts AC, 60 cycle resistive (open relay @+25°C). DC: 4 amps 28 volts DC resistive.

COILS:

Voltage: AC: To 230 volts 60 cps. DC: To 220 volts.

Resistance: DC: 55,000 ohms maximum.

Power: AC: 4.37 voltamps. DC: 65 milliwatts per movable arm minimum, 5 watts maximum @+25°C.

Duty: Continuous.

RIDE THE AMF MONORAIL AT THE NEW YORK WORLD'S FAIR

STANDARD P&B RELAYS ARE AVAILABLE AT LEADING ELECTRONIC PARTS DISTRIBUTORS

POTTER & BRUMFIELD

Division of American Machine & Foundry Company, Princeton, Indiana

In Canada: Potter & Brumfield, Division of AMF Canada Ltd., Guelph, Ont.

Circle 101 on Inquiry Card

NEW TECH DATA

ROTARY COMPONENTS

Motors Catalog

This catalog describes 5 types of shaded-pole and permanet split-capacitor motors. It lists the different variations in hp, voltage freq., RPM and dimensions for each of the 5 motors. Available shaft sizes and other optional features are also indicated where applicable. The Leece-Neville Co., Georgia Div., Athens Hwy., Gainesville, Va.

Circle 361 on Inquiry Card

Fan

Bulletin F-3201 describes half-size AX-2 fan designed to meet military specs. for use in ground support equipment and airborne installations. The AX-2 measures 1⅛ in. deep; 2 in. dia.; delivers 30 cfm of air against relatively high static pressures found in compact electronic assemblies. Motors are available from 115 to 220vac, single or 3-phase, and 60 to 1600 CPS. Bulletin lists complete technical and performance data. Rotron Mfg. Co., Inc., Woodstock, N. Y.

Circle 362 on Inquiry Card

Rotating Devices

This 1964 catalog features a full line of small ac motors and rotating devices made to military and high quality commercial specs. It includes blowers, fans, blower cabinets, servo and gear motors, induction and synchronous motors and the new polarized synchronous and brushless dc motors. It is completely detailed and contains full dimensions, performance curves and electrical specs. and data on all equipment shown. Rotating Components, Inc., Dept. C, 1560 Fifth Ave., Bay Shore, N. Y.

Circle 363 on Inquiry Card

Servo Motor Catalog

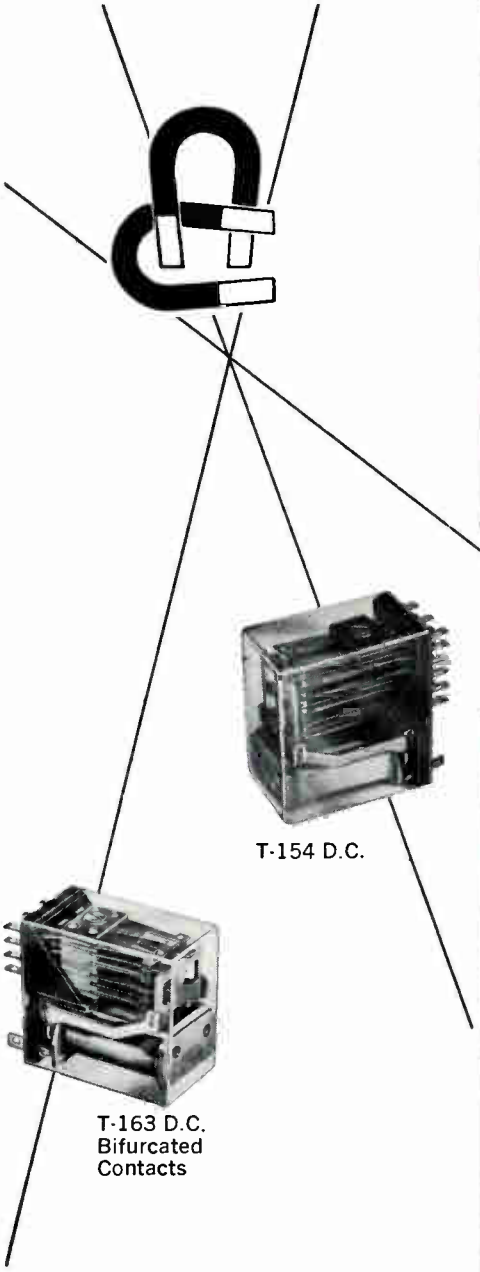
This 48-page catalog gives extensive electrical and mechanical characteristics on a wide line of synchros, servo motors, precision computing resolvers, linear transformers, motor tachometers and many more rotating components. Synchro data is included for sizes 8, 10, 11, 15, and custom designed gyro pick-off synchros. Also included is detailed data on a line of 360° angle counters. The catalog contains considerable information of a general nature relative to the rotating components and servo mechanisms field. Clifton Precision Products, 5050 State Rd., Drexel Hill, Pa.

Circle 364 on Inquiry Card

Motors/Servos Catalog

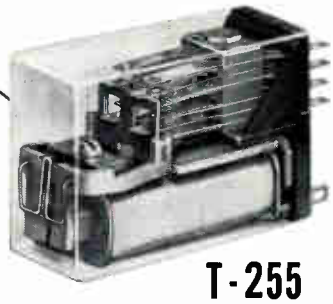
This 10-page catalog contains photos and specs. for a line of motors, motor generators, precision gearing, synchros, resolvers, wirewound and induction pots. Data is also given for brakes and clutches. Kearfott Div., General Precision Aerospace, Little Falls, N. J.

Circle 365 on Inquiry Card



NEW ALLIED a-c TELEPHONE TYPE RELAY small...hum-free...versatile

Latest addition to Allied's line of cradle® relays



T-255
Actual Size

- LOW COST
- VERSATILE—Up to four-pole, gold plated contacts for low level up to 2 amps.
- UNUSUALLY QUIET—Unique split armature* design provides hum-free a-c operation. Coils available up to 220V-ac
- FLEXIBLE—Plug-in base identical to Allied's widely used T-154 d-c type
- DUST COVER—At no extra cost
- SMALL SIZE—Smallest 4-pole a-c relay with dust cover
- DURABLE—Mechanical life over 50,000,000 operations
- ADAPTABLE—Terminals are pierced—can be soldered to directly
- CONTACT OPTIONS—Five amp. contacts or bifurcated (for extreme low level conditions)

*PAT PENDING

SEND FOR T-255 CATALOG SHEET

ALLIED CONTROL COMPANY, INC.
2 EAST END AVENUE, NEW YORK, N. Y. 10021

AL-282

NEW TECH DATA

Torque Motor

Model 5125—160 precision "pancake" is a dc direct-drive torque motor. Designed for such uses as supplying torque on stable platform gimbals, satellite orientation systems, and capstan drives, it is applicable for other servo uses where direct drive positioning is needed. The new torque motor provides a torque of 700 oz.-in. @ 135w. input. The unit weighs 5 lbs. and has a damping factor of 30 oz. in/rad/sec., a no-load speed of 230 rpm and an electrical time constant of 0.002 sec. For details contact Magnetic Technology, Inc., 13735 Saticoy St., Van Nuys, Calif.

Circle 366 on Inquiry Card

Components & Cooling Devices

This 12-page condensed catalog describes a line of servo components and cooling devices. The catalog includes data on instrument servomotors, power servomotors, resolvers, phase shifters, servo amplifiers, commercial instrument motors, precision cooling devices, and SCR and electro-mechanical packages. The Singer Co., Diehl Div., Somerville, N. J.

Circle 367 on Inquiry Card

Synchronous Motors

The Slo-Syn Synchronous Motors are designed for high-vacuum, high-temp. and high-radiation uses. They are available in torque ratings from 25 to 1800 oz.-in. They are bidirectional, permanent magnet ac motors having a basic shaft speed of 72 RPM synchronous with a line freq. of 60 cycles and possessing instant start, stop and reverse characteristics. They can also be used for phase-switched dc stepping. More data available from The Superior Electric Co., Bristol, Conn.

Circle 368 on Inquiry Card

Servo Hardware

This catalog lists a complete new line of servo hardware items. Synchro mounting clamps, gear clamps, cam assemblies, precision cam followers, precision collars, slip clutch assemblies and couplings are available. All parts are manufactured to the latest military specs. Special hardware can be supplied on request. Anatronic Systems, Inc., 909 Pico Blvd., Santa Monica, Calif.

Circle 369 on Inquiry Card

Right-Angle Drive

This remote-control system component is used for transmission of rotary motion where interferences, obstructions, or sharp bends are encountered between the drive and driven members of servo mechanism, instrumentation, remote control, and similar systems. Unique features incorporated in this drive are described in detail in Bulletin #6496. Kupfrian Mfg. Div., Robinson Technical Products Inc., 169 Prospect Ave., Binghamton, N. Y.

Circle 370 on Inquiry Card

ROTARY COMPONENTS

Total figures for the entire market that includes servo motors, synchros, resolvers, blowers and fractional and sub-fractional hp motors, are either not available, or they include too many varieties of motors and other rotary units for general usage, in addition to electronic.

	1964	1965	1966
	(in millions of dollars)		
Small Motors—Fractional and Sub-Fractional hp (including precision type for Instruments and EDP.)	$75	$85	$90
Blowers—for instruments, computers, etc.	34	43	44
Synchros & Resolvers	32	32	33
Servo Motors	29	30	33

(Figures based on a limited EI survey among 300 leading component manufacturers.)

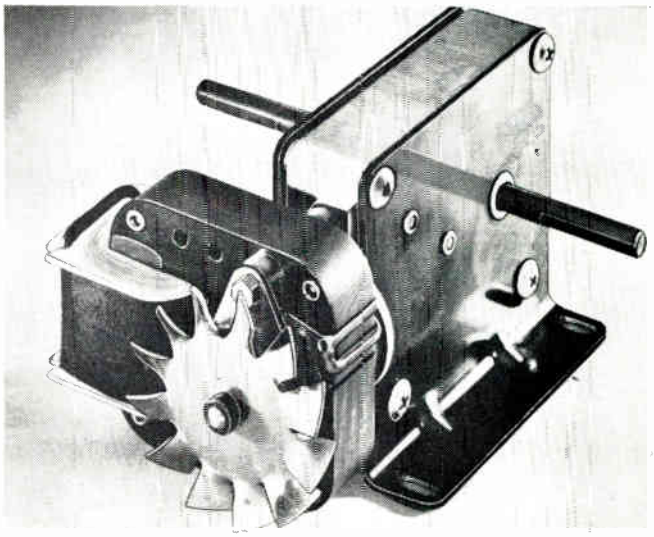
ELECTROMECHANICAL COMPONENTS SWITCHES

Accurate figures for the numerous varieties of switches for electronic use are hard to determine. Average total sales for 1964 are estimated at $29 million for all types. The sample categories listed below are not the entire switch market.

	1964	1965	1966
	(in millions of dollars)		
Total Switch Market	$29	$31	$33
Slide Switches	6	7	8
Push Button Switches	.34	.37	.39
Coaxial Switches	4.5	4.8	5.2

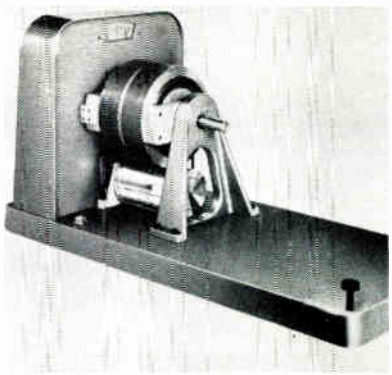
(Figures based on a limited EI survey among 300 leading component manufacturers.)

ROTARY COMPONENTS: DEVICES FOR CONTROL, MEASURING, AND COOLING



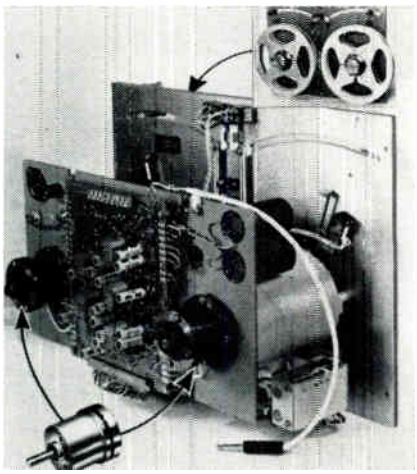
Type LA sub-fractional hp worm-drive gearmotor is an ac 2-pole unit. Made by Bravel Products, it has output speeds from ¾ to 150rpm and output torque to 50 in.-lb. They are available in voltages from 24-220v, 50-60cps.

Hurst's PC Series is instantly reversible with a start-stop capability of 10 msec.

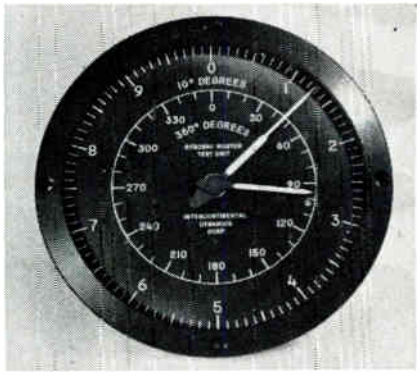


Magtrol's HD-805 dynamometer is available in three torques. Speed range to 8000rpm.

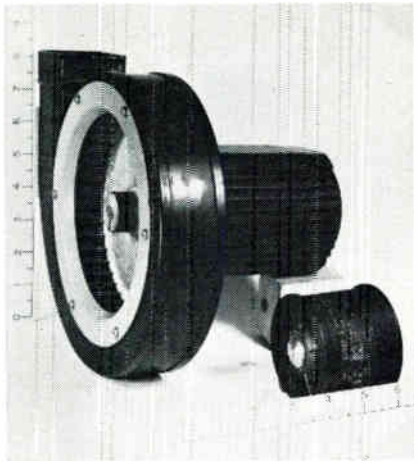
Type 6212-01-02 motor tach generator, developed by John Oster Mfg. Co., has a ±3° phase shift. Linearity is 0.09%; freq. variation is 0.06%/cycle. Stall torque, 0.1 in. oz.



Simplatrol 60 brakes stop in msec. high-speed reels operating at 700rpm.



Intercontinental Dynamics' SM 12834 reads-out the angle of a synchro transmitter.

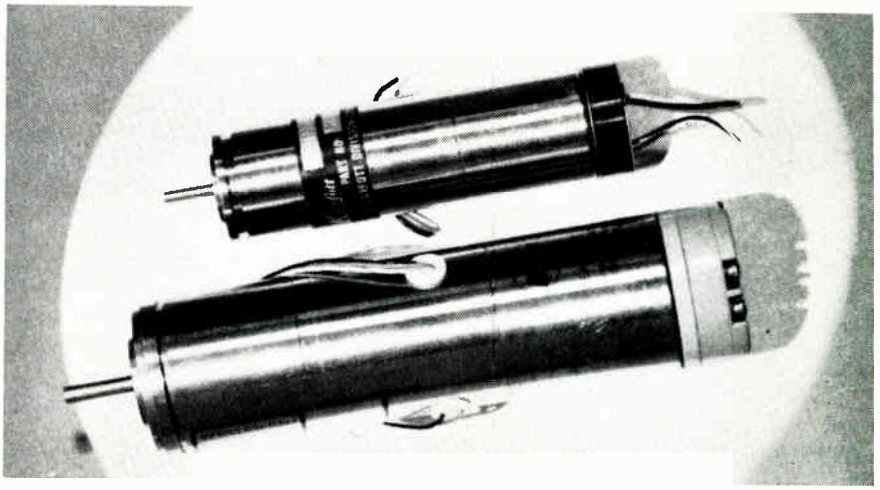


Rotron's small vaneaxial fan does the same job as the larger squirrel-cage unit.

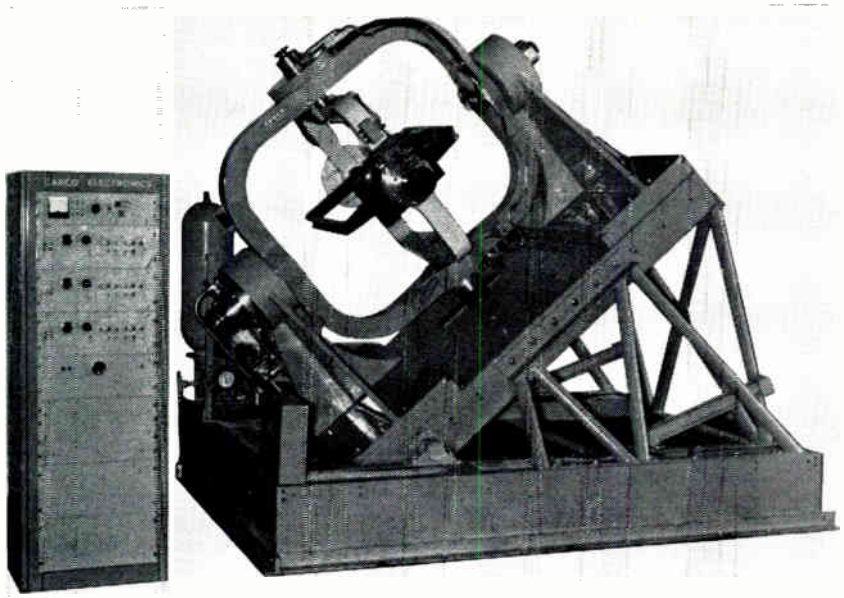
ROTARY COMPONENTS (Continued)

Model PPR-22 allows any synchro or resolver output to be converted to parallel, decimal code. The digital representation drives 4-digit indicators and printers. Accuracy of the unit is 1 part in 3600. It is a product of Theata Instrument.

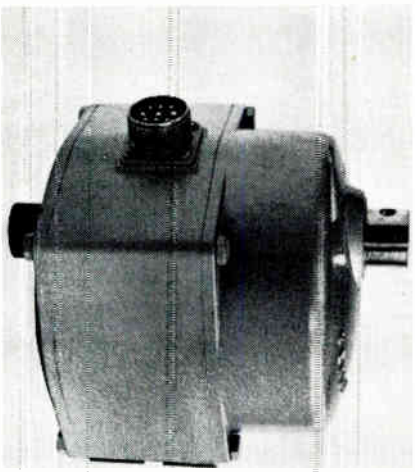
A packaging concept, developed by General Precision Aerospace, allows tandem packaging of two synchros. This has produced a tandem synchro that has no gears or backlash.



This motor speed control, by Minarik, is a feedback unit with 20:1 speed range.

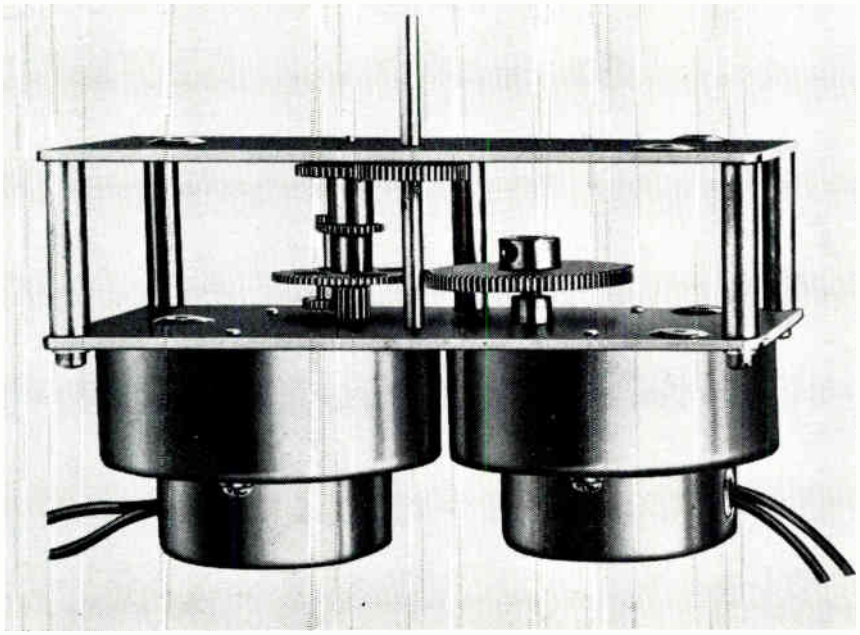


Carco's model S-480A 3-axis flight simulator provides a dynamic velocity ratio of over 1,750,000 to 1. Angular acceleration exceeds 37,000°/sec².; freq. response above 23cps.



ITT's model DM-8 is a heavy-duty, electric - gear - driven device. It is designed for converting manually activated valves —ball, plug, gate, or globe-screw stem— or dampers, to remote manual control.

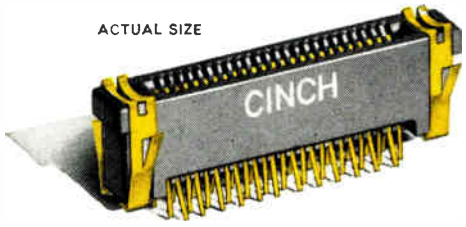
Model 42 dual-speed synchronous motors can rotate in the same or opposite directions at speeds of 180 to 1rpm. Made by Bristol Motors, they can be used in chart drives, control devices, or timers.



Cinch ELECTRONIC COMPONENTS

Cinch Tykon®* versatile miniature .050" centers

ACTUAL SIZE



PRINTED CIRCUIT BOARD CONNECTORS

Here is the industry's most adaptable, high density (.050" centers) connector for $\frac{1}{16}$" double-sided board. TYKON leads can be wire-wrapped, welded, hand soldered or dip soldered. TYKON can be mounted above the chassis or semi-flush with the surface.

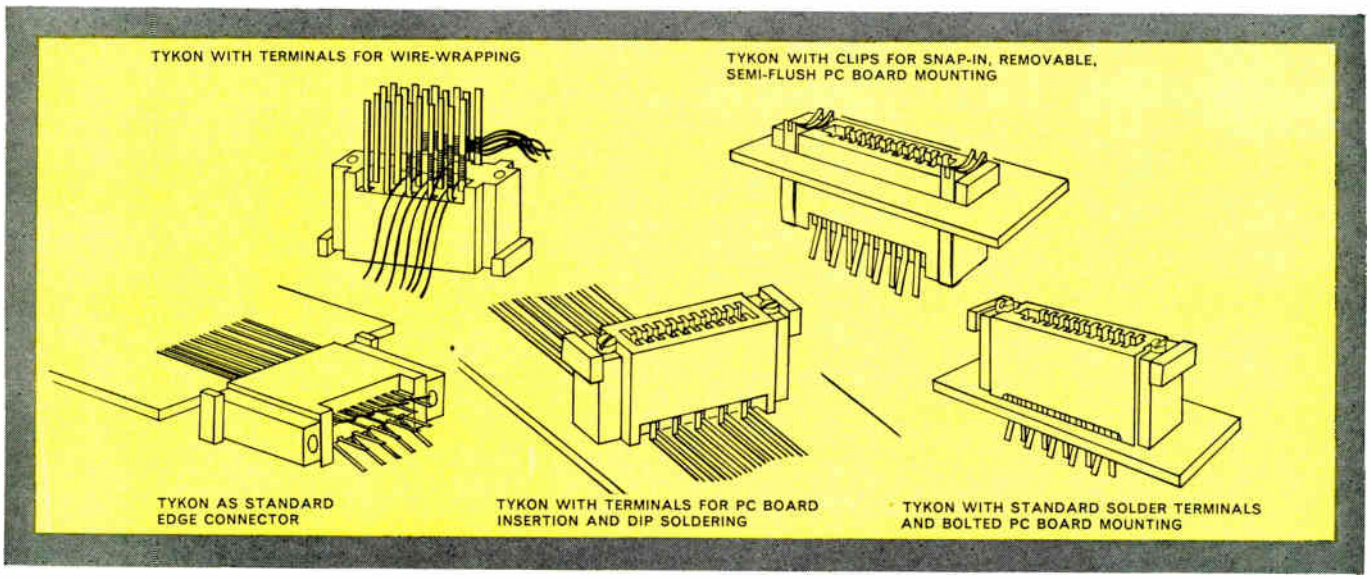
TYKON's ribbon-type, flexing action contacts provide a large contact surface for positive, reliable connections. You can use the Cinch TYKON in standard and thin film memory planes, diodes on insulating substrates, all types of modular plug-in devices, and a multitude of other high density applications.

Specifications:

6, 10, 15, 20 and 25 double contact positions are standard and intermediate sizes are available on special order. Contacts are phosphor bronze, 30 micro inches gold over copper flash; insulators are glass filled diallyl phthalate per MIL-M-14F, type SDG-F. Insertion and withdrawal force is from 5 to 23 pounds, depending upon connector size. The mounting clip is carbon steel with cadmium plate plus yellow chromate finish.

For detailed information and technical data write for Product Bulletin PBM-13.

*Patent Pending



CM-6312

CINCH MANUFACTURING COMPANY
1026 South Homan Avenue, Chicago 24, Illinois
Plants located in Chicago, Illinois; Shelbyville, Indiana; City of Industry, California; and St. Louis, Missouri.

DOT A DIVISION OF UNITED-CARR FASTENER CORPORATION, BOSTON, MASSACHUSETTS

Circle 111 on Inquiry Card

NEW DEVELOPMENTS IN INTERCONNECTION TECHNIQUES

ELECTRONIC INDUSTRIES
REFERENCE ISSUE
CIRCUIT INTER-CONNECTORS

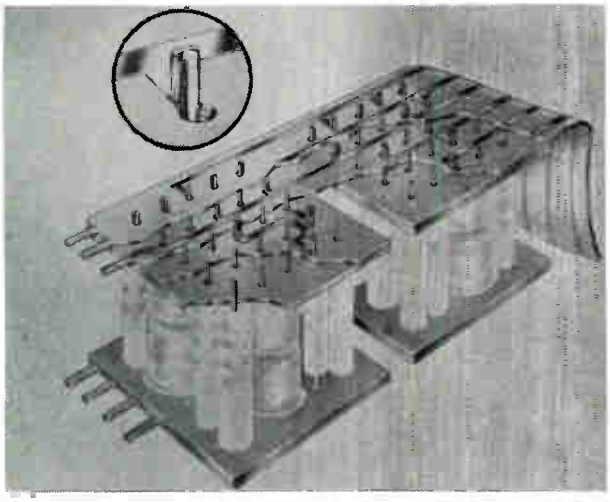


Fig. 1: One form of intra-module package is the cordwood.

By WARREN V. BUSTER
Engineering Manager, Systems Packaging
Amphenol, A Div. of the Amphenol-Borg Electronics Corp.,
Broadview, Ill.

THE DEMAND ON EQUIPMENT MANUFACTURERS to reduce the size and weight of equipment and increase reliability has caused the packaging engineer to use every available source of improved interconnecting methods. (*Continued on page* 130)

Fig. 2: Planner is for miniature uses.

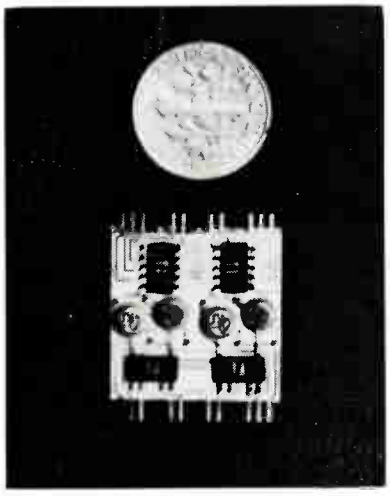


Fig. 3: This intra-module is a hybrid substrate with separate header and interconnections.

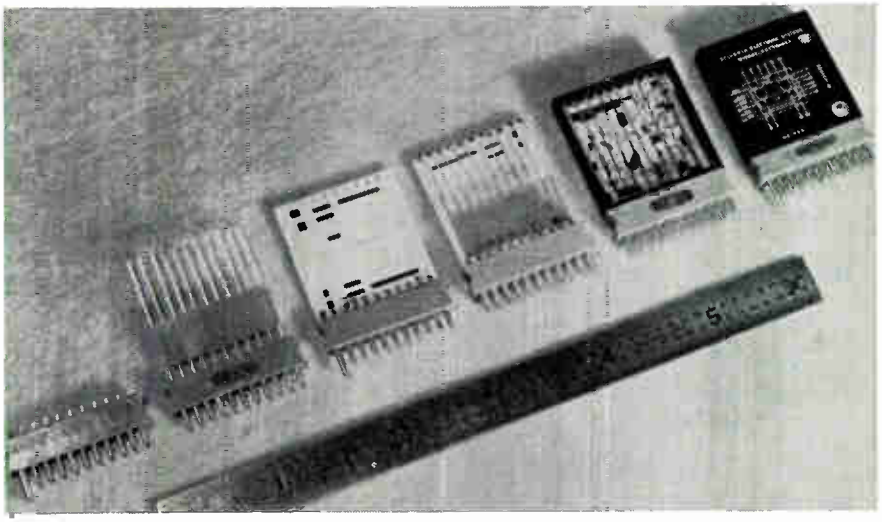


Fig. 4: A hybrid ceramic header with integral header is another package.

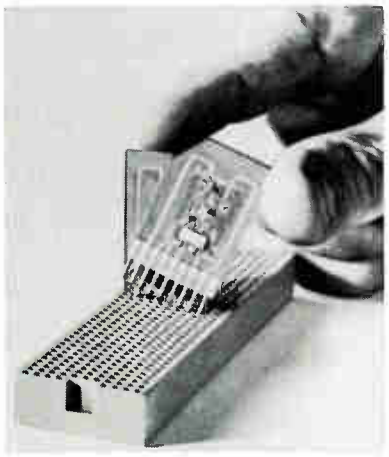


Fig. 5: In this module-to-motherboard configuration, interconnections may be soldered, welded, or crimped. Wire wrapping and mating connectors may also be used.

INTERCONNECTION TECHNIQUES (Continued)

In the past, the standard spacing used for component and connectors was based on centers of 0.156, 0.200 and 0.250 in. The development of semi-conductors caused the industry to reduce the size of the other components used in systems, including connectors and interconnections. Thus, connectors and interconnecting devices with spacings of 0.100, 0.050, and 0.025 in. were developed.

Best Compromise

Interconnections have always been made by connectors which are the best compromise between maximum reliability and ease of servicing. The basic part of any connector is the individual contact. Predominant in this field has been the pin and socket contacts with solid machined male-pin and flexible female counterparts. But as contacts of this type become smaller, their cost rises sharply. Fortunately, design efforts and state-of-the-art improvements in automated assembly techniques have produced economical miniature contacts. These contacts are produced in a variety of sizes with some small enough to fit on centers 0.075 in. and still include the poke-home feature. Interconnections are made by crimping, welding, soldering or wire wrapping, depending upon the contact configuration and /or the individual designer's preference.

In some cases the contacts may be applied directly to modules, printed-circuit cards, or motherboards. In others the associated connector bodies may be used as furnished or cut and cemented together to form special motherboards or module headers.

Different Techniques

The techniques used to establish interconnecting circuitry offer considerable freedom to the packaging engineer. These choices vary from the highly sophisticated welding techniques used on integrated substrates or hybrid thin-films, to the established methods of welding or flow soldering on printed-circuit boards.

Welding active components to thin-film passive circuitry, or external interconnections to and from integrated substrates is usually done by parallel gap welding or variations of thermal-compression bonding. Although soldering can be used for thin-film interconnections, it greatly limits the designer in the degree of miniaturization or packaging density that can be achieved.

The less sophisticated but still highly required techniques of intra-circuit interconnections may be accomplished by soldering or welding. Soldering may be done by hand or with the aid of a flow soldering

(*Continued on page* 132)

SOMEDAY MIL-SPECS WILL REQUIRE WHAT THIS NEW MICRODOT CONNECTOR PROVIDES TODAY

You're looking at a revolutionary hermetic design utilizing crimp-type contacts in a multi-pin layout. Developed by Microdot Inc., it represents an important breakthrough in connector technology. For example, leakage rate exceeds the requirements of MIL-C-26482 and MIL-C-26500B by a factor of approximately 100; temperature rating is from −67°F to +257°F; insulation resistance is more than 5000 megohms between pins; the connector is rated for 1000 V test, 750 V rms working at sea level, 350 V rms at 70,000 feet.

The unique Microdot design results in a superior strength seal by compression bonding the glass insert within its hermetic housing. Up to 61 double-ended pins spaced on 80 mil centers can be embedded in this insert. **No heat damage can occur . . . not to the glass seal, not to the insulation!**

Behind the insert is an insulator with the appropriate number of recesses containing *crimp-type power sockets.* A spring-loaded follower assembly keeps the insulator immune to vibration. Standard interchangeable parts are used wherever possible and only a standard hand crimping tool is required for connecting conductors to sockets.

This state-of-the-art breakthrough could not have been anticipated when present MIL-SPECS were written. But because this connector far exceeds these MIL-SPECS, numerous deviation requests have been initiated by subcontractors and it is now incorporated in their military equipment. Doesn't your equipment deserve the latest, newest connector?

For full information on the industry's first hermetically sealed, circular, multi-crimp connector, write direct or use reader service card.

MICRODOT INC.

220 Pasadena Ave., South Pasadena, Calif.

INTERCONNECTION TECHNIQUES (Concluded)

machine, depending upon the size, shape or complexity of the items being interconnected. Welding, considered more reliable than soldering, may be done by interconnecting metallic ribbon. A more preferred method is using one of several types of miniature prepositioned weldable circuitry presently available on centers as low as 0.050 inch.

INTERCONNECTION APPROACHES

INTRA-MODULE. A module is a combination of components or devices contained in one package or common to one mounting which provides a complete function. Modules have many different forms: cordwood (Fig. 1), planner (Fig. 2), hybrid substrate with separate header and interconnections (Fig. 3.) and hybrid ceramic header with integral header (Fig. 4). The module shown in Fig. 4 is made from a newly developed precision moldable ceramic material. Here, connector contact grooves are molded as an integral part of the substrate. The circuitry was formed by the thin-film deposition process, and the active components are added by parallel-gap welding.

MODULE-TO-MOTHERBOARD. The motherboard is the first point of circuit distribution which must be considered. The interconnections at this point may be done by soldering, welding, crimping, wire wrapping and mating connectors (Fig. 5). Although the connector method adds to the size of the overall package, it gives the important advantage of serviceability.

INTRA-MOTHERBOARD. The circuit distribution which makes up the motherboard wiring is done by using a point-to-point method with its many types of wire terminations. This method, however, is time consuming and adds to the bulk of the system. The use of single or multi-layer Intercon® prepositioned wiring may be used to reduce the bulk factor and greatly increase system reliability.

MOTHERBOARD-TO-BACK PANEL. Many systems do not use back-panel wiring. But if they do, interconnections between the motherboards and the back panel may be done by interconnecting cables which are terminated by connectors suited for the currents to be distributed.

INPUT/OUTPUT. Interconnections which feed power and signal into and out of a system are generally made by connectors that easily mate and unmate.

CONCLUSION

The interconnecting devices and methods discussed are only a few that have been developed to solve individual package problems. Many systems use methods that cause interconnections to become as an integral part of the structure. These methods will become more prominent as the technology of materials, adhesives and techniques for plating on dielectric are improved.

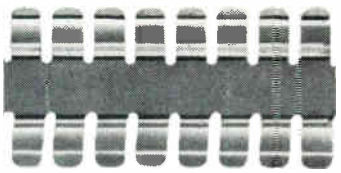
® Registered trademark of Amphenol-Borg Electronics Corp., Chicago, Ill.

BTI

CUSTOM OR STANDARD PRECISION STAMPINGS IN BERYLLIUM COPPER

- Switch and Contact Springs
- Contact Strips and Rings
- Wiping Contacts
- Printed Circuit Board Connectors
- Fuse Clips; Retainers For Diodes, Transistors Capacitors, Etc.
- Tube Shields and Socket Clips
- Crystal Holders
- Diaphragms

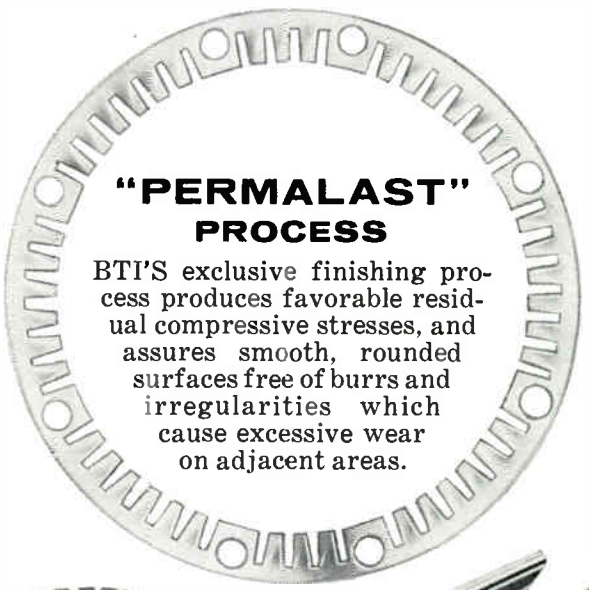
Intricate Shapes



- Multi-Springs
- Grounding Strips
- Spring Washers

Braun Tool & Instrument Company, leading supplier of Beryllium Copper components to the electronics industry, offers not only the most complete line of standard formings, but also unequaled engineering experience in this specialized area. BTI engineers stand ready to consult with manufacturers on their particular requirements, providing a depth of skill and understanding that can come only with years of practical experience.

For details on BTI engineering assistance, write, outlining your requirements, to the Applications Engineering Department at the address below.



All stock BTI components are of beryllium copper. However, custom orders can be filled in any material appropriate to the particular application. In addition, deposition of gold or silver on contact surfaces by the BTI Golbond or Silbond processes, is obtainable on many standard and custom parts.

BTI

140 Fifth Avenue, Hawthorne, New Jersey HAwthorne 7-1773 • TWX-201 427-2532

BRAUN TOOL & INSTRUMENT CO. INC.

SINGLE CONNECTOR FOR JETLINER

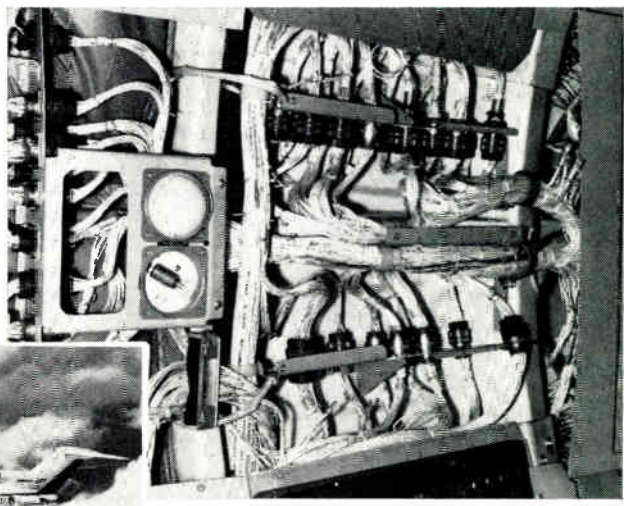


Photo of Boeing 727 cockpit overhead (r) shows MIL-C-26500 connectors and others used in instrument panel, power distribution, components and actuating devices, etc. Other photo (below) shows the 727 in flight.

Boeing is installing, almost exclusively, in each *727* jet airliner, connectors that meet Military Spec. Mil-C-26500. In using these connectors almost exclusively in the plane, Boeing is attacking two major problems: Logistics and reliability.

Since one type of connector is used so widely throughout the plane, fewer spare parts are needed than for earlier jets, where several different connector types were used.

Reliability is improved because crimped design has eliminated soldering, and the skill level required of the mechanic is reduced; and Mil-C-26500 connectors have good high-altitude, all-environment characteristics.

Mil-C-26500 calls for operating from sea level to 350,000 ft., withstanding temperature cycling from −55°F to +392°F, surviving 50 g's, resisting exposure to contaminants that cause malfunction of the equipment, and operating after an altitude immersion test that calls for altitude pressure cycling of a mated connector submerged in salt water while carrying a current.

The Mil-C-26500 Bayonet-Type connectors used on the *727* maintain an absolute environmental seal for two design-construction reasons: A heat resistant silicone insert dielectric; static peripheral and 'O' ring shell seals grommet holes with double risers that seal the wire entrance. Mating halves of the Mil-C-26500 connectors are 1-piece monoblock assemblies. The monoblock construction prevents contaminant entrapment between the insert and the grommet or shell.

A front-release contact system is used. Contact crimp and removal tools meet standard military specs.

The majority of the Mil-C-26500 connectors for the *727* are supplied by Amphenol, div. of Amphenol-Borg Electronics Corp., Chicago, Ill.

GENERAL PHYSICAL CONSTANTS RECOMMENDED BY NAS–NRC Adopted by NBS[1]

Constant	Symbol	Value	Est.* error limit	Unit: Systeme Intern. (MKSA)		Unit: Centimeter-gram-second (CGS)	
Speed of light in vacuum	c	2.997925	3	$\times 10^{8}$	$m\ s^{-1}$	$\times 10^{10}$	$cm\ s^{-1}$
Elementary charge	e	1.60210	7	10^{-19}	C	10^{-20}	$cm^{1/2}g^{1/2}$†
		4.80298	20	.....	.....	10^{-10}	$cm^{3/2}g^{1/2}s^{-1}$‡
Avogadro constant	N_A	6.02252	28	10^{23}	mol^{-1}	10^{23}	mol^{-1}
Electron rest mass	m_e	9.1091	4	10^{-31}	kg	10^{-28}	g
Proton rest mass	m_p	1.67252	8	10^{-27}	kg	10^{-24}	g
Faraday constant	F	9.64870	16	10^{4}	$C\ mol^{-1}$	10^{3}	$cm^{1/2}g^{1/2}mol^{-1}$†
Planck constant	h	6.6256	5	10^{-34}	J s	10^{-27}	erg s
Fine structure constant	α	7.29720	10	10^{-3}	.....	10^{-3}	.....
Charge to mass ratio for electron	e/m_e	1.758796	19	10^{11}	$C\ kg^{-1}$	10^{7}	$cm^{1/2}g^{-1/2}$†
		5.27274	6	.....	.....	10^{17}	$cm^{3/2}g^{-1/2}s^{-1}$‡
Rydberg constant	R_∞	1.0973731	3	10^{7}	m^{-1}	10^{5}	cm^{-1}
Gyromagnetic ratio of proton	γ	2.67519	2	10^{8}	$rad\ s^{-1}T^{-1}$	10^{4}	$rad\ s^{-1}G^{-1}$†
(Uncorrected for diamagnetism, H_2O)	γ'	2.67512	2	10^{8}	$rad\ s^{-1}T^{-1}$	10^{4}	$rad\ s^{-1}G^{-1}$†
Bohr magneton	μ_B	9.2732	6	10^{-24}	$J\ T^{-1}$	10^{-21}	$erg\ G^{-1}$†
Gas constant	R	8.3143	12	10^{0}	$J°K^{-1}mol^{-1}$	10^{7}	$erg°K^{-1}mol^{-1}$
Boltzmann constant	k	1.38054	18	10^{-23}	$J°K^{-1}$	10^{-16}	$erg°K^{-1}$
First radiation constant ($2\pi hc^2$)	c_1	3.7405	3	10^{-16}	$W\ m^2$	10^{-5}	$erg\ cm^2s^{-1}$
Second radiation constant	c_2	1.43879	19	10^{-2}	m°K	10^{0}	cm°K
Stefan-Boltzmann constant	σ	5.6697	29	10^{-8}	$W\ m^{-2}°K^{-4}$	10^{-5}	$erg\ cm^{-2}s^{-1}°K^{-4}$
Gravitational constant	G	6.670	15	10^{-11}	$N\ m^2kg^{-2}$	10^{-8}	$dyn\ cm^2g^{-2}$

*Based on 3 std. dev., applies to last digits in preceding col. †Electromagnetic syst. ‡Electrostatic syst. [1] Reprinted from NBS Technical News Bulletin, Oct. 1963.

ANOTHER EXAMPLE OF "TOTAL VALUE" ASSURANCE...

Cannon's new KV/PV Series enables a degree of connector standardization and economy never before accomplished in the industry

The KV and PV Series are designed to meet the new industry specification (NAS 1599) which incorporates features of layout and configuration of two existing specifications (MIL-C-26500 and MIL-C-26482) into one standardized specification with improved design and performance characteristics. Utilizing the same contacts, backshells and accessories, military crimping tool and expendable plastic insertion/extraction tool, both the KV and PV reduce costly connector inventories. This new series also lessens user assembly training time and simplifies control and specification drawings and user qualification testing programs.

Featuring the "Little Caesar" Rear Release System, Cannon's KV/PV Series are miniature circular high environmental plugs developed to provide reliability where it counts most...CONTACT STABILITY — POSITIVE CONTACT MATEABILITY — STRONGER, SIMPLIFIED CONTACTS. To support existing major aerospace programs, the KV (threaded coupling) and PV (bayonet coupling) intermate respectively with 26500 and 26482 type connectors. For design and performance data write for Cannon's KV/PV Catalog.

Our 50th Year

ITT

CANNON ELECTRIC INC.

3208 Humboldt Street, Los Angeles 31, California

A SUBSIDIARY OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION.

CANNON® PLUGS

NEW TECH DATA

INTERCONNECTORS

Molded Phone Plugs

Bulletin E-512 describes 4 new molded right-angle phone plugs which accept cable diameters up to 0.260 in., provide protection against moisture, minimize noise, eliminate shorts and assure positive electrical connections. The new molded right-angle phone plugs are available in cable assemblies with terminations of another right-angle phone plug, straight phone plug, extension jack, phone plug, spade lugs, alligator clips, etc. Switchcraft, Inc., 5555 N. Elston Ave., Chicago, Ill.

Circle 336 on Inquiry Card

Strip Connectors

The Ministrip miniature strip connectors come in 6 in. lengths. Simplicity of design permits the user to cut and stack connector configurations to meet specific circuit and space needs. They are available with either 0.100 or 0.075 in. Minim pin and socket contact spacing. Data available from Methode Electronics, Inc., 7447 W. Wilson Ave., Chicago, Ill.

Circle 337 on Inquiry Card

Fasteners Catalog

Catalog No. 63, 244 multi-color pages, is a complete guide to fasteners of all types. It is divided into 4 sections: 1 and 2 contain specs.; section 3 lists stock sizes; and section 4 presents engineering data. In addition, AN and MS Charts appear at the end of each product section, and a glossary of terms commonly used to designate fasteners and manufacturing methods is given. Allmetal Screw Products Co., Inc., 821 Stewart Ave., Garden City, N. Y.

Circle 338 on Inquiry Card

Connector Report

A 36-page report on a field study of connector reliability is now available. The report documents effects of terminations, seating and contamination on reliability. Copies of Report RC3-008 may be obtained from Amphenol, a div. of Amphenol-Borg Electronics Corp., 1830 S. 54th Ave., Chicago 50, Ill.

Circle 339 on Inquiry Card

Taper Pins

Bulletin P-1, 12 pages, lists the complete line of Kent Taperstrip™ and Tapertite™ products available. Solid taper pins in a plastic carrier strip are applied by machine. Series 53 solid taper pins and insulated solid taper pins are shown with dimensional drawings and catalog numbers. Also cataloged are special solid pins and a unique series 78 step-tapered tab receptacle. Hand tools for applying, insertion and extraction are shown. Kent Corp., Princeton, N. J.

Circle 340 on Inquiry Card

Coaxial Connector Catalog

This catalog describes Series GM microminiature r-f coaxial connectors. Designed for use with the newest types of tiny, lightweight cable in missile, satellite, avionic, undersea, and other equally-important applications, the GM series are the only microminiature connectors featuring a unique, protective finger design which couples the ground path to the mating connector. The catalog provides complete tech. descriptions and specs. for a wide range of GM plugs, jacks, receptacles, adapters, etc., in various configurations. Also shown are complete GM cable assembly instructions. General RF Fittings, Inc., 702 Beacon St., Boston, Mass.

Circle 341 on Inquiry Card

Components Catalog

Catalog EF46M, 44 pages, describes standard-configuration and MIL-Spec. connectors, binding posts, tube shields and sockets, plugs and other related electronic connecting devices. The catalog contains extensive dimensional drawings, physical specifications and photos, as well as electrical information, for over 700 electronic component parts. Hugh H. Eby Co., 4701 Germantown Ave., Phila., Pa.

Circle 342 on Inquiry Card

High-Current Feed-Thrus

A new flange-mounted high-current feed-thru consists of a high reliability alumina ceramic-to-metal seal with a solid OFHC copper conductor brazed into it. This is welded to a stainless-steel type 304 flange. The high-current feed-thrus are available in 3 basic current ratings: 300, 400, and 500a. Called VAC-THRU, the components can withstand bakeouts as high as 800°C. It is suitable for use in systems of 10^{-10} Torr range. Data available from Advac Products, Inc., 174 Richmond Hill Ave., Stamford, Conn.

Circle 343 on Inquiry Card

Plug Catalog

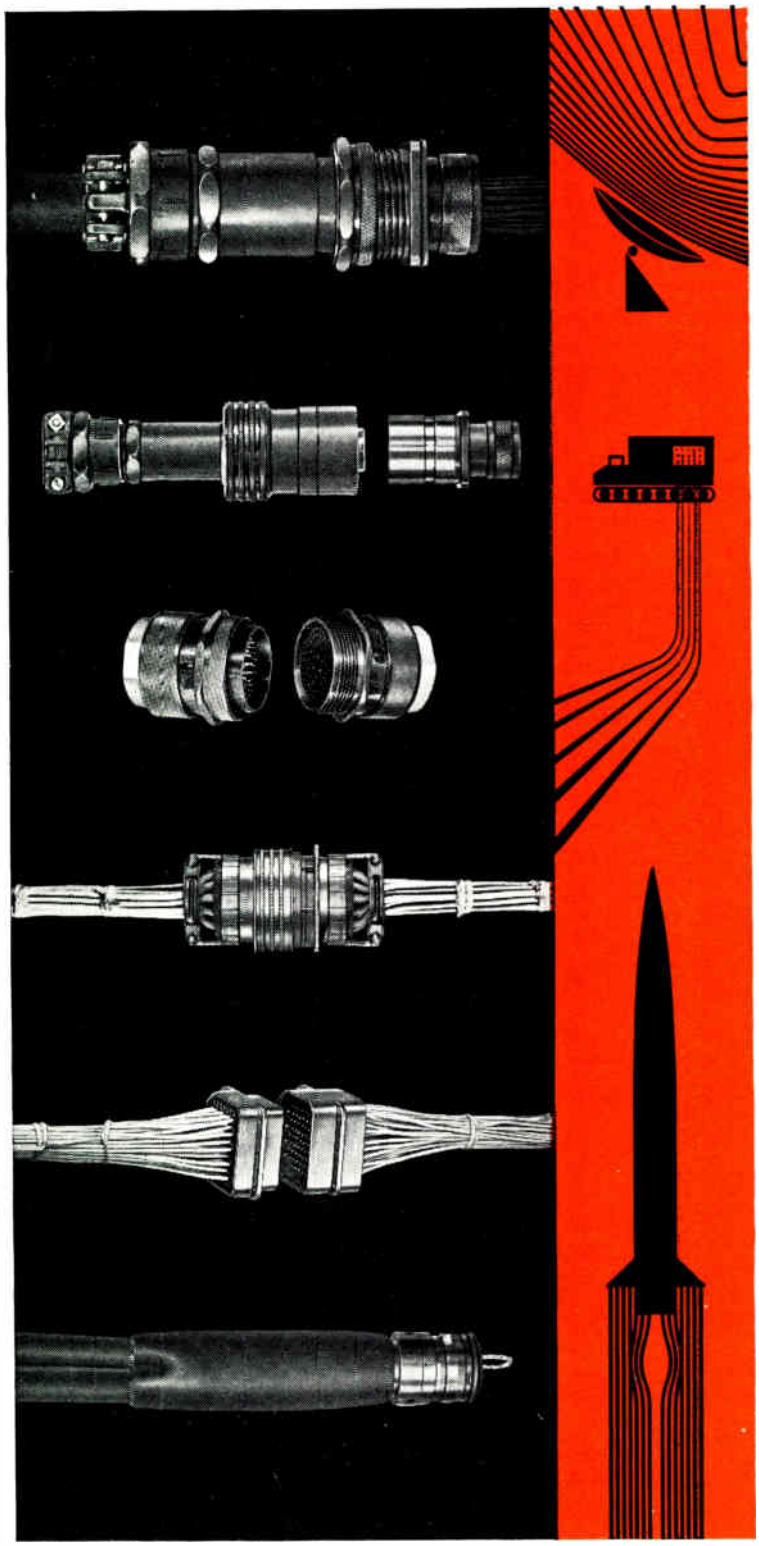
Catalog LR/MR-3 contains complete data on a series of weatherproof plugs. The LR/MR connectors are particularly suited for government uses such as missile ground support equipment and radar installations. They are also used in railroad equipment, radio and TV stations, and harbor and marine equipment. ITT Cannon Electric, Inc., Adv. Dept., 3208 Humboldt St., Los Angeles, Calif.

Circle 344 on Inquiry Card

Connectors Catalog

This 12-page catalog contains complete details on a line of multi-pin connectors. Included are technical features, mounting dimensions, descriptions of the wide range of sizes and insert layouts, and assembly instructions. Also included is data on a hermetically sealed crimp-type multi-pin connector. These new multi-pins are sealed under compression and cannot be affected by adverse atmospheric changes. In the hermetic, the quick-disconnect, and the threaded multi-pin lines, up to 61 power contacts can be provided within a shell 1 9/64 in. in dia., or up to 19 power contacts in a 49/64 in. shell. Microdot Inc., 220 Pasadena Ave., S. Pasadena, Calif.

Circle 345 on Inquiry Card



PYLE-NATIONAL EXCELS IN MEETING EXTRAORDINARY "SPECS" FOR CONNECTORS. The challenging state of sophisticated circuit connection problems spurs the State of the Art at Pyle-National. Many rely on our imaginative engineering to help them solve such tricky application requirements as: rough environments, compact size, reduced weight, rugged construction, RFI, and uncanny configurations.

Here's demonstrated proof of our capabilities in imaginative engineering....

Pyle-Star-Line® Neptune Series, heavy-duty environmental connectors. Resist moisture, shock, chemicals, corrosion, pressure, temperature extremes. Offered with inserts having: I, captive solder contacts; II, push-in crimp removable contacts; III, collet retained, rear entry and release crimp contacts. Five shell sizes, 150 insert configurations.

Pyle-Star-Line, Class Q, quick connect and disconnect connectors. Speed-up coupling and uncoupling of cable networks with straight push and pull. Field indexable with same insert configuration to 16 key positions. High reliability and durability proven under worst field conditions.

Pyle-Star-Line Test Connectors. Prevent physical and electrical damage to connector contacts while monitoring circuits. Test Probe connector couples to connector under test; Test Cable connector is potted, molded and terminated to testing cable. Easy multiple indexing.

Pyle-Star-Line, Mercury-Series, Miniature Connectors. Eliminate corrosion possibilities, extend wear-life with stainless steel shells. Qualified and exceeds rigorous MIL-C-26500B specs. Accessories meet almost every extreme operating condition, including RFI.

Ractanglar™ Rack and Panel Connectors. Permit collet-retained contacts to be snapped in and removed from terminating side of rigid inserts. Features: high-density contact configurations... chamfered closed-entry socket block... rugged aluminum alloy shells... plastic tool.

Harness Connectors. Facilitate connector terminating, potting and molding to cables. Eminently-qualified by special equipment and experience to work with cable assemblies of varying wire sizes, insulations, and jackets.

State your interest—we'll send appropriate literature. State your unsolved circuit connection problem—we'll try to provide a solution—idea.

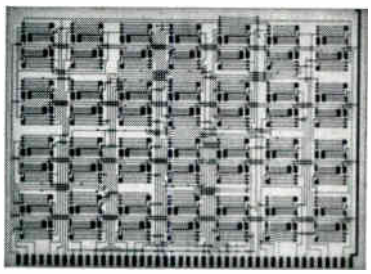
CONNECTOR DIVISION, THE PYLE-NATIONAL COMPANY, 1334 NORTH KOSTNER AVENUE, CHICAGO 51, ILLINOIS

ALSO MFD. IN CANADA BY: PYLE-NATIONAL (CANADA) LTD., CLARKSON, ONTARIO

Pyle-National

ELECTRICAL CONNECTORS LIGHTING EQUIPMENT CONDUIT FITTINGS

Technologies in systems design at IBM



Project: to produce angstrom-thin units automatically

An automatic film-fabrication process is essentially a miniature "factory." It has the problems of a full-sized plant squeezed into the space of a closet. The carefully controlled conditions of a laboratory thin film process must be maintained—but at the same time, the process steps must move reliably and at high speed.

To produce a circuit with the correct electrical or magnetic properties on its one and only pass through the vacuum fabrication process, many variables such as temperature, pressure and deposition rate must be held in delicate balance. This calls for solution to a host of instrumentation problems in measurement and control, and a basic understanding of the physical and chemical nature of the deposition process.

IBM engineers and scientists have made substantial progress in the field with development of a number of experimental thin film "factories." IBM developed the first continuous thin film fabrication line for the Navy in 1962.

This line moves substrates successively through four vacuum chambers. The line turns out hundreds of circuits an hour, containing thousands of resistive and capacitive components.

Recently, IBM scientists automated a fabrication process for experimental cryogenic circuits. The process variables needed for a particular circuit configuration are stored on punched cards and fed to a control system. All fabrication steps and process conditions are automatically controlled, resulting in thin film circuits with highly uniform, reproducible electrical properties.

But any factory can be improved. Now IBM is developing processes to fabricate different varieties of thin film circuits. Fabrication speed is being increased as well. There are many opportunities right now to make important contributions to these and other IBM scientific and engineering projects. Send your resume to: Manager of Corporate Employment, IBM Corp., Dept 557T, Armonk, New York 10504. IBM is an Equal Opportunity Employer.

There is room for achievement at

IBM®

	TO-46 Case	MAXIMUM VOLTAGES BV_{CBO} (Volts)	BV_{CEO} (Volts)	BV_{EBO} (Volts)	I_{CBO} Max. @ 25°C (μA)	h_{FE} Min.	Max.	@ I_C (mA)	V_{CE}(SAT) Max. (Volts)	f_T Typ. (MC)
NPN	2N2518	125	80	8	.005	40	100	5	0.5	175
PNP	2N2599	—125	—80	—7	—.025	40	100	—5	—0.5	90
NPN	2N2519	125	80	8	.005	80	200	5	0.5	200
PNP	2N2600	—125	—80	—7	—.025	80	200	—5	—0.5	120
NPN	2N2459	100	60	8	.002	40	80	5	0.3	175
PNP	2N2590	—100	—60	—7	—.025	40	80	—5	—0.4	75

	TO-46 Case	MAXIMUM VOLTAGES BV_{CBO} (Volts)	BV_{CEO} (Volts)	BV_{EBO} (Volts)	I_{CBO} Max. @ 25°C (μA)	h_{FE} Min.	Max.	@ I_C (mA)	V_{CE}(SAT) Max. (Volts)	f_T Typ. (MC)
NPN	2N2460	100	60	8	.002	70	130	5	0.3	200
PNP	2N2591	—100	—60	—7	—.025	70	135	—5	—0.4	100
NPN	2N2461	100	60	8	.002	120	180	5	0.3	225
PNP	2N2592	—100	—60	—7	—.025	115	200	—5	—0.4	125
NPN	2N2462	100	60	8	.002	170	230	5	0.3	250
PNP	2N2593	—100	—60	—7	—.025	160	275	—5	—0.4	150

31234

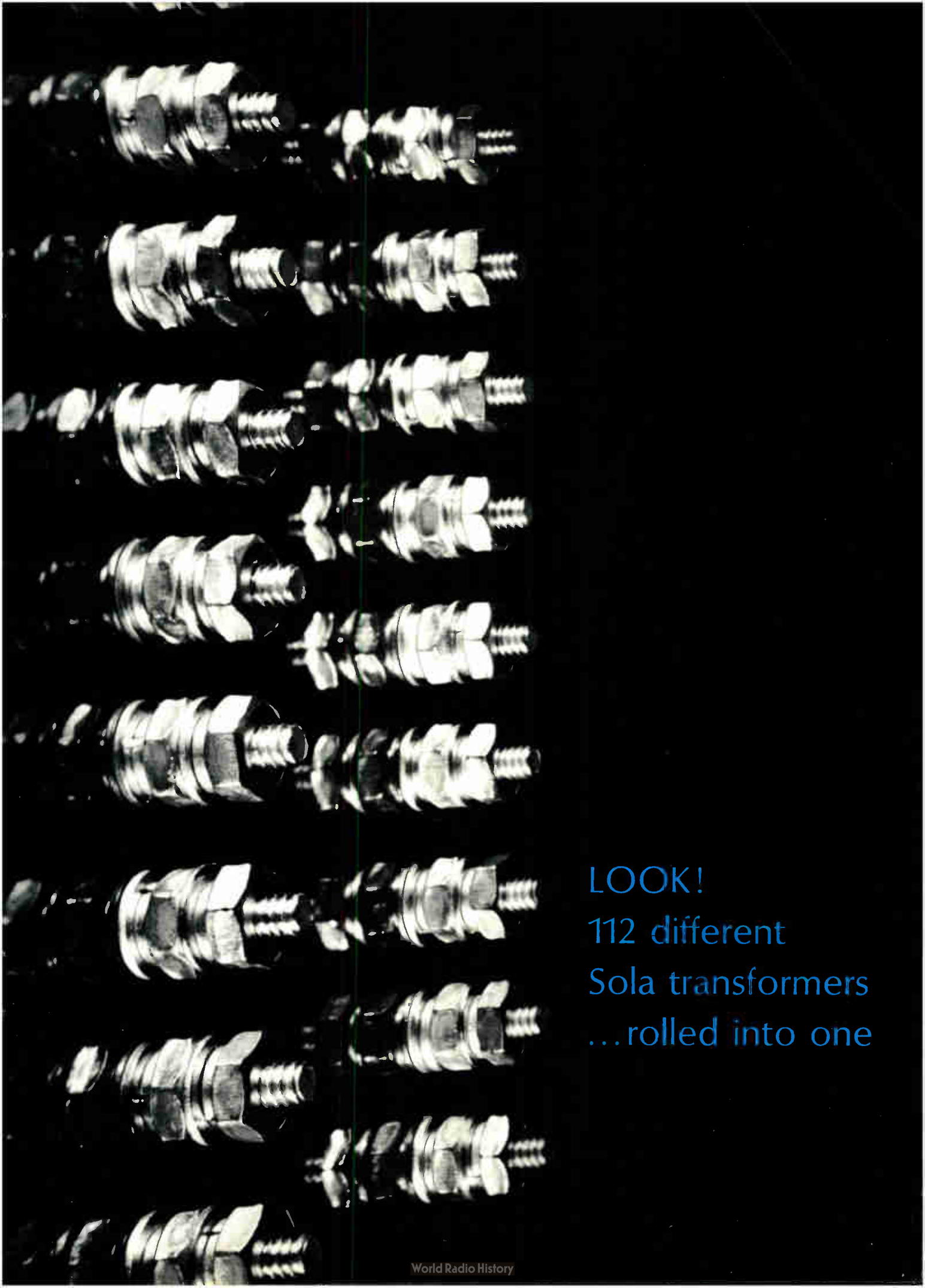
Thorough evaluation leads to a good decision. Many problems involving high voltage complementary transistors can be answered with the type numbers listed above – they represent the industry's largest high voltage line of complementary planar transistors. In fact, Sperry Semiconductor produces the industry's first *full line* of PNP/NPN Complementary Silicon Planar Transistors. Notice the close matching characteristics – we make them that way (not just pick a PNP that is close to an NPN). This is another example of Sperry's leadership of PNP low level silicon planar transistors. Our record of reliability is important – it validates our credentials for the future. Question them, inspect them, use them – they can help on your military projects and in your industrial control work. Whether you need volume production or personal attention in custom engineering – contact Sperry Semiconductor. ☐ Eastern Regional Office: 69 Hickory Drive, Waltham, Massachusetts; Midwest Regional Office: 3555 West Peterson Avenue, Chicago 45, Illinois; Western Regional Office: 1680 North Vine Street, Hollywood 28, Calif. Sales Representatives: Orbit Electronics, 250 Carroll Street, Fort Worth, Texas; Perrott Associates, Incorporated, 2321 East South Street, Orlando, Fla. ☐ *Keep in touch – with SPERRY SEMICONDUCTOR, Norwalk, Connecticut.*

SPERRY

DIVISION OF SPERRY RAND CORPORATION

Circle 121 on Inquiry Card

Circle 122 on Inquiry Card →



LOOK!
112 different
Sola transformers
...rolled into one

NOT SPECIALS, they're ready for you now at your Sola distributor's — in ratings from 40 to 450 VA

New Sola Multi-Tap constant-voltage transformer gives your electronic lab, prototype shop, service or repair department 112 regulated output voltages in one unit.

New Sola Multi-Tap: It's like having 112 different special-output constant-voltage transformers available for use at a moment's notice. A lot more convenient and a lot less costly, too! Only one standard compact unit covers the entire output range.

Now you can tap off the output voltage you want from a wide range of regulated voltages. You have an off-the-shelf power source for ac or dc outputs. Or a combination of both!

Primarily for rectifier applications, Sola Multi-Tap eliminates specials — eliminates bulky multiple-output and regulating transformer combinations.

No longer do you have to wait six or eight weeks to get a "special" rectifier voltage. And then, if your voltage specs change, end up stuck with the transformer.

Or, you might have bought an unregulated double-wound transformer with multiple-output taps. Next, you had to get a familiar Sola CV transformer for its regulating ability. You had to set it ahead of the first transformer. A cumbersome deal.

Our new Multi-Tap has changed all that. With its regulated voltage line-up you save time and money. Change your voltage specs. You're never trapped with a special. So economical. So compact. You'll want to build Sola Multi-Tap right into your finished product. Think about it.

So keep several Sola Multi-Taps on your shelves. Use them as you need them. Compact enough to save inventory space. Priced to save important dollars.

And no waiting for delivery. You get Sola Multi-Taps as quickly as your local distributor can run them over. Pronto!

Why not mail the reply card. It brings you Sola Multi-Tap literature that tells all.

Versatile Sola Multi-Tap regulates line fluctuations to within ± 1% over input voltages of 105-125. Tap output for AC or DC loads from 3.4 to 30 volts.

Much like any tapped multiple-output transformer, voltages may be tapped off from the minimum to maximum-rated voltage in about 10% increments. (The table below shows representative output voltages.)

How wide is the Sola Multi-Tap transformer line? You can get units in six ratings: 40, 75, 150, 225, 300 and 450 va. Sola Bulletins CV-175 and CV-181, detail specific output and tap combinations. Use the attached reply card for return mail literature service.

Application flexibility? These typical Sola Multi-Tap hook-ups demonstrate its all-around utility.

As an ac power source, Sola Multi-Tap offers regulated output for energizing tube filaments, signal lights and similar applications. Remove the resonance capacitor and use it as a high-reactance transformer. With the capacitor, use Sola Multi-Tap as a nearly constant-current source at higher voltages.

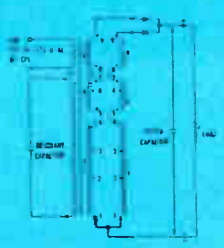
As a dc power source Sola Multi-Tap can be used in a single-output, full-wave center-tap or bridge-rectifier regulated power supply. Use it in a tube-rectifier power supply. Use it as a pre-regulator for transistor-series or transistor-shunt regulated power supply. Or put it in your battery charger. Whatever your intended application, feel free to contact your Sola sales office or electronic distributor for assistance.

SPECIFICATIONS: Input range for all units: 105-125 volts.

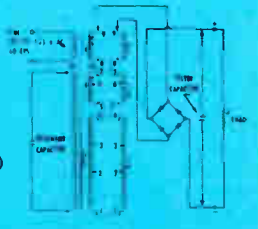
CATALOG NUMBER	AC LOAD	DC LOAD							
		Full-wave Center Tap				Full-wave Bridge			
		Resistive Load		Capacitive Load*		Resistive Load		Capacitive Load**	
		Secondary vac	Output vdc	Secondary vac	Output vdc	Secondary vac	Output vdc	Secondary vac	Output vdc
73-13-115 150 va.	31.4	30.8	13.0	31.0	14.5	30.8	27.8	31.2	32.9
	27.2	27.2	11.4	28.3	12.6	27.4	24.4	27.6	28.6
	24.0	24.0	9.9	25.0	10.9	24.3	21.4	24.2	24.8
VAC Output at 5 amp.	22.0	22.0	9.0	23.0	9.9	22.2	19.5	22.3	22.6
	20.2	20.4	8.3	21.0	8.8	20.2	17.8	20.3	20.4
FW-CT Output at 8 amp.	18.4	18.7	7.4	19.2	7.9	18.6	16.0	18.4	18.3
	16.0	16.5	6.3	16.8	6.6	16.4	13.9	16.1	15.8
FW-Bridge Output at 4 amp.	14.9	15.0	6.0	15.7	6.3	15.0	12.8	15.1	14.0
	13.4	13.6	5.3	14.0	5.4	13.6	11.4	13.6	12.5
	12.6	12.8	4.9	13.0	5.0	12.8	10.6	12.8	11.6
*4000 mfd. **2000 mfd.	11.6	11.6	4.4	12.0	4.5	11.6	9.6	11.8	10.4
	10.8	10.8	4.0	11.0	4.0	10.8	8.8	10.8	9.5

What's *your* count? We count 112 different output combinations from these schematics. If you get a higher total tell us so on the postcard.

CONNECTIONS FOR AC OUTPUT



CONNECTION FOR FULL WAVE, CENTER-TAP RECTIFICATION (FOR MAX. OUTPUT)



CONNECTIONS FOR FULL WAVE, BRIDGE RECTIFICATION (FOR MAX. OUTPUT)

SOLA WAVE NO. 3

One of these men is your man . . . at Sola!

When you want prices, application data, information on progress of an order from a supplier . . . you want it accurate and you want it *promptly!*

And that's how you get it from Sola. When you phone Sola, you don't get bucked from one mysterious voice to another . . . you do business with just one man, the same man every time.

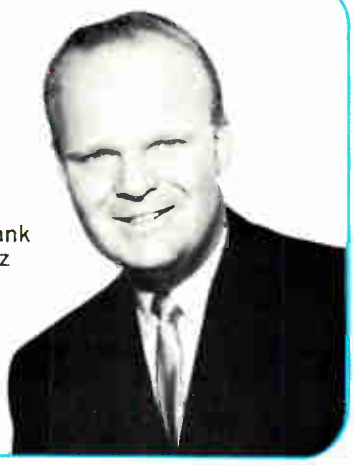
He'll be one of these three men — whether it's about specifications, engineered recommendations, prices, application data, drawings, or the taking of an order. Each man handles all customers for specific field salesmen. If you don't know the man to call, your Sola salesman will tell you. Here they are, our Sales Application Engineers:

Jerry Girten

Jim Kimball

Dick Johnson

Once your order has been placed and entered into work, then you can check its progress and other details with our Order Service Administrator: Frank Raz. Frank expedites your order through Sola's manufacturing facilities.



Frank Raz

Don Schuett

And on repair and warranty service matters, you can check with our Repair and Warranty Service Administrator: Don Schuett. He will have prompt information for you on the status of repair orders.

Now you've met them — our Customer Service people. They have but one main objective: to make dealing with Sola easier and more satisfactory to you, our customer.

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Arlington Heights, Illinois

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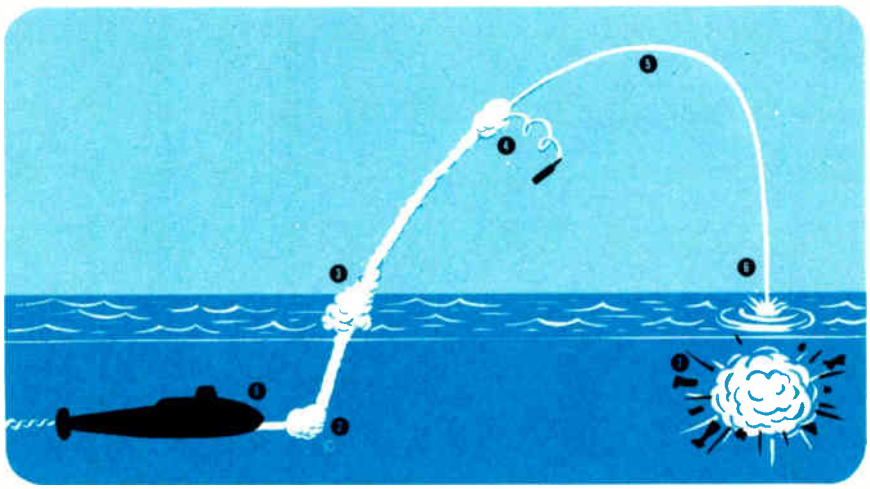
1717 Busse Road
Elk Grove Village, Illinois

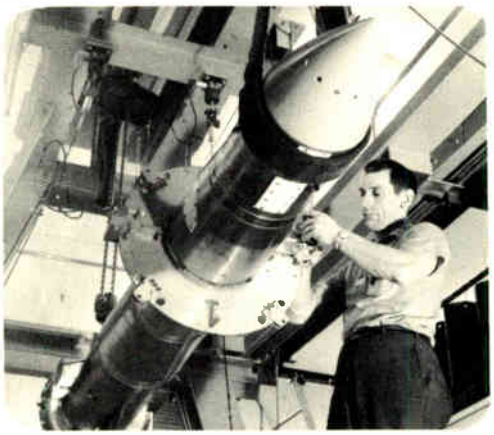
Dept. 107EI

Because this Navy Weapons System requires ultra-high reliability, Sola's Constant-Voltage Regulator was specified for Subroc missile test gear



Actual firing of Subroc anti-submarine missile: (1) the missile is launched from a conventional torpedo tube; (2) the rocket motor ignites a safe distance from the ship and (3) thrusts the missile upward and out of the water; (4) the rocket motor separates the nuclear depth bomb; (5) a guidance system and automatic controls regulate the flight of the missile; (6) the missile re-enters the water at supersonic speed, and (7) the nuclear warhead explodes, destroying the enemy submarine.

Goodyear Aerospace Corporation is prime contractor under technical direction of U.S. Naval Ordnance Laboratory for Subroc, the Navy's underwater - to - underwater weapon.



Close-up view of Subroc, anti-submarine missile. Here, testing apparatus pinpoints the center of gravity and the moment of inertia on the missile.

Subroc . . . underwater-launched anti-submarine missile, seeks out and sinks enemy submarines

The Navy's most advanced anti-submarine weapon — Subroc, is a submarine-launched, rocket-propelled, inertially-guided, nuclear depth bomb for long-range destruction of hostile submarines.

In operation, Subroc is ejected from conventional torpedo tubes. Once it is a safe distance from the launching submarine (submerged) the rocket motor ignites and propels the missile out of the water. At a predetermined range, the rocket separates from the nuclear depth bomb, which continues onward toward the target, re-enters the water, sinks and explodes.

The Sola Constant-Voltage Regulating Transformer is located in test gear aboard an auxiliary vessel, a Submarine Tender. This gear pre-tests the missile before delivery to the submarine.

The Sola transformer was selected to supply necessary regulation because of its high degree of reliability proven in its many years of uninterrupted service.

More off-the-shelf availability! Sola self-regulating transformers and power supplies are stocked by your local electronic distributor

Such local availability means you get immediate delivery on Sola products in stock. You save time and shipping costs from the factory. So consult your electronics distributor, or ask the Sola office nearest you for the name of the Sola distributor in your area.

For Sola product details by return mail —

check-off the items in which you are interested and mail this card.

- ☐ I figure one new Sola Multi-Tap equals___transformers.
- ☐ New Multi-Tap CVR Transformer Bulletin CV-175.
- ☐ Sola CV Transformer Bulletin CV-150.
- ☐ Send me your list of Sola distributors in my area.
- ☐ Inverter Bulletin AC-136
- ☐ Solatron Bulletin VR-160

NAME _____

TITLE OR POSITION _____

COMPANY _____

ADDRESS _____

SOLA

BPC

Division of Basic Products Corporation

SOLA ELECTRIC CO.
1717 Busse Road, Elk Grove, Ill.
HEmpstead 9-2800
IN CANADA: Sola-Basic Products, Ltd., 377 Evans Ave., Toronto 18, Ontario

THE RECENT ADVANCES IN DRY BATTERIES

Both industry and the consuming public have shown that they want the advantages that portability gives to electronic devices. This article describes advances which have been made in portable power packages. Examples are used to show how advances in technology have opened up new uses and improved older ones.

ELECTRONIC INDUSTRIES
REFERENCE ISSUE
POWER SOURCES

DURING THE LAST DECADE, a quiet revolution has been taking place in packaged power—dry batteries. A few years ago, little thought was given to the possibilities of complete portability in electrical or electronic devices needing more than a minimum of power, say one or two watts. Even devices which needed this much power could only be operated intermittently. This was because the operating efficiencies of dry cells at high discharge rates left something to be desired and battery replacement costs were fairly high.

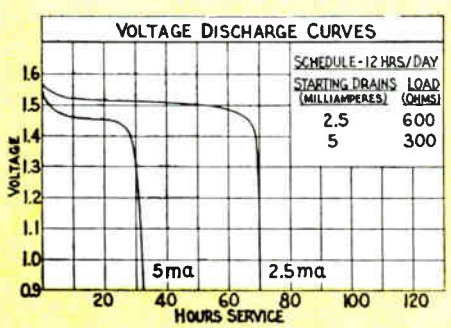
Introduction of new electrochemical systems with new battery constructions in recent years has improved this picture. Now devices needing several hundred watts input power can be considered feasible and quite portable. The capabilities of these new portable energy reservoirs permit higher power uses, low temperature operation, increased energy densities and continuous delivery of constant output.

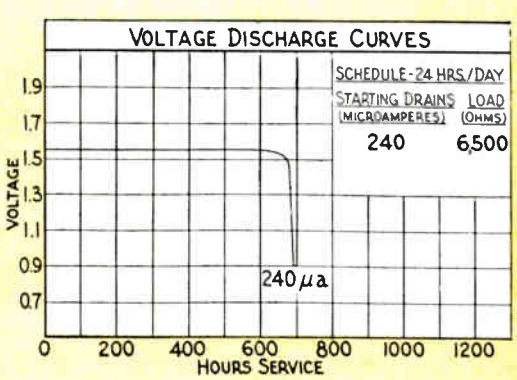
Shortly after World War II, only two important primary or non-rechargeable battery systems were used in consumer devices. These were the LeClanché or carbon-zinc and the mercuric oxide-zinc electrochemical systems. Other less widely known types such as the air-depolarized zinc and the copper oxide-zinc were used in railroad and industrial applications. Few batteries from these systems ever reached the public. In the field of secondary or rechargeable batteries, the most widely used type was, and still is, the lead-lead dioxide battery, today's automobile battery. Various applications, particularly in the mining field have used the nickel-iron batteries, but these are also unfamiliar in the consumer field.

Following wartime advances in electronics and the later development of the transistor, much emphasis was placed on the miniaturization of both devices and batteries. Improvements in battery systems and the perfection of manufacturing methods for smaller cells of both the carbon-zinc and the mercury types, permitted the equipment designer to take advantage of the added convenience that reduced size and increased portability yielded. Development of the pocket size radio showed that devices using these miniature batteries could enhance leisure hours. Demand for this type of product increased until manufacturers found a ready market for all manner of portable devices. These ranged from radios and toys to industrial electronic devices.

This growing need also put pressure on battery manufacturers. They had to provide capabilities not

Silver oxide cell discharge curves for "Eveready" No. S76E hearing aid cell (below left) and No. 303 watch cell (rt.).





By S. R. CONVERSE
Union Carbide Corp.
Consumer Products Div.
270 Park Ave.
New York, N. Y. 10017

DRY BATTERIES (Continued)

The silver oxide battery is used to power hearing aids, watches, etc. These cells are now finding use in electronic equipment.

This rechargeable alkaline battery is used to power miniature TV sets.

A variety of power tools have been made portable by battery power packs such as the one seen here.

Battery power pack is used to power hedge trimmer. Once considered impractical, portable power packs such as these are being used in a variety of equipment.

only in reduced size but in operating characteristics to meet needs that had been considered impractical a few years before. The need for continuous operation at high energy levels was felt. Systems that could deliver substantial power at sub-zero temperatures were needed. Rechargeable cells which did not need the maintenance that existing secondary cells required were sought. R&D was motivated to answer the needs expressed by both industry and the consumer; and, as time passed, new systems were introduced that could meet these expanded needs.

Ideal Characteristics

What would a battery be like if it had ideal features? It would have a high energy density both in terms of weight and of volume. It could be practically produced in a wide range of sizes. It would have a constant voltage output and operate efficiently under both continuous and intermittent current drains. It should have a long shelf life, be free from any tendency to leak, have high rate discharge capabilities and be capable of delivering energy under temperature extremes. It should have low dc resistance and ac impedance which would stay relatively constant over the discharge period, and it would be low in cost. Quite an order!

While it is still not possible to meet all of these needs in a single battery type, it is seldom that any one use requires all of these features. As with most engineering problems, a compromise design is reached. This design accents the desirable or required features and minimizes the need for the unattainable features. But, this silent revolution is in its infancy. Impressive R&D efforts are adding continuously to our store of knowledge about practical electrochemical systems and the best ways of packaging them. As each new system is introduced, areas of application are opened up which can use the advantages of the added type.

Much publicity has been accorded recently to some of the new types and constructions. There has been a rash of articles about the available types and about the cordless age that is upon us. These articles were a result of widespread interest in the capabilities of the familiar carbon-zinc cells, the mercury types, the alkaline manganese dioxide-zinc heavy duty primary types, and the recent availability of several secondary systems, the most notable of which is the sealed nickel-cadmium type.

Space limitations prohibit covering all available battery systems in depth. But, to show how an innovation in battery technology can open up new uses or improve older ones, we have chosen two examples each using a new system. Both types have been made suitable for consumer uses and the technology of both was pioneered under the "EVEREADY" trademark. The first, the silver oxide-zinc cell, was developed in miniature form. The second is an adaptation of the existing alkaline manganese dioxide-zinc primary cells into a rechargeable form.

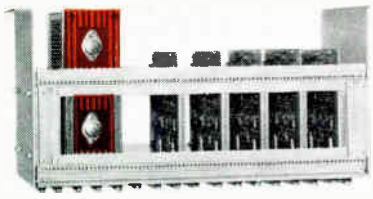
(*Continued on page* 148)

REDULE *

THE NEW
MODULAR CONCEPT
CARD BIN POWER SUPPLY

by POWER DESIGNS

• The philosophy of redundant modular circuits extended to compatible power sources. • Two independent regulated DC supplies. • Choice of 12 pre-programmed output voltages. • Positive or negative output polarity. • Series or parallel connection. • Single plug-in package. • Mounts in both 3½" and 5¼" card bins. • All silicon semiconductor circuitry.



POWER DESIGNS INC.
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3381 JUNIPERO SERRA • PALO ALTO, CALIFORNIA

* Trademark

DRY BATTERIES (Continued)

Silver Oxide Batteries

The silver oxide battery uses a high surface area zinc anode, a highly alkaline electrolyte of sodium or potassium hydroxide, and a cathode of silver oxide (Ag_2O). Its nominal operating voltage is 1.5 and in its miniature form is available in capacity ratings up to 165 ma-hrs. Energy densities in the range of 50 w hrs/lb are practical. In performance these cells offer a flat voltage characteristic with a moderate drain regulation of about 5% over the entire discharge cycle and 2% over the "plateau" of the discharge curve. In light drain uses the voltage variation over this so-called constant voltage period can be less than 0.5% over long periods of time. Impedance is low and constant over the entire useful discharge period. Because of the 1.5 v working voltage, these cells have a greater milliwatt output than other cells of equal size. Due to the patented construction of the cells, they can perform well at sub-freezing temperatures. Cost factor, however, makes these cells most suitable in miniature sizes where the value of the high cost silver oxide used is a small portion of the total manufacturing cost. In this range, cell cost is equal to comparable cells of other systems.

Use of this cell type has first taken place in three major areas with a fourth assuming greater importance recently. The impact of this innovation has already been felt in the fields of hearing aids, electric watches and miniature lighting devices. Electronic equipment needing miniature power sources, particularly in the area of voltage reference, have recently used these cells.

In the hearing aid industry the practice has been to design the bulk of the amplifiers around the mercuric oxide-zinc system. The generalized use of germanium (Ge) transistors in the design of these miniature devices has been due to the low noise, high gain and relatively low cost of these circuit elements. Until recently, silicon (Si) transistors were not used in hearing aids because of their higher noise level and lower gain. Also, their cost was higher due to greater production problems. Recent strides in the technology of Si transistors has wiped out these differences and, most important, have provided the designer with a semi-conductor with much better temperature stability than previously available.

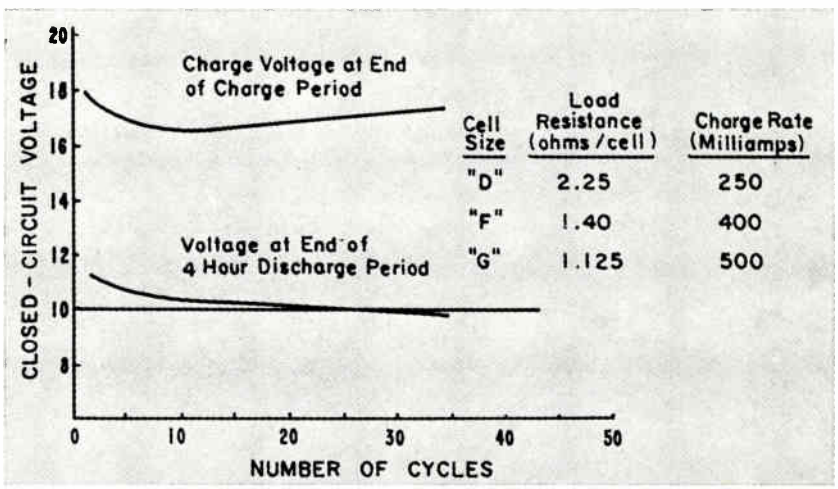
It immediately became desirable to make use of these new transistors so that improved temperature stability could be achieved with simpler circuits using fewer components. The Si transistor for this use has, however, a higher working voltage need than can be satisfactorily met with the single mercuric oxide cell with its 1.3 v. The silver oxide cell with its 1.5 v characteristic, however, meets these needs.

Net result of this was that almost all hearing aid manufacturers began designs around this power package available to them for the first time. As of the present, almost all new sub-miniature hearing aids will make use of this series of cells. In this case, it is evident that the introduction of a new battery type with better features has resulted in a marked improvement in an existing device.

Alkaline Manganese Dioxide-Zinc Types

A half-dozen years ago there began a build-up in interest in truly portable TV sets that is now a rapidly-expanding boom. The original set was operated by a power package that had never been seen before. In fact, it had been designed specifically for this use. Due to a number of reasons, the miniaturized TV set was slow to achieve success. Initial designs were the province of the American manufacturer. But, it was not until the Japanese started whittling down the size of TV receivers that real progress took place. This first Japanese version was designed around the lead-lead dioxide system. But, as soon as the first sets were imported into this country, marketing experts found that the consumer would not take enough care of the batteries to assure long life and prevent damage resulting from spilled electrolyte. Again "EVEREADY" was approached concerning a low cost rechargeable battery suitable for operating these

(*Continued on page* 150)



Discharge and charge voltage characteristics of an "Eveready" alkaline manganese dioxide secondary battery containing ten "D," "F" or "G" cells—constant current charging.

NEED DC POWER SUPPLIES FOR—

- Lab or systems use?
- Rack or modular mounting?
- Low or high power?
- Precision or loose regulation?

TRYGON HAS THEM ALL!

SILICON MODULES

Low Power

Regulation:
0.02% load, 0.01% line
Ripple: 0.5 mv RMS max.
Recovery Time:
Less than 25 microseconds
Remote Programming:
Provided on all units over output range

Model	Volts	Amps	Size (See Series Chart)	Price*
PS20-400	0-20	0-0.4	1	$140
PS32-250	0-32	0-0.250	1	$140
PS50-150	0-50	0-0.150	1	$155
PS3-1.5F	2.5-3.5	0-1.5	1	$130
PS6-1F	4-8	0-1	1	$120
PS12-900F	10-14	0-0.9	1	$115
PS18-800F	16-20	0-0.8	1	$120
PS24-700F	22-26	0-0.7	1	$120
PS28-600F	26-30	0-0.6	1	$120
PS48-400F	46-50	0-0.4	1	$130
PS10-2A	0-10	0-2	2	$160
PS20-1.5A	0-20	0-1.5	2	$160
PS32-1.25A	0-32	0-1.25	2	$165
PS50-750A	0-50	0-0.75	2	$180
PS10-4A	0-10	0-4	4	$195
PS20-3A	0-20	0-3	4	$195
PS32-2.5A	0-32	0-2.5	4	$200
PS50-1.5A	0-50	0-1.5	4	$215

*Price listed for quantities of 1 to 14. Discounts available for larger quantities.
Note: "F" models are also available with reduced current output at lower prices.

Series Chart—Dimensions:

Series	Width	Depth	Height
1	3 1/4"	4 1/8"	5"
2	4 5/8"	5 3/16"	6"
4	5"	6 11/32"	6"

HALF RACK SERIES

Low and Medium Power

Regulation:
Line — 0.01% or 2 mv
Load — 0.05% or 10 mv
(.01% or 3 mv for units with suffix "A")
Recovery Time: Better than 50 μsec

- Constant Voltage/ Constant Current Operation
- Remote Programming
- Rack Adapters Available
- Coarse and Fine Voltage and Current Controls

Model	Volts	Amps	RMS Ripple mv	Price
HR20-1.5*	0-20	0-1.5	0.25	$164
HR40-750*	0-40	0-0.75	0.15	149
HR20-5A	0-20	0-5	0.5	299
HR20-10A	0-20	0-10		379
HR40-2.5A	0-40	0-2.5		299
HR40-5A	0-40	0-5		349
HR60-2.5A	0-60	0-2.5		379
HR60-5A	0-60	0-5		449
PHR20-5A	0-20	0-5		250
PHR20-10A	0-20	0-10		325
PHR40-2.5A	0-40	0-2.5		250
PHR40-5A	0-40	0-5		295
PHR60-2.5A	0-60	0-2.5		325
PHR60-5A	0-60	0-5		395

*Single Meter Units

Models prefixed "P" are Series 8 Modular Supplies with blank front panels and voltage control on back. Units may be intermixed on same rack adapter used for Silicon Modules —or may be front-panel mounted with conventional rack adapters.

MERCURY INSTRUMENT

Medium and High Power

Regulation: 0.01% or 3 mv all units with Suffix "A." 0.05% or 15 mv all other units
Ripple: 1 mv RMS max.
Recovery Time: Better than 50 μsec

- Constant Voltage/ Constant Current Operation
- Remote Programming
- Remote Sensing
- Variable Current Limiting Short Circuit Protection

Model	Volts	Amps	Panel Ht.	Price
†M 15-5	0-15	0-5	3½"	$425
†M 15-10	0-15	0-10	3½"	$510
†M 36-2.5	0-36	0-2.5	3½"	$415
†M 36-5	0-36	0-5	3½"	$445
†M 60-2.5	0-60	0-2.5	3½"	$490
†M 160-1	0-160	0-1	3½"	$515
M 15-15A	0-15	0-15	5¼"	$595
M 15-30A	0-15	0-30	5¼"	$695
M 15-50A	0-15	0-50	7"	$945
M 36-10A	0-36	0-10	5¼"	$550
M 36-15A	0-36	0-15	5¼"	$645
M 36-25A	0-36	0-25	7"	$725
M 36-30A	0-36	0-30	7"	$795
M 60-5A	0-60	0-5	5¼"	$565
M 60-10A	0-60	0-10	5¼"	$725
M 60-15A	0-60	0-15	7"	$895
M 160-3A	0-160	0-3	5¼"	$725
M 160-5A	0-160	0-5	7"	$925

Includes ammeter, voltmeter, complete range remote programming, variable current limiting and constant current operation. †Constant current not included in these models but is available as an option.

HIGH-EFFICIENCY SERIES

High Power

Regulation:
0.2% or 50 mv, SR36-25, SR36-40
0.3% or 50 mv, SR20-40, SR20-70
Ripple: 100 mv RMS max
Recovery Time: 10 millisec

- High Efficiency operation
- Economy provided by unique regulation techniques
- Variable Current Limiting Short Circuit Protection
- Highest quality components
- Remote Sensing

Model	Volts	Amps	Panel Ht.	Price
SR20-40	2-20	0-40	7"	$695
SR36-25	2-36	0-25	7"	695
SR20-70	2-20	0-70	8¾"	925
SR36-40	2-36	0-40	8¾"	850

Note: Standard Semi-Regulated Supply Includes ammeter, voltmeter, complete range remote programming and variable current limiting.

TRYGON ELECTRONICS INC.

111 Pleasant Avenue Dept. EI-17 Roosevelt, L.I., N.Y.
(516) FReeport 8-2800 TWX (516) 863-7508

sets. In this case, the company had a "system looking for an application" in the batteries designed for the original TV use. Battery engineers, after studying features of the sets, found that the alkaline manganese dioxide system fit the needs like a glove.

Alkaline secondary batteries are a rechargeable power source. They are maintenance free, hermetically sealed, and will operate in any position. They can be used best where low initial cost and low operating cost are paramount. Modification of the heavy duty alkaline primary cells has provided these cells with a moderate rechargeable capability. They provide an inexpensive battery that in many cases also offers a lower operating cost than can be obtained from nickel-cadmium batteries.

Individual cells that comprise the alkaline secondary battery use electrodes of zinc and manganese dioxide with an electrolyte of potassium hydroxide. These are then put together in a special inside-out cell construction. Each cell has a nominal voltage of 1.5. Since they are a modified version of the primary cells, they take on some of the attributes of these cells. They are made and shipped to the customer in the charged condition. They have a shelf life characteristic similar to the primary type battery which is superior to any other rechargeable system in the charged state. The voltage upon cell discharge slowly decreases as energy is withdrawn. Shape of the discharge curve changes slightly as the battery is repeatedly charged and discharged, and the total voltage drop for a given energy withdrawal increases as the number of cycles increases. Being basically high energy, low impedance cells, the alkaline cells deliver their capacity at high discharge rates. They operate at low temperatures of the magnitude of −40°F. They are completely sealed and need no maintenance other than charging.

During the early part of its cycle life, there is a large power reserve in the alkaline manganese dioxide secondary battery. This usually amounts to as much as 200% of the rated ampere-hour capacity of the battery. During these early cycles, the terminal voltage may measure 1.0 to 1.2 v/cell after the battery has delivered its rated capacity. If it is discharged beyond its rated capacity, however, total battery life will be reduced. Nevertheless, this reserve power can be used in situations where immediate power is more important than obtaining the maximum cycle life. During the latter part of the over-all life of the battery, there is little or no reserve power available and the terminal voltage will fall to between 0.9 and 1.0 v/cell.

The requirements for this special miniature TV use were few but important. The batteries had to be low in cost and maintenance free. These conditions were met. The batteries had to deliver about 50 w hrs in a package that could be easily carried. This was also possible with this power system. A convenient overnight charging need was easily satisfied with these batteries. Although it was desirable to have the voltage characteristic constant throughout the discharge period, this did not fit the typical characteristic of alkaline cells. This need was solved by building a battery which, when freshly charged, was higher in voltage than the design center and which would deliver the needed service before the minimum or cutoff voltage was reached. This proved to be possible with the new system. At present, eight manufacturers have entered this new market and in all cases are satisfactorily using or are planning to use this new power source. Success of the pioneers in the field has been so obvious that the rapidly developing market is attracting all of the important manufacturers in the field.

The results with this type of battery prompted more intensive examination of the charging methods used. It was found that the constant current method of charging as recommended, while suitable for good results with the system, was not necessarily the best method. Development of a method using a regulated voltage supply (±3% regulation) in series with a resistor to limit the charging current when the battery is first placed on charge allowed an increase in the expected cycle life (of about 100%) due to an automatic limitation of the amount of overcharge the battery is subjected to. With the constant current method, the life expected was about 30 charge-discharge cycles. With voltage regulated charging, this increased to about 60 rated capacity discharges. Choice of the proper charging system to be used is governed mainly by the cost-cycle life relationship.

SOURCES OF POWER

Sources of power, including batteries and regulated power supplies are expected to continue rising slowly in total yearly sales in general through the next few years. Experts predict increasing use of small dry cells and various rechargeable batteries, including nickel-silver and nickel-cadmium types. Total sales for such batteries may hit $131 million by 1966.

Regulated transistor power supplies, units, power-packs, etc., of the low voltage high current type, are expected to rise in total sales at about the same rate. Total sales for these power supplies may reach $121 million by 1966.

Increases in sales of standard power supplies, of the transformer/electron tube types, with outputs of 100 volts and above, are doubtful in some quarters as their apparent need slackens more.

	1964	1965	1966
	(in millions of dollars)		
Transistor power supplies (0 to 100 volts)	$110	$115	$121
Batteries, Dry Cell Radio A, B, C, portable, Etc.	35	38	41
Rechargeable Batteries (non-auto)	69	80	90

NEW TECH DATA

Data File

Data-file provides concise, practical guides in solid-state dc power-supply techniques, individual monographs cover analysis of needs, selection of circuitry, optimum combinations, avoidance of pitfalls, tells how to choose, specify power supplies for all applications. Trio Laboratories, Inc., Plainview, L. I., N. Y.

Circle 528 on Inquiry Card

Voltage References

Bulletin 66-363 describes the A4R series of voltage references. A typical unit, the AR6.2-10, delivers 10ma at 6.2vdc into a fixed load. A 100K megohm leakage resistance and 20pf capacitance from output to ground are among the 7 isolation parameters that specify this Isoply® series. The capacitance from output to primary has been held to 0.1pf. This small unit provides a stable reference that can be applied across any 2 circuit points regardless of ground point. Noise and hum to ground does not exceed 10μv, p-p/thousand ohms to ground. Elcor, 1225 W. Broad St., Falls Church, Va.

Circle 529 on Inquiry Card

Hall Effect Generator

Data Sheet 64756 describes new low-cost Model 331 Hallefex® voltage generator. It features high sensitivity and reliability, and measures 0.240 x 0.240 x 0.020 in. Electrical and environmental specs., a photograph, dimensional drawing, and prices are also included. Helipot Technical Information Service, 2500 Harbor Blvd., Fullerton, Calif.

Circle 530 on Inquiry Card

Power Modules

Catalog 137, 2-color, provides full descriptive data covering a recently introduced line of Mil Spec. dc power modules. The catalog includes data on transparent encapsulated modules intended for type testing applications, repairable militarized modules using germanium semiconductors, and repairable Mil silicon modules for high temp. applications. All units described meet environmental or component requirements of MIL-E-4158, MIL-E-5400, MIL-E-16400, MIL-E-5272 and others. Electronic Research Associates, Inc., 67 Factory Pl., Cedar Grove, N. J.

Circle 531 on Inquiry Card

Regulated Power Supplies

VIX voltage/current mode indicators and signal circuit used in the design of voltage/current regulated power supplies is described in Brochure No. 146-1025. These power supplies are used in monitoring and control circuits. Kepco Inc., 131-38 Sanford Ave., Flushing 52, N. Y.

Circle 532 on Inquiry Card

Power Modules

These data sheets describe a line of precise, compact dc power modules. They are available with outputs of 4 to 30v. and 4 to 6.5a. in both military and industrial configurations. While maintaining the low output impedance and good transient response of transistor regulation, these modules additionally feature SCR preregulation resulting in a more efficient power control. The SCR circuitry is well isolated so that the unit meets military RFI requirements. Sample specs. are 0.01% regulation; 0.5mv ripple; 50μsec. transient response; size 4 x 6½ x 7 in. ACDC Electronics, Inc., 2979 N. Ontario St., Burbank, Calif.

Circle 533 on Inquiry Card

NEW METHOD FOR FOCUSING KLYSTRONS

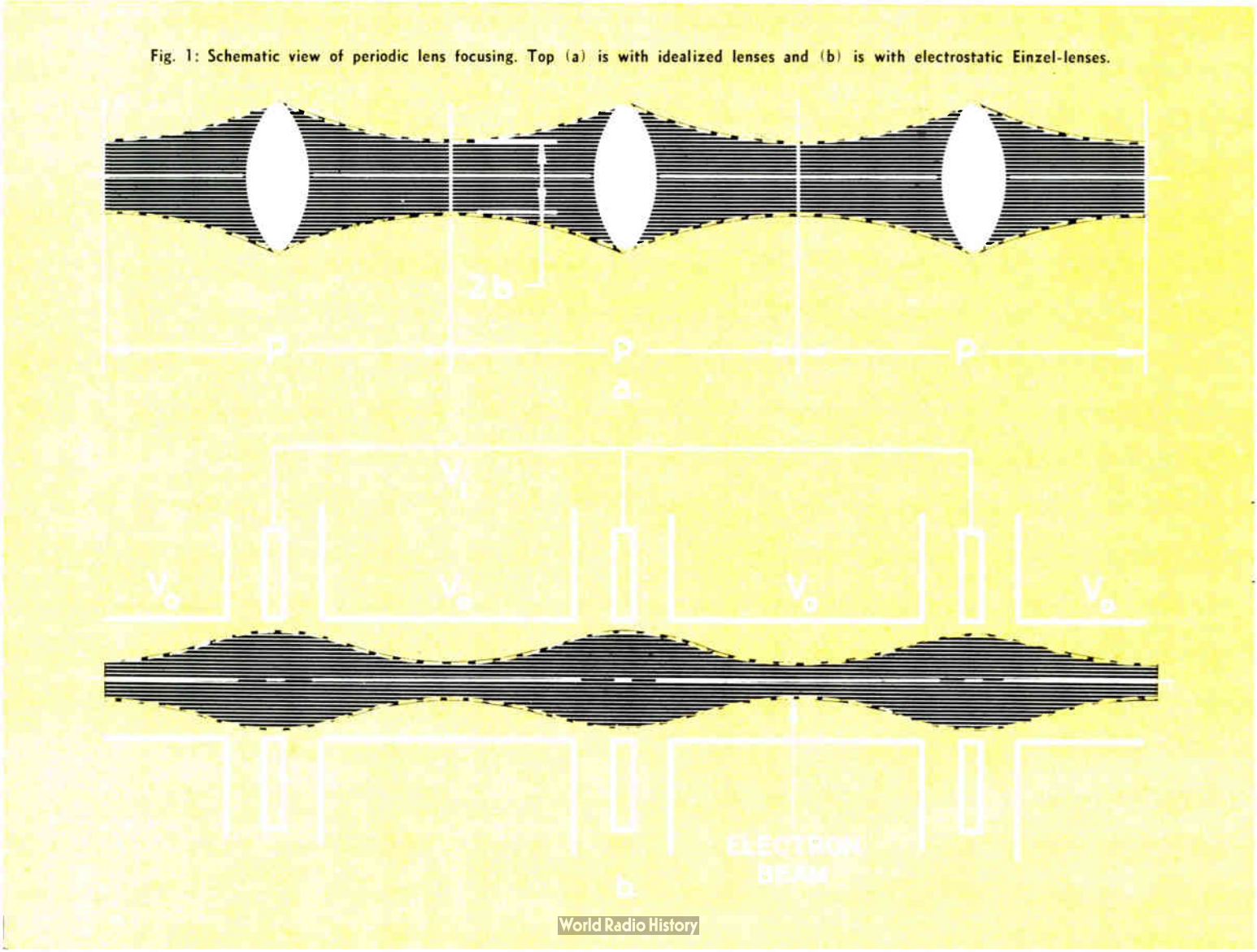
By DR. A. J. PROMMER,
Engineering Manager, Linear Beam Dept.
Electron Tube Div., Litton Industries
San Carlos, Calif.

Electrostatic focusing has been successfully applied to high power klystron amplifiers, thus eliminating the need for conventional magnetic focusing structures. Greatly reduced weight and size, high efficiency and reliability are important features.

ONE OF THE MAJOR CHALLENGES IN MICROWAVE ELECTRONICS is the urgent need for reducing size and weight of high power amplifiers. New requirements for high power systems in space, missile and airborne electronics, in multi-element phased array antenna systems and in highly mobile ground based equipment have generated a strong demand for power amplifier packages which are much smaller in size and weight, and which are more efficient and more reliable than present units. Many new system concepts depend on a successful solution to the weight and size miniaturization problem.

The device now most widely used for high power microwave amplification is the klystron amplifier. High gain and efficiency, high power capability and long life, simplicity and ruggedness in construction, and high reliability are the features which make the klystron amplifier attractive. The conventional klystron amplifier has, however, one major drawback —it needs external magnetic focusing structures. These are heavy and bulky. They add many times the weight and size of the actual klystron amplifier. If the magnetic field has to be generated by an electromagnet, then additional power supplies are needed.

Fig. 1: Schematic view of periodic lens focusing. Top (a) is with idealized lenses and (b) is with electrostatic Einzel-lenses.



This further adds weight and size and reduces the overall efficiency.

Unfortunately, the electron beam characteristics needed for high efficiency, high power klystrons cannot be achieved without a focusing arrangement which confines the beam. Because the required beam perveances are high, strong space charge forces exist. If not balanced by a focusing force, the beam will diverge too rapidly.

Electrostatic Focusing

Electrostatic focusing for klystron amplifiers was first proposed by Hahn and Metcalf[1] in their original paper on velocity modulated tubes. Since then the potential advantages of electrostatic focusing have attracted many workers and a great number of focusing schemes have been proposed and evaluated[2]. But, the high space charge forces present in high power beams, and the problem of compatibility of the focusing arrangement with the r-f interaction fields, have presented difficult problems and, until recently, progress in electrostatic focusing has been rather slow.

The first effort towards eliminating magnetic focusing was the development of so-called space charge focused tubes[3, 4, 5]. This name is a misnomer because no real focusing force is involved. The beam is generated by a convergent gun and is allowed to spread freely under the influence of the space charge forces. Beams which are short in length and large in diameter are the result. Gridded gaps have to be used to couple this wide beam effectively with the cavity fields.

The use of this principle is restricted because of the limited beam shapes which can be achieved. However, a number of devices based on this principle have been developed for specialized applications. The Sperry Gyroscope Company has developed a number of L and S band tubes[3]. Typical of their effort is the SAL-89, a 3 cavity klystron amplifier. It delivers 25 kw of peak r-f power at a maximum duty of 2.5%. The tube weighs about 30 lb. Varian Associates has a line of light-weight multi-cavity amplifiers in X and Ku band[4, 5]. Typical of their effort is the VA-832. This tube is a 3 cavity amplifier in X-band with a power output in excess of 100 watts, a gain of 20 db and an efficiency in excess of 10% This tube weighs only 12 ounces.

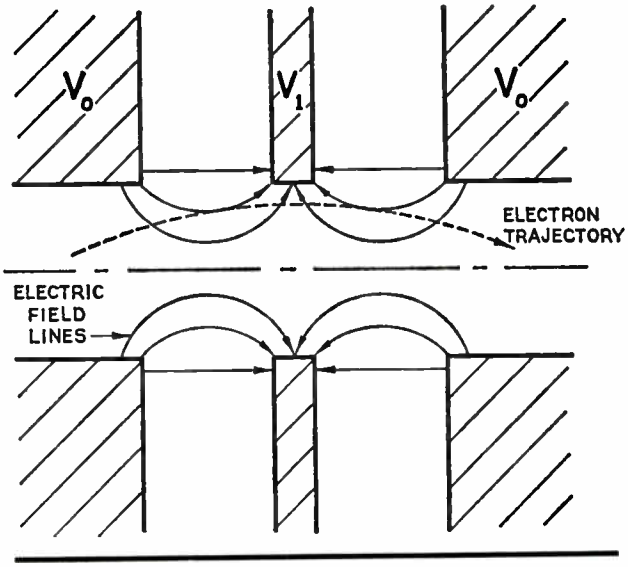
For higher beam power levels periodic electrostatic beam focusing has been proposed[6, 7]. If sinusoidal electrostatic potential variations are assumed, then it can be shown[2] that the maximum beam perveance which can be focused is given by:

$$K = 60 \times 10^{-6} \left(\frac{V_i}{V_o}\right)^2 \left(\frac{2b}{p}\right)^2$$

where K is the beam perveance, V_i and V_o the maximum and minimum electrostatic potentials, 2_b the mean beam diameter and p the focusing period.

It can be seen from this formula that for strong

Fig. 2: Converging lense action by electrostatic Einzel-lens.



focusing forces a short period is important. Thus, this focusing principle has received special attention for TWT applications where the properties of the delay circuit allow a rather short focusing period. Much has gone into the development of such electrostatically focused traveling wave amplifiers[8, 9, 10].

The application of periodic electrostatic focusing to klystron amplifiers was much more difficult. The long cavity spacings and the size of the cavities needed for high power klystron amplifiers dictate a large focusing period and correspondingly, a small b over p ratio. However, recent work by R. Hechtel[11] has produced a breakthrough in the use of electrostatic focusing for klystron amplifiers by solving the application of electrostatic Einzel-lens focusing to high power klystron amplifiers. With the help of modern computing, Hechtel analyzed the complex beam dynamics problem and established a firm basis for the design.

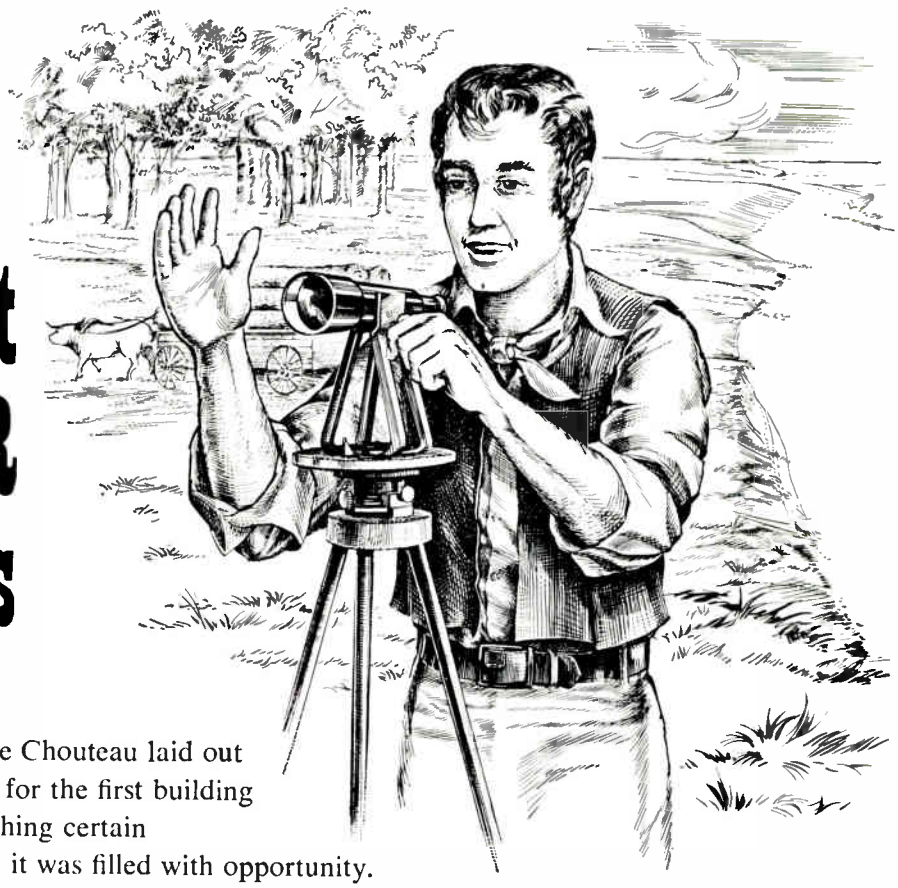
Einzel-Lens Focusing

The basic concept of periodic lens focusing is shown in Fig. 1a. The system is designed so that the converging lens exactly balances the diverging

(*Continued on page* 156)

THOUGHTS ON
CREATIVE PIONEERING

The First ENGINEER in St. Louis



When young Auguste Chouteau laid out the foundations for the first building in St. Louis in 1764, the only thing certain about his future was that it was filled with opportunity. There was challenge; there were dangers; but there was opportunity for *a man with the ambition and energy to work his way to the top.*

Two hundred years of civilization have changed St. Louis — the trading post on the edge of the West has become a great city at the center of the Nation — but for an engineer in the field of electronics, *with ambition and energy*, a frontier opportunity still exists in St. Louis.

In the recently created Electronic Equipment Division at McDonnell, engineers and scientists are encouraged to be individually resourceful, to break away from time-honored patterns and tradition-bound concepts to develop new product lines. Here, a new man enters a new organization where his growth is limited only by his contribution. His ideas and suggested solutions are encouraged and activated by others equally intent on progress. And he knows the satisfaction of finding success amid the challenges of a new organization.

While the programs under study virtually run the gamut of the electronic spectrum, engineers enjoy the advantages of clearly defined and supported corporate objectives that lead projects out of the laboratories and into application. Current programs include:

• Optical & RF Space Communications • Artificial Intelligence • Medical Electronics • Spacecraft Attitude & Flight Control • Computers • Enhancement Systems • Thin Films • Bionics • Welded Wire Techniques • Microelectronics • Steerable Arrays • High Temperature Antenna Systems • Microwave & Acoustic Dispersive Lines

The scope and diversity of these advanced development programs furnish room for the EED engineer and scientist to move about intellectually. In addition, well equipped engineering and manufacturing facilities combined with continued support by company management provide latitude for exploration and the creation of new electronic products.

Men with the experience and vision to head up and assume technical direction of these or related projects will find an opportunity to put to work all their skills, experience, and ideas in pursuit of personal and divisional growth.

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Name_____ Home Address_____

City & State_____ Phone_____ Age_____

Education: BS_____ (Date) MS_____ (Date) Ph D_____ (Date) Major Field:_____

Primary Experience Area:_____ Present Position:_____

_____ Number of Years_____ _____ I would like to receive application form ☐

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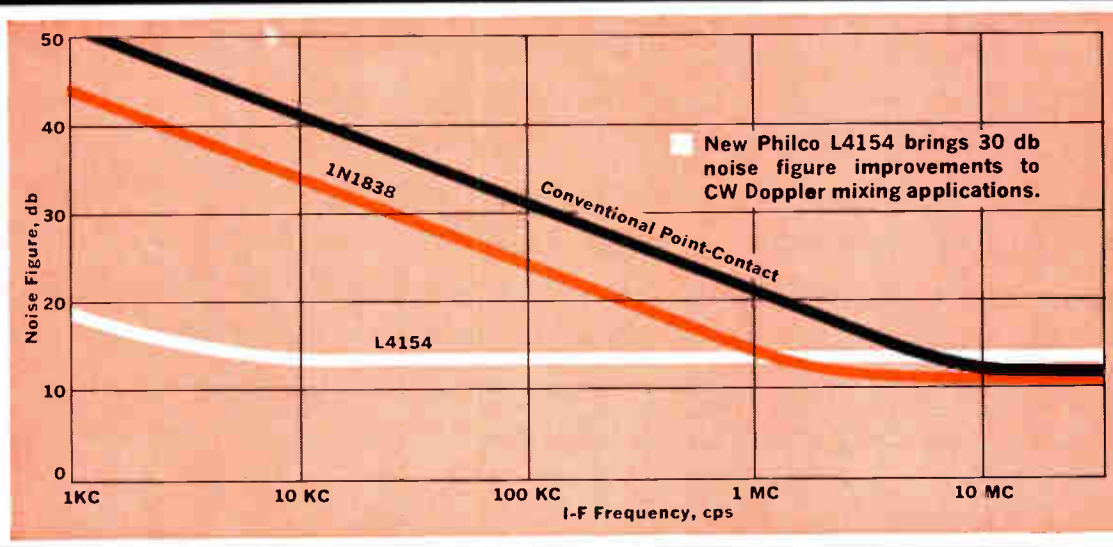

Philco L4154 Ultra-low Noise Microwave Backward Diode

New Backward Diode Technology provides advantages in CW Doppler and many other microwave mixing and detecting applications!

■ Recent Philco developments in the new Backward Diode Technology now make possible low noise, ultra-stable performance in microwave mixing and detecting applications.

■ The new Philco L4154 combines the advantages of alloyed-junction techniques and operation on the quantum tunneling principle with welded ceramic packaging. Result: low noise, high burnout, high reliability, high current sensitivity, and order-of-magnitude improvements in radiation resistance.

■ Though the most extensive benefits are attained in CW Doppler radar systems (typical noise figure improvements of 30db!), the new Philco L4154 is also superior to the inherently less reliable point-contact diode in many other microwave mixing and detecting applications. For example, the L4154 is ideal for use in power monitor applications such as discriminator systems, especially where maximum reliability and stability are required. It is also ideal for video detector applications.

■ Essentially, the new Philco L4154 gives equal or better performance than conventional point-contact diodes in many microwave mixing and detecting applications to 14Gc . . . *with significantly higher reliability!*

■ Hermetically sealed in the welded ceramic package that has become a standard for maximum reliability, the Philco L4154 meets applicable MIL-S-19500/C requirements and is now available for delivery in quantity.

■ For specifications and a special report on the advantages of the new Backward Diode Technology, write Dept. EI664.

SPECIAL
PRODUCTS OPERATION

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A SUBSIDIARY OF *Ford Motor Company*

LANSDALE DIVISION, LANSDALE, PA.
IN CANADA: Don Mills Road, Don Mills, Ontario
Circle 128 on Inquiry Card

SOLID-STATE CENTER U.S.A. ™

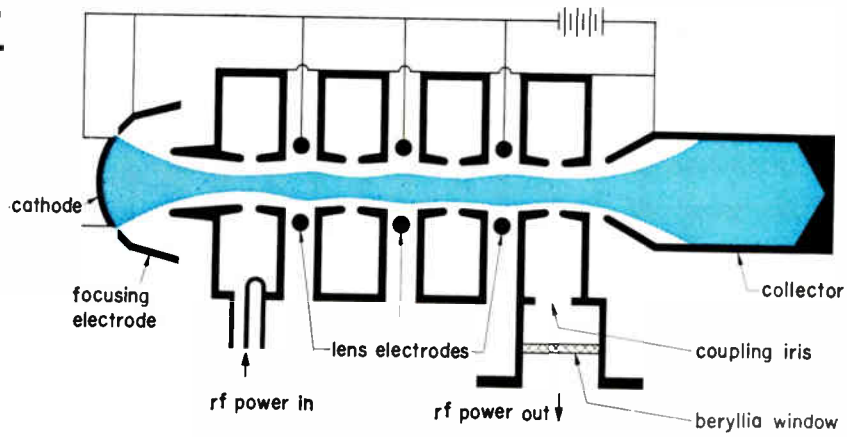


Fig. 4 (above): This 4-cavity, S-band klystron is electrostatically focused and has a peak power output of 50 kw.

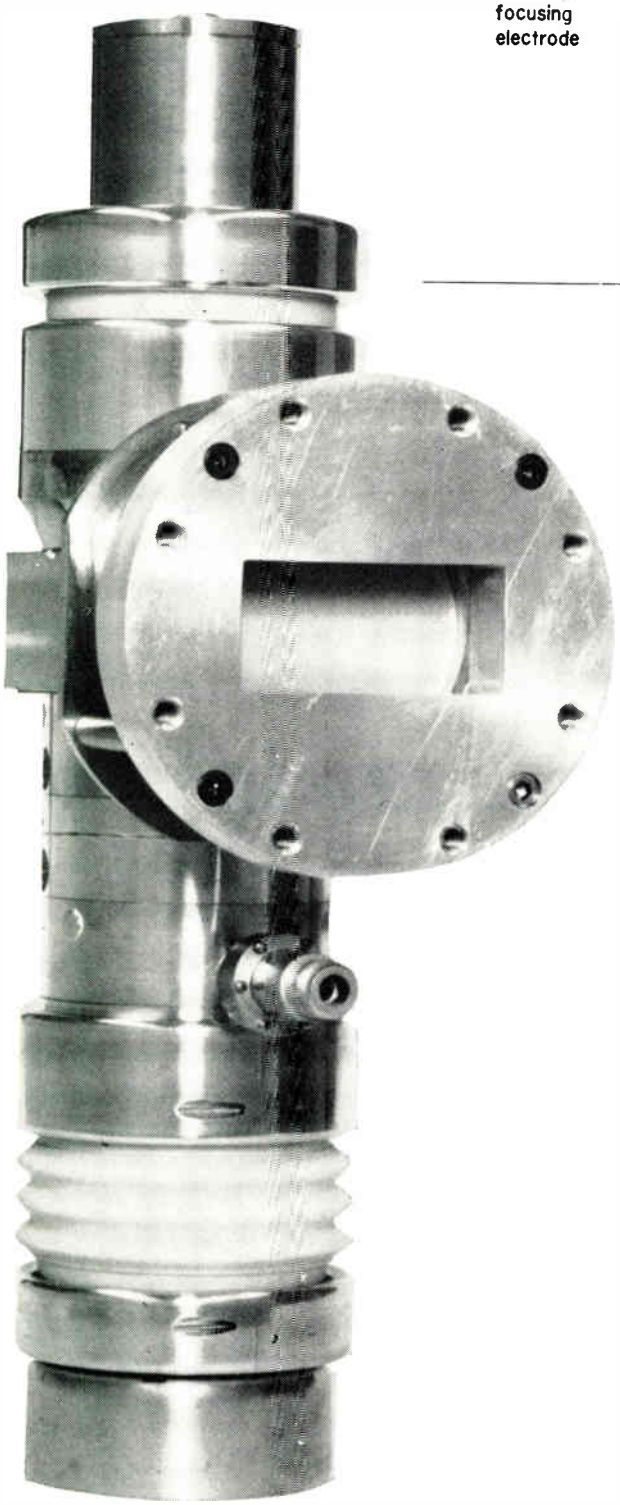


Fig. 3: Electrostatically focused klystron with negative lens electrodes internally connected to the cathode.

space charge effects in each period. The converging lens action is provided by a so-called electrostatic Einzel-lens arrangement shown in Fig. 2. One lens consists of 3 electrodes. The outer two are at the same potential. The potential of the middle electrode can be either higher or lower, in either case a convergent lens results. The schematic view of a periodic electrostatic Einzel-lens system is shown in Fig. 1b. The convergence of the Einzel lens must be designed so that it not only compensates for the space charge effects in the lens region, but also for the effects in the drift region.

The description given in the previous paragraph is highly idealized and in practical systems the lens and drift regions cannot be as conveniently separated. Each period has to be treated as one unit.

An exact theoretical analysis of the electron flow in such a complicated field arrangement becomes extremely difficult. However, because of the complexity of the problem at least an approximate solution of the beam dynamics is mandatory. The use of analytical methods is almost hopeless because the simplifying assumptions required would make the results meaningless. The use of analog and numerical methods is the alternative. A high precision resistance network analog, in combination with a high speed digital computer, has been used to analyse the electron flow under the influence of the focusing fields in detail[12]. The application of this technique was one of the keys to the successful development of the electrostatically focused klystron amplifier. The focusing arrangements for all klystron amplifiers, which have been developed so far, have been designed with this technique. Excellent agreement exists between the computer results and the test data.

Fig. 3 shows the periodic electrostatic Einzel-lens system as it was originally proposed by R. Hechtel. The lens electrode potential has been chosen negative and by proper design of the lens geometry this lens can be made to run at cathode potential. The lens electrode can then be internally connected to the

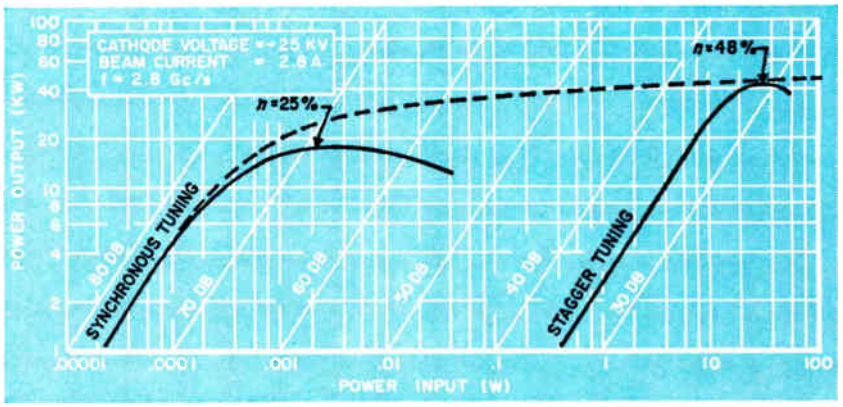


Fig. 5 (above): R-F performance of the klystron amplifier shown in Fig. 4.

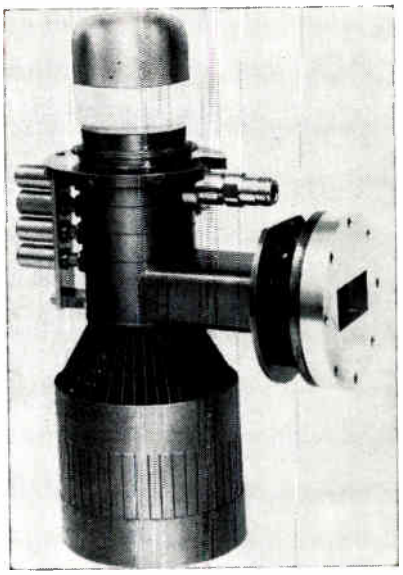


Fig. 6 (right): Electrostatically focused 1 kw klystron for C-band tropo communications.

cathode, and no outside lens connections are required.

In practice, beams up to a perveance of 1.5×10^{-6} have been focused with focusing geometries compatible with klystron operation. DC beam transmissions are excellent; above 99% can easily be achieved in well-designed systems.

R-F Performance

The first electrostatically focused high power klystron which was developed by R. Hechtel and his co-workers at the Research Laboratory of the Litton Industries Electron Tube Division, the L-3668, is shown in Fig. 4. This tube is a 4 cavity S-band amplifier. Its operating characteristics are shown below. Operating characteristics of L-3668H, a 50 kw electrostatically focused klystron (ESFK) amplifier:

Frequency	2800 MC
Beam Voltage	28 kv
Beam Current	3.8 a.
Output Power	
Peak	50 kw
Average	3 kw
Efficiency	48%
Saturated Gain	35 db
Electronic Bandwidth (3 db)	27 MC

Typical r-f performance of this tube is shown in Fig. 5. At low drive level maximum power output is achieved with synchronous cavity tuning. The small signal gain in this case is in excess of 76 db. With increasing drive power the penultimate cavity has to be detuned to a higher frequency to achieve optimum current bunching. The maximum efficiency was 48%, which is remarkably high for a klystron at this power level. The efficiency enhancement is caused by the properties of the electrostatic focusing principle. Slow electrons in the output gap are no longer focused and are collected before they can get out of phase and re-absorb energy from the r-f fields.

Recent Advances

The characteristics of the electrostatically focused klystron amplifier make it attractive for a wide variety of uses. It is, of course, especially of interest for applications where light weight and small size are important. A number of different tube types, each aimed for a specific have either already been developed or are in the developmental state. The present state-of-the-art is illustrated by a review of some recent developments.

A 1 kilowatt CW C-band electrostatically focused klystron amplifier is shown in Fig. 6. This tube has been developed specifically for use in light-weight troposcatter communication transmitters. The tube is air cooled and weighs 15 lb. which is less than one quarter the weight of a comparable magnetically focused tube.

Low weight, small and compact size and the freedom from stray magnetic fields are the features which make this tube attractive for use in light-weight mobile communication equipments. An improved version of this tube, which will produce 1.4 kw of output power without any increase in weight and size, is currently under development.

A 20 watt S-band ESFK for space communications is shown in Fig. 7. This tube is designed for 2 output power levels: 20 watts with a beam power of 1400 volts and 5 watts with a beam voltage of 900 volts. The tube is heatsink cooled and has been specifically developed for space environmental conditions. The total weight is below 2 pounds.

The attractive feature of the ESFK for space communication is the combination of the basic ruggedness of the klystron amplifier, both in its mechanical construction and its heat dissipation capability, with the light-weight electrostatic focusing principle. Simplicity in construction and wide safety margins insure reliability.

Fig. 7 also shows two mechanical models of low power ESFK designs for missile and spaceborne applications. The X-band version supplies an output of 20 watts CW. This tube weighs about 14 ounces. The last tube is designed for a power output of 15 watts CW in Ka band. This tube weighs 8 ounces.

(Continued on page 158)

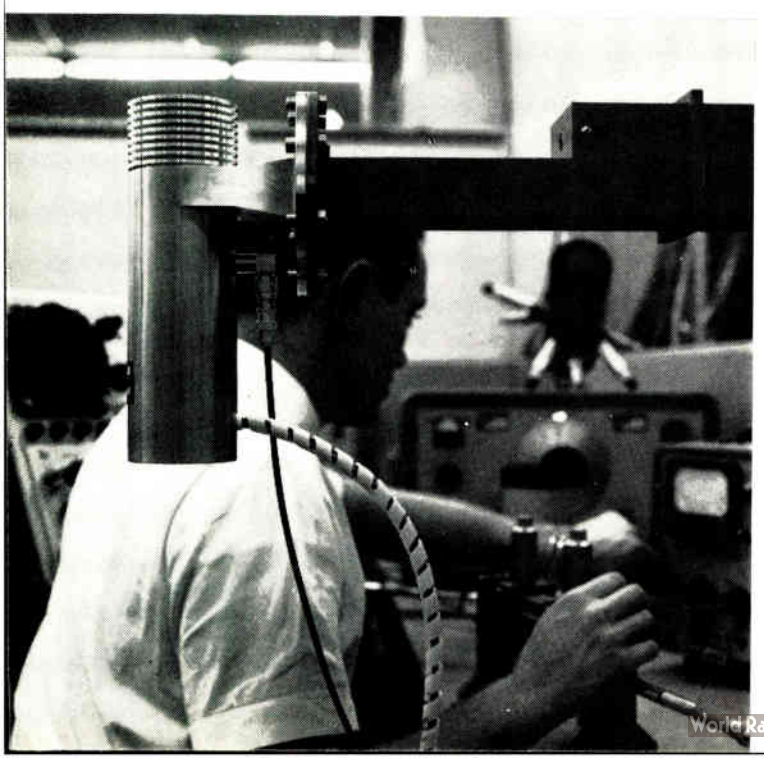
KLYSTRON AMPLIFIERS (Concluded)

Electrostatically focused klystron amplifiers for phased array radar systems are receiving much attention. Their small size, good form factor and freedom from magnetic focusing field requirements make them good for packaging in a multi-element array. The life expectancy of an electrostatically focused klystron amplifier is greatly improved in comparison with the magnetically focused klystron amplifier because of the absence of ion backbombardment of the cathode. The electrostatic focusing fields provide for constant ion drainage. Ions are swept out of the beam region before they can get back to the cathode.

Development programs for ESFKs for phased array applications are in progress. The programs are aimed at power levels in the 50 kw to 300 kw power range in S-band. Fig. 8 shows a 50 kw S-band ESFK for phased array systems.

Fig. 7: Three electrostatically focused klystrons for space communications. Shown are a 20w. S-band tube, a 20w. X-band and a 15w. Ka band tubes. The latter two are design models.

Fig. 8: 50kw S-band klystron for phased array systems is shown under test. Note the small size of this tube.



Future Developments

Besides the advantage in size and weight, the electrostatically focused klystron amplifier also has some other distinct advantages in comparison with the conventional klystron amplifier. We have seen that its interaction efficiency is higher because of a velocity sorting mechanism in the output gap, it is free from spurious ion oscillation effects and ion bombardment of the cathode surface because of the automatic ion drainage, and reflected electrons are not focused back down in the drift tube and cannot cause electronic feedback type instabilities.

The main limitation on the high power capability of electrostatically focused klystrons is caused by the voltage holdoff problem in the lens area. The full beam voltage occurs between the focusing lens electrode and the cavity walls.

As the focusing system design is improved further and the special features of the interaction mechanism in electrostatically focused klystron amplifiers are explored, more fully interaction efficiencies up to 60% should be realized. The use of depressed collectors and improved bunching and output circuits along with other schemes for enhancing power extraction from the beam may increase the efficiency even further. Improvements will also be achieved by the use of higher perveance beams. This would permit the achievement of higher powers and wider bandwidth.

For still higher peak power requirements multiple beam arrangements can be used. Because of the simplicity of the focusing arrangement, multiple beams can be easily clustered together in a compact package.

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NEW TECH DATA

MICROWAVE

SSB Generator

Bulletin GS-1 gives details and specs. on a new single-sideband generator that provides upper and lower sideband freqs. at separate outputs over the design band without adjustment. Units are guaranteed at 5 mw output with 20 db suppression. Outputs of 10 mw and more are feasible. Microwave Development Laboratories, Inc., 87 Crescent Rd., Needham Hts., Mass.

Circle 534 on Inquiry Card

Data Handling Systems

A 32-page illustrated brochure, "Information Handling Systems," is available featuring aerospace and ground information-handling systems applicable to telemetry systems, analog and digital-acquisition systems, digital-data processing systems, digital command systems, display systems, antenna tracking systems and transmitters and receivers. The systems fulfill many aerospace, military and industrial needs. Radiation Inc., Melbourne, Fla.

Circle 535 on Inquiry Card

Microwave Amplifier

This data sheet describes the models 560 to 563 microwave amplifiers. The 560 series provides lw. output from 1 to 12.4GC in 4 bands. Min. gain, 30db; r-f impedance, 50Ω. Rise time for models 560 and 561 is less than 2μsec.; for models 562 and 563 it is 4μsec. Alfred Electronics, 3176 Porter Dr., Palo Alto, Calif.

Circle 536 on Inquiry Card

Coaxial Switches

Data is available on the CC-11 series of coaxial SP2T, r-f switches. They switch r-f or microwave power from 1 input to either of 2 outputs in a 50Ω coaxial transmission line. Conversely, 1 of 2 input signal sources may be connected to a single output port. Freq. is from dc through 6GC. Quantatron, div. of Teledyne, Inc., 1131 Olympic Blvd., Santa Monica, Calif.

Circle 537 on Inquiry Card

Plasma Diagnostics

"Plasma Diagnostics with Millimeter Waves" presents a technical discussion of typical experimental microwave set-ups for studying plasma properties. Basic plasma equations are covered and 5 different system configurations are explained, varying from the simple measurement of plasma attenuation to the measurement of attenuation, reflection and phase shift. All the systems shown can be arranged using standard TRG millimeter microwave components. The 16-page brochure also includes formulas for designing antenna systems based on the use of small horns, collimating antennas and focussing antennas. TRG Inc., 400 Border St., E. Boston 28, Mass.

Circle 538 on Inquiry Card

X-Band Oscillators

A family of new X-band triode oscillators is described in detail with complete specs. in a new brochure. The oscillators, available in small quantities at present from 9.1 to 9.4GC, can be modified to broader X-band freqs. with manual tuning up to 500MC, electronic tuning of 20MC minimum or fixed freq. Trak Microwave Corp., 5006 N. Coolidge Ave., Tampa, Fla.

Circle 539 on Inquiry Card

Noise Performance

Nomograph 196, 18 pages, describes the noise performance of FM microwave systems using SSB carrier multiplex equipment. In the paper, sources of noise are discussed in terms of their effect on signal-to-noise ratios in the derived voice channels. Also covered by the paper are the methods of calculating and measuring noise, and recommendations for noise performance. Lenkurt Electric Co., Inc., Dept. A134, 1105 County Rd., San Carlos, Calif.

Circle 540 on Inquiry Card

Cavity Wavemeters

Direct reading and micrometer head cavity wavemeters for 2.6 to 140GC freq. ranges are discussed in detail in a technical bulletin. The 6-page, 2-color bulletin gives specs., dimensions and ordering data, plus a technical article with notes of special interest to users of cavity wavemeters. De Mornay-Bonardi Div., Datapulse Inc., 780 S. Arroyo Pkwy., Pasadena, Calif.

Circle 541 on Inquiry Card

Microwave Catalog

This 178-page catalog contains data for more than 600 microwave instruments and components; complete specs. and prices are included. In addition, a standard waveguide data chart plus 20 additional pages of technical data and charts are included. Narda Microwave Corp., Plainview, L. I., N. Y.

Circle 542 on Inquiry Card

Multi-Hole Coupler

Bulletin CS-1 is a 2-color brochure describing a new series of 10, 20 and 30db sidewall multi-hole couplers. These models in WR90 and WR112 are detailed electrically and mechanically. Microwave Development Laboratories, Inc., 87 Crescent Rd., Needham Heights, Mass.

Circle 543 on Inquiry Card

Power Dividers

This series of stripline power dividers cover the freq. range from 1 to 12 GC in four small, light-weight units. They feature ±3° phase tracking between outputs, high isolation between outputs, and low insertion loss and VSWR. Additional data available from Electronic Specialty Co., 5121 San Fernando Rd., Los Angeles, Calif.

Circle 544 on Inquiry Card

Waveguide Switch

Model C994111010 high r-f power waveguide switch is suited to switching high power radar systems under full power. The switch is offered in a small, 3-port SPDT lightweight package. It operates under powers greater than 600kw. Further information is available from Micro-Radionics, Inc., 14844 Oxnard St., Van Nuys, Calif.

Circle 545 on Inquiry Card

Microwave Detector

This microwave detector has extreme temp. stability over a range of −35°C to +85°C. It is a high-impedance device operating on the principle of majority carrier excitation by the r-f field. The detection action is fast enough to follow each r-f cycle at freqs. up to a calculated 100GC, although the first in the MSI series is limited to 18GC. The natural sq. law response of the type 640 hot carrier diode make them extremely useful as a replacement for the 1N32 video detector. Data sheets available from MSI Electronics Inc., 116-06 Myrtle Ave., Richmond Hill, N. Y.

Circle 546 on Inquiry Card

Microwave Measurements

Microwave swept freq. measurements are discussed in Microline Application Note No. 2 available from Sperry Microwave Electronics Co., P. O. Box 1828, Clearwater, Fla. The 28-page, full illustrated note includes typical setups and the general philosophy of swept measurements. Errors and their causes for different setups are discussed.

Circle 547 on Inquiry Card

Filter Monograph

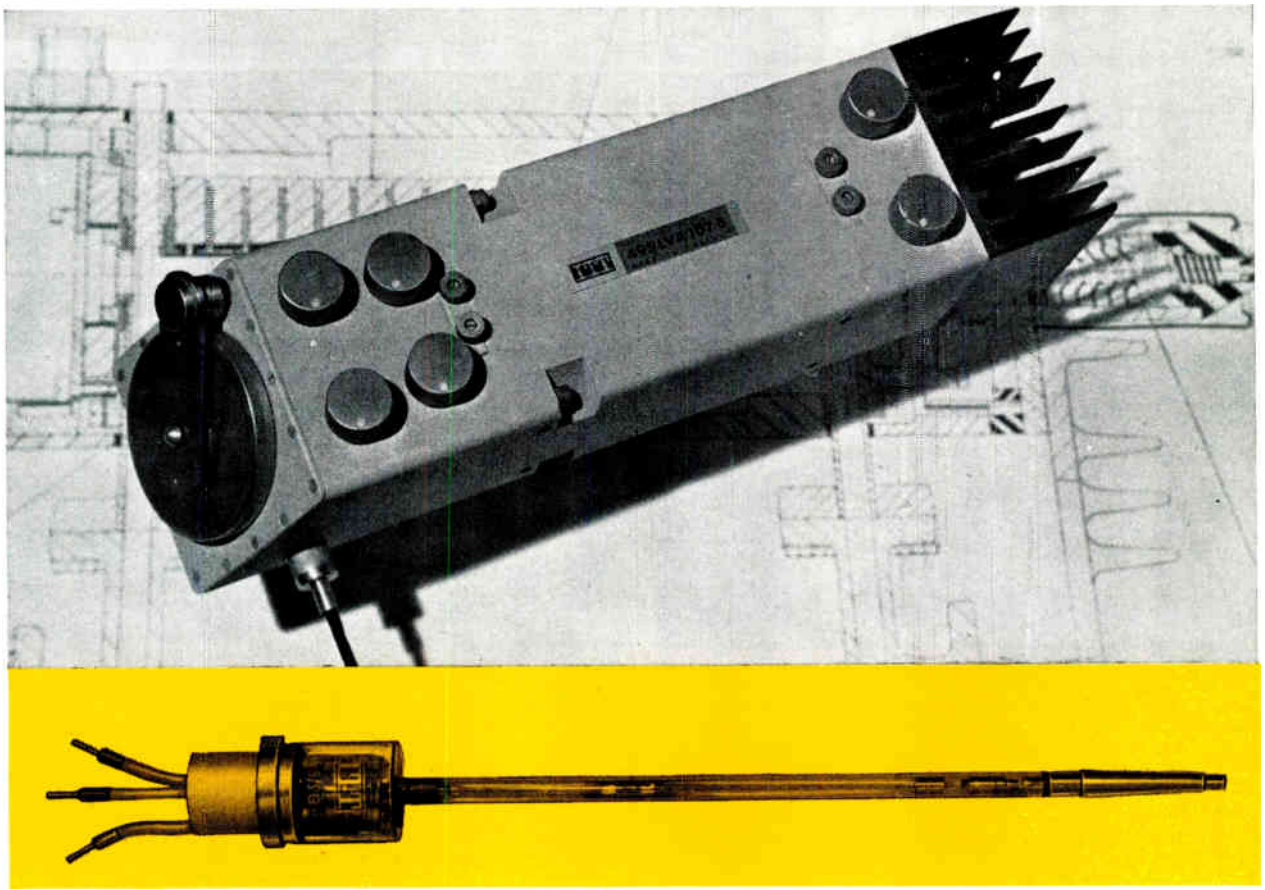
This engineering monograph, "Optimizing Subminiature Subcarrier Telemetry Filter," is illustrated with performance curves, tables, and block diagrams. It presents a straightforward pre-design spec. technique intended to permit the telemetry engineer to get exactly what he wants electrically, mechanically, and economically. Requests on company letter head to Kenyon Transformer Co., Inc., 1057 Summit Ave., Jersey City, N. J.

Circle 548 on Inquiry Card

Waveguide Attenuators

Model AW-751 fixed attenuator covers 10-15GC, with attenuation values of 3, 6, 10, 20, 30, 40db and other values within 1-40db available. VSWR is 1.15 max., with bilateral matching. Model AW-755 with max. vswr of 1.20 and bilateral matching also covers 10-15GC. It is a step attenuator for 0, 20, 40, 60, max. db. Both attenuators dissipate at least 1w., and fit WR-75 waveguide. The attenuators use the rotary-vane principle for superior flatness of attenuation vs. freq. More data available from The Singer Co., Metrics Div., 915 Pembroke St., Bridgeport, Conn.

Circle 549 on Inquiry Card



More Microwave Tubes

More Microwave Tubes from STC — leaders in the design and production of microwave components and systems. STC microwave tube development and production programs have resulted in improved gain, higher synchronous saturated output, lower noise factor and lower phase modulation distortion. These features are combined with a high degree of reliability and simplicity of operation.

S-BAND

For the Communication frequencies of this band (3·6 to 4·2 Gc/s) there are two STC travelling wave tubes: Type W7/3G performance has been proved in national and international microwave systems in fourteen countries.
Type W7/4G is a higher gain version of the W7/3G. It is provided with a periodic permanent magnet mount which incorporates simple mechanical adjustments for obtaining the very best performance from any tube of this type.

ABRIDGED DATA

Tube Type	Mount Type	RF Connexion (W.G. Flange)	Frequency Range (Gc/s)	Sync. Sat. Output (W)	Gain (db)	Noise Factor (db)
W7/3G	495-LVA-104	12A*	3·6 to 4·2	8 to 10	28	27
W7/4G	495-LVA-101A	12A*	3·6 to 5·0	8 to 12	38 to 42	27

* Transition pieces to WR229 available

C-BAND

Travelling wave tube type W5/1G has an established reputation in microwave link repeaters operating at about 5·0W output level in the 6·0 Gc/s band. A modified tube type W4/1G can be used in the same periodic permanent magnet mount as the W5/1G to cover the upper frequencies of this band (7·0 to 7·8 Gc/s). Type W5/2G has been especially designed for 1 800 channel link systems and is intended for operation with a 10 to 15W output.

ABRIDGED DATA

Tube Type	Mount Type	RF Connexion (W.G. Flange)	Frequency Range (Gc/s)	Sync. Sat. Output (W)	Gain (db)	Noise Factor (db)
W4/1G	As for W5/1G	As for W5/1G	7·0 to 7·8	8 to 11	37 to 40	26
W5/1G	495-LVA-105B 495-LVA-105C 495-LVA-105D	UG344/U CMR137 UG344/U	5·85 to 7·2	8 to 11	35 to 39	26
W5/2G	495-LVA-107B	UG344/U	5·85 to 7·2	16	39 to 72	27
W4/2G	WM108	UG51/U	7·0 to 8·5	8 to 11	36	26

For full information, write, 'phone or Telex for Data Sheets to STC Valve Division, Brixham Road, Paignton, Devon, England. U.S.A. enquiries for price and delivery to ITT Electron Tube Division, Box 104, Clifton, New Jersey.

high-grade electronic components by **STC** COMPONENTS GROUP

64/2MS

NEW TECH DATA

MICROWAVE

Telemetry Discriminator

Bulletin F-112/A describes the salient features of the FDS4/A bandswitching frequency discriminator. Solid-state circuitry is used throughout and the modular construction permits substitution of channels other than the IRIG bands normally provided. Airpax Electronics Inc., Seminole Div., Ft. Lauderdale, Fla.

Circle 371 on Inquiry Card

A-D Converters

Bulletin C16 describes and illustrates the series 210S solid-state high-speed analog to digital converters. These units can be used for ground systems such as missile and satellite testing, checkout and analysis of industrial processes. It has a bit rate capacity of 160KC, including recovery time. For special requirements, bit rates to 300KC are available with the accuracy of 0.05% (±½ least significant bit). Bipolar inputs from a few mv to 100v. are accepted. Decimal readout display is available. Gulton Industries, Technical Publications Dept., 212 Durham Ave., Metuchen, N. J.

Circle 372 on Inquiry Card

Phase Nomograph

A phase calculation nomograph, covering the freq. range from 200MC to 10GC is offered. The nomograph permits quick conversion from wavelength to distance in centimeters and is especially useful in Smith Chart calculations in conjunction with slotted-line measurements. General Radio Co., West Concord, Mass.

Circle 373 on Inquiry Card

Waveguide Loop Couplers

Bulletin LT-1 provides detailed electrical and mechanical data on a new series of waveguide loop couplers covering EIA waveguide sizes from WR430-2100, considered to be the most compact in the industry. All models, with one exception, are but 1.5 in. in length. Included in the bulletin is a short discussion concerning the use of waveguide couplers as well as complete mechanical drawings of the 2 types of couplers available. Also included is detailed ordering data as well as modifications available. Microwave Development Laboratories, Inc., 87 Crescent Rd., Needham Heights. Mass.

Circle 374 on Inquiry Card

Antenna/Microwave Catalog

Bulletin 10-1 is a short-form catalog showing a line of antennas, microwave components, and semiconductor testers. American Electronic Labs., Inc., Box 552, Lansdale, Pa.

Circle 375 on Inquiry Card

X- and K-Band Catalogs

Two short-form catalogs describe a full line of microwave components for X- and K-band applications. The catalogs, SF-8000 for X-band and SF-8100 for K-band, outline with electrical specs. over 800 microwave components including duplexers, magnetrons, TWTs, BWOs, solid-state sources, solid-state switches, limiters, phase shifters, mixer and detector diodes, varactors, tunnel diodes, switching diodes, ferrite isolators and circulators, waveguide components and test equipment. The product listings are broken down by both type and electrical characteristics and are illustrated with photos. Microwave Associates, Inc., Northwest Ind. Park, Burlington, Mass.

Circle 376 on Inquiry Card

Radomes Bulletin

This bulletin describes a standard line of metal space frame radomes. They can house up to 140 ft. antennas. Features of the metal-space frame radomes include broad bandwidth response, 150 mph wind operation, negligible boresight drift, low transmission loss, long life, equal performance in any climate, and simple erection and assembly. Electronic Space Structures Corp., Old Powder Mill Rd., W. Concord, Mass.

Circle 377 on Inquiry Card

Filter Cavities

Data is available on filter cavities for both the 150 and the 450MC band. The new cavities incorporate cylindrical construction and cast copper end plates for greater mechanical rigidity. They have adjustable coupling loops to vary both selectivity and insertion loss to obtain the optimum combination of these 2 variables. In both frequency ranges the cavities are offered in single, double and triple cavity combinations. Decibel Products, Inc., 3184 Quebec St., Dallas, Tex.

Circle 378 on Inquiry Card

Telemetry Filters

This 2-color brochure describes a new line of subminiature subcarrier filters for FM-FM telemetry. Block diagrams, performance curves, application and performance data are included. Kenyon Transformer Co., 1057 Summit Ave., Jersey City, N. J.

Circle 379 on Inquiry Card

Telemetry System

Bulletin SY64397 describes the Model 4400 PAM/PDM ground telemetry system. The bulletin gives a comprehensive, detailed description of the system's operation, specs., and applications. Scope tracings of typical signals are also given to illustrate the system's capabilities to acquire, track, and decommutate signals through severe noise environments. Beckman Instruments, Inc., Systems Div., 2500 Harbor Blvd., Fullerton, Calif.

Circle 380 on Inquiry Card

Coaxial Switch

Detailed specs. are available on a new single-pole, 9-throw coaxial switch featuring a wide selection of actuators. The switch operates up to 11GC, providing isolation of 50db min. @ 3.0GC, VSWR 1.3 max. @ 3.0GC and insertion loss of 0.2db max. @ 3.0GC. TRW Microwave Div., 20945 Plummer St., Chatsworth, Calif.

Circle 381 on Inquiry Card

Microwave Facilities

Research, engineering, manufacturing, and quality assurance capabilities in the fields of military, commercial and industrial microwave applications are described in this brochure. Photos and tables illustrating typical operations, products and areas of special competence are included. Available on company letterhead from Comtek, Inc., 135 Main St., Woburn, Mass.

Circle 382 on Inquiry Card

Microwave Antenna Brochure

Bulletin A-1 describes the 800 series of standard millimeter parabolic antennas and conical horn lenses. High precision parabolics up to 48 in. are available in question-mark feeds and Cassegrain versions. Nine and 12 in. dia. conical horn lenses listed extend this standard series to 6 covering, A, B, V, E, F and G-bands (26 to 220GC). Special millimeter-wave antennas are included. TRG Inc., 400 Border St., E. Boston 28, Mass.

Circle 383 on Inquiry Card

Voltage-Control Oscillator

This data sheet describes the Model 200070 voltage-control oscillator. The unit represents a new approach in telemetry components and is fully capable of surviving the environs of outerspace. Mean-time to failure is 15,000 hrs. minimum and long-term stability. Additional specs. such as channel data, performance data and environmental qualifications are described. Datametrics Corp., 8217 Lankershim Blvd., No. Hollywood, Calif.

Circle 384 on Inquiry Card

Timer Brochure

Brochure TDS-264 contains data on a newly developed line of electronic timing devices for myriad uses in aerospace and electronic industries. General features, operating characteristics, and configurations of the 9 standard off-the-shelf units are highlighted in the brochure. Leach Corp., 1123 Wilshire Blvd., Los Angeles 17, Calif.

Circle 385 on Inquiry Card

ELECTRONIC INDUSTRIES
REFERENCE ISSUE
MATERIALS AND HARDWARE

New Designs in SHOCK AND VIBRATION PROTECTION

Equipment often must operate under rugged shock and vibration environments. Proper packaging and mounting are necessary for its protection. Learn what has been done lately to insure proper protection of the equipment.

THE CABLE-ISOLATION SHOCK AND VIBRATION CONTROL system introduced several years ago had one major drawback—each isolator system had to be designed from scratch. Performance data on available models was incomplete due to the system's newness. Uses were limited to situations where the increased cost of a custom vibration isolation system was offset by the cable isolator's advantages over conventional mounts.

Cable-isolator parameters are not sharply defined. Standardization of components is quite difficult. When normal design parameters are exceeded, isolation efficiency falls off very slowly, rather than sharply as in the case of conventional mounts. Although the isolator has excellent performance characteristics within a wide range of operating conditions, this is not the case with standard design practices.

Performance

Isolator performance improves or degrades with change in input, but varies slightly with a large parameter change. By combining data from life tests, overall operating and reliability tests, performance tests under extreme environmental conditions, and tests under extreme conditions of shock, acceleration and high-amplitude vibration, an optimum overall performance vs. input conditions curve can be drawn. From this curve standard isolator designations can be made, with resonant frequency as the major standardization criteria.

Standard isolators protect loads from 4 lbs. to 150 lbs. against vibrations above 10 CPS. The isolators are classed according to resonant frequency (7, 10, 15 and 20 CPS) and according to load.

Cable Isolators over Cup Mounts

Conventional cup mounts have a relatively narrow load vs. isolation efficiency range. The live part of the mount bottoms and ceases isolating vibration when the vibratory output exceeds a transmissibility of from 3 to 5. Load ratings of ±200% of the specification load result in uncontrollable vibration, high transmissibility, and virtual non-control of vibration and shock.

In contrast, cable isolators have a load range capability of 10:1; that is, a cable isolator designed for use with a 1 lb. load performs within acceptable transmissibility standards with a 10 lb. load. Doubling the vibratory input (from 0.06 to 0.12) gives only a 50% increase in transmissibility. Even at transmissibilities of 5 the cable isolator does not bottom, and still partially protects the package against vibration.

Shock forces applied to a unit suspended on cable isolators cause an unusual reaction. The supported package goes into an elliptical motion, whereas conventional mountings move in one direction. This characteristic enables cable isolators to provide excellent shock protection in a smaller space envelope. Attentuation of shock to 15G from 100G input is practicable, based on a typical 5-6 msec. sinusoidal pulse.

Cable isolators perform equally well under severe environments such as temperatures from −100°F to over +500°F, high vacuum, and attack by most solvents. They do not deteriorate in storage.

Outstanding features of the system are:

The supported mass is isolated in all three planes, assuring all-attitude protection.

Isolator systems are available to protect masses from 4 oz. to over 2000 lbs.

Resonant frequency can be changed by altering the isolator.

Steady-state acceleration, such as that encountered in missile-flight or rocket-sled motion, does not significantly affect isolation performance.

Shock loads are attenuated, not magnified.

Cable Isolator performance exceeds the requirements of MIL-E-5272C, MIL-C-172C, MIL-E-5400D, BuSHIPS-16E4, and MIL-S-901B (Navy Hammer Test).

Isolator System Design

Isolators are normally used to suspend packages to be protected in

By ROY BUTLER
Aeroflex Laboratories Inc.
Plainview, N. Y.

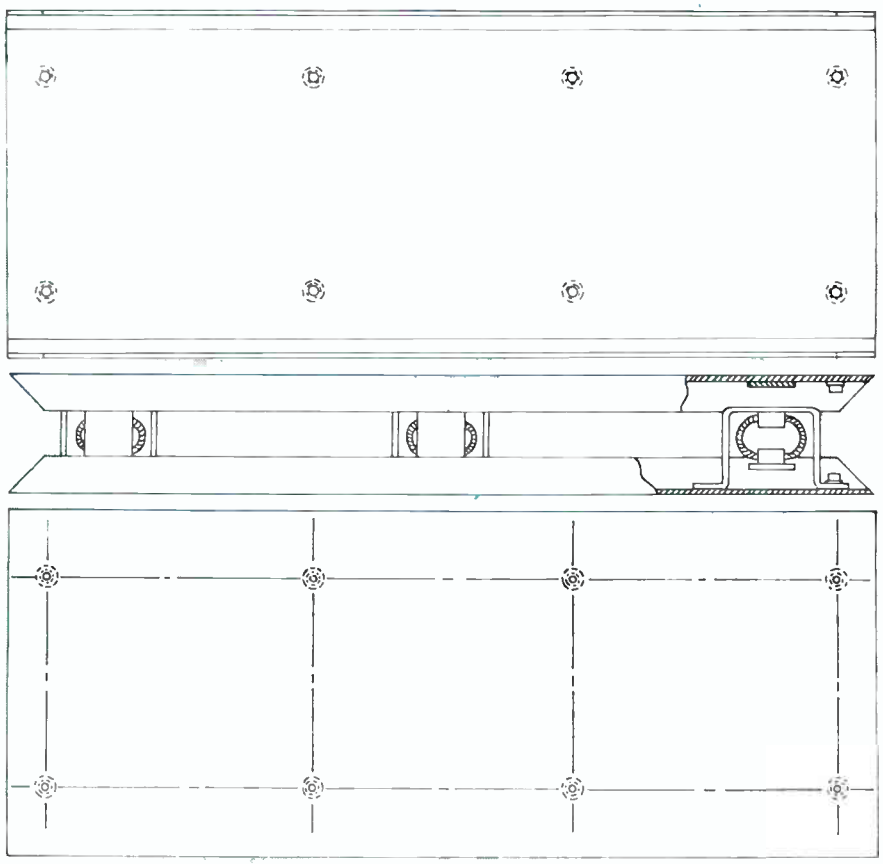
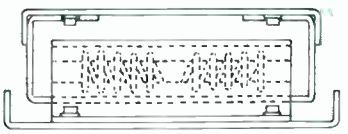
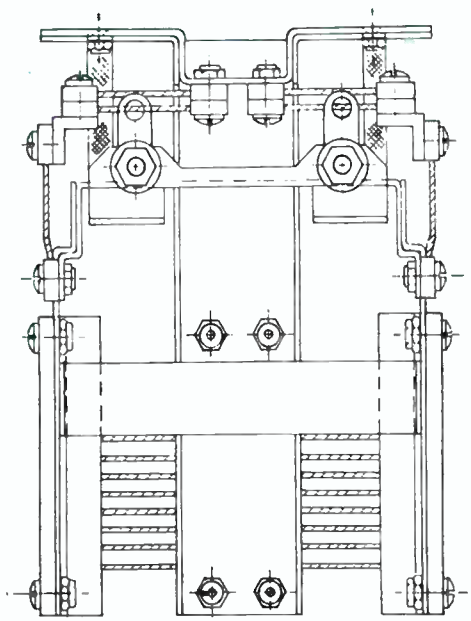


Fig. 1: Isolators held in double cradles.





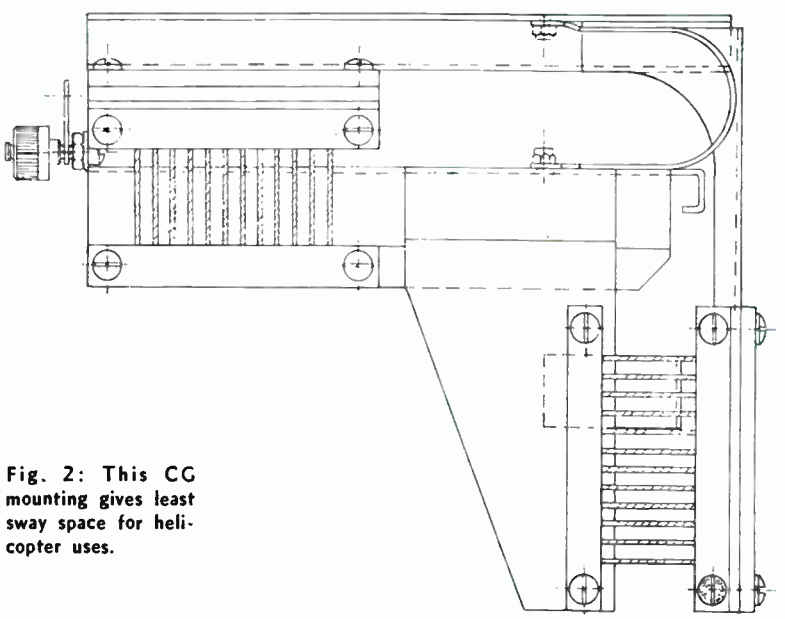


Fig. 2: This CG mounting gives least sway space for helicopter uses.

a symmetrical arrangement. Two pairs of right-angle isolators are usually sufficient. Right-angle isolators are used because a symmetrical arrangement provides substantially equal vibration and shock protection in all axes.

In base mounting or where the space envelope for package translation under loads is limited, the helical-wound cable isolator is often specified.

Mounting-System Design

The most important design consideration in determining the cable-isolator control system is the mounting system. Primary design criteria specify the space required for the mounting system and the dynamic translation of the package. The environmental control designer is often given the space he must work in, and must design a system to fit the space.

The attaching structure should have a stiffness at least ten times the

(*Continued on page* 166)

spring rate of the cable-isolator system.

Vibration mounting systems, whether conventional cup or cable isolators, are mounted in one of three ways. The most common method is to mount the package to a base through the vibration isolation device. Unfortunately, this simple mounting system operates under the worst possible conditions, particularly for horizontal inputs. Package sway is due to the couple created by the lack of coincidence between the spring-force center and the center of gravity (CG). Hence, base-mounted systems must frequently use a stiffer mount incorporating motion limiters, and run the risk of high transmissibility or increased Gs at resonance.

The most desirable arrangement is the system mounted along axes that pass through the CG. Here coupling is reduced to a minimum, forces transmitted to the package are small, package movement (translation) is less, and shock loads are easily withstood.

Mountings located off the CG plane, or not symmetrical about the CG, are less desirable because a coupled condition is created which is similar to but not as bad as the base-mount arrangement. They are usually used because CG mounting is not possible due to structural considerations. Compensation for CG imbalance is normally made by using isolators of different capacities and/or sizes. Typically, isolator vibration and shock performance is altered by an off CG mounting. The change in the characteristics of the cable isolator and its performance is minimal by comparison.

Base Mount

Here is a typical base-mount problem. During shipment, a base-mounting system is required to protect a 280-lb. mass from 0.030 in. double-amplitude vibratory input at 10 to 55 cps. Protection to 10G shock is also needed.

The critical thing here is a 1.5 in. top-sway limit.

(*Continued on page* 118)

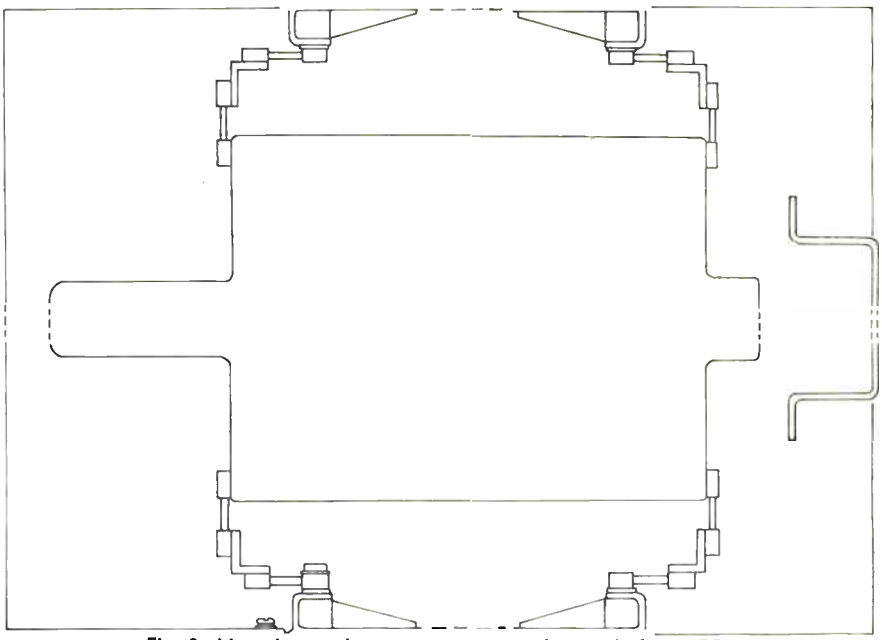


Fig. 3: Mounting used to protect memory-drum unit from 15G.

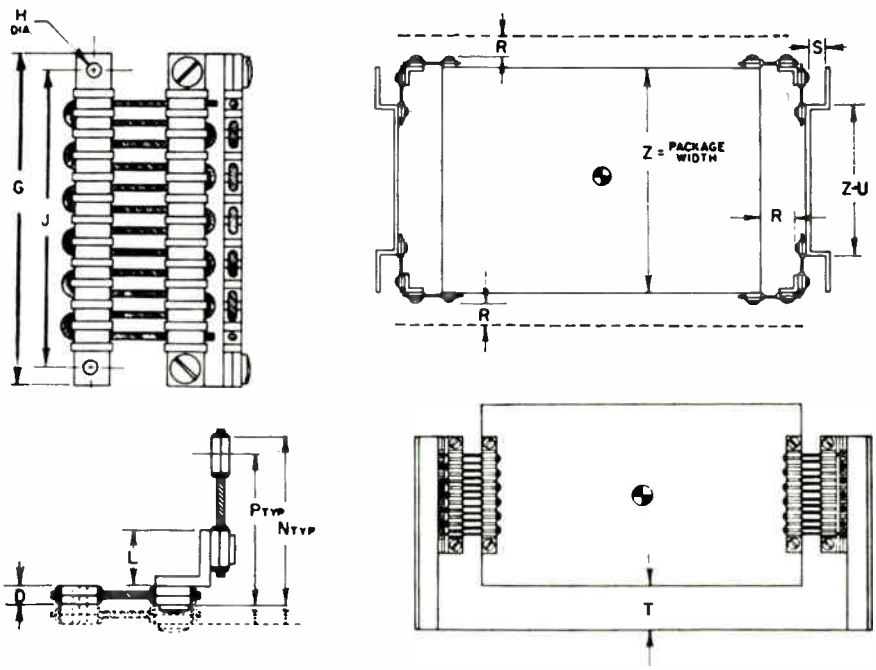
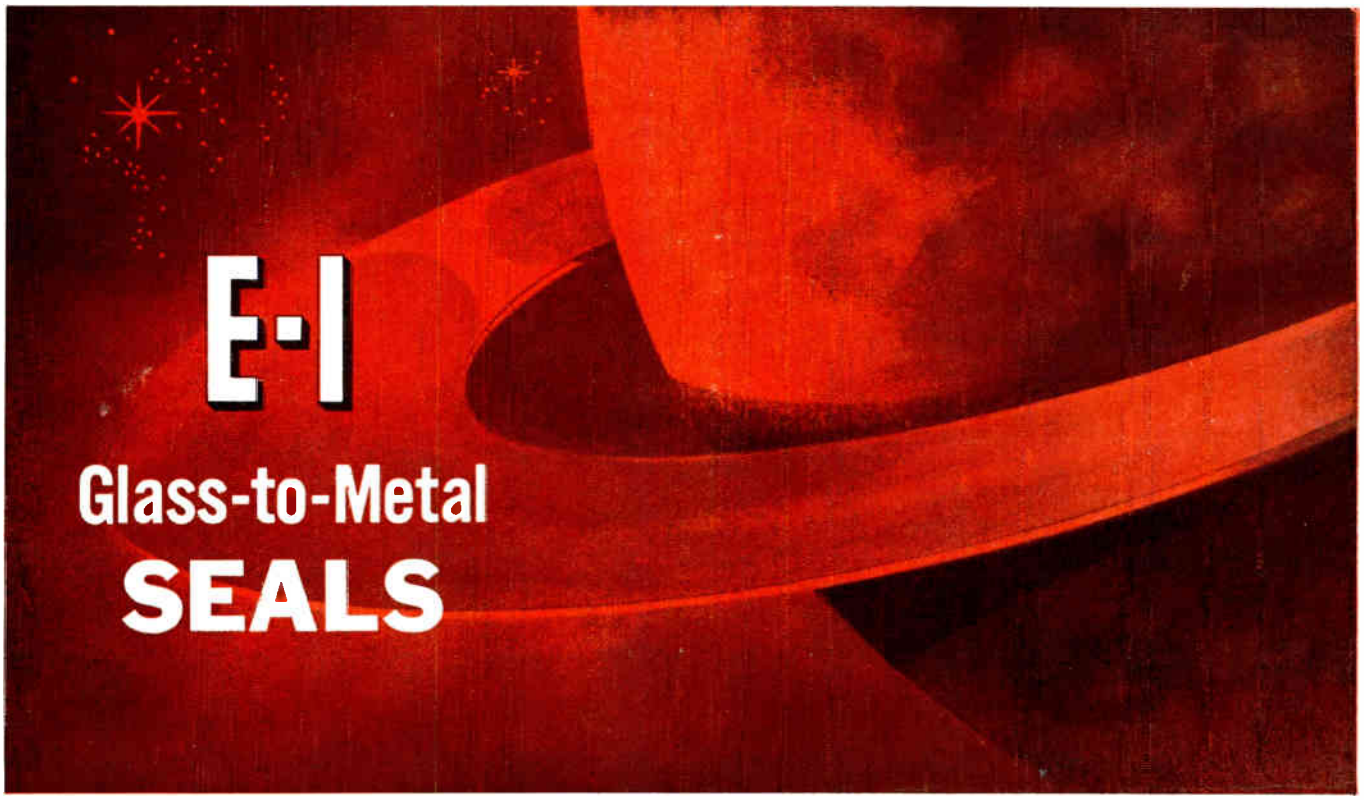


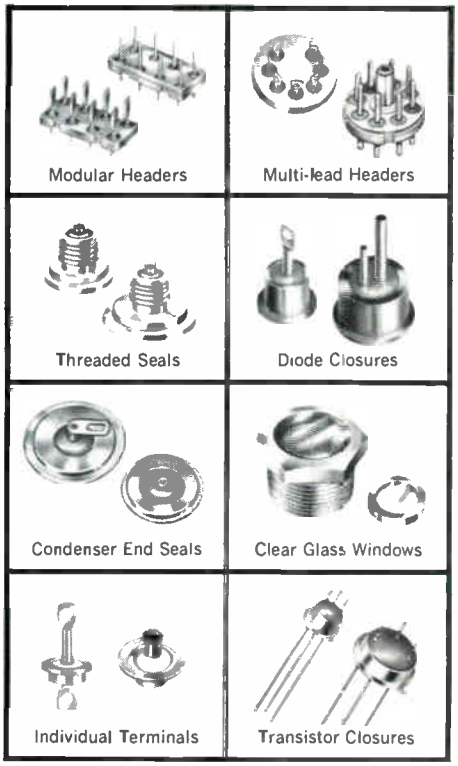
Fig. 4: Ladder Isolation Design Guide.

Load	Part Number	G	J	N	P	D	H	L	R	S	T	U
4	C2- A -712-1	3.12	2.688	1.93	1.73	.16	.177	.50	.65	.33	.98	2.75
7	C2- -512-1	↓	↓	1.69	1.49	↓	↓	↓	.48	.24	.69	2.25
10	C2- -412-1	↓	↓	1.56	1.36	↓	↓	↓	.40	.20	.55	2.00
15	C3- -712-1	↓	↓	2.38	2.13	↓	↓	↓	.58	.29	.88	3.25
20	C3- -610-1	4.42	3.950	2.25	2.00	.25	.196	.75	.56	.28	.83	3.00
25	C3- -612-1	↓	↓	2.25	2.00	↓	↓	↓	.56	.28	.83	3.00
30	C3- -512-1	↓	↓	2.13	1.88	↓	↓	↓	.46	.23	.66	2.75
40	C3- -410-1	↓	↓	2.00	1.75	↓	↓	↓	.40	.20	.55	2.50
50	C3- -412-1	↓	↓	2.00	1.75	↓	↓	↓	.41	.21	.57	2.50
75	C4- -408-1	5.00	4.500	2.12	1.84	.31	.257	.75	.41	.21	.57	2.50
100	C4- -412-1	↓	↓	2.12	1.84	↓	↓	↓	.41	.21	.57	2.50
150	C4- -308-1	↓	↓	2.00	1.72	↓	↓	↓	.30	.15	.38	2.25

Universal in Application...



Universal in Reliability...



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SHOCK AND VIBRATION (Concluded)

Helical isolators are specified with a nominal transmissibility of 3 at resonance 0.030 in. Double Amplitude (D.A.) input. Helical isolators that perform to specifications are loaded to stretch rather than compress. For this configuration, the isolators are held in double cradles fabricated from sheet stainless (Fig. 1). The cradles also restrain the motion of the helixes from the forces transverse to the isolators' long axes.

The system was subjected to a specified 30 minutes on the bounce-test machine. Competitive cup and organic mounts failed after three minutes, while the high strength of the steel cable isolators allowed this system to exceed 30-minutes.

Center-of-Gravity Mounting

This problem was encountered in a CG mount. Twenty-four hundred pounds must withstand a resonance of 5 CPS, transmissibility of 3 or less with 0.5 in. D.A. vibratory input.

Vibratory input was so severe in this large piece that CG mounting was mandatory. The CG was found through conventional techniques. In order to provide isolator-axes CG intersection, mounting bosses were needed since normal isolator location could not provide CG mounting. Top-mounting bosses were added to the product on unit. An existing collar provided the bottom mounting.

This isolator system provided a transmissibility of 2.5 with 1.0 in. D.A. input at reasonance without bottoming.

For a helicopter environment electronic packages were required to withstand 0.1 in. D.A. vibratory input from 5 CPS to 20 CPS. The severe restrictions on mounting space are shown in Fig. 2. When conventional organic mounts in the required mounting area could not pass the requirements of MIL-E-5400, a resonant frequency between cable isolators was specified. A 5 to 10 CPS was desired in all planes with a maximum allowable transmissibility of 3 at resonance in all planes.

CG mounting was determined to give the least sway space. Space requirements, which had been determined by the system designers from bottom mounting data, showed the units needed cradles to accommodate bottom-mounted center-of-gravity systems. Stiffened aluminum cradles were designed to accommodate isolators within the specified mounting envelope.

The final system provided resonant frequencies between 3 and 8 CPS and transmissibilities between 1.3 and 2.7 in all planes.

Here is another example of CG mounting. A customer required that a memory-drum unit be protected to 15Gs when subjected to the Navy High-Impact Hammer Test, MIL-S-901B. This included both 3 ft. and 5 ft. hammer drops in vertical and horizontal planes.

Input to the system exceeded

100Gs in some instances. A 1¾ in. clearance on an 18 in. package was allowed. Cable isolators met or exceeded the requirements in all planes (Fig. 3).

Standard Specification Procedure

For standard specification procedure, follow these steps:

1. Refer to 10 CPS system resonant frequency in Ladder-Isolator Design (Fig. 4).
2. Note that isolation is 75% at 26 CPS, or, inversely, 25% transmissibility.
3. Read down page to 30-lb. load.
4. Read across to correct isolator part number. (C3-A-512-1). Use 4 pieces.
5. Read across for all pertinent dimensions relative to the isolator and attachment points, which includes 15 Gs shock input clearance.

If CG is not on the conroid:

1. Determine the proportionate share of the weight at each mounting location for the equipment to be isolated.
2. Multiply the weight of the heaviest mounting location by 4. This number becomes the design load.
3. Select the resonant frequency that provides the allowable transmissibility at the critical frequencies of the supported equipment.
4. Select the appropriate isolator part number (e.g. C3A-812-1) based upon the design load calculated in 2 above.
5. Note that the isolator selected has a specific number of cables.
6. Set up proportions of the share of weight supported to the number of cables in the isolator, starting with the heaviest load proceeding to the lightest load.

10 lb. = 12 cables, 10 lb. = 12 cables, 10 lb. = 12 cables
8 lb. = 10 cables, 5 lb. = 6 cables, 4 lb. = 5 cables

7. a. After the mountings have been received, the two center cables in each leg of the isolator assembly at the 8 lb. load location should be cut and completely removed.
   b. At the 5 lb. load location, the six center cables in each leg of the isolator should be completely removed.
   c. At the 4 lb. load location, the seven center cables in each leg of the isolator should be completely removed.
8. This application of surgery to the mounting assures the performance of the system in accordance with the prediction.
9. The mountings may now be installed at the appropriate load points. Clearances and dimensions have already been determined from the tabular data under the resonant frequency desired. The mountings should be installed on a plane that intercepts with the CG of the equipment.

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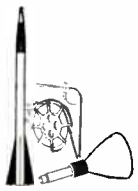
MAPICO

IRON OXIDE REAGENTS



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(e) give controlled shrinkage
(f) give controlled electronic characteristics
(g) are produced in ample supply by a large, modern, technically staffed plant

DATA ▶ MAPICO PRODUCTS	COMPOSITION	PARTICLE SHAPE	PREDOMINANT PARTICLE SIZE (Microns)	SURFACE AREA	Apparent Density		TYPICAL CHEMICAL ANALYSIS									
							% PURITY	% MOISTURE (Loss at 105° C)	LOSS ON IGNITION	% WATER SOLUBLE SALTS	% SiO_2	% TiO_2	% SO_3	% Al_2O_3	% Cu	% Mn
				m^2/g ***	S.V.†† Gms./CM^3	Tapped Gms./CM^3	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.	Min. Max.
Yellow Light Lemon 100	ferric oxide hydrate	acicular	0.4-0.8	22.4	.14	.35	98.8 99.2	.30 .50	11.5 12.0	.04 .08	.05 .15	.002 .004	.20 .60	.001 .002	.03 .05	.015 .025
EG-1*	magnesium ferrite	acicular	0.4-1.2	4.7	.18	.40	99.3 99.6	.10 .20	.05 .10	.35 .45	.05 .10	.002 .004	.10 .30	.001 .002	.02 .04	.015 .025
EG-2**	zinc ferrite	acicular	0.4-1.2	3.5	.27	.59	99.5 99.7	.10 .20	.05 .10	.05 .10	.10 .20	.002 .004	.02 .04	.001 .002	.02 .04	.010 .015
EG-3	gamma ferric oxide	cubical	0.3-1.2	8.7	.39	.71	98.0 99.0	.10 .20	.80 1.20	.10 .15	.03	.02 .04	.15 .20	.002 .005	.002 .004	.10 .20
Red 110-2	alpha ferric oxide	cubical	0.3-1.2	5.4	.33	.67	99.1 99.4	.05 .10	.25 .35	.10 .15	.03	.02 .04	.10 .15	002 .005	.002 .004	.08 .15
EG-60	alpha ferric oxide	cubical	2.0-4.0	2.8	.45	1.00	99.3 99.6	.05 .10	.20 .30	.10 .15	.03	.02 .04	.10 .15	.002 .005	.002 .004	.06 .10
Red H.P.	alpha ferric oxide	cubical	2.0-4.0	2.8	.45	1.00	99.7 99.8	.02 .05	.07 .15	.02 .04	.03	.005 .02	.03 .06	.002 .005	.002 .004	.04 .06
EG-80	alpha ferric oxide	cubical	3.8-5.9	1.3	.85	1.74	99.4 99.7	.05 .10	.10 .20	.10 .15	.03	.02 .04	.05 .10	.002 .005	.002 .004	.06 .10
Red 297	alpha ferric oxide	spheroidal	0.3-0.8	8.4	.30	.59	99.3 99.6	.05 .20	.30 .60	.08 .20	.05 .15	.001 .003	.05 .25	.01 .02	.001 .003	.01 .02
Red 347	alpha ferric oxide	spheroidal	0.3-0.9	7.4	.32	.61	99.4 99.7	.05 .20	.20 .50	.05 .20	.05 .15	.001 .003	.05 .20	.01 .02	.001 .003	.01 .02
Red 387	alpha ferric oxide	spheroidal	0.3-1.1	6.5	.33	.69	99.4 99.7	.05 .20	.20 .50	.05 .20	.05 .15	.001 .003	.05 .15	.01 .02	.001 .003	.02 .03
Red 477	alpha ferric oxide	spheroidal	0.4-2.0	5.9	.36	.74	99.5 99.8	.05 .15	.15 .45	.04 .15	.05 .15	.001 .003	.05 .10	.01 .03	.001 .003	.02 .04
Red 567	alpha ferric oxide	spheroidal	0.4-2.6	4.9	.37	.74	99.5 99.8	.05 .15	.15 .45	.04 .15	.05 .15	.001 .003	.05 .10	.01 .03	.001 .003	.03 .06
Red 617	alpha ferric oxide	spheroidal	0.4-3.7	3.9	.39	.74	99.5 99.8	.05 .10	.15 .35	.04 .10	.05 .15	.001 .003	.05 .10	.01 .03	.001 .003	.03 .10
Red 516-M	alpha ferric oxide	acicular	0.3-1.0	26.4	.14	.32	97.0 98.3	.10 .30	1.0 2.2	.10 .30	.10 .20	.002 .004	.20 .40	.001 .002	.03 .05	.015 .025
Black†	synthetic magnetite	cubical	0.2-0.8	6.7	.34	.71	99.0 99.2	.05 .20	.70 .90	.05 .10	.03 .06	.02 .04	.03 .06	.002 .004	.002 .004	.20 .25

*MgO (as $MgO.Fe_2O_3$); 18.7-19.2%—U.S. Patent 2,502,130
**ZnO (as $ZnO.Fe_2O_3$) 32.6-32.8%—U.S. Patent 2,904,395
***As determined by nitrogen adsorption
†FeO (as $FeO\cdot Fe_2O_3$) 21-22%.
††Scott Volumeter

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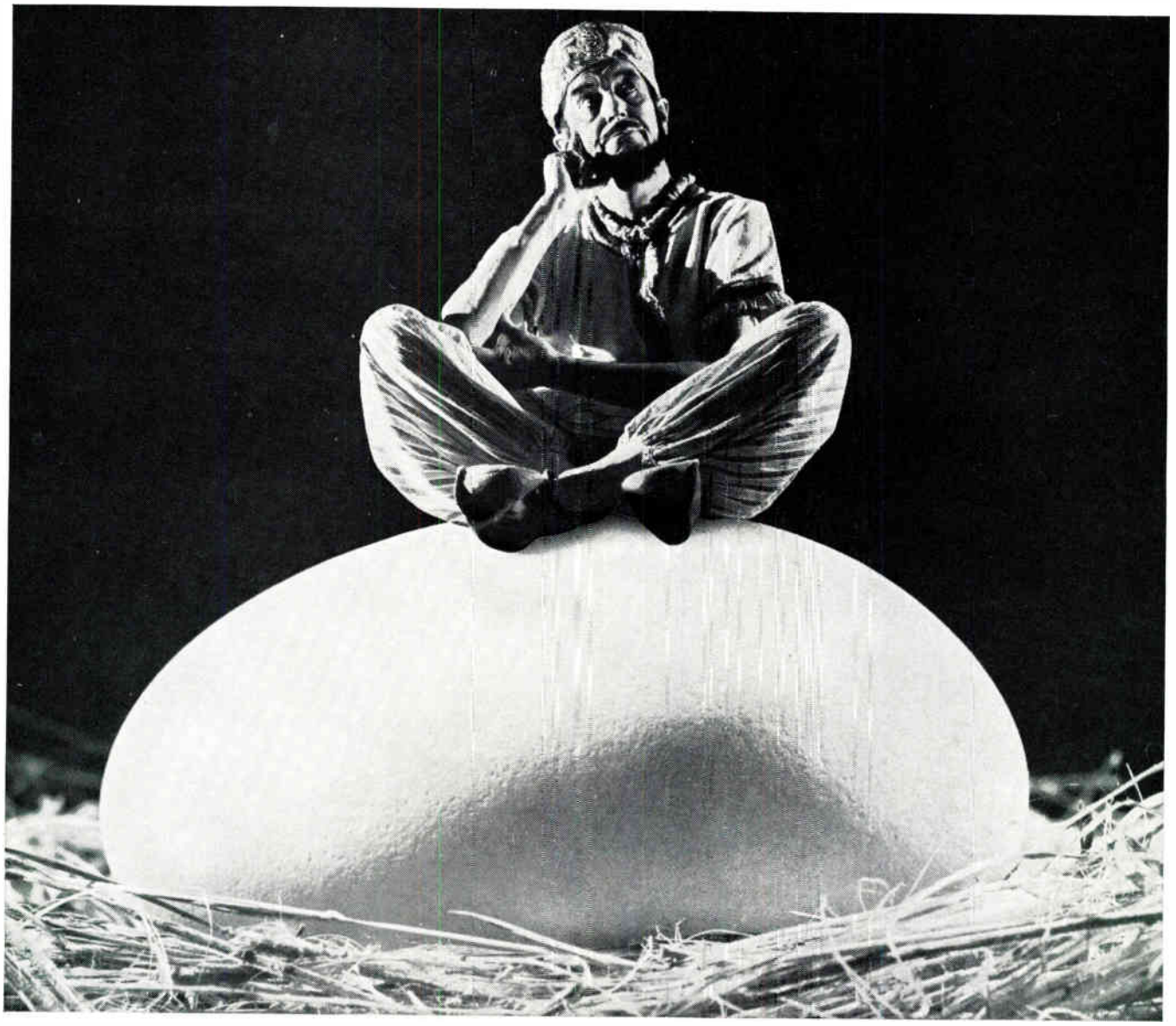

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NEW TECH DATA

MATERIALS & HARDWARE

Soldering Tip Aid

The GC-76, a high temp. mil-spec. lubricant and disassembly compound is available. This tough waterproof solvent resistant compound remains in permanent suspension indefinitely in temps. exceeding 3000°F. It was developed because of the industry wide need to protect the soldering tips from locking or seizing due to high temp. soldering and where dissimilar metals come together. The compound also eliminates solder-tip breakage and does away with penetrants. General Compounds Co., 6105 W. Washington Blvd., Culver City, Calif.

Circle 309 on Inquiry Card

Switch Shields

Data Sheet 169 describes a new line of non-shock sensitive Co-Netic magnetic shields with minimal retentivity designed to reduce magnetic radiation from switches. Magnetic Shield Div., Perfection Mica Co., 1322 No. Elston Ave., Chicago, Ill.

Circle 310 on Inquiry Card

Thermosetting Materials

A 3-color, file-size folder, "Cordopreg, Pyropreg," containing data sheets on thermosetting ablative and insulating molding material is available. Data sheets list properties and characteristics on high-temp., custom-formulated molding materials. Materials are either filled or unfilled resin systems, pre-impregnated into reinforcements such as high silica, graphite, carbon, quartz, asbestos or synthetic fibrous substrate. Cordo Div., Ferro Corp., 34 Smith St., Norwalk, Conn.

Circle 311 on Inquiry Card

Laminated Plastic

Grate G-9, an improved glass-melamine laminated plastic which qualifies under the Mil spec. for Type GME, is described in Bulletin No. 4.5.3. The physical, mechanical and electrical properties of G-9 are listed. Made from continuous filament woven glass fabric base laminate bonded with an improved melamine resin, G-9 is suggested for use in applications requiring high dielectric strength plus mechanical strength. Taylor Corp., Valley Forge, Pa.

Circle 312 on Inquiry Card

Unicabinet Console

A new console for rack mounted equipment incorporating rack space in a unit that also provides a large work table surface is described in a brochure. The rack portion of the Unicabinet console may be considered a module; it may be arranged in single, multiple, L-shaped, U-shaped, and kidney-shaped units. Dahlstrom Mfg. Corp., Jamestown, N. Y.

Circle 313 on Inquiry Card

Copper Strip

This data sheet covers analysis properties, and usage of Brush 10 Alloy strip and Brush 35 Alloy strip. These alloys possess the highest electrical and thermal conductivities of any beryllium copper alloy. Brush 10 Alloy is used in current carrying springs, switch parts and similar components. Brush 35 Alloy is used for casting and forging applications, and recent refinements now permit its use in rod, bar, wire and strip forms. The Brush Beryllium Co., 17876 St. Clair Ave., Cleveland 10, Ohio.

Circle 314 on Inquiry Card

Hardfacing Alloy

Bulletin 151 describes the Metco 15F hardfacing alloy used to apply nickel-chromium-boron coatings. The material is a self-fluxing powder which produces thin, hard, dense, corrosion-resistant coatings when flame-sprayed and fused. The powder meets AMS Spec. 4775-A. Metco Inc., Dept. 172, Westbury, L. I., N. Y.

Circle 315 on Inquiry Card

Stripping Agent

This highly efficient epoxy stripping agent works rapidly at ambient temps. and does not affect metal. Especially developed for trimming and cleaning conductive materials, the product is also excellent for salvaging metals and removing epoxy type potting materials. Samples available on request. Hasa Products Co., Inc., 109 N. Vineland Ave., City of Industry, Calif.

Circle 316 on Inquiry Card

Plating Guide

A guide for meeting exacting Mil specs for plating with precious metals, base metals and alloys is available. The comprehensive 16-page booklet lists and describes current plating mil/specs and tells how to meet them. It also discusses end-uses with an analysis of required metallurgical properties. Lea-Ronal, Inc., 130-19 180th St., Jamaica 34, N. Y.

Circle 317 on Inquiry Card

Brazing Alloy Brochure

This brochure contains the advantages of new vacuum processed oxide free (VPOF) brazing alloys. Typical applications and melting points are given for Wesgo's low vapor pressure, ultra-high purity VPOF brazing alloys. Used in vacuum tube components and other critical high temp. uses such as turbine rotors, jet and rocket engines, VPOF alloys are available in wire, sheet, ribbon, preform and Flexibraze ribbon. Western Gold and Platinum Co., 525 Harbor Blvd., Belmont, Calif.

Circle 318 on Inquiry Card

Blower Cabinets

This line of blower cabinets for standard 19 in. rack provides quiet, clean, filtered cooling in a compact package. The blower cabinets are available in 2 panel styles, standard and recessed. Grilles are of stainless steel and filters are washable, permanent, and can be easily removed and cleaned from the front. Motors are 115 vac, 50/60 cps, 1 phase, and 40 cps polyphase, all voltages. They have low input power and current and rated for continuous duty. Data available from Rotating Components, Inc., 1560 Fifth Ave., Bay Shore, L. I., N. Y.

Circle 319 on Inquiry Card

Flame-Out Epoxy

High temp., semi-flexible epoxy resin system, called Scotchcast Brand electrical resin No. 255, is a filled low-cost product with a flame-out time of 10 seconds or less. It is suitable for continuous operation at Class B (130°C) temp. Scotchcast 255 is expected to meet and surpass the requirements of MIL-I-16923, Type D, spec. New data sheet lists physical and electrical properties and uses. Flame-out is shown with photos. The 3M Co., 2501 Hudson Rd., St. Paul, Minn.

Circle 320 on Inquiry Card

Plastics Designing

How to design and apply plastics in sliding or plane surface bearing applications is outlined in an illustrated brochure, "Plastics in Sliding Bearings." Discussed are material selection, loads and speeds, effects of temp., cold flow and suggested configurations. Plastics most suitable for sliding bearings are compared from standpoint of bearing design. Cadillac Plastic & Chemical Co., 15111 Second, Detroit, Mich.

Circle 550 on Inquiry Card

Metals Catalog

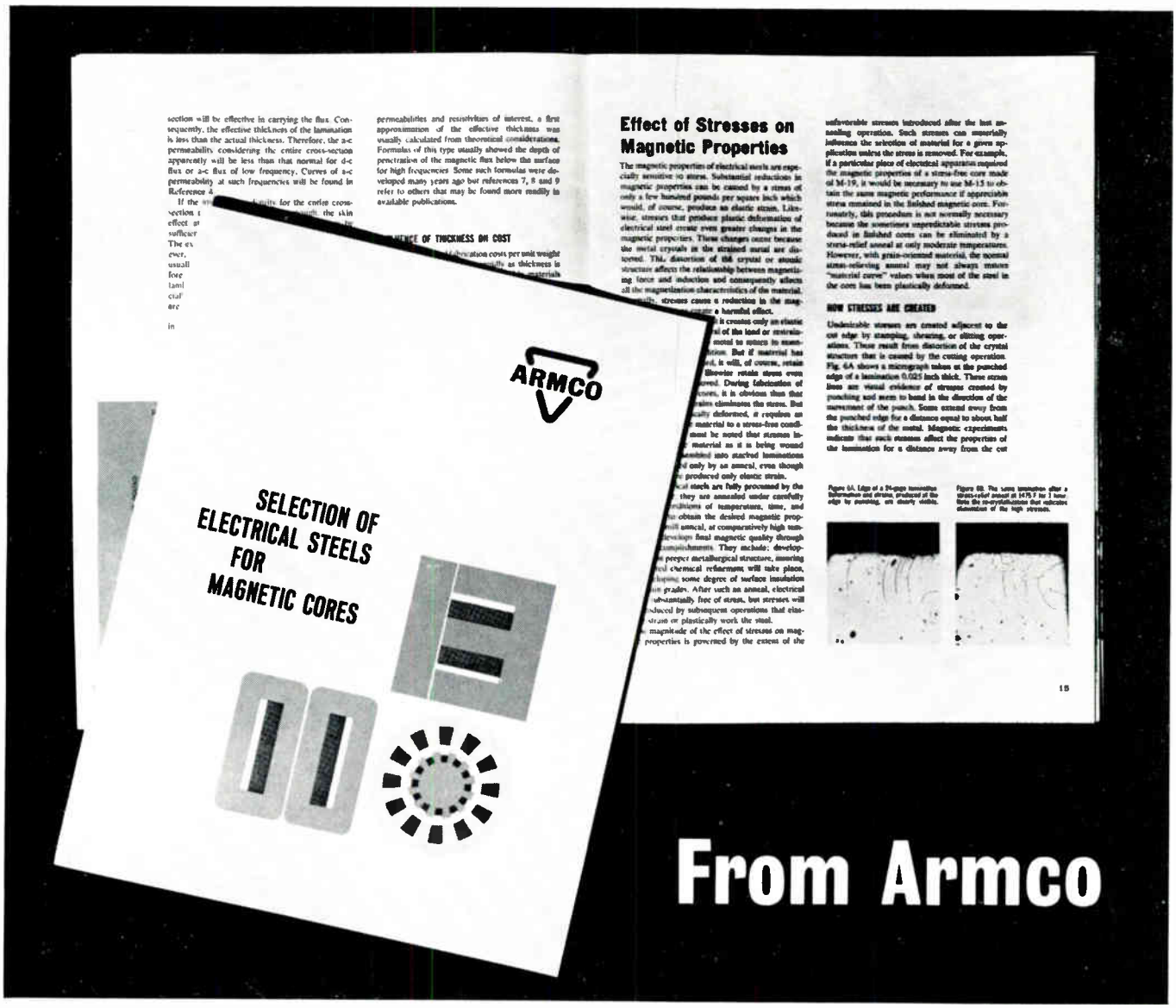
New 1964 catalog lists a complete line of ultra pure metals and chemicals in purities ranging up to 99.9999+%. They are available in various forms such as ampoules, bars, foil, lumps, powder, rods, sheet, shot, single crystals, turnings and wire. Leytess Metal & Chemical Corp., 500 Fifth Ave., New York, N. Y.

Circle 551 on Inquiry Card

Bus-Bar Bulletin

A new technical bulletin describing laminated and molded bus bars is available. It is involved with the fundamental theories, purpose and use of a laminated and molded bus for power distribution. Designing of a power bus, both from electrical and mechanical viewpoints, is made clear. Eldre Components, Inc., 1239 University Ave., Rochester 7, N. Y.

Circle 552 on Inquiry Card



. . . a new and useful reference on electrical steels

"Selection of Electrical Steels for Magnetic Cores" presents a discussion of the fundamental as well as practical factors that affect the selection and use of electrical steels.

This informative 32-page booklet describes the classification, manufacture and types of magnetic materials but emphasizes certain important subjects not covered in most references. For example, sections on the effect of stresses on magnetic properties, mechanical properties, and surface insulation discuss the important influence of those factors on both design and fabrication.

Reports from design and production engineers as well as purchasing agents state that they have found "Selection of Electrical Steels for Magnetic Cores," a valuable and most useful reference.

Get your free copy of this new Armco booklet today. Just write us. **Armco Division, Armco Steel Corporation, Dept. A-2034, P. O. Box 600, Middletown, Ohio 45042.**

ARMCO **Armco Division**

NEW TECH DATA

MATERIALS & HARDWARE

Nonburning Laminate

G-11 type, all purpose, copper-clad laminate can be dip soldered, and/or electroplated, and/or vapor degreased without detrimental effect. It uses a resin compound which allows it to retain at least 50% of its flexural strength after exposure for 1 hr. at 300°F. The Mica Corp., 4031 Elenda St., Culver City, Calif.

Circle 326 on Inquiry Card

Solder-Preforms Bulletin

A new illustrated technical bulletin on the careful design, proper use, and mass production techniques involved in the use of solder preforms is available. Bulletin TR 1010 contains data on the preform shapes used, basic design steps to consider, tips on preform use, and photos. Alpha Metals, Inc., 56 Water St., Jersey City, N. J.

Circle 327 on Inquiry Card

Plastic-To-Metal Seal

This data describes a true 100% plastic-to-metal hermetic seal. Through a unique process involving heat and metal treatment, a molecular bond is created between the metal oxide and the fluorocarbon which is Teflon FEP. This hermetic bonding of plastic-to-metal possesses absolute zero moisture absorption, temp. range from −450°F to +400°F, extremely low dielectric constant and dissipation factor, abrasion and shock resistance, exceptional high surface and volume resistivity plus indefinite shelf life. Carmer Industries, Inc., Parsippany, N. J.

Circle 328 on Inquiry Card

Assembly Tools

A new series of tools designed for miniature and subminiature parts handling, potting and encapsulating are explained in 4 bulletins. Complete specs., application data, prices and ordering information are included. Philip Fishman Co., 7 Cameron St., Wellesley 8, Mass.

Circle 329 on Inquiry Card

Alloy Bulletin

Bulletin T-38, 37 pages, contains technical data on composition, physical and thermal properties, corrosion resistance and heat treatments for Inconel alloy X-750. Detailed information on metallurgy and microstructure is included. New information is presented covering fabrication, machining, welding, and annealing. This alloy provides high creep and rupture strength and excellent corrosion and oxidation resistance at temps. up to 1500°F. Applications include pressure vessels, gas turbines, jet engines, airframe and missile structures. Huntington Alloy Products Div., The International Nickel Co., Inc., Huntington, W. Va.

Circle 330 on Inquiry Card

NEW TECH DATA

MATERIALS & HARDWARE

Technical Ceramics

This 16-page brochure describes the mechanical, physical, and electrical properties of four basic types of high alumina ceramic as well as Steatite, Cordierite and electrical porcelain materials. The brochure contains detailed data on the design considerations involved in the fabrication of ceramic parts and includes information on techniques of metalizing of ceramic materials. Also included is a detailed listing of standard metalized ceramic tubes which are available for insulation and encasement of electronic components. Centralab, P. O. Box 591, Milwaukee, Wis.

Circle 331 on Inquiry Card

Insulating Products

Data and samples of 9 of its Class-F insulating products have been assembled in this brochure. Designed for engineering reference, the brochure contains general description, application and property data for 5 insulating products. Dept. F4-184, 3M Co., 2501 Hudson Rd., St. Paul, Minn.

Circle 332 on Inquiry Card

Miniature Socket

A miniature socket for 10-lead, TO-5 case integrated circuits has been developed. The socket measures 0.375 in. in dia. and is 0.296 in. high when mounted on a PC board. It is designed to permit easy insertion and removal of the integrated circuit, and simplifies testing and maintenance procedures. Data available from Cinch Mfg. Co., 1026 So. Homan Ave., Chicago, Ill.

Circle 333 on Inquiry Card

Lock Nut Wall Chart

This 36 x 24 in. wall chart illustrates an entire line of locking fasteners. There are free spinning and prevailing torque type lock nuts, locking screws, cap nuts, weld nuts, and new nylon insert lock nut. MacLean-Fogg Lock Nut Co., 5535 N. Wolcott Ave., Chicago, Ill.

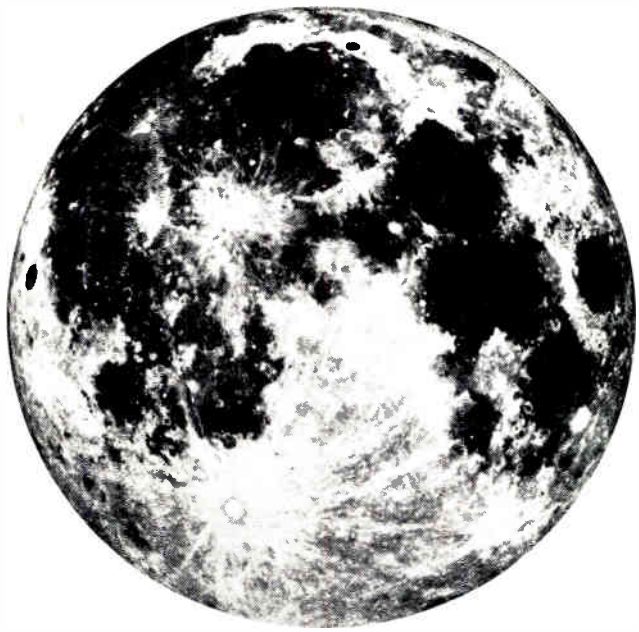
Circle 334 on Inquiry Card

Dye-Developer Product

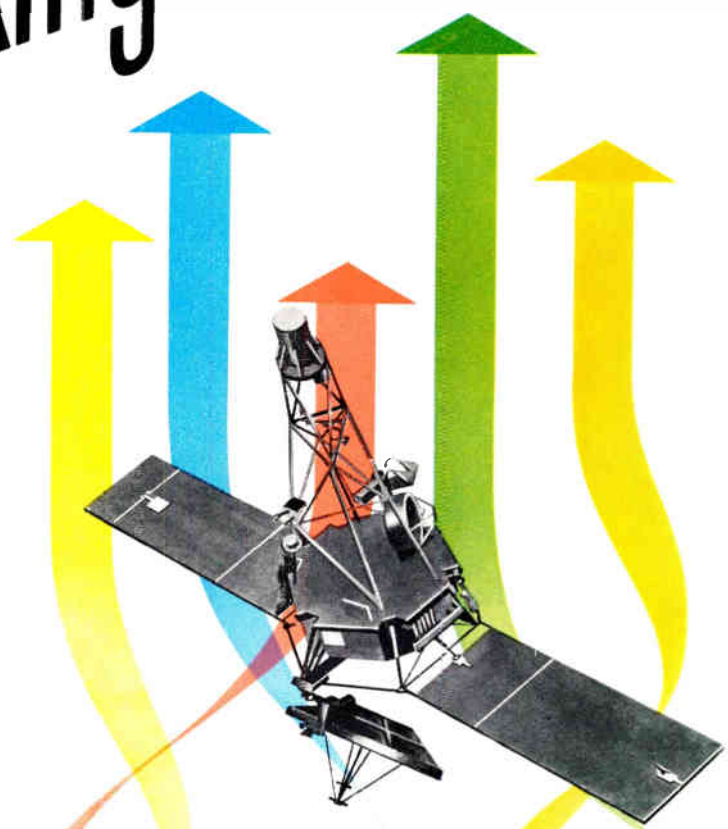
A new combination dye-developer product used in manufacturing photo-processed printed-circuits is fully described in a product data sheet. Called Metex Dy-velop, the product replaces the conventional 3-stage operation of developing, rinsing and dyeing with a single product. Processing time and labor are reduced, and inspection is simplified. Boards normally rejected after dyeing can be re-run through Dy-velop until the image is sharp and black. Wet boards can be immersed in the solution safely, and adhesives used to bond copper foil to plastic laminates are not attacked. Mac Dermid Inc., Waterbury, Conn.

Circle 335 on Inquiry Card

Circle 142 on Inquiry Card →



kaupp metal working techniques



—help to straighten production "kinks" in aerospace projects

KAUPP facilities include high efficiency metal forming machines housed in ultra-modern metal-working plants. KAUPP craftsmen have been supplying precision metal components to industry since 1924, and are thoroughly familiar with the problems of forming modern metals and alloys for both commercial and military requirements.

KAUPP

. . . Metal Craftsmen since 1924

For complete data on KAUPP capabilities please refer to reverse side—

kaupp metal working facilities

HYDROFORMING Special service is available to design and development engineers with simpler tooling, faster set-ups and improved quality. KAUPP hydroforming provides economical and fast delivery.

SPINNING A minimum of tooling saves time and reduces costs on prototype pieces, sample parts and short production runs. KAUPP offers years of experience in this method of metal forming.

DEEP DRAWING Carbon steel or "space age" alloys, KAUPP engineers have the "know how" and the equipment needed, to hold work to closest tolerances and maintain uniformity during all phases of production.

WELDMENTS Weldments and subassemblies can be produced for military electronics and nucleonics, and for experimental parts in research and development work.

TOOL DEPARTMENT One of industry's most efficient tool and die departments is maintained by KAUPP to assure the economical production of all dies, punches, jigs and fixtures. Delays waiting for tools are thus eliminated.

High Accuracy Equipment for Fast Prototype and Production Service

KAUPP experience solves unusual metal forming problems. Our engineers are familiar with problems involved in making unusual shapes and sizes.

Consult KAUPP for special components for rockets, missiles, aircraft and radar. Complete service including piercing, notching, embossing, annealing, spot welding and fabricating.

MU METAL	TITANIUM
BRASS	CARBON STEEL
INCONEL	MULTIMET*
ALUMINUM	HAYNES* No. 25
COPPER	STAINLESS STEEL
SILVER	HASTELLOY* X
NICKEL	MAGNESIUM
NIMONIC	WASPALLOY

KAUPP engineers will suggest the most efficient method of producing your specific components. Estimates on metal parts will be supplied on receipt of your blueprints.

*Union Carbide Corporation Trademarks

HYDROFORMS
1 8" PRESS 1 12" PRESS
2 19" PRESSES

PRESSES
1 BLISS NO. 4A SINGLE CRANK DOUBLE ACTION
1 BLISS NO. S-100—100 TON 10" STROKE PNEUMATIC CUSHION 15 TON
1 BLISS NO. 305 90 TON 10" STROKE PNEUMATIC CUSHION 15 TON
3 NIAGARA NO. H 3 ½A—45 TON
2 NIAGARA NO. H 2 ½—25 TON
1 BLISS NO. 20B—32 TON
3 BLISS NO. 18 HORN
2 BLISS NO. 18 INCLINABLE
3 BLISS NO. 18C INCLINABLE
1 CONSOLIDATED NO. 72 PNEUMATIC CUSHION—5 TON
1 LOSHBOUGH & JORDAN NO. 2 SPECIAL
1 LOSHBOUGH & JORDAN NO. 3 SPECIAL
1 ZEH & HANNEMAN NO. 4
1 ZEH & HANNEMAN NO. 2 INCLINABLE

SPINNING LATHES
1 HAAG GAP LATHE 26 to 48
1 GRABO GAP LATHE 24 to 60
1 PRYBIL LATHE 26
1 GRABO LATHE 26
1 HAAG LATHE 22
3 GRABO LATHES 22
1 GRABO LATHE 16

LATHES
1 MONARCH—12 x 30
1 MONARCH—16 x 54
2 LE BLOND—17 x 54
1 SOUTH BEND—14 x 36
2 SOUTH BEND—10 x 36
2 SOUTH BEND—9 x 36
1 CINCINNATI—26 x 60
1 LE BLOND—22 x 48

MILLING MACHINES
1 MILWAUKEE RAM HD. 5 HP
1 MILWAUKEE VERT. 2 HP
1 MILWAUKEE UNIV. 2 HP
1 HARDINGE PLAIN
2 BRIDGEPORT ½ HP
2 CINCINNATI TOOLMASTERS
3 BRIDGEPORT 1 HP
1 SIMMONS HORIZONTAL PRODUCTION

GRINDERS
1 CINCINNATI UNIVERSAL 14 x 36 INTERNAL EXTERNAL HYDRAULIC
2 BROWN & SHARPE NO. 5 6 x 12 x 18 SURFACE
1 THOMPSON—6 x 12 x 18 SURFACE HYDRAULIC
1 REID—6 x 12 x 18 SURFACE
1 NEVEN BENCH GRINDER COMPLETE WITH DIAMOND WHEEL
1 MONOSET TOOL & CUTTER GRINDER

SAWS
1 GROB BAND FILING FAB NO. 18
2 GROB BAND DIE CUTTING
1 MARVEL POWER 6 x 8
1 MARVEL POWER 10

JIG BORER
1 PRATT & WHITNEY 1 ½B

SHEARS
1 NIAGARA SQUARING SHEAR 6'
1 NIAGARA SQUARING SHEAR 4'
1 FOOT SHEAR 3'
1 NIAGARA POWER CIRCULAR SHEAR & FLANGER
3 NIAGARA POWER RING & CIRCULAR SHEAR
1 HAND CIRCULAR SHEAR

SPOT WELDERS
1 PEER 15 KVA & TIMER
1 EISLER 10 KVA & TIMER
1 TAYLOR WINFIELD 50 KVA

MISCELLANEOUS
1 GOULD & EBERHARDT UNIVERSAL SHAPER 14"
1 MULMAT HIGH SPEED SENSITIVE DRILL PRESS
1 LELAND GIFFORD 26" SINGLE SPINDLE PRESS
1 BUFFALO 16" DRILL PRESS
4 WALKER TURNER 14"
1 DROP HAMMER 200 LB.
2 ATLAS LATHES PROD. WORK TRIM
1 WALKER TURNER 10" TILTING ARBOR TABLE SAW
3 30" x 60" SURFACE PLATE & ANGLE COMPUTER

Estimates supplied on receipt of blueprints — call, write or wire today!

C. B. KAUPP & SONS · INC

METAL CRAFTSMEN SINCE 1924

32 NEWARK WAY, MAPLEWOOD, N. J. — Telephone: POplar 1-4000 (Area Code 201)

NEW TECH DATA

MATERIALS & HARDWARE

Aluminum Soldering

This bulletin describes Paraco-Bond '61, an alloy that allows soldering of aluminum to aluminum without flux. It does away with cleaning before and washing afterwards. It melts at 717°F; actual application takes a few seconds. Paraco Metals, Inc., 45-02 83rd St., Elmhurst 73, N. Y.

Circle 436 on Inquiry Card

Divider-Card Module

Bulletin B100-10 describes a versatile decade divider-card module. The new illustrated bulletin gives complete specs. and operating data on Model B100-10. Engineering diagrams and a detailed dimensional drawing are also included. Janus Control Corp., Hunt St., Newton, Mass.

Circle 437 on Inquiry Card

Magnet Manual

A 52-page magnet manual lists over 400 types and sizes of permanent magnets. It also contains application data and technical information on the use of magnets in a wide variety of industries. Bunting Magnetics Co., Dept. EX39A, 4447 W. Fullerton Ave., Chicago, Ill.

Circle 438 on Inquiry Card

Silicone Products Chart

This handy reference wall chart describes silicone rubber products. The chart lists the important physical and electrical properties, handling characteristics of silicone encapsulants, foams, and coatings. The chart is in color and well illustrated. Emerson & Cuming, Inc., Canton, Mass.

Circle 439 on Inquiry Card

Barrier Strips

This brochure features illustrations, specs. and descriptive data on terminal coding, variations of standard terminals and special terminals. Conectrix, Inc., 9025 Exchange Place, Franklin Park, Ill.

Circle 440 on Inquiry Card

Hermetic-Seal Process

Elimination of 96 fabricating steps and 32 individual parts in a hermetic seal through the use of a new TFE hermetic sealing process is reported in a technical bulletin issued by the producer. The report describes the use of the Hermaflon® bonding process to fabricate an all-TFE electrical feedthrough header for airborne electronics equipment. Included in the report are data on thermal cycling, expansion, and mechanical characteristics, as well as the process by which the chemically-inert, resilient seal is produced. Tri-Point Industries, Inc., 175 I.U. Willets Rd., Albertson, L. I., N. Y.

Circle 441 on Inquiry Card

Fact is, this newest entrant to 3M's fluorochemical coolant family, 3M Brand Inert Liquid FC-77, is cutting the cost of coolants at least 25%! These new prices make FC-77 practical for many new electronic and aerospace designs.

FC-77 takes the heat away faster than non-volatile organic liquid coolants. Secret? It boils at about 100° C. Thus it vaporizes and carries off heat at a higher rate than other conventional convective coolants. FC-77 easily handles high heat fluxes with minimal changes in temperature of component. Retains its high electric strength (in excess of 35 KV) when changing from liquid to vapor. And unit size can be reduced as much as 4 to 1, weight by 2 to 1.

FC-77 is neither affected by, nor does it affect, metals, plastics, elastomers—chemically or electrically. And when used in an efficient closed system, it lasts as long as the equipment it cools.

Find out more about FC-77 and other members of this fluorochemical coolant family, FC-75 and FC-43. Write Chemical Division, Dept. KCQ-64, 3M Company, St. Paul, Minnesota 55119.

Chemical Division 3M COMPANY

NEW TECH DATA

MATERIALS & HARDWARE

Engineering Catalog

More than 15,000 types of electronic parts and hardware are illustrated in this completely revised full-line engineering catalog. Organized for convenient use by design engineers, this 176-page catalog is arranged in parts categories that simplify location of every item, with part differences shown clearly in comprehensive diagrams and tables. Detailed line drawings and engineering data are included for every category, and military specs. are identified where applicable. Cambridge Thermionic Corp., Cambridge, Mass.

Circle 442 on Inquiry Card

Ferrite Materials

Data is available on 2 new ferrite materials, TC-3, 4, and 6. They offer a low and linear change of inductance over a broad range of temps. and freqs. In addition, these new LTC ferrites provide exceptional stability with time high Q, high initial permeability and low losses. Detailed engineering data plus complete specs. on each of the 3 ferrite materials is available. Indiana General Corp., Electronics/Ferrites Div., Keasbey, N. J.

Circle 443 on Inquiry Card

Setting Welder Electrodes

Bulletin U-2 shows how to speed up setting of welder electrodes and how to eliminate costly sample testing with the aid of a small-size universal force gauge. The data provides information for the precise setting of weld pressures to meet even the most rigid government specs. Dimensional drawings, engineering data on capacities from 0—25 lbs. through 0—10,000 lbs., and prices are included. W. C. Dillon & Co., Inc., 14620-1 Keswick St., Van Nuys, Calif.

Circle 444 on Inquiry Card

Midget Screw Drivers

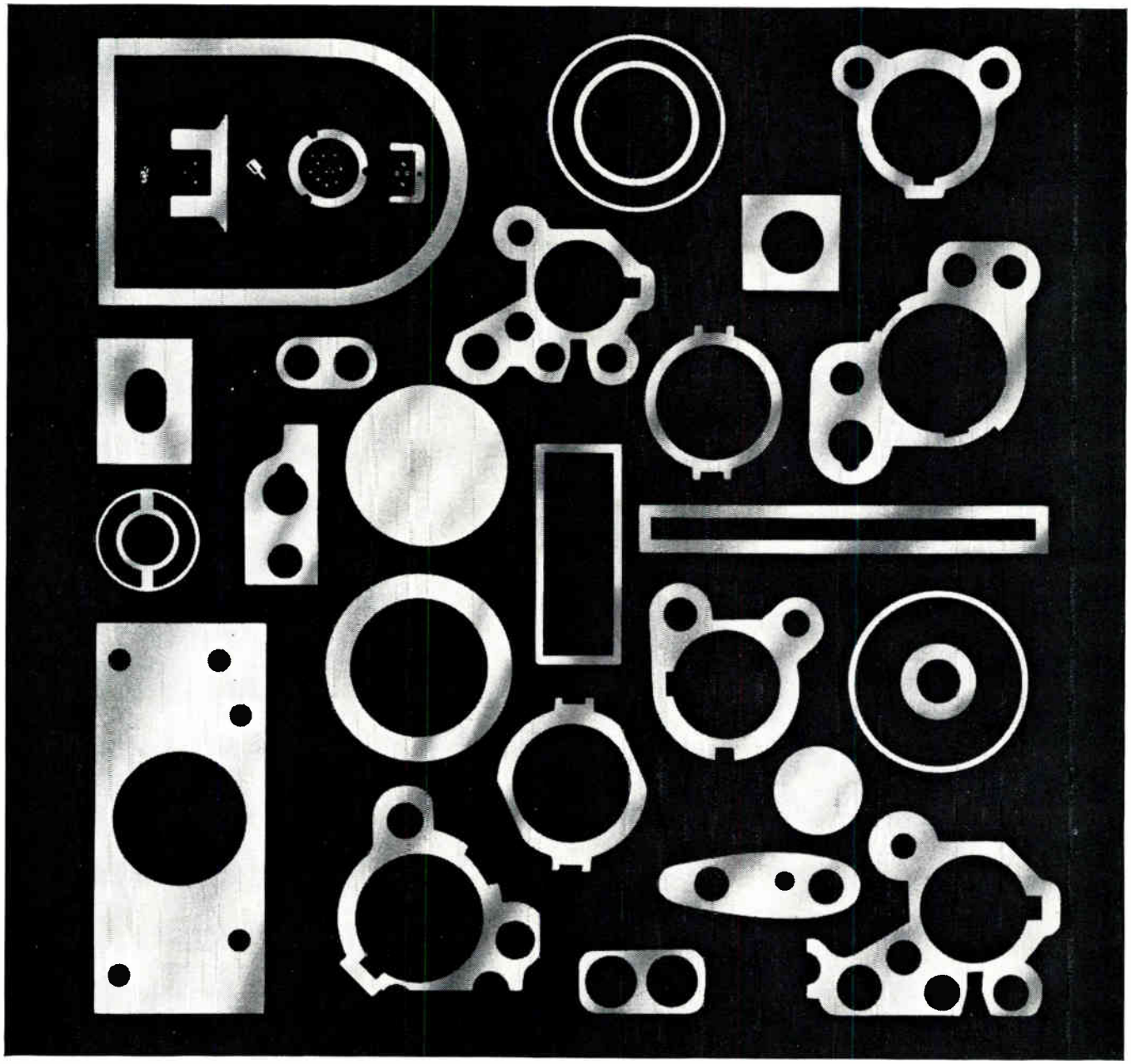
This spec. folder, Form 5401, details a line of 288 midget screw drivers for work with miniature components in the aircraft, computer, appliance, and electronic fields. Ingersoll-Rand Co., 11 Broadway, New York, N. Y.

Circle 445 on Inquiry Card

Pre-Assembled Fasteners

The speed, simplicity and locking efficiency of Impco Sems, an automatically pre-assembled washer and screw, is detailed in Form No. IMP-10263. The pre-assembled fastening unit requires no special handling and can be stocked as one inseparable item. The literature illustrates the assembling process and shows how the washer is free to turn but cannot drop off the screw. Also shown is the variety of screws, head styles and washer types available. Indiana Metal Products Co., Box 259, Rochester, Ind.

Circle 446 on Inquiry Card



Kester "Solderforms" come in any shape or size to save you production time and money

When you order Kester "Solderforms," your specific requirements determine the exact shape, size and alloy of solder. "Solderforms" are made-to-order, prefabricated forms of solder. You automatically get the right amount of solder and flux needed for each application. No more, no less . . . no waste.

"Solderforms" offer unequaled efficiency in production line soldering. You can assemble units with "Solderforms" in position—solder intricate assemblies faster and better. No question, "Solderforms" save you time and money . . . insure quality soldering!

Solder and soldering fluxes are Kester's only business. Have been for 65 years. That's why no one knows solder like Kester.

Write for our free "Solderforms" booklet. It contains detailed information on "Solderforms"—plus 10 pages of valuable Solder Engineering Data and Tables.

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NEW TECH DATA

MATERIALS & HARDWARE

Printed-Circuit Sockets

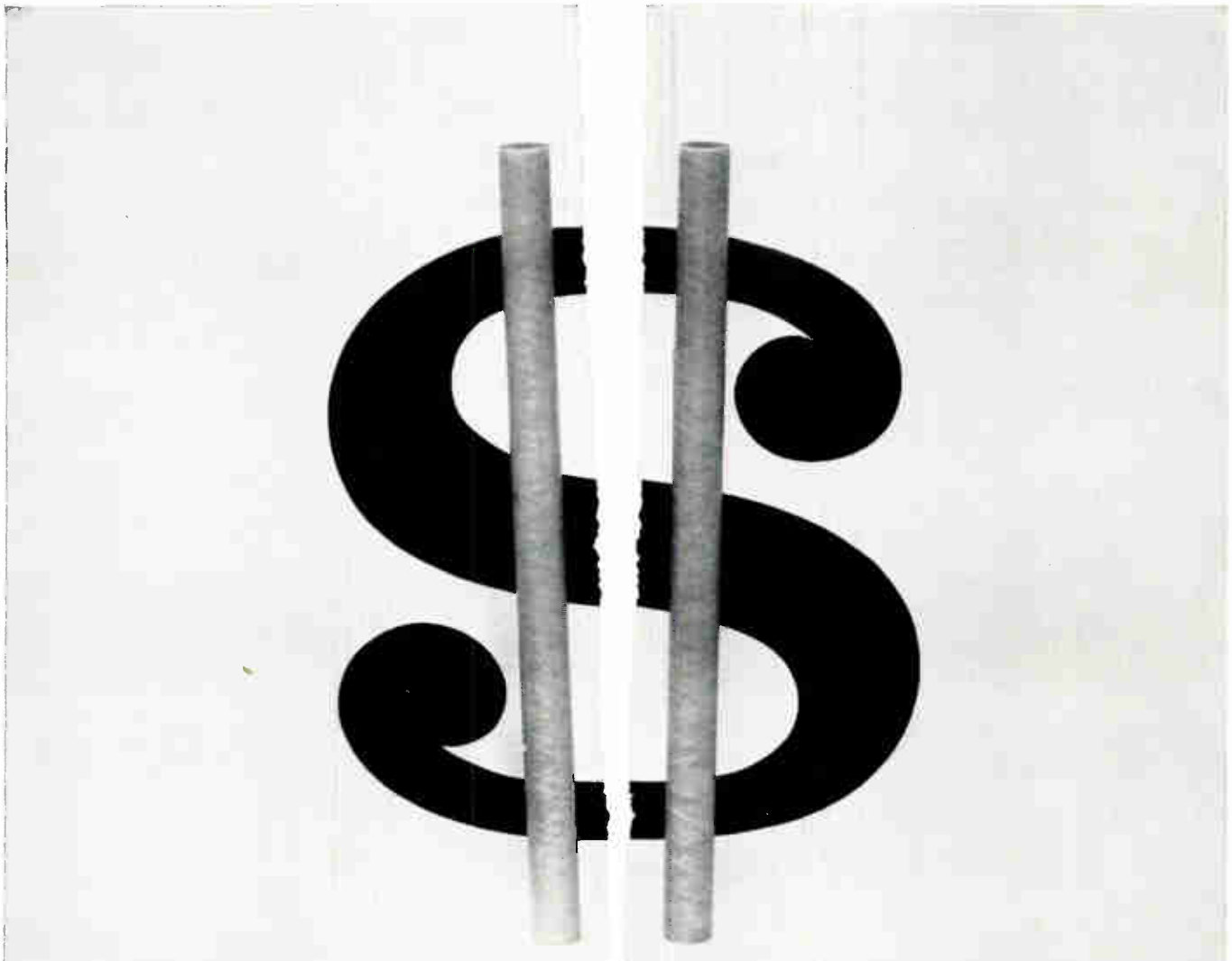
A line of novel and miniature tube stand-off PC circuit sockets for 1/16 in. boards is described in this literature. The sockets are supplied in 4 types: general-purpose black phenolic or mica-filled low-loss phenolic, with or without center shields. Each has snap-in contact tails to provide mechanical retention prior to soldering. Center shields are of brass, hot solder dipped. Cinch Mfg. Co. 1026 So. Homan Ave., Chicago, Ill.

Circle 447 on Inquiry Card

Magnetic Shunt Ring

Data Sheet 167 pictures and describes a Netic or Co-Netic magnetic shunt collector ring with corona guards. The device restricts radiation of magnetic fields generated during the ionization cycle of a thyratron or gas discharge tube, as well as in analogous applications in which a field is being propagated radially from a central conductive media. Magnetic Shield Div., Perfection Mica Co., 1322 N. Elston Ave., Chicago, Ill.

Circle 448 on Inquiry Card



STARTING TODAY THE COST OF FIBERGLASS REINFORCED TUBING IS 50% LOWER— AND THE QUALITY WAS NEVER HIGHER!

HYSTRAN® FILAMENT WOUND PLASTIC TUBING is available now at costs averaging half those of other NEMA grade fiberglass base tubing. This means you can start today to save from 40¢ to 60¢ on every dollar spent for tubing of NEMA grades G-3, -5, -7, -9, -10, -11, -12 or GPO-1, -2. Or you can upgrade your tubing from paper, cotton, asbestos and other cheap bases without increasing your costs.

OUTSTANDING PROPERTIES OF FILAMENT WINDING — HYSTRAN tubing not only costs less, it is actually superior to other tubing which may have the same NEMA grade but is merely rolled or molded. HYSTRAN is *filament wound* for better electrical and mechanical properties all down the line — including dielectric, moisture, temperature, strength/weight.

ALL SIZES, NO LIMIT ON LENGTHS — Forget the old limitations on length and size that have been hampering you. HYSTRAN tubing comes in standard lengths of 96" (more than double the current average standard.) Standard I.D. sizes from ½" to 3", and walls from 1/32" to ¼" give you a complete choice. And on special orders, it's available in *any* length or size!

THE PROOF IS IN THE PRICING — This price and performance breakthrough has been achieved by the development of super-speed, automated filament winding techniques and equipment. Whether you're already a fiberglass tubing user, or a near-user who's been held back by price, here's your chance to get off the cost spot. Phone or TWX us direct right now for a fast, firm quote on your tubing needs. Ask for Mr. Stewart — he's waiting to save you money.

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TEL 516-694-2000 TWX 516-694-3366

NEW TECH DATA

MATERIALS & HARDWARE

Caps/Plugs

These plastic caps and plugs provide low-cost protection for quick-disconnect couplings from dust, dirt and other contaminants. Made from a combination of tough, flexible elastomeric and linear polyethelene, the caps and plugs will not chip, break, shread or collapse. The plastic can withstand temps. from —70°C to 200°F and resist attack by acids and most common chemical reagents and solvents. Available in sizes from ¼ to 1 in. Additional information available from Dept. C&P, Snap-Tite, Inc., Union City, Pa.

Circle 449 on Inquiry Card

Ceramics

This bulletin covers a line of pure beryllium oxide ceramics in standard and customs shapes, ceramic-to-metal assemblies, and other pure metal oxides and specialty materials. The illustrated bulletin gives details on the properties and uses of Berlox pure beryllium oxide, including semiconductor heat sinks, semiconductor packages, and metallized and brazed ceramic-to-metal seals. National Beryllia Corp., First & Haskell Aves., Haskell, N. J.

Circle 450 on Inquiry Card

Design Aid

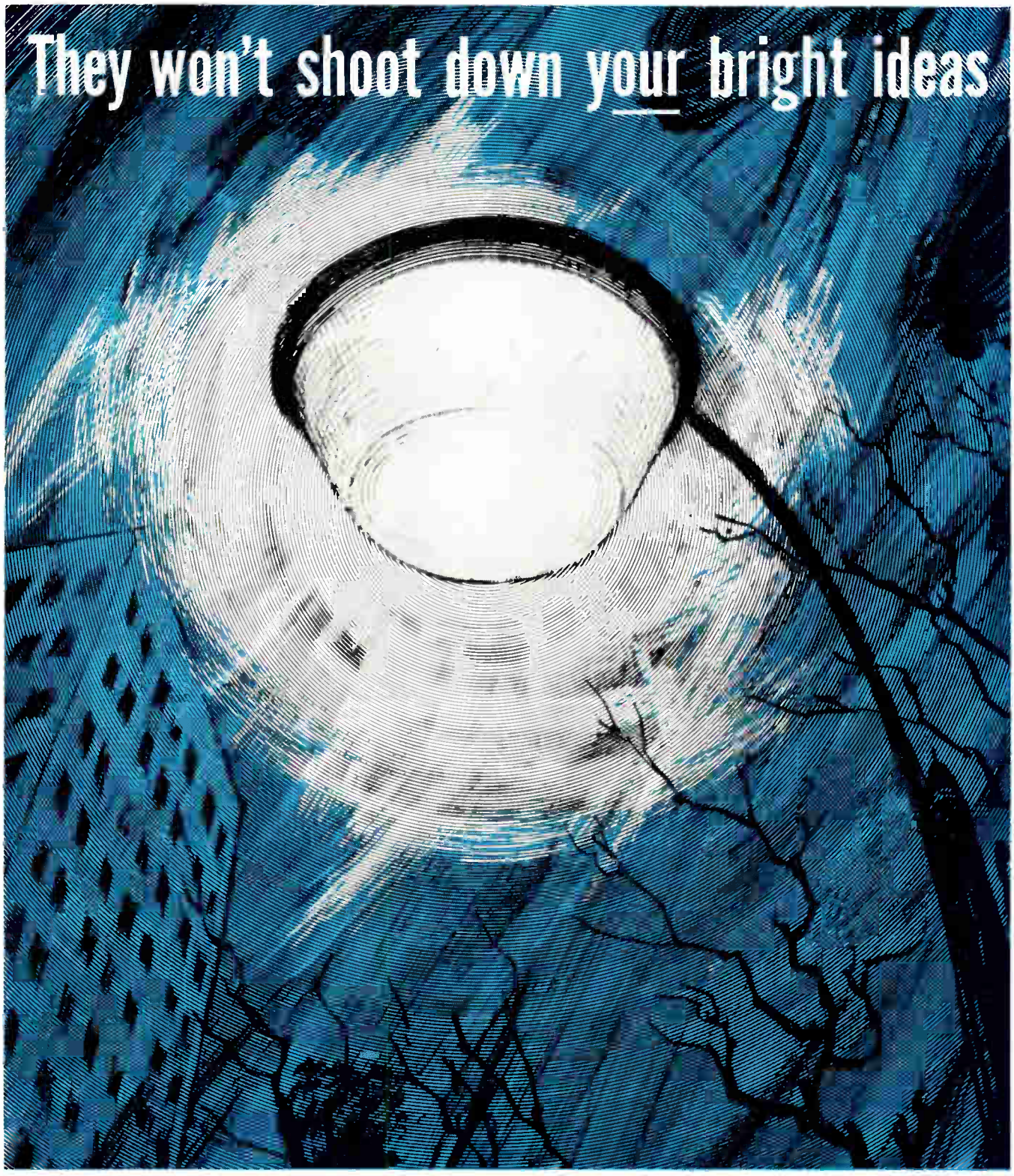
"How To Design O-Ring Drives" is a short course for engineers and designers on the uses of precision-molded rubber O-rings as drive belts in light-duty power transmissions. O-ring drives are quiet-running and vibration free, they offer excellent economies and long life. The article details concisely where to use O-ring drives, how to design them, and their limitations. Tables and formulas are given to determine belt tension, tension modulus, cord diameter, belt length, etc. E. F. Houghton & Co., 303 W. Lehigh Ave., Phila., Pa.

Circle 451 on Inquiry Card

Thermoplastic Polymers

Definitive information on ABS thermoplastic polymers has been compiled, condensed and published in collected form. Intended as the introduction to a forthcoming series of technical bulletins, the 3-color, 16-page booklet comprehensively outlines the nature and capabilities of Cycolac ABS. Major sections cover processing, properties, advantages, application and general description. Photographs, charts, and drawings are also included. Marbon Chemical Div., Borg-Warner Corp., Washington, W. Va.

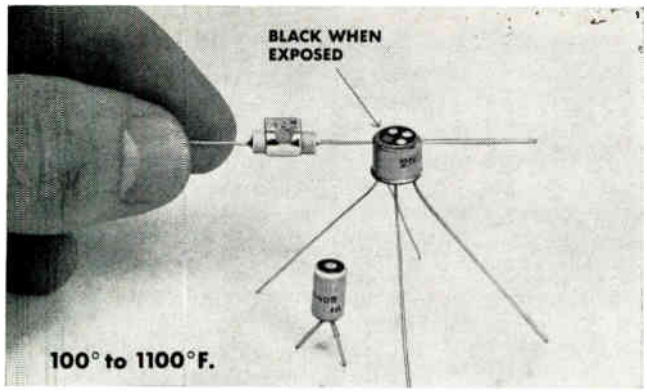
Circle 452 on Inquiry Card



if you mold them of MERLON® polycarbonate

Case in point: This outdoor lighting lens can withstand sledge hammer blows, hurled brickbats, even shotgun blasts. Yet, it combines the most sought-after plastic engineering properties—high impact strength, transparency, heat resistance, good dimensional stability at high and low temperatures, UL-listed electrical and self-extinguishing properties—the high-performance combination that spells MERLON polycarbonate. For the full story on properties, processing and application possibilities write: Mobay Chemical Company, Code EI-2, Pittsburgh 5, Pennsylvania.

MOBAY®



TEMP-PLATE®

DETECTS ELECTRONIC OVERHEATING

Overheating is detected in a positive, direct manner by Temp-Plate. Simple, easy to use, immersible and irreversible, Temp-Plate is the little plastic tab that sticks to a unit, turns black at any desired value from 100° to 1100°F. Available in both standard and miniature sizes, in any combinations of activating temperatures, Temp-Plate is impervious to production line handling and ambient temperatures—accurate to ±1%, it provides for absolute indication of heat damage.

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FOR FREE SAMPLE.

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Openings for qualified fluid components designer for missile and space systems.

Circle 153 on Inquiry Card

ELECTRONIC INDUSTRIES

M-A-P

Marketing Assistance Program

M-A-P can go to work for you with the six basic marketing tools you need to sell or study the Electronic Original Equipment Market.

(1) Census of electronic plants on IBM cards.
(2) Marketing map of U. S. electronic plants.
(3) Market studies by a headquarters research staff and 250 field interviewers.
(4) Computer center for processing inquiries.
(5) Direct mail service program.
(6) Marketing statistics.

Ask your Electronic Industries representative to help you start using it now or write—Edward G. Shaud, Jr., Marketing Manager, Electronic Industries, Chestnut & 56th Streets, Philadelphia, Pennsylvania 19139.

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Instant drafting with symbols and drawing details preprinted on tri-acetate sheets ready for use. Your own engineering details can be applied in seconds, rather than drawn in hours.

The STANPAT formula gives permanent adhesion without ghosting. Crisp, clean reproduction everytime on all types of tracing media. Excellent for microfilm reproduction.

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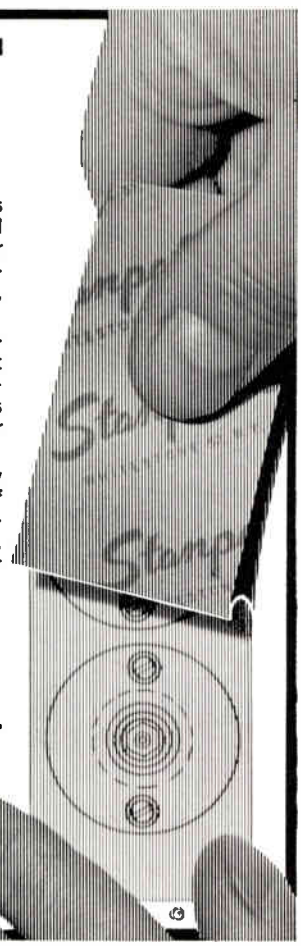

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NEW TECH DATA

MATERIALS & HARDWARE

Electronic Plier

Bulletin 464 introduces an entirely new concept in a cutting plier. It is designed for end cutting but has all of the best characteristics of a diagonal plier. High hardness of the cutting knives permits cutting of nickel ribbon. Handles coated with dipped plastic. Supplied with coil springs. Available in 4 and 5 in. lengths. Mathias Klein & Sons, Inc., 7200 McCormick Rd., Chicago, Ill.

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Tubular Fabrications

Data sheet 1163, 4 pages, describes the many different ways in which parts can be fabricated from small, seamless tubing. More than 40 examples of close-tolerance fabrication of tubular parts are illustrated and described. The data describes the advantages of tubular fabrications, and the extent to which thin-wall tubing can be worked. Uniform Tubes, Inc., Collegeville, Pa.

Circle 454 on Inquiry Card

Terminal Blocks Catalog

Catalog No. 17, 68 pages, presents a clear, concise and orderly arrangement of data on terminal blocks. It is now possible for design and specifying engineers to prepare drawings specs. with minimal consultation. Many new types of terminal blocks, representing the latest advances in the technology, appear for the first time anywhere, in the new catalog. Kulka Electric Corp., 633 South Fulton Ave., Mt. Vernon, N. Y.

Circle 455 on Inquiry Card

Tubing Catalog

Catalog AT/63 describes a line of heat-shrinkable products. Described are plastic, extruded, and fiberglass tubing, cords and tapes, termination caps and shrinkable wire markers. The catalog contains photos and properties charts. Alpha Wire Corp., 200 Varick St., New York, N. Y.

Circle 456 on Inquiry Card

Tools Catalog

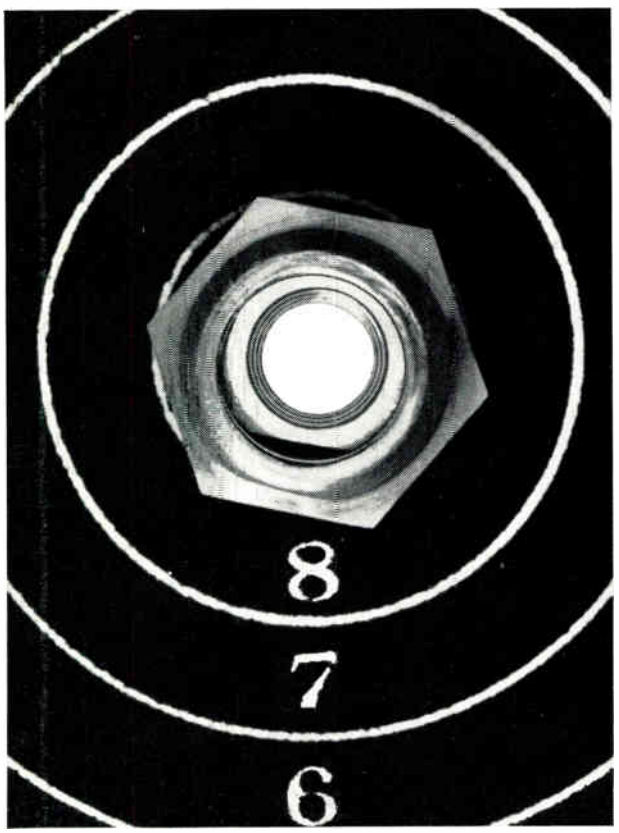
This 16-page catalog includes a complete line of tools for servicing, adjusting, testing, trouble shooting, assembly and production-line work. It includes a special unique line of tools for servicing and adjusting relays of every type. Jonard Industries Corp., Prec. Tools Div., 3733 Riverdale Ave., Bronx, N. Y.

Circle 457 on Inquiry Card

Terminal Boards

These boards are available in a variety of the most needed widths and lengths, featuring terminals spaced ¼, 7/32 and ⅜ in. apart. Insulation and materials conform to Mil Specs. Additional information from Keystone Electronics Corp., 49 Bleecker St., New York, N. Y.

Circle 458 on Inquiry Card



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NATIONAL'S NEW FLOATING CAPTIVE NUTS AUTOMATICALLY IMPROVE YOUR AIM

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37 Washington Street, Melrose, Massachusetts 02176
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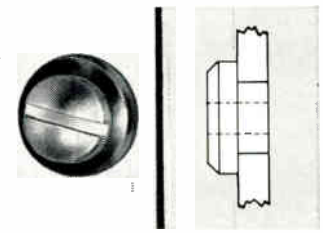
Weckesser NYLON WASHERS

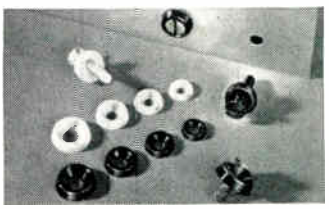
NEW SHOULDER WASHERS

Full insulating protection for metal screws. Also used as bushing, spacer or bumper. Available from stock for No. 2, 4, 6, 8, 10, ¼-20 and ⅜-16 screws. Black or natural.



FINISHING WASHERS

Prevent cutting and scratching of instrument and control panels, cover misaligned holes, used as glides, protective feet etc. For use with No. 6, No. 8, No. 10 and ¼" counter-sunk metal or nylon screws. Black or natural.



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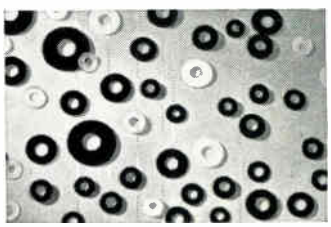
Stamped from extruded nylon strip. Used as insulating or cushioning washers, spacers, thrust washers. Black or natural.



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prices. However, now Japanese and West European electronic component makers are turning to automation because they face steadily mounting costs. The international electronic components market was fostered in some part by U.S. electronic interests. Some U. S. purchasing agents shrewdly use foreign prices as levers to help equalize, that is "drive down," U. S. components prices in certain cases.

New Pressures

All of the foregoing developments have contributed new pressures on component company managements. In turn, these management and marketing decisions represent a composite of practices in the U. S. components industry:

(1) Pushing the state of the art to develop new products, often company-funded if the firm wants to have proprietary interests; (2) Broadening product lines faster by acquiring domestic or foreign companies with proven products; (3) Integrating *downward* by acquiring or developing capabilities in component raw materials: plastics, chemicals, glass, organics, alloys, metals, ceramics and ceramic-metal "cermets"; (4) Integrating *upward* by moving into microcircuitry, modules, sub-assemblies or equipments; (5) Reducing or controlling costs by reorganizing or consolidating operations to cut overhead or move into modern plants with more efficient facilities; (6) Entering joint ventures, in the U.S. or abroad, to share risks and profits; (7) Selling or liquidating plants or divisions with unprofitable products to "plug profit drains"; (8) Either marketing more seriously or giving lip service to "marketing" while doing business as usual.

One leading components maker sums up his marketing approach thus: "We believe it is not enough to design an excellent product, build it efficiently and price it competitively. It is even more important in today's and tomorrow's rapidly expanding and changing economy to anticipate customers' needs." This firm further strongly supports marketing, especially in three critical areas:

(1) New product planning and development, for commercial and government applications; (2) Sales engineering, and (3) More comprehensive advertising.

In practicing what it preaches, this company has increased its marketing staff. It also uses computers to keep track of inventories, deliveries, present and projected customer needs, market potentials, and competitors' activities. Other companies have seen the marketing light, and now are becoming market-oriented rather than product-oriented.

That is, instead of selling the products *they make*, they're selling products that *customers need*.

The rectifier-type indicating instrument has been around for years and is especially popular for ac volt, db, and VU meters. Many improvements have been quietly made over the last few years. Here is a rundown on these improvements and their significance.

THE STATUS OF RECTIFIER-TYPE METERS

THE RECENT AVAILABILITY OF THE TRUE RMS ELECTRONIC VOLTMETER has stirred up a major controversy. Which type to use, the true RMS, peak, or average responsive? This article is concerned only with rectifier indicating instruments, but here too, the same question has wide interest.

To the user of portable and panel indicating instruments, the choice of meter type has never been a serious problem. Such basic types as the electrodynamometer, iron vane, and the permanent magnet moving coil meters have been with us for many years. They have been generally well understood and correctly applied by the user. The rectifier type has been used for applications requiring higher sensitivity in the audio frequency range and where an overall accuracy of about 3 to 5% was sufficient. The waveform error resulting from the RMS calibration with a basic average response has been of little concern.

But here too, the outlook is changing. One might question an accuracy as high as 0.1% when offered in a conventional rectifier instrument; or the choice between highly expanded scale ac voltmeters, one average responsive and the other RMS responsive.

The Rectifier Outlook Today

What has caused these and other changes in the rectifier type meter? When first introduced more than 35 years ago, the only practical rectifier was the copper oxide type. The generally poor rectification ratio resulted in high temperature error and large disc size gave poor frequency response. While it is true that optimum size, material, and processing of the copper discs have greatly improved the original

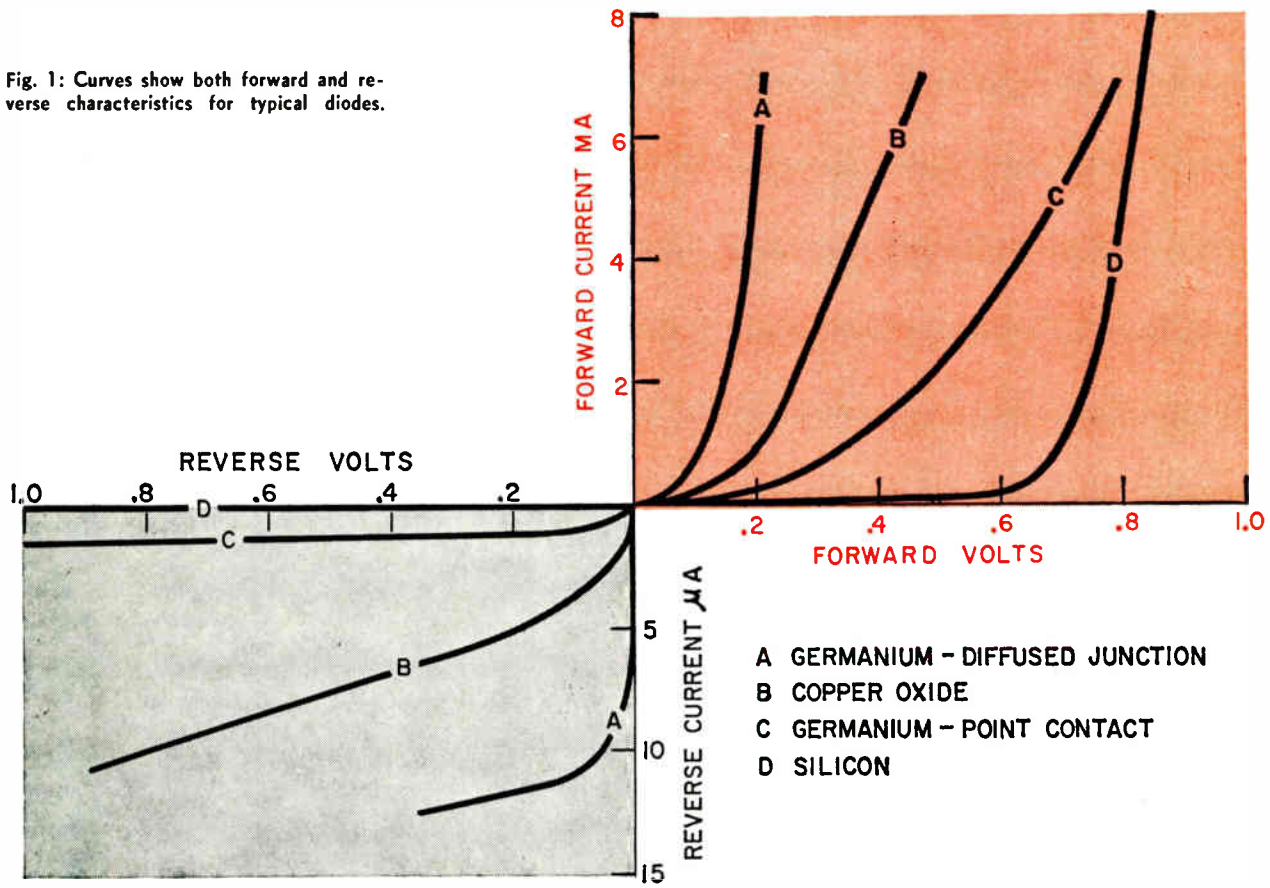


Fig. 1: Curves show both forward and reverse characteristics for typical diodes.

rectifier, they are being replaced by germanium and silicon diodes. The selenium rectifier has found some minor application because of improved ratio, but is too high in resistance and does not have the desired stability.

Fig. 1 shows typical dc characteristics of the more common rectifiers. These are single diodes or discs. Four would generally be used in a full bridge configuration; or for low voltage, two would be replaced by bridge arm resistors giving a half bridge arrangement. Voltmeter sensitivity is often 200 μa and generally not over 5 ma. Current meters can run to several amperes using silicon rectifiers.

To generalize the selection of instrument rectifier, we might select the copper oxide type for ranges to 10 volts, and with a half bridge, germanium diodes from 10 to 30 volts, and silicon diodes for high ranges. This selection results in the lowest overall temperature error. In the copper oxide type, the decreased ratio with increasing temperature is offset by the overall decrease in the rectifier bridge resistance. On the other hand, the silicon diode shows negligible reverse current and is therefore ideal for non-critical resistance circuits or for high voltage ranges. This is perhaps an oversimplification. There are many considerations involved in designing a rectifier instrument. Where special requirements are involved, such as a specific frequency range, extreme temperatures, etc., the design may need special rectifiers and compensation.

The bulk of the panel rectifier meters today are still made with copper oxide rectifiers. This is not entirely a matter of economics. For example, they are less subject to pulse damage than germanium diodes. The VU meter, which requires a full scale voltage of only 1.73 volts, is almost always supplied with copper oxide rectifiers. Germanium diodes of the diffused junction type, while lower in resistance than the copper oxide type, do not show any improvement in rectification ratio, and are inferior in frequency response.

Military and ASA Status

How do Military Instrument and the American Standards Association Specifications rate rectifier instruments today? Frankly, not very high. This becomes understandable when it is realized these specifications cover standard instruments. Here the iron vane meter is preferred since it reads true RMS. The rectifier type finds its widest use for special applications such as highly sensitive multimeters, the VU meter, etc., which are generally covered by separate specifications.

Originally rectifier instruments were provided against the ac requirements of the Ruggedized Meter Specification MIL-M-10304. They were able to meet the severe temperature requirements by using special diodes. But, since the specification did not require a sine wave source, their accuracy was subject to serious waveform error. The B edition allows only iron vane ac meters for this reason.

ASA C39.1, covering electrical indicating instruments, includes plates for rectifier panel instruments. The current edition shows an accuracy of 5% of full scale value with a 60 CPS sine wave. It is doubtful that any catalog listings show this degree of inaccuracy, and the next printing is expected to change this to 3%. No attempt has been made to limit or specify temperature influence error since it varies

Fig. 2: AC calibrator used with average responsive standard.

By L. W. PIGNOLET
Weston Instrument & Electronics Div.
of Daystrom Incorporated
Newark 14, New Jersey

greatly with scale deflection, range or sensitivity, and the type of rectifier used. This is an acknowledgement of the varied and special applications of the rectifier type meter.

High Accuracy Meters

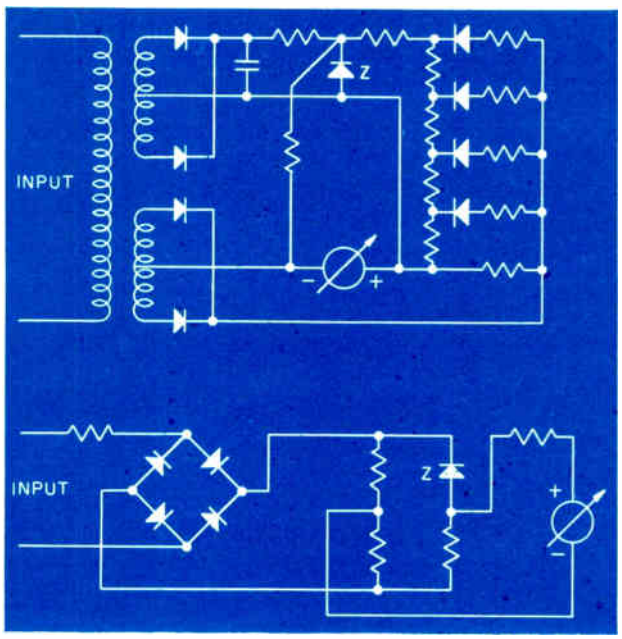
The silicon diode has made high accuracy rectifier meters possible. In general, they can be made to the same accuracy as the basic permanent magnet moving coil instrument with which they are used. This includes the 0.1% accuracy class of A.S.A. Instrument Specification C39.1.

For current measuring meters, since there is no reverse current, the calibration is linear except when circuit resistance is limited. Therefore, the meter can be calibrated to the RMS value of a true sine wave by using the average dc equivalent or 0.9 times the RMS value. The highest range is limited by the current rating of the diode or rectifier used. From a practical viewpoint, the most sensitive range is limited by the rectifier bridge resistance. At 10 μa this exceeds 100,000 ohms.

The same holds true for voltmeters. The diodes do not conduct below about a half volt, and this must be calibrated into the meter scale. This quadratic region of the diode causes a slight error, but this is negligible in the higher range instruments.

The accurate rectifier instrument is finding wide use for the calibration of rectifier and other average responsive meters. Where an RMS calibration is used, the standard is calibrated in RMS of a sine wave. Any distortion of the test voltage would have the identical influence on the standard and the meter being tested, eliminating the effect of waveform error.

Fig. 3a (top): Schematic shows an expanded scale voltmeter, true RMS type. The lower drawing (3b) is the circuit for an expanded scale voltmeter, average reading type.



A typical test set-up is shown in Fig. 2. A Weston Model 63 A-C Calibrator is being used for a low frequency check of an average responding vacuum tube voltmeter. The portable meter at the extreme left is a 0.25% rectifier standard Weston Model 315. It is being used to replace the electrodynamometer mechanism standard built into the basic 0.5% calibrator. The rectifier meter is connected to the monitoring or calibration posts of the calibrator, and after the initial setting, only an occasional check is required. The monitoring voltage is 300 volts and this meter is checked against a dc potentiometer or calibrator at 270 volts.

Obviously, the use of an average reading standard is ideal for checking any average responding instrument. Previously a sine wave generator was used and careful wave analysis checks made at the calibration terminals.

Other Responses

The rectifier diode can be adapted to read true RMS. Basically, this occurs when the current read by the meter is proportional to the square of the input current or voltage. This condition is approximated by a diode at low potential in the quadratic portion of the dc characteristic. The more easily controlled arrangement is the shaping network consisting of several diodes which become conductive in succession as the potential increases to approximate the E^2 requirement.

Fig. 3a shows a suppressed ac voltmeter with a range of 105-125 volts[1]. A zener diode in the secondary circuit of a transformer serves a two-fold purpose. It provides a suppression current to the meter and a bias to the several diodes in the shaping circuit. A rectified current from the output of the transformer feeds the measurement circuit of the meter and also achieves the square law response through the shaping network.

In contrast, Fig. 3b shows a similar circuit giving average response. Here a voltage divider network across a zener diode provides the suppression current and an upscale reading is obtained only after the zener voltage has been exceeded.

There are other circuit schemes to alter the basic response of the rectifier meter. It is possible to make a peak reading meter by using an inductor in series with the meter movement in the output of a rectifier bridge. But, such a meter serves little purpose and does not have the high frequency response and high impedance of the electronic type. The basic response of a rectifier meter can also be altered by a capacitor across the movement. In some instances this also reduces the harmonic error. The possible variations and uses of the rectifier meter are almost endless and cannot be fully covered here.

(*Continued on page* 196)

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Type AX Hermetic
Similar to Type MX but to close on temperature rise. Wide selection of terminals and mounting provisions, highly responsive non-ferrous metal housing. 2 to 6°F differential. Bulletin 3200.

Type C Hermetic
Field-adjustable, positive-acting. Electrically independent bimetal strip type for operation from —10° to 300°F. Nickel-silver case with or without plating, depending on specifications. Turret terminals or wire leads. For ratings, etc., Bulletin 5000.

Type A Hermetic
Electrically independent bimetal disc and high-response brass case for quick, snap-action control from —10° to 300°F. Various non-ferrous metal enclosures, wide variety of terminal arrangements and mounting provisions, including brackets. Bulletin 3000.

*Above Stemco Thermostats are designed and manufactured to meet most requirements of applicable MIL specifications.

A-7222A

RECTIFIER METERS (Concluded)

Which Type?

Which type is not a difficult question for the rectifier meter. In many applications, an average response with average calibration or the RMS equivalent (1.11 times average) is needed. This includes average calibration standards. In core loss testing with ac, the peak flux value is proportional to the average value of the induced voltage and a precise rectifier voltmeter is specified.[2] It applies as well to many magnetic devices, and db or VU meters as used in sound systems.

The rectifier meter is unsurpassed for low cost, high sensitivity voltmeters of moderate accuracy. The possible error of an average response as compared to an RMS response must be considered where severe waveform distortion is present.

The true RMS rectifier transducers are becoming more in evidence and are offered as replacements for the thermocouple meter and other basic RMS responsive instruments. Here they should be carefully evaluated against the detailed requirements of A.S.A.[3]

References

1. Weston Model 871
2. A.S.T.M. Standard A34-39
3. American Standards Association, Electrical Indicating Instruments, C39.1-1959

Oscilloscope Catalog

A complete line of oscilloscopes and accessories are contained in this 20-page catalog. Each product is accompanied by a photo and description. In addition, a reference section lists the oscilloscope by number and gives such characteristics as vertical signal delay, calibrated sweep delay, calibrated sweep range, magnifier max. calib. sweep rate, and accel. potential. Tektronix, Inc., P. O. Box 500, Beaverton, Ore.

Circle 464 on Inquiry Card

Current Pulse Generators

Bulletin 63-H describes programmed current pulse generators. The 3 models test digital devices and circuits by producing preset current pulse programs of up to 16 discrete steps. Computer Test Corp., Rt. 37 & Longwood Ave., Cherry Hill, N. J.

Circle 465 on Inquiry Card

Pulse-Height Analyzer

The ND-180, 512 channel pulse-height analyzer system combines an analog-to-digital converter with a 512 channel memory, a readout control unit, and a signal averaging programmer all in 1 package. The analyzer system can handle a wide range of signal shapes and sizes ranging from nuclear spectroscopy to signal-to-noise enhancement. Complete specs. available from Nuclear Data, Inc., P.O. Box 451, Palatine, Ill.

Circle 466 on Inquiry Card

Time Interval Counter

Model 793 is a 1 nsec. time-interval counter which features ± 0.5 nsec. accuracy without usual ± count digital error. A new tech. data brochure describes the applications and specs. for this instrument, plus circuit block diagram and theory of operation. Eldorado Electronics, 601 Chalomar Rd., Concord, Calif.

Circle 467 on Inquiry Card

Test Instruments Catalog

Catalog digest 64A, 12 pages, gives data for a line of test instruments, standards, converters, calibrators, power supplies, and an impedance bridge. A photo for each product is given along with complete specs. John Fluke Mfg. Co., Inc., P. O. Box 7428, Seattle, Wash.

Circle 468 on Inquiry Card

Crystal Test Set

Data is available on a crystal/crystal filter test set that measures characteristics of high Q elements over a wide freq. range, while maintaining a freq. stability commensurate with unit under test. The choice of a logarithmic or linear detector plus a calibrated r-f attenuator allow precision measurements over a wide dynamic range with extremely high resolution. Designated Model 7321, it has a freq. range of 850KC to 50MC. R-f power level is 1v. max. into 50Ω. Attenuation measurement range is 90db. Sweep range of the unit is variable from 0 to 5% of freq. with the sweep rate 0.1 to 10 CPS. Systems Inc., 2400 Diversified Way, Orlando, Fla.

Circle 469 on Inquiry Card

NEW TECH DATA

TEST EQUIPMENT

Voltage-Current Calibrators

Bulletin No. 63-I presents data on Models 1082/1085 voltage-current calibrators, instruments for amplitude analysis of ac, pulse, or dc signals from 1mv to 200v. The instruments apply a calibrated dc voltage reference to one side of a mechanical chopper mounted directly at the input of an oscilloscope. The unknown input signal is applied to the opposite side of the chopper. The output is displayed on the oscilloscope for comparison and measurement. Photos, specs., and operating principles are included. Computer Test Corp., Cherry Hill, N. J.

Circle 470 on Inquiry Card

Dielectric Tester Brochure

This brochure describes the model PDA-1 dielectric breakdown tester. The data describes in detail the operation of the unit which is designed to provide a safe, simple, and accurate means of determining dielectric strength and breakdown voltage in the laboratory or production line. Complete technical specs. are provided for all electrical and mechanical characteristics. Application for performing tests using ac or dc voltages is covered. Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.

Circle 471 on Inquiry Card

Instrument Catalog

Catalog 501, 12 pages, gives complete details on a line of rack-mounted 3 and 5 in. oscilloscopes, ac and dc voltmeters and wattmeters, and fixed and variable oscillators. Each of the completely self-contained units may be mounted directly on standard 3½, 5½ or larger rack panels making them ideal for multiple installations. Ruggedized components provide conformity to military needs. Benrus Technical Products Div., 30 Cherry St., Waterbury, Conn.

Circle 472 on Inquiry Card

Capacitance Bridge

Catalog Sheet C-55 describes the Model 976 Portametric Capacitance Bridge, a battery-operated portable transformer arm bridge especially suited to field or production line measurement of either 2 or 3-terminal capacitance. Accuracy of the unit is 0.1% range from 0 to 1.2μf in 4 ranges. Bridge circuit design permits grounded or ungrounded measurements, making the bridge ideal for telephone cable matching or quality evaluation. Specs., circuit diagram and a detailed drawing are included. Electro Scientific Industries, 13900 N.W. Science Park Dr., Portland, Ore.

Circle 473 on Inquiry Card

Differential Voltmeter

This informative Engineering Note, Volume 12, No. 1, describes and illustrates the Model 662 DC Differential Voltmeter that features a 0.01% limit of error with 0.005% stabilized zener diode reference. A list of applications and details of the circuit design and characteristics are included. It also gives complete technical specs., a list of available accessories, and a circuit block diagram. Keithley Instruments, Inc., 12415 Euclid Ave., Cleveland, Ohio.

Circle 474 on Inquiry Card

Testing Aid

How to use AS-Series test sockets to measure contact resistance in the checkout and reliability testing of solder terminal relays is described in brochure AS-3. The data shows how dual contacts simplify resistance measurements within the relay under test. The brochure also provides a basic guide of 54 socket types which will test hundreds of varieties of relays. Electronic Engineering Co. of Calif., Box 58, Santa Ana, Calif.

Circle 475 on Inquiry Card

DC Current Meters

Data is available on a new series of ultra-sensitive, wide range dc current meters. Model 700US series offers full deflection across a 6 in. sliderule scale for currents as low as 200, 250 and 300na without the aid of amplifiers or other circuitry. As many as 23 ranges can be included in a single meter to permit complete coverage of the μa, ma and low ampere current bands. These unusual meters are available with full scale accuracies of $\pm$0.25% and $\pm$0.5%. Greibach Instruments Corp., 315 North Ave., New Rochelle, N. Y.

Circle 476 on Inquiry Card

Rectilinear Recorder

A 6-page brochure on the new type SC Dynograph Ink Rectilinear Recorder is available. It describes with photos and actual samples of traces the Type SC Dynograph Ink direct-writing oscillographic recorder. The unit is designed specifically for analog computer or telemetry write-out uses. Complete specs. are given. Beckman Instruments, Inc., Offner Div., Schiller Park, Ill.

Circle 477 on Inquiry Card

Tuning-Fork Oscillator

This tuning-fork oscillator features dual outputs in an economical package. Model 11 offers both squarewave and sinewave output in a single package with output freqs. between 50 to 6000 cps. It uses a bimetallic temp. compensated tuning fork, and is built entirely of Mil spec. parts. Freq. accuracy, 0.005% to 0.1%. Further details from Fork Standards, Inc., 211 Main St., W. Chicago, Ill.

Circle 478 on Inquiry Card

NEW TECH DATA

TEST EQUIPMENT

Measurement Magazine

Metrics, a quarterly technical house organ is for business and engineering management people who have interest in the broad field of electrical and electronic measurement. The editorial format of the magazine is directed toward broadening knowledge and understanding of measurement technology. Although the subject matter covered in Metrics is highly technical, it is presented in laymen's language to provide fast informative and meaningful reading. Articles are supported by numerous illustrations and range from the theoretical to the practical. Requests on company letterhead to Singer Metrics Div., The Singer Co., 915 Pembroke St., Bridgeport, Conn.

Circle 479 on Inquiry Card

Function Generator

This 2-color brochure describes the Model SG-88 V.L.F. generator. In the SG-88, the conventional oscillator circuit is replaced by interchanging rotating discs, scanned by a narrow light beam. Printed on each disc is an opaque pattern representing, in polar coordinates, the wave shape or function to be produced. To achieve freq. accuracy and stability, the chosen disc is driven by a servo-controlled motor via a 4-speed gear box. The range of wave shapes that can be generated is virtually limitless, requiring only that the function from which it is derived be single-valued and repetitive. Houston Instrument Corp., 4950 Terminal Ave., Bellaire, Tex.

Circle 480 on Inquiry Card

Signal Generator

Model 1021 portable signal generator is a compact device for testing receivers, decoders, and other components of command control, telemetry, and similar systems. It produces CW or FM signals in the 216-260 or 400-550MC bands. Freq. stability, ±0.005% (UHF) and ±0.001% (VHF). Additional specs. are contained in this data sheet from R. S. Electronics Corp., 795 Kifer Rd., Sunnyvale, Calif.

Circle 481 on Inquiry Card

Frequency Standards

The 440 combines tuning-form stability with a miniaturized, silicon transistorized oscillator. The result is a precise, stable and reliable freq. standard, particularly suited for spacecraft, ground support equipment and general-purpose applications. Freq. range is from 800 CPS to 4KC. In spacecraft applications, with an operating temp. range of 0° to 55°C, accuracy is ±0.01%. In ground support equipment, with operating temps from 0° to 55°C, accuracies up to ±0.005% can be provided. For other applications with operating temp. ranges varying from −55°C to +100°C, accuracy is up to ±0.03%. Data is available from The Gyrex Corp., 3003 Pennsylvania Ave., Santa Monica, Calif.

Circle 482 on Inquiry Card

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Job Title	Foreman	Operations Manager	Project Engineer	Supervisor			Personnel Manager	Chief Engineer	Traffic Manager	
Education	H.S.	B.S.	M.S.	H.S.	H.S.	B.A.	B.A.	B.S.	B.S.	
Time (hrs.)	11.3	10.5	9.4	13.3	19.0	8.0	13.8	11.3	9.5	11.8 hrs.
Age (yrs.)	36	22	44	48	52	34	47	47	50	34 yrs.
Examination Score (%)	94	97	97	94	92	90	87	80	79	90.1%

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PERT Critical Path concept.

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1
The powerful managerial technique which allowed the initial Polaris project to be completed ahead of schedule is known as __rogram __valuation __eview __echnique commonly abbreviated as ____ ____ ____ ____.

Program Evaluation Review Technique PERT

2
PERT is used for scheduling interdependant events and activities. By completing the following 5 items, you can teach yourself to find the critical path in a PERT network.

Activities occupy time.
Events do not occupy any time.

Start motor test is an event.
Testing the motor is an activity.

End prototype production ☐ *does* ☐ *does not* take time. It is an ☐ *event* ☐ *activity*.

does not; event

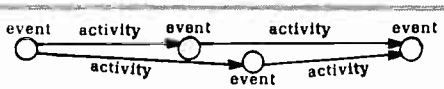
Recruit project members ☐ *does* ☐ *does not* take time. It is an ☐ *event* ☐ *activity*.

does; activity

Data analysis ☐ *does* ☐ *does not* take time. It is an ☐ *event* ☐ *activity*.

does; activity

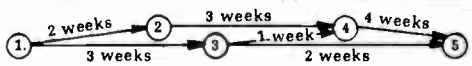
3



The circles in this PERT network refer to _____s.
The arrows in this PERT network refer to _____s.

events
activities

4



1. Start research
2. Start developing pilot model.
3. Start preparing presentation and start interviewing prospective staff.
4. Presentation completed; start awaiting approval.
5. Formal approval received; start project.

The numbers in the circles refer to ☐ events ☐ *activities*.

events

The numbers next to the arrows refer to the number of weeks taken up by the _____ which the arrows represent.

activities

How many weeks would it take to complete path ①→③→⑤?
___ weeks

5

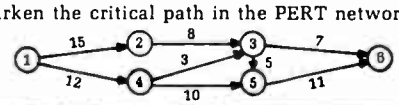
How many weeks would it take to complete path ①→③→④→⑤? ___ weeks

8

Which is the longest path in the PERT network above?
☐ ①→③→⑤ ☐ ①→③→④→⑤ ☐ ①→②→④→⑤

①→②→④→⑤

5
The longest path in a PERT network is called the *critical path*. Darken the critical path in the PERT network below.



6
Did you answer the last question correctly?
☐ Yes ☐ No

If your answer is yes, you have proved to yourself what the U.S. Air Force, du Pont, IBM, Sperry Rand, Raytheon, and General Motors have already discovered: that programmed instruction is a fast, effective, and easy way to learn.

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TEST AND MEASURING

MEASURING RELAY CONTACT-BOUNCE

Measuring contact-bounce with an oscilloscope introduces the possibility of operator error and fatigue. This device increases accuracy and a printout device eliminates the need for an operator.

By T. ERICKSON
Test Engineering Manager
Allied Control Co., Inc.
New York 21, N. Y.

CONTACT-BOUNCE PHENOMENON can be translated into parameters compatible to electronic time measurement techniques. These parameters are positive and negative voltage changes (contacts open or closed) plus voltage amplitude discrimination. Since a time measurement displayed in digital form is desired, a standard electronic Time Interval Meter (TIM) becomes a needed accessory of a contact-bounce measuring instrument.

A TIM is controlled by negative or positive voltage changes of proper slope and magnitude applied to the start and stop gates. For a particular measurement, however, the gate polarities must be pre-set in accordance with the control signal. Controlling these gates with a control-bounce signal permits measurement of only one bounce because the gates would be turned on and off from one positive and negative voltage change.

The contact-bounce measurement consist of supplying two gate signals to a TIM. Hence, stages that select, generate, and pulse-shape the gate signals must be provided.

The test circuit in Fig. 1 shows that when the test-contact closes, a positive-voltage output is generated; when the test-contact opens, a negative voltage occurs. The typical contact-bounce voltage signals in Figs. 1 and 2 show that the initial and final contact closures generate positive voltage signals. Therefore, any positive signal generated after the first positive signal will be suitable for controlling the stop gate, provided there are no subsequent contact openings for the remainder of the test period. A pre-set sensing (delay) period after each contact closure furnishes a means of determining the final contact closure. A positive signal (contact closure), therefore, initiates the sensing period, but a negative signal (contact opening) resets it to zero. This occurs for every contact opening and closure. An interval between openings that is longer than the pre-set sensing period signifies that the contacts are fully made and a stop-gate control signal is generated. The sensing period is made long enough to cover the maximum range of bounce values to be measured (typically 10 to 100msec).

The time between the initial contact-bounce signal and the final TIM stop-gate signal includes contact bounce time plus the pre-set stop-control-gate sensing time. Subtracting the pre-set stop-control-gate delay period gives the true bounce time. This subtraction is done by delaying the start-control-gate signal by a period equal to the pre-set delay for the stop-control gate. Fig. 2 shows the relationship of the contact-bounce and gate-control signals vs. the time period being measured.

Circuit Details

Fig. 3 shows the grouping of the stages needed to perform the timing function. The contact-bounce voltage signal travels through two different paths to perform its function—the common input stage and

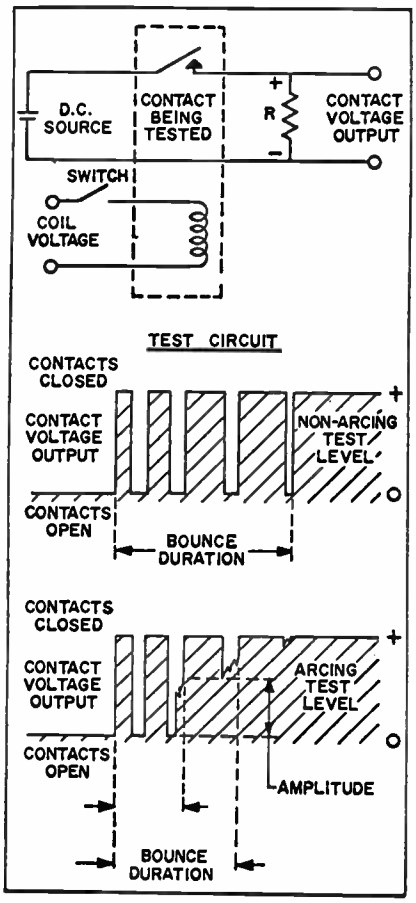

Fig. 1: A test circuit with typical contact bounce voltage signals.

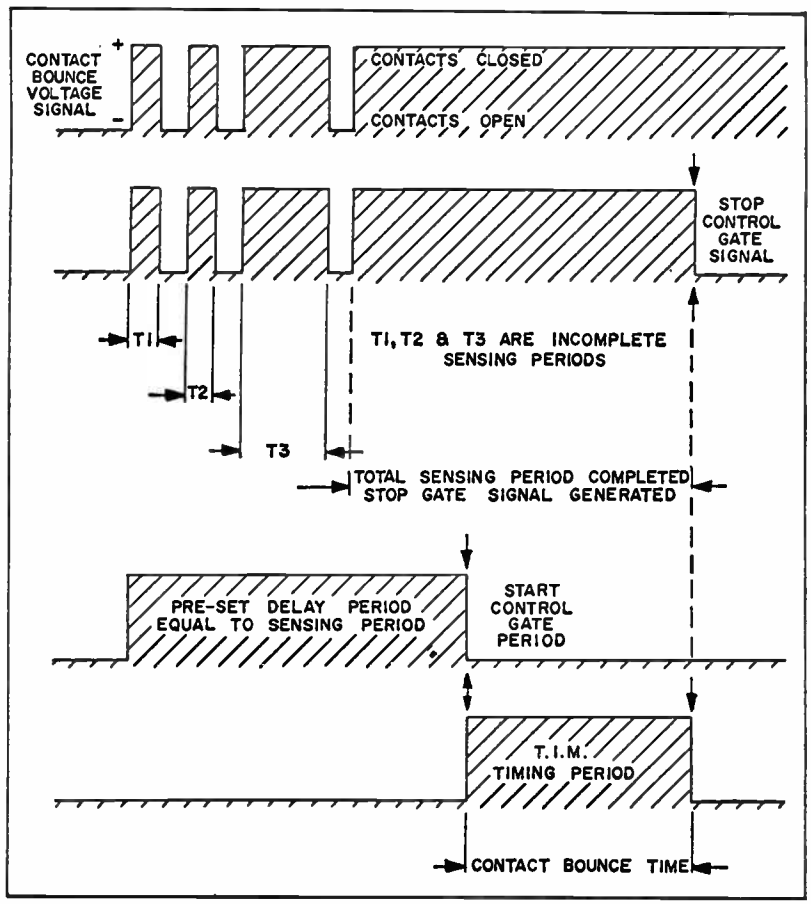

Fig. 2: Contact bounce and gate-control signals vs. the time period being measured.

the TIM start- and stop-control stages. The block and circuit diagrams of Figs. 3 and 4 show that the stages used to develop the TIM start- and stop-gate signals are almost identical. The important difference is the monostable gating stage before the start-gate circuitry. A detailed description of the various stages follows. (Refer to Figs. 3, 4 & 5 for additional clarification).

Common Input Stage. The input stage consists of a signal-attenuating resistive voltage divider, a differential transistor amplifier, and a transistor switch. The amplifier has two outputs: one is directly coupled to the monostable gate that controls the input to the start-gate control stage, and the other is directly coupled to the base of a transistor which serves as a simple switch. This transistor shunts one branch of a resistive voltage divider. When the transistor is turned on and off it controls the voltage-divider output. Two pre-set output voltages result whose magnitudes depend primarily on the value of the voltage-divider resistances. The voltage output from the divider drives the stop-delay control gate on or off.

Since the differential amplifier amplifies only a pre-set voltage level, a voltage criterion on the bounce signals to be measured can be set. Voltages caused by contact-resistance variations, contact arcing levels, or complete contact openings can be differentiated by a change in the voltage detection level of the amplifier. To increase the range of voltage-level discrimination, an additional transistor is used as a common-emitter load. Here relatively large voltage signals are being detected, and the gain of the amplifier is not important. But the rapid switching action when the input voltage level exceeds a pre-set level is. The low time constants of the components used in this stage allows switching to occur in less than a microsecond.

Timer-Gate Stop-Control Stage. The timer-gate stop-control stage consists of a stop-delay control gate, a resistor-capacitor network, a pre-set delay, and output pulse generator. The stop-delay control gate is an arrangement of transistors which serves as a rapid-acting switch. This switch is normally closed when the contacts under test are open. It is important that the transistor switch can be turned on by a minute change in its bias voltages, since the transition time from an off to an on state is extremely fast. Another prerequisite of the switch is low equivalent resistance in the on state. Speed and low resistance affect the ability of the control gate to respond to contact-bounce control signals of extremely short duration. Circuitry with low time constants is needed to perform the switching and shorting functions properly. (*Continued on page* 216)

Tektronix oscilloscope displays both time-bases separately or alternately

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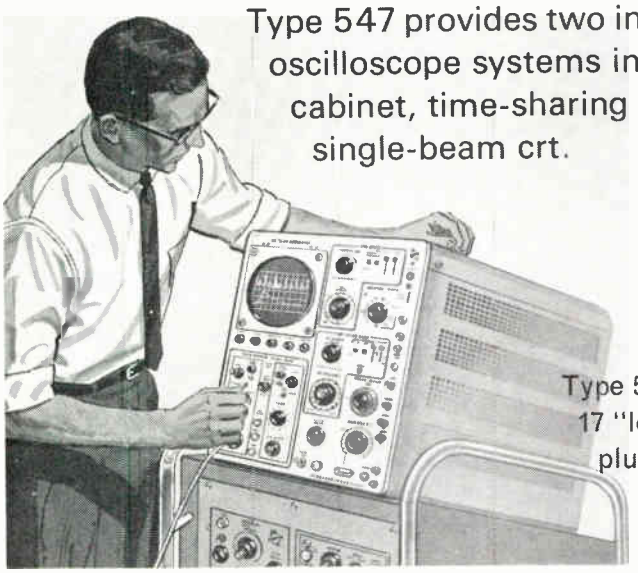

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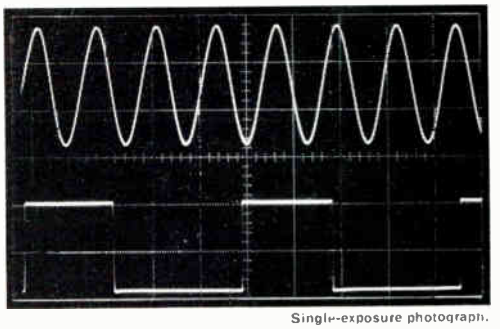


Single-exposure photograph.

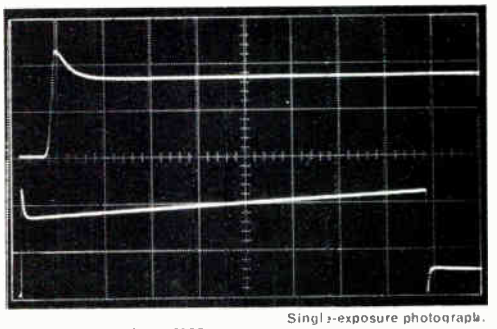
2 signals — different sweeps

Upper trace is Channel 1/A sweep, 1 μsec/cm.
Lower trace is Channel 2/B sweep, 10 μsec/cm.

Using same or different sweep rates (and sensitivities) to alternately display different signals provides equivalent dual-scope operation, in many instances.

Triggering internally (normal) permits viewing stable displays of waveforms unrelated in frequency.

Triggering internally (plug-in, Channel 1) permits viewing frequency or phase differences with respect to Channel 1.

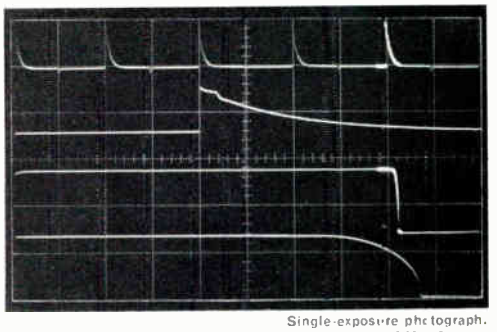


Single-exposure photograph.

same signal — different sweeps

Upper trace is Channel 1/A sweep, 0.1 μsec/cm.
Lower trace is Channel 1/B sweep, 1 μsec/cm.

Using different sweep rates to alternately display the same signal permits close analysis of waveform aberrations in different time domains.



Single-exposure photograph.

2 signals — portions of each magnified

Trace 1 is Channel 2/B sweep, 10 μsec/cm.
Trace 2 (brightened portion of Trace 1) is Channel 2/A sweep, 0.5 μsec/cm.
Trace 3 is Channel 1/B sweep, 10 μsec/cm.
Trace 4 (brightened portion of Trace 3) is Channel 1/A sweep, 0.5 μsec/cm.

Using sweep delay technique—plus automatic alternate switching of the time bases—permits displaying both signals with a selected brightened portion and the brightened portions expanded to a full 10 centimeters.

B sweep triggering internally from Channel 1 (plug-in) assures a stable time-related display without using external trigger probe.

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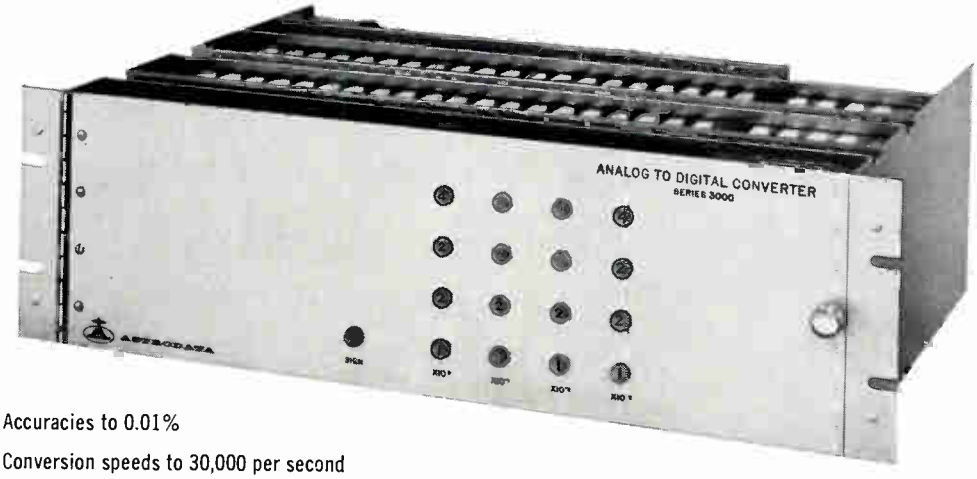

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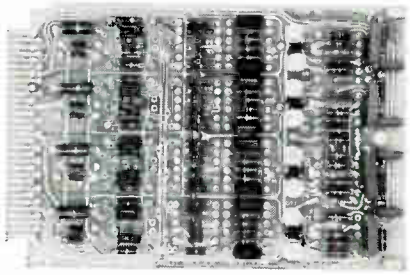

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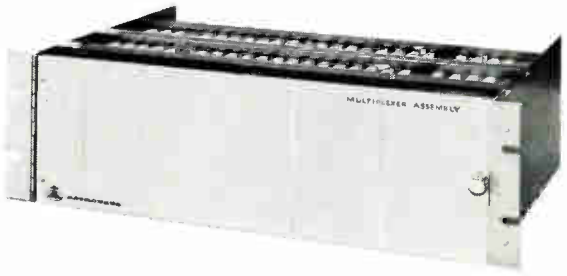

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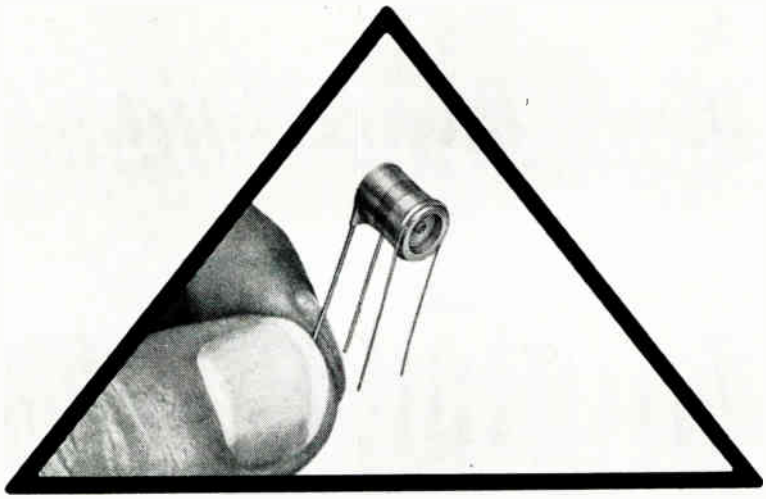

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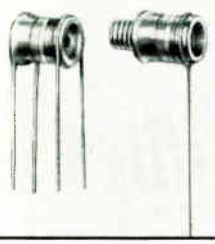

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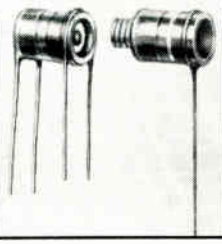

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1-A EI-229 JUNE, 1964

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- ☐ (08) Component Mfr.
- ☐ (09) Sub-System Assembly Mfr. (Modules, Assembled Circuits)
- ☐ (10) Materials & Hardware Mfr.
- ☐ (11) Industrial Co. Using Any Electronic Equipment In Their Manufacturing, Research or Development Activities (other than Electronic Cos.)

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☐ Mfg. Plant (*) ☐ Mfr's R&D Lab. (&) ☐ Other (explain) _____

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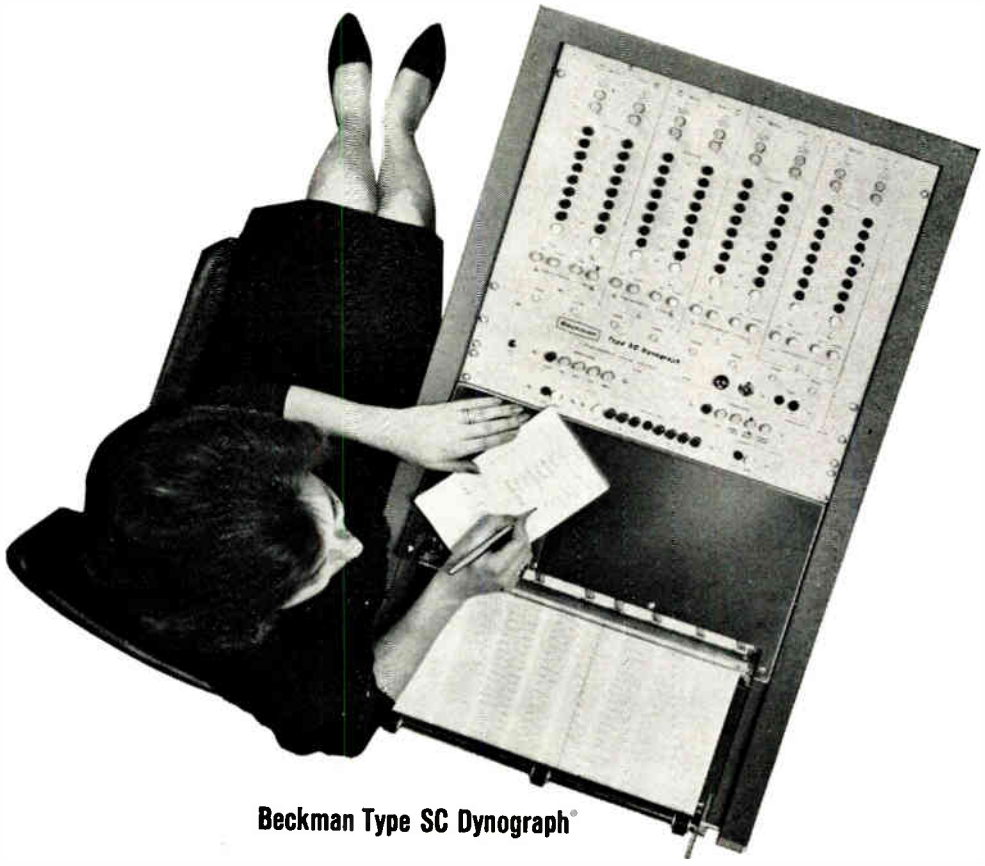

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All the desirability of the Dynograph ink-rectilinear recorder, in a design for complete compatibility with analog computers

Famous Locked-In Accuracy at the tracing! Servo system constantly compares pen tip and input signal for maximum accuracy and linearity.

Reliable Solid-State Circuitry eliminates drift, component aging. No warm-up time; low total power consumption (230 w. max., for 8 channels).

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- Width: 40 mm (50 divisions) /channel
- Sensitivity Range: 2.5–250 volts full scale
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- Local-remote Controls: "Chart Speed," "Event Marker"
- Centralized Push Button Controls: "Sensitivity," "Paper Speed," "Calibrate," "Polarity," "Local-Remote"
- Pressurized inking system
- Paper Capacity: 1,000 ft. high gloss maximum contrast
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- Timing Marker: one/sec or remote; second marker optional

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CONTACT BOUNCE (Continued)

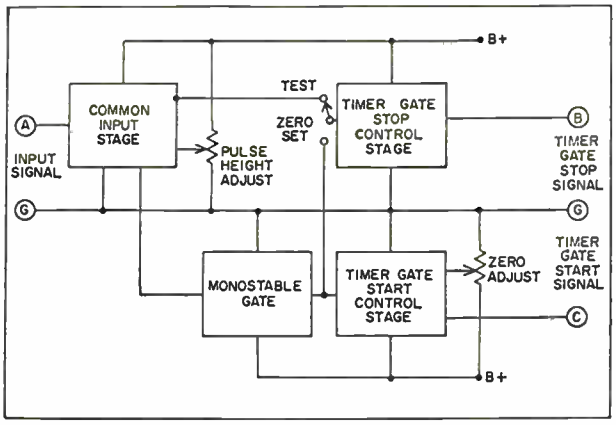


Fig. 3: Electronic stages required to perform the timing function.

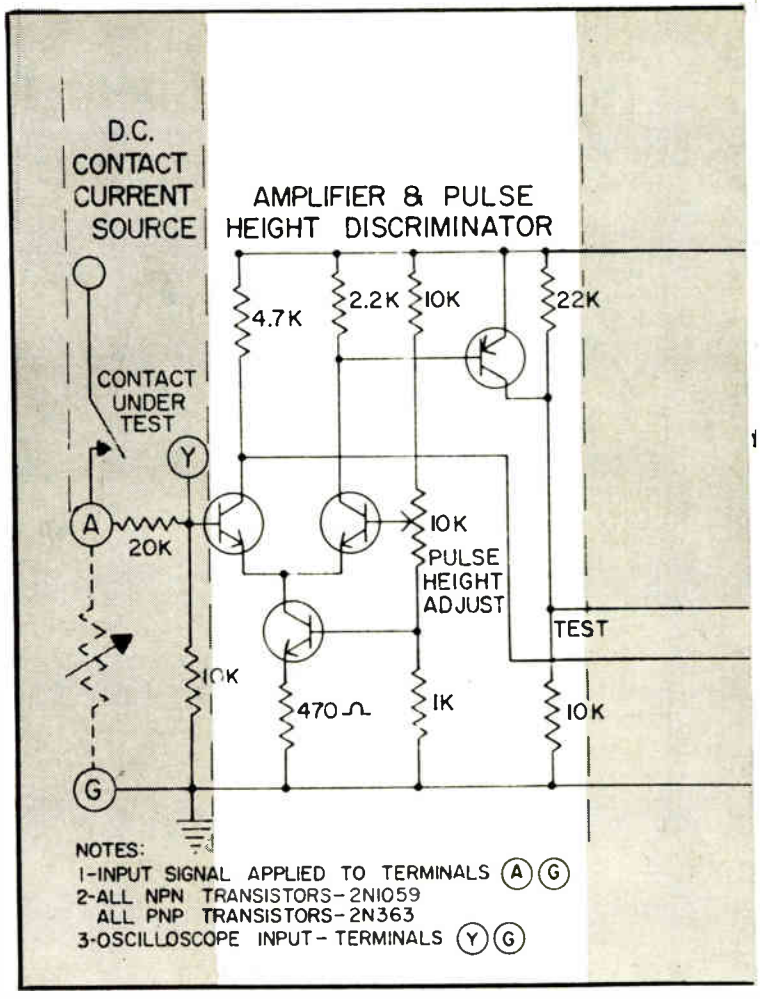


Fig. 4: The circuit diagram for the contact-bounce measuring instrument.

The values of resistance and capacitance used in the R-C network determine the maximum duration of the sensing period. This duration is decreased by the bias on the two transistor switches shunting the capacitor.

The pre-set time delay and output-pulse generator use the same transistor arrangement to get rapid switching when a pre-set voltage bias is reached. Rapid turn-on insures the steep-rising voltage signal needed for timer-gate action. This transistor switch is normally off until the end of the delay period. The associated voltage divider determines the transistor turn-on point, and therefore the time-delay before the output signal is generated.

This timer-gate control stage can be replaced by a simple resistor, capacitor, and switch network (Fig. 5). Here the capacitor is shunted by two switches—one normally closed and the other normally open. The operation of the gate-control stage occurs in the following sequence:

1. Contact under test closes and transistor switch SW-1 is turned off.

2. Capacitor C begins to charge through limiting resistor R and the sensing period begins.

3. Unless the contact under test reopens, capacitor C continues to charge.

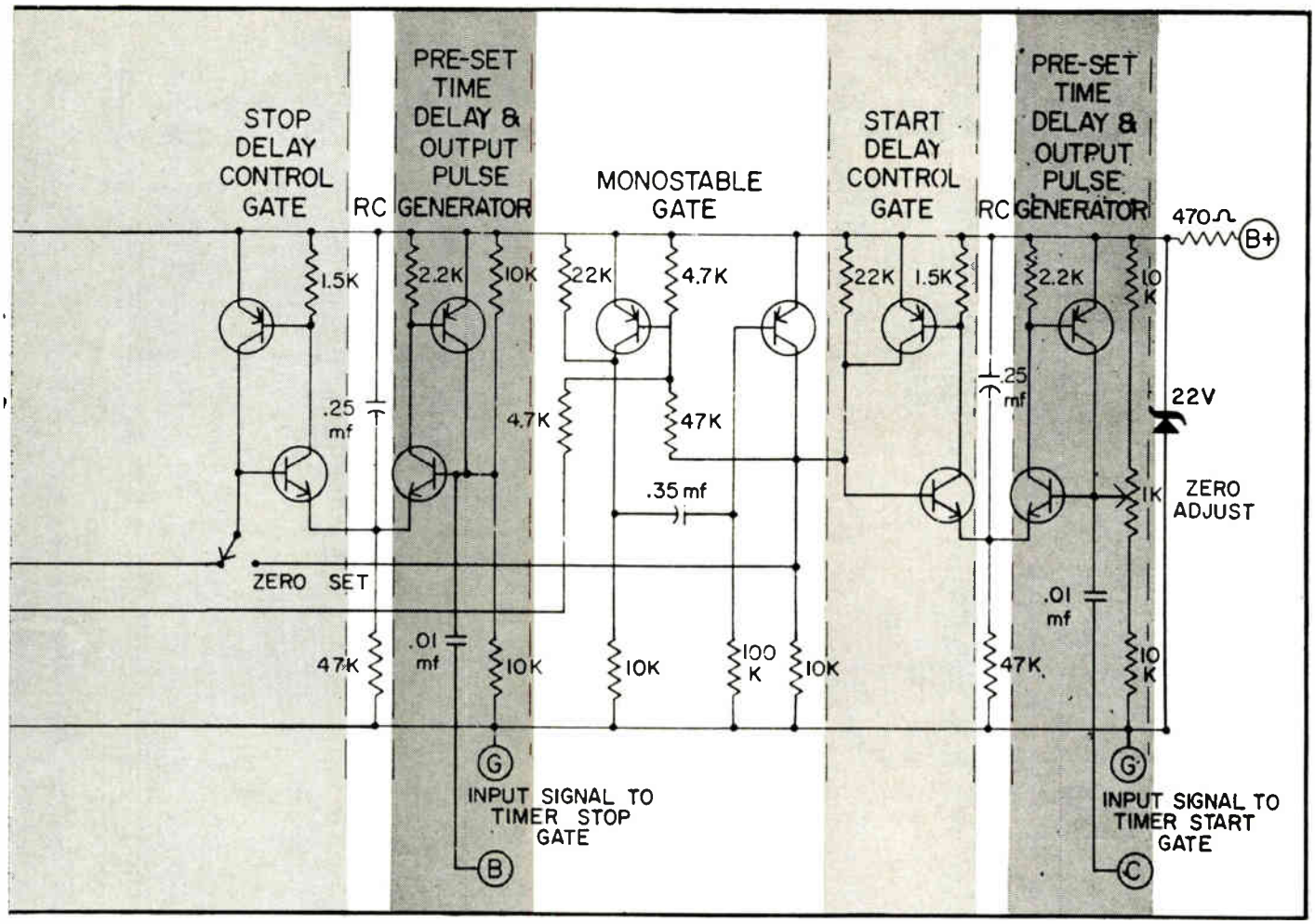
4. Transistor switch SW-2, which is normally open, turns-on (closes) when the voltage developed across capacitor C reaches a pre-set trigger voltage.

5. Operation of transistor SW-2 produces a positive output pulse which can be used to control the timer-stop gate.

Timer-Gate Start-Control Stages. The operation of the timer-gate start-control stage is identical to the timer-gate stop-control stage except that the signal to the start-control gate comes through the monostable gating stage. The monostable gating-stage circuit has a stable and quasistable state. After an interval determined by the circuit parameters (RC), it returns to its stable state where it remains until it is triggered again.

The contact voltage signal from the differential amplifier goes directly to the input of the monostable gate (Fig. 4). This signal is transmitted with negligible time lag and drives the monostable gate into the quasistable state. It also causes a transistor switch shunting one branch of a resistive voltage divider to turn on, initiating the time-delay for the start-gate control stage. These actions occur simultaneously with the first positive voltage signal generated when the test contacts close.

Any subsequent opening of the contact has no effect because the monostable gate is in its quasistable state. The time delay before the monostable gate re-



turns to its stable state is controlled by a resistor-capacitor network. The values of these components are selected so that the monostable gate responds to no signal but the first for the duration of the measurement period. This duration is longer than the maximum bounce time plus the sensing time.

Calibration. The accuracy of the contact-bounce measurement depends on the ability of the test circuitry to respond and transmit the bounce signal within a microsecond. This is fulfilled by keeping the inherent time constants associated with the electronic stages at very low values. Since the adding and then subtracting of a pre-set delay period needed to perform the timing function is done artificially, these periods must be equal. The first requirement depends on proper circuit design, but the second requirement depends on the TIM used.

As shown in Figs. 3 and 4, a zero-set position and a zero-adjust control is available. With the instrument in the zero-set position, any test-contact closing signal goes through the monostable gating stage. This initiates the sensing periods for both stop-and start-gate control stages. These stages generate an output pulse after the pre-set delay period. The time between these timer-gate control pulses indicates the difference between the stop-gate sensing delay and the start-gate delay. The difference is important because the start-gate delay period is subtracted from the stop-gate delay period in the measurement. Timing accuracy depends on maintaining this difference as small as possible. Reducing this difference is accomplished with the aid of the TIM, which measures this difference directly from the timer-gate signals. The zero-adjust control is then varied so that the timer reading is reduced to the lowest digit value available. Reduction to a zero-value reading may cause the stop-gate delay period to be less than the start-delay period, which causes the timer-gate stop signal to be applied before the timer-start signal. This effect is evident because the timer cycles continually.

The overall accuracy of the bounce-time measurement depends primarily on the capability of the TIM used. In the application, the maximum resolution of the TIM used was 10μsec.; but if a TIM is available with higher resolution, greater accuracy is possible.

Summary

Some unique features become apparent when the operation of this instrument is compared to the standard measuring techniques that use an oscilloscope. The test current specified in many applications is the

(*Continued on page* 218)

CONTACT BOUNCE (Concluded)

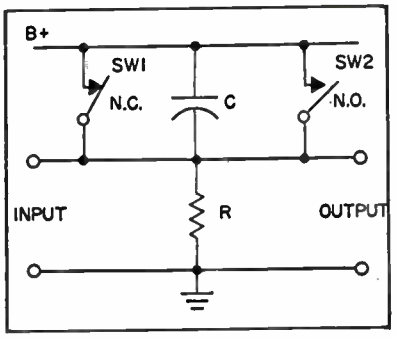
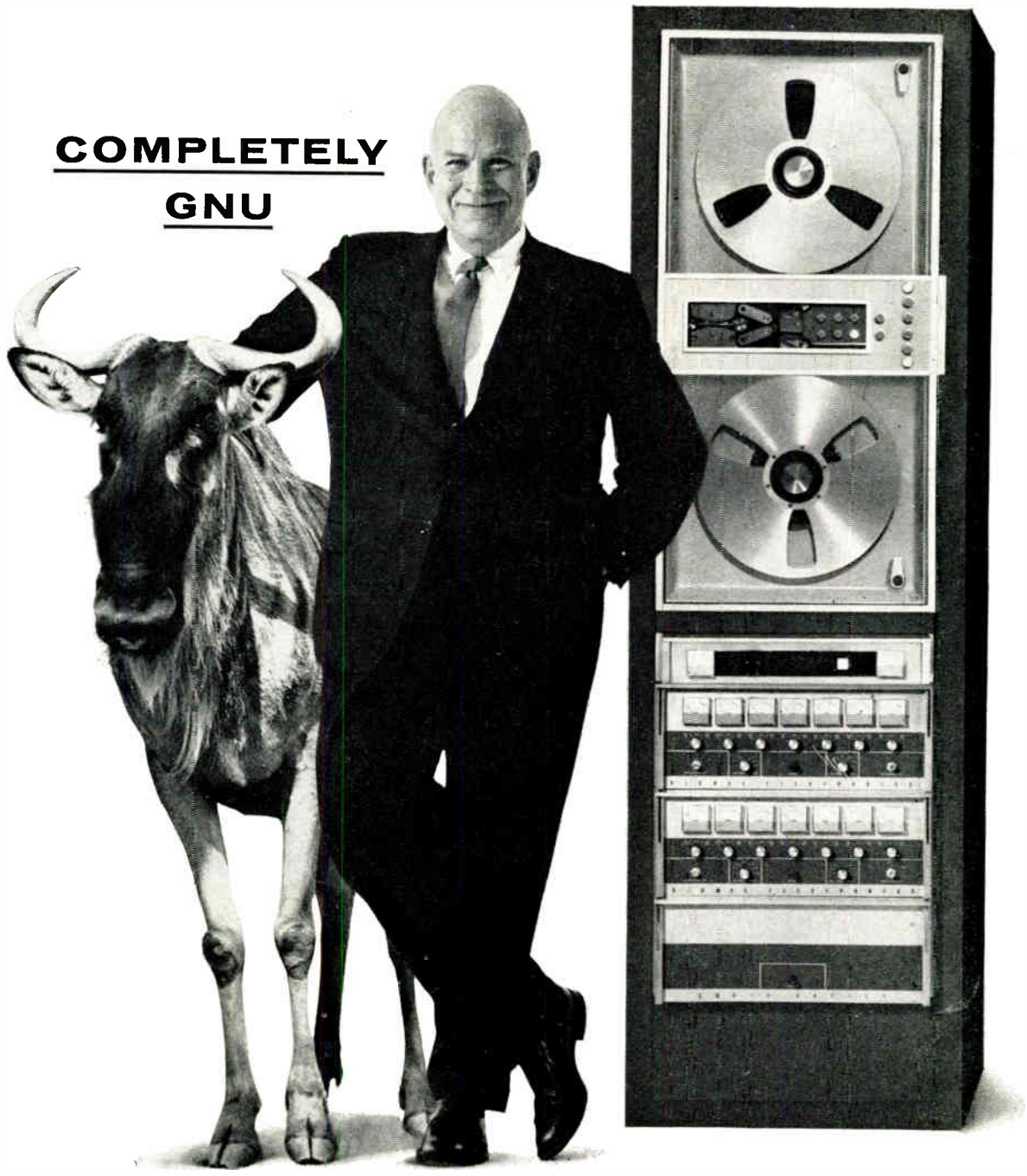


Fig. 5: Simplified equivalent circuit of timer-gate stop- or start-control stage.

contact current rating of relay. However, satisfactory visual observation using an oscilloscope generally requires a pulse rate (5 to 10 operations per second) that may injure the relay contacts. A measurement using a TIM requires only one switching operation. In addition, continued observation of the oscilloscope trace becomes tedious and fatiguing. Measurements using an oscilloscope are too dependent on consistent judgment from operator to operator. Using an instrument with a digital readout results in greater accuracy and ease of operation.

A major feature of this instrument is the fact that it is adaptable to uses involving automatic testing techniques. No operator readout is necessary if a print-out device is available.

* * *



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NEW TECH DATA

TEST EQUIPMENT

Transducers

Data is available on solid-state transducers that measure electrical quantities associated with power systems. Included are transducers for measurement of ac volts, amps, watts, vars, freq. and power factors. Each has a high-level dc output that can be applied to graphic recording instruments. More data available from Esterline Angus Instrument Co., Inc., P. O. Box 596, Indianapolis, Ind.

Circle 483 on Inquiry Card

Thermistor Probes

Bulletin T-107 describes and illustrates a line of thermistor probe assemblies. Information, including application data, is given for the basic types. The new probe assemblies are supplied with thermistors that operate from −80°C to +300°C in aerospace, industrial, oceanographic, medical and meteorological applications. Resistant values range from 100Ω to 10 megohms and temp. coefficients of resistance ranging from −3%°C to −6.8%°C. Gulton Industries, Technical Publications Dept., 212 Durham Ave., Metuchen, N. J.

Circle 484 on Inquiry Card

Instruments Catalog

This instruments and components catalog contains a complete description of slotted lines and accessories, hybrids, r-f bridges, dipoles, line stretchers and other r-f instruments and coaxial components. Alford Mfg. Co., 299 Atlantic Ave., Boston, Mass.

Circle 485 on Inquiry Card

Monitoring Instruments

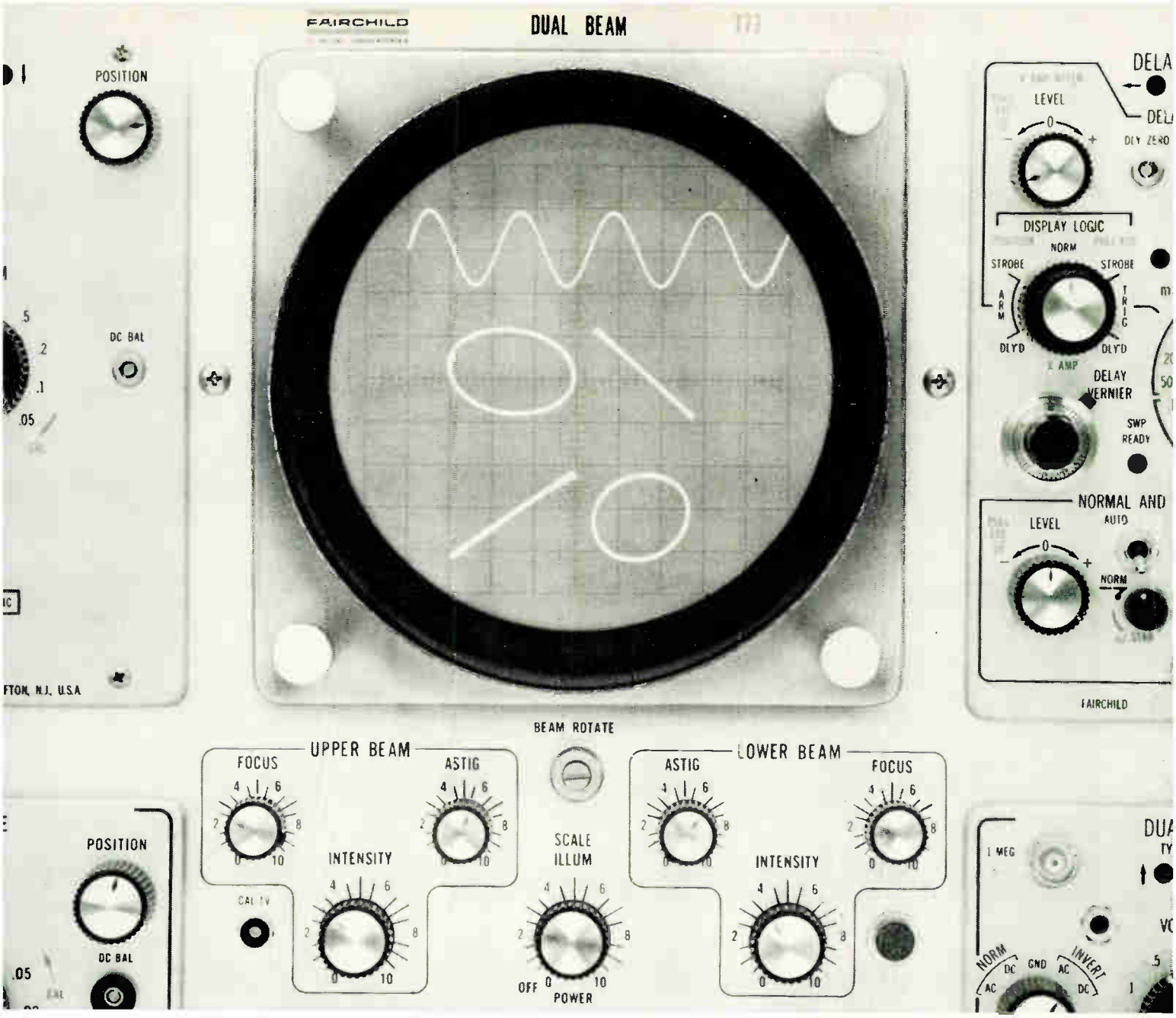
This brochure describes a complete line of instruments for particle analysis. Some instruments include an aerosol recording camera, an aerosol photometer, an airborne particle monitor with aerosol photometer, and an airborne particle monitor with analog readout. Each unit is accompanied by a photo and description. Royco Instruments Inc., 440 Olive St., Palo Alto, Calif.

Circle 486 on Inquiry Card

Primary Pressure Standards

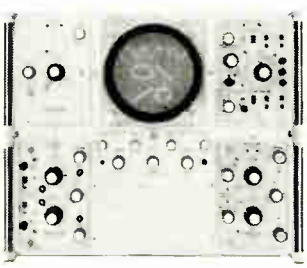
Bulletin PC-100 describes automatic primary pressure standards for pressure generation, calibration, and control. The bulletin describes the systems' applications to acceptance testing of purchased transducers; production testing of transducers by manufacturer; recalibration of transducers after use; checkout of pressure transducers in a system immediately before a test; precision pressure generation for pneumatic force systems, and measurement of an unknown steady state pressure. Eight different systems are illustrated and basic operation of the systems is shown in a block diagram. Gilmore Industries, Inc., 3355 Richmond Rd., Cleveland, Ohio.

Circle 487 on Inquiry Card



It Had To Be Done With The New Fairchild 777 —No Other Scope Can Do It!

Here, Fairchild's new Dual Beam 777 is monitoring a crystal controlled oscillator and four phase shift plots. No other scope can do it — because only in the Dual Beam 777 are four plug-ins completely interchangeable in both X and Y cavities. (For this plot 1 Time Base and 3 Amplifier plug-ins were used.) Up to 8 channels of information can be displayed. The 6 x 10 cm display area of the 13 kv dual beam tube provides 5 cm overlap between beams for optimum resolution. Other outstanding features of the new Fairchild 777 include bandwidth to 100 mc, solid state circuitry for compactness and light weight, and rack-mount capability. Applications for this versatile instrument range from monitoring 8 channels of telemetry to EKG vector studies in medical research. For more details on the Dual Beam 777—and many other new precision Fairchild scopes—write, on letterhead, please, for complete 92-page "Scientific Instrument Catalog." It's just off the press. Fairchild Scientific Instrument Dept., 46 Bloomfield Ave., Clifton, N. J.



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Circle 182 on Inquiry Card

NEW TECH DATA

TEST EQUIPMENT

Circuit Evaluator

Programmed automatic and recorder (Pacer), GEA-7667, describes a system for isolating, testing and evaluating individual components on a printed circuit board. The brochure describes the tape-controlled unit, the 10 parameters it will automatically measure along with features and specs. General Electric Co., Schenectady 5, N. Y.

Circle 488 on Inquiry Card

Oscillator Brochure

This brochure, "Twangers Topics," covers the history, recent technical advancements and uses for tuning fork oscillators. Accutronics, Inc., 12 South Island, Batavia, Ill.

Circle 489 on Inquiry Card

Thermistor Thermometer

The model 61 high-temp. thermistor thermometer covers the range of 250° to 500°F in 2 overlapping ranges. Its absolute accuracy over most of that range is ±3°F, and its readability and repeatability are better than ±1°F. Thermistor probes are available for measurements in liquids, gases, on surfaces and in semi-solids. Complete specs. available from Yellow Springs Instrument Co., Inc., Box 279, Yellow Springs, Ohio.

Circle 490 on Inquiry Card

Data Bibliography

This technical data bibliography provides detailed listing of current supporting tech. material for ESI's line of precision measuring instruments and components. Listed are engineering bulletins, catalog sheets, application bulletins, tech. reports, tech. articles for ESI bridges and accessories; voltage dividers; standards; decade impedance units; and the ESIAC algebraic computer. Electro Scientific Industries, 13900 N.W. Science Park Dr., Portland, Oregon.

Circle 491 on Inquiry Card

Performance Monitors

This brochure sets forth the theory of operation of Radio Performance Monitors (RPM), their characteristics, features, and a typical RPM specifications sheet. Airborne Instruments Laboratory, div. of Cutler-Hammer, Inc., Deer Park, L. I., N. Y.

Circle 492 on Inquiry Card

RMS Voltmeter

This spec. sheet describes the Model 2417 rms voltmeter, an instrument which provides accurate, true rms readout for measuring narrow-band random noise and vibration signals. Measurements on noise bands as narrow as 3 CPS can be made to within 0.5 accuracy, and the freq. range is 2 KC to 20 KC. B&K Instruments, Inc., 3044 W. 106th St., Cleveland 11, Ohio.

Circle 493 on Inquiry Card

DC to AC Inverters

Catalog No. 300 describes more than 60 static dc to ac inverters and static-freq. converters rated at 6 to 15Kva. The units, with standard output freqs. of 50, 60, and 400 cycles and freq. stabilities to ±0.001%, are used in aviation, military, ground support and shipboard equipments, materials handling devices, field vehicles and in standby power and industrial controls systems. Variable freq. ac power sources are also described. CML, Inc., 350 Leland Ave., Plainfield, N. J.

Circle 494 on Inquiry Card

Frequency Generator

The Model 6292 is a miniature crystal-controlled frequency generator utilizing thin-film microcircuit dividers. A 0.01% freq. tolerance is maintained from −55°C to +100°C without a crystal oven. The 6292 can be customized for most requirements by dividing the crystal freq. by 2^n using any number of TF dividers. Crystal freqs. from 1.5 to 3MC are available. It requires 42ma at 12v. for the 400 CPS version. Varo Inc., Special Products Div., 2201 Walnut St., Garland, Tex.

Circle 495 on Inquiry Card

Analog Voltage Comparator

The Model 1010 FCOM, described in this bulletin, provides a rapid method of performing high and low limit comparisons to ±0.01% accuracy. Limits are adjustable and output is front panel indicator lights and isolated output contact closures. Solid state, 1 to 10 channels, and includes power supplies, references, and limit cards. California Instruments Corp., 3511 Midway Dr., San Diego, Calif.

Circle 496 on Inquiry Card

Meter Movement

Bulletin P-13 describes the capabilities of an ultra-thin meter movement. It describes and illustrates a few special applications typical of the many unusual uses to which the movement has been applied. Extreme compactness, resistance to burnout, immunity to acceleration-shock damage, self-shielding, the variable damping factor, and economy, are some of its features. Parker Instrument Corp., 200 Harvard Ave., Stamford, Conn.

Circle 497 on Inquiry Card

Power Meter

The PRD 686 can be used with temp. compensated and uncompensated thermistor mounts utilizing negative coefficient elements with operating resistances of 100 and 200Ω, without the use of additional accessories. Full scale readings from 0.01 to 10mw are covered in 7 steps, with a bridge accuracy to ±3% of full scale. With uncompensated thermistor mounts, the power range is limited to 0.1mw at the low end with an accuracy of ±5% full scale. Two self-balancing bridges in the transistorized PRD 686 essentially renders the unit drift-free. Because of this high stability, continuous zero setting is not required even on the most sensitive range. Data available from PRD Electronics, Inc., subs. of Harris-Intertype Corp., 202 Tillary St., Brooklyn, N. Y.

Circle 498 on Inquiry Card

TUBE HUM

(*Continued from page 90*)

result, photoelectric hum appears as the second harmonic of the line frequency. In a limited number of observations, photoelectric hum had a constant value for zero grid resistance which increased as the grid resistance increased. Phase of the hum was such that the grid would become negative as the light intensity increased.

In critical uses, the tube should be shielded and the equipment placed in a dark enclosure. If the latter precaution cannot be taken (e.g., during testing of the unit), tubes with top-mounted getters should be used. This feature aids in making the tops of the tubes opaque to light. An alternative to this suggestion is to make the exposed portion of the tube opaque to light by any suitable means.

Tube Selection

Because hum exists to some degree in most tubes with an ac power source, it is essential that the proper tube type be selected for critical uses. By following the recommendations of the tube manufacturer, and by adhering to established circuit design and layout, minimum hum output can usually be assured.

There are also several design features of the tube which indicate its acceptability for critical uses. These tube criteria include: (1) internal shielding; (2) heater design; (3) pin-basing arrangement; (4) getter-flash shielding; (5) getter placement; (6) pinched cathode tips (in absence of getter-flash shielding); (7) leakage slots in the micas; and (8) heater and heater-stem-lead separation from stem leads and connectors to the tube electrodes.

Another important design procedure to be followed in achieving low hum output is minimum use of series wiring from the ac heater supply. If, for economic reasons, series-string heater wiring must be used, the tube amplifying the lowest signal level should be placed at the lowest-potential end of the string. For dc series-string heater systems

(*Continued on page 225*)

with a small amount of ac ripple, the tube amplifying the lowest signal level may be placed at the high-potential end of the string to take advantage of the positive dc bias on the heater.

References

1. Knight, C. A. and A. P. Haase, "New Low Noise Input Tube," *Radio and TV News*, March, 1949.
2. W. Graffunder, "Concerning Hum in Indirectly Heated Amplifier Tubes," *Die Telefunken Rohre*, April, 1938, No. 12, p. 46 ff.
3. Ibid.
4. Radiotron Designer's Handbook, 1953, 4th ed., 7, 2.ii.a.
5. General Electric Co., "A Study of Films in Electron Tubes," *Contract NObsr—81225 First Quarterly Report*, May 1, 1960 to Aug. 1, 1960, p. i ff.
6. Ibid.
7. Sylvania Electric Products, "Heater-Cathode Leakage Investigation," *Contract AF19-(604)1734 First Quarter Report*, Feb. 1, 1956, to May 1, 1956, p. 2.
8. Ibid., *Fourth Quarterly Report*, Nov. 1, 1957, to Feb. 1, 1957, p. 3.
9. Op. Cit., Graffunder.
10. Op. Cit., Graffunder.

NEW TECH DATA

Charge Power Amplifier

A charge amplifier designed to detect, amplify and monitor signals between 0.1 G and 10,000 G from piezoelectric accelerometers is described in technical data sheet T-145. Complete specs. are given, with a photo of 3 Model 7000 modules in a bench type cabinet. Columbia Research Laboratories, Inc., McDade Blvd. and Bullens Lane, Woodlyn, Pa.

Circle 525 on Inquiry Card

High-Impedance Amplifier

Model HA150 is described in a technical data sheet which contains specs., applications, general description, and a block diagram. The amplifier has a voltage swing of 300v.; a dynamic range of greater than 1 million to 1; an input impedance of 100KΩ; and a gain accuracy of better than 1ppm. It is assembled on a 5 x 8 in. plug-in printed-circuit card. Adage Inc., 292 Main St., Cambridge 42, Mass.

Circle 526 on Inquiry Card

Operational Amplifiers

All-silicon Model 1506 operational amplifier has a dc gain of 100,000, 1Mc unity gain bandwidth, and output of ±10v. at 20ma in a 1 cu. in. module. This new amplifier draws only 5ma quiescent current from a dual 15v. supply and is stable with up to 10μfd of capacitive loading. Model 1507 rated output current is 2 ma. Both units are specified from −40°C to +85°C and features 0.3na/°C input current drift. Model 1513 uses germanium transistors for laboratory environment with Model 1507 performance. Data sheets available from Burr-Brown Research Corp., P. O. Box 6444, Tucson, Ariz.

Circle 527 on Inquiry Card

ELECTRONIC INDUSTRIES Professional Profile

Please type or print

The ELECTRONIC INDUSTRIES Job Resume Form for Electronic Engineers

Name _____ Tel. No. _____

Street Address _____ Zone _____

City _____ State _____

☐ Single ☐ Married ☐ Citizen ☐ Non-Citizen Date of Birth _____

Will Relocate ☐ Yes ☐ No. If Yes ☐ Another City ☐ Another State

Salary Desired to Change Jobs in present area _____

Salary Desired to Change Jobs and relocate in another area _____

Professional Memberships _____

College or University	Major	Degree	Dates

RECENT WORK EXPERIENCE

Company	Div. or Dept.	Title	Dates

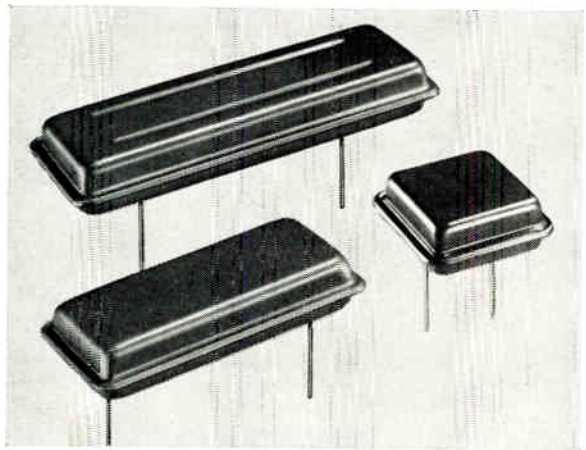
SIGNIFICANT EXPERIENCE AND OBJECTIVES

STATE ANY FACTS ABOUT YOURSELF THAT WILL HELP A PROSPECTIVE EMPLOYER EVALUATE YOUR EXPERIENCE AND JOB INTERESTS. INCLUDE SIGNIFICANT ACHIEVEMENTS, PUBLISHED PAPERS, AND CAREER GOALS.

Mail to: ELECTRONIC INDUSTRIES—Professional Profile—56th & Chestnut Sts.—Philadelphia, Pa. 19139. This resume is confidential. A copy will be sent only to those Companies advertising for engineering personnel in this issue, whose number you circle below.

800 801 802 803 804 805 806 807 808 809 810

REEVES-HOFFMAN CRYSTALS, FILTERS, FREQUENCY STANDARDS AND OVENS

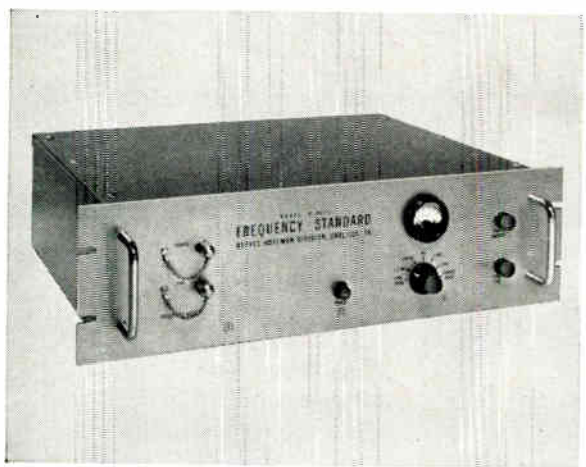


NEW COLD-WELDED METAL CRYSTAL HOLDERS...

eliminate solder and flux, provide a leak-proof seal, increase reliability and stability, allow further miniaturization. Precision crystals available in new cold-welded holders in frequency range of 1 kc to 100 mc.

Ultra-precision crystals are available in a frequency range of 1 mc to 5 mc.

REEVES-HOFFMAN CRYSTALS ARE USED IN ALL NETWORKS TO ASSURE STABILITY AND RELIABILITY

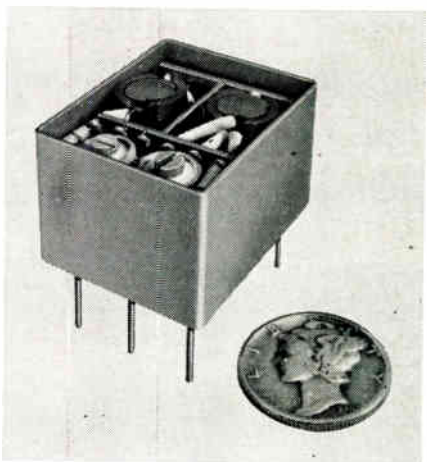


FREQUENCY STANDARDS

2.5 mc standard has stability of 2 x 10^{-11} per day after one year (at a constant ambient). Provides simultaneous output frequencies of 100 kc, 1 mc, 5 mc. Crystal frequency is adjustable to within 1 x 10^{-11}.
Other ultra-stable standards with a basic frequency of 5 mc are available with stabilities up to 1 x 10^{-9} per day. Can be packaged to your specifications.

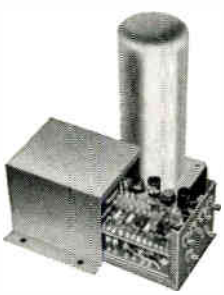
FREQUENCY SOURCES

Transistorized, packaged oscillators are available in a frequency range from 30 cps to over 100 mc. Stabilities are up to 1 x 10^{-9}. Packaged to your specifications.



CRYSTAL FILTERS

Filters are available in a frequency range of audio to 30 mc. Side band, band pass, band reject and discriminators can be packaged to your specifications.



OVENS

PROPORTIONALLY CONTROLLED OVENS for precise frequency standards hold within 0.001° C at any fixed ambient. Thermostatically and Snap-Action Controlled ovens also available.

Reeves-Hoffman also manufactures fractional horsepower motors and resolvers.

REEVES-HOFFMAN

CARLISLE, PENNSYLVANIA

DIVISION OF DYNAMICS CORPORATION OF AMERICA

Circle 191 on Inquiry Card

NEW TECH DATA

TEST EQUIPMENT

AC Converter

The Model 1100 ac-to-dc converter is for use with Models 5000A and 5100 digital voltmeters. The converter is a plug-in for 2 accessory power supplies—Models 1600 and 1610. Automatic ranging and average reading time is less than 150msec. Max reading time without range change is below 300msec. Freq. range is 30CPS to 10KC; accuracy is ±0.1% of reading or 2 digits. More data is available from Hughes Instruments, 2020 Oceanside Blvd., Oceanside, Calif.

Circle 521 on Inquiry Card

Signal Generators Catalog

This 32-page catalog provides descriptions and specs. on Sweep/Signal Generators and accessory equipment covering audio to 3GC. The catalog includes data on sweep measurement techniques and a general treatment of sweep generator operation. Telonic Industries, Inc., 60 N. First Ave., Beech Grove, Ind.

Circle 522 on Inquiry Card

Crystal Thermistor

This single-crystal silicon carbide thermistor combines in one miniature sensor a set of characteristics never before available in a single thermal transducer. The brochure lists the properties of the new thermistor and many of its possible uses. It also contains characteristic data on temp. vs. resistance and voltage vs. current. The Carborundum Co., Electronics Div., Dept. SDP, P. O. Box 337, Niagara Falls, N. Y.

Circle 523 on Inquiry Card

Instruments Catalog

This 1964 short-form catalog lists a line of new instruments. Two such instruments include model 121 true RMS wideband voltmeter that measures from 1 mv to 300 v., full scale, from 15 CPS to 50 MC, ±5%; and model 104 wideband amplifier, that amplifies from 25 CPS to 150 MC, ±0.5 db, for a gain of 100. In addition to these new instruments, abbreviated specs. are given for a line of ac voltmeters, ac amplifiers, dc microvoltmeters, dc differential voltmeters, dc high voltage supplies, resistance measuring devices, electrometers and picoammeters. Keithley Instruments, 12415 Euclid Ave., Cleveland 6, Ohio.

Circle 524 on Inquiry Card

EQUIPMENT, MATERIALS, PARTS & COMPONENTS

NEW TECH DATA

TEST EQUIPMENT

Instruments Catalog

Catalog C-100 describes a product line of instruments and components. Specs., illustrations and descriptions are given for the Model EM-20 electron microscope; electron optical systems and components; dc high-voltage generators; automatic valving vacuum systems; etc. Mikros Inc., 7634 S.W. Capitol Hwy., Portland, Ore.

Circle 499 on Inquiry Card

Spectrum Analyzers

Brochure No. 31104 describes 36 models of Multiple-Filter Spectrum Analyzers. These instruments provide real time analysis with an elemental bandwidth as low as 1 cps in some models. Wide band models provide an analysis band of 50 kc. Spectran Electronics Corp., 146 Main St., Maynard, Mass.

Circle 500 on Inquiry Card

Voltage Limit Detector

A completely fail-safe voltage limit detector that monitors both upper and lower voltage limits is described in detail in a new data sheet. The monitored voltage is sampled by a threshold carrier amplifier through a 10K Ω/volt program resistor. Range is 1 to 1K vdc. Elsco Systems, Inc., 4516 Stone Way N., Seattle, Wash.

Circle 501 on Inquiry Card

RF Voltmeter

This technical data sheet describes Model 91D Sensitive RF Voltmeter. It includes a functional description, applications data, and full specs. of Model 91D, which is a highly compact instrument for voltage measurements over a range from 300μv to 300v., and from 20kc to beyond 1200mc. Boonton Electronics Corp., Parsippany, N. J.

Circle 502 on Inquiry Card

Test Equipment

Catalog 64-A, 34 pages, describes a line of r-f test equipment with freq. range from audio to 3gc. The data contains application data, photos, block diagrams, and tabulated characteristics. Telonic Industries, Inc., Beech Grove, Ind.

Circle 503 on Inquiry Card

Test Gauges

Bulletin M-60 describes a complete line of precision test gauges. The bulletin explains the advantages of 360° test gauges over ordinary 270° test units. It points up the advantages of greater scale length, and diagrams show how the gauge is calibrated to the dial. It also contains a scale length comparison chart. Martin-Decker Corp., 3431 Cherry Ave., Long Beach, Calif.

Circle 504 on Inquiry Card

ELECTROMECHANICAL COMPONENTS
VARIABLE CAPACITORS

Variable capacitors of all types, including ganged tuning and trimmer types, are on a slow rise in sales value at the rate of about 6% a year. Current estimates put variable capacitor sales for 1964 at about $33 million.

	1964	1965	1966
	(in millions of dollars)		
Variable Capacitors—all types	$33	$35	$37

(Figures based on a limited EI survey among 300 leading component manufacturers.)

ELECTROMECHANICAL COMPONENTS
POTENTIOMETERS

Some industry sources believe that resistors in general, and potentiometers in particular, are on a slight downward trend in total sales as shipments of units seem to increase. Other sources insist the resistor curve is going up—slowly, but up. Average total sales for all potentiometers for 1964 have been forecast at about $145 million, with the leader being the wire wound varieties at $99 million.

	1964	1965	1966
	(in millions of dollars)		
Potentiometers—Total Market	$144	$154	$165
Carbon—all types	55	57	62
Wire Wound—all types	89	97	103
Precision Pots (Carbon & Wire Wound)	80	83	86
Trimmer Pots (Carbon & (Wire Wound)	23	25	28

(Figures based on a limited EI survey among 300 leading component manufacturers.)

$R(t) = e^{-\lambda t}$

$t = 2.5$ hours

$\lambda = 0.048$ / million hours

$R(2.5) = 2.7183^{-0.048(2.5)\times 10^{-6}}$

$R(2.5) = .99999988$

As reliable as $R(t) = e^{-\lambda t}$

. . . and that's pretty reliable.

Our new 217 Series rack-and-panel connector meets the requirements of MIL-C-26518b (USAF), the R&P equivalent of MIL-C-26500. Connectors made to this companion specification have already put in millions of operating hours (in the Minuteman program, as well as on the Boeing 707 and 720) with a failure rate of only 0.048 per million operating hours . . . far below that of any other commercially available connector.

Fully sealed, the Amphenol 217 completely resists environmental contamination. It performs in ambients ranging from −67 to +500 F, and at ultra-high altitudes. Splash it with salt water, hot lube oil, hydraulic fluid, UDMH, or nitrogen tetroxide. The 217 Series connector will keep right on going . . . and going . . . and going.

Beveled entryways in the hard dielectric sockets guide contacts (either power or RF) surely and positively into position . . . very important in the "blind" mating conditions so common in rack-and-panel applications.

Ask your Amphenol Sales Engineer about the 217 Series. Or write: Ned Spangler, Vice President-Marketing, Amphenol, 1830 S. 54th Avenue, Chicago 50, Illinois.

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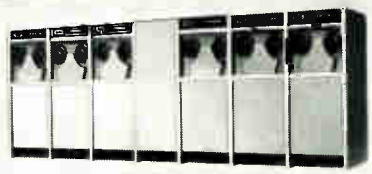
Circle 199 on Inquiry Card

These 13 RCA transistors can improve the SPEED, CAPACITY, RELIABILITY of almost any computer circuit.

In the SPEED, CAPACITY, and RELIABILITY of your circuitry, these 13 RCA computer transistors can give you a decided competitive edge. The table below indicates at a glance what RCA transistors offer:

IF YOU'RE NOW USING THESE TRANSISTORS	YOU COULD BENEFIT FROM USING THESE RCA DEVICES	HERE'S WHY
Arithmetic & Control Section (MAIN FRAME)		
(SILICON TYPES)		
2N2369	RCA TA-2332*	5 nsec propagation delay in practical logic circuits
2N744 or 2N2501	RCA 2N2938	7 nsec propagation delay in practical logic circuits
2N706 or 2N708	RCA 2N706 or 2N708	exceptional uniformity of electrical characteristics
2N709	RCA 2N2475	fastest switching at currents up to 30 ma
(GERMANIUM TYPES)		
2N960	RCA 2N960	Rugged trapezoid construction
2N797	RCA 2N955A	6 nsec propagation delay in practical logic circuits
2N393	RCA 2N1301	Availability, outstanding reliability
2N404	RCA 2N404	Availability, outstanding reliability
HIGH-SPEED MEMORIES		
(SILICON TYPES)		
2N2218 or 2N2845	RCA TA-2420*	35-volt min V_{CEO}, 40 nsec total switching time (typ.)
2N918 2N2415 (Germanium) 2N2996 (Germanium)	RCA 2N2857	4 db typical noise at 450 Mc
PRINTERS, TAPE READERS, MAGNETIC TAPE STATIONS, ETC.		
(GERMANIUM TYPES)		
2N393	RCA 2N1301	Availability, outstanding reliability
2N404	RCA 2N404	Availability, outstanding reliability



*Developmental Type

You are missing opportunities to get higher speeds, greater capacities, and better reliability, if you are not using RCA's competitively-priced transistors in your computers or digital communications equipment.

For more information to show you why you should select RCA switching transistors, call your RCA Representative or write: Commercial Engineering, Section CJ-6, RCA Electronic Components and Devices, Harrison, N. J.

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Circle 200 on Inquiry Card