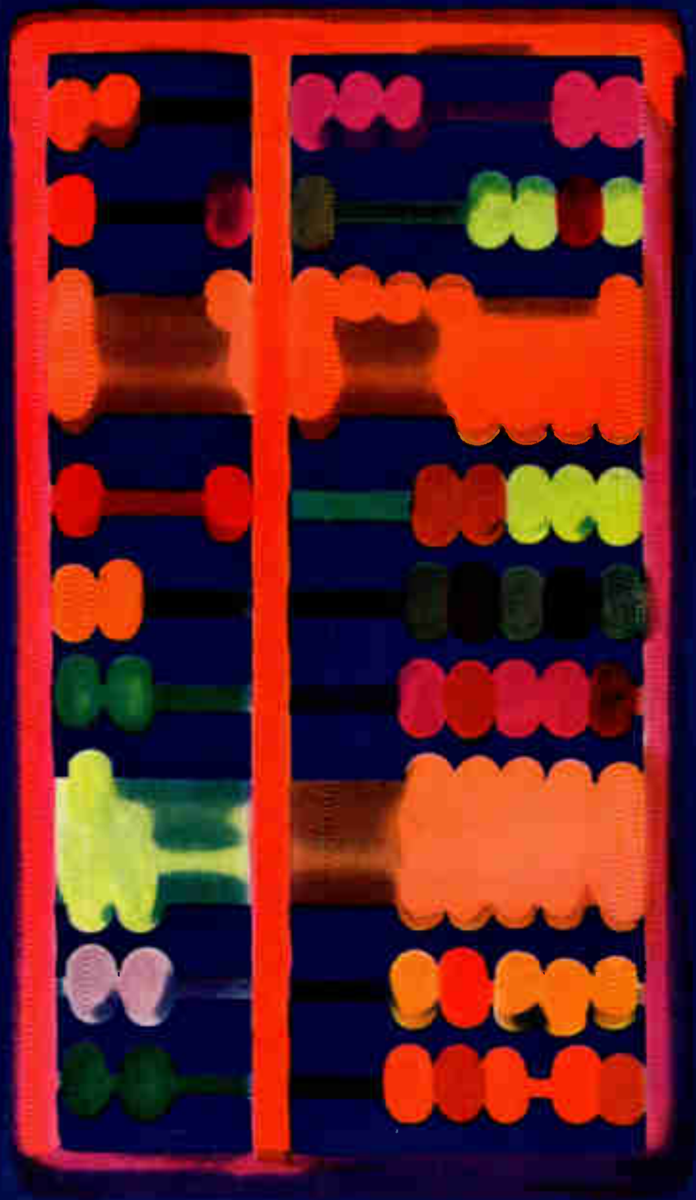
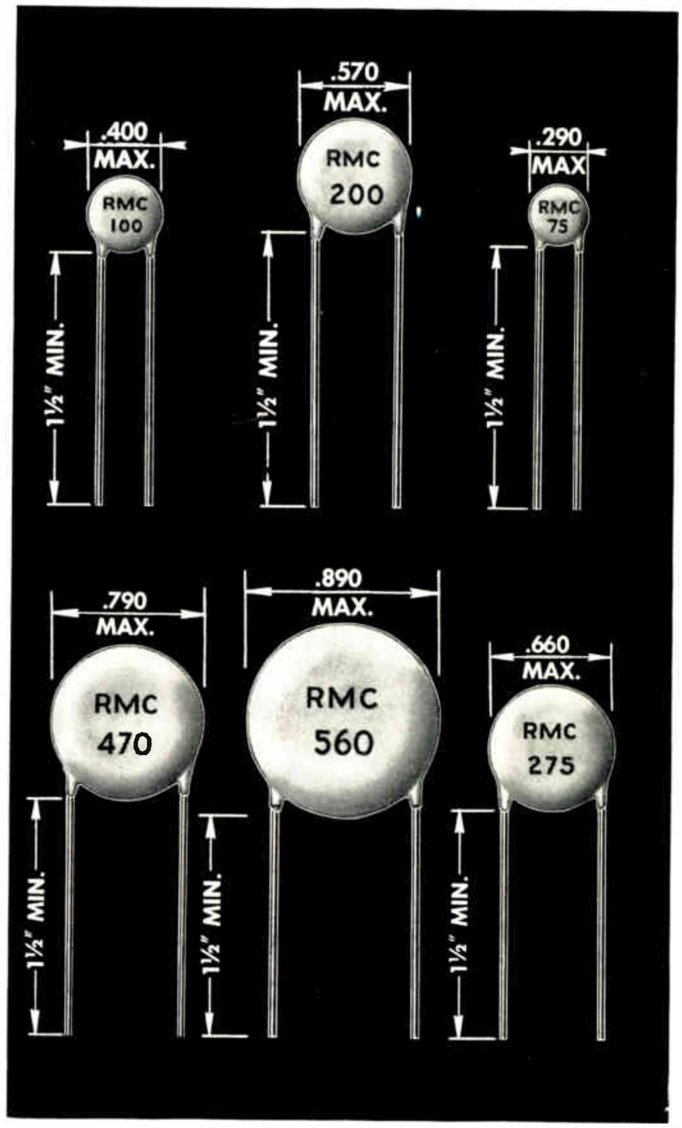
ELECTRONIC INDUSTRIES



SEPTEMBER 1963

MATHEMATICS FOR DESIGN



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Reliability is an important reason why RMC Type C temperature compensating DISCAPS rank so high with users. It makes them the ideal cost-cutting replacement for tubular ceramic and mica capacitors. Rated capacities will not change under voltage. Smaller sizes permit compact circuit designs. Greater mechanical strength means lower cost production operations. Type C DISCAPS are rated at 1000 working volts yet cost no more than ordinary 600 volts capacitors.

TC	.290	.400	.570	.660	.790	.890
P-100	1- 5 MMF	6- 10 MMF	11- 20 MMF	—	—	—
NPO	1-15	16- 33	34- 69	70- 85 MMF	86-115 MMF	116-175 MMF
N- 33	1-15	16- 33	34- 69	70- 85	86-115	116-175
N- 75	2-15	16- 33	34- 69	70- 95	96-130	131-190
N- 150	2-15	16- 36	37- 67	68- 95	96-130	131-230
N- 220	2-15	16- 36	37- 75	76-100	101-160	161-230
N- 330	2-20	21- 51	52- 75	76-115	116-190	191-270
N- 470	2-20	21- 51	52- 80	81-120	121-200	201-275
N- 750	2-32	33- 75	76-155	156-220	221-300	301-470
N-1500	10-74	75-140	141-220	221-399	400-550	551-800
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ELECTRONIC INDUSTRIES

THE ENGINEER IS IN BUSINESS, TOO!

IT IS TIME THAT ENGINEERS take a long, hard look at the "business" side of electronics.

Designing and building equipment is fine. But until it is sold, there is no money for anyone—neither the engineers, salesmen, management nor stockholders.—It's as simple as that.

Part of the trouble has been that management feels sales figures are none of the engineer's business; that the less he knows, the better. And engineers, strangely, have gone along. There is a certain weird sense of security in being insulated from the problems of sales and management.—"We build the equipment. It's up to them to sell it!"

That arrangement just won't work. This is much too complicated a business. For his own sense of security, and for his future professional development, the engineer must become familiar with the facts of business life.

There is certain basic information that the engineer should know about his firm, things that management should tell him.

For instance, engineers should know how products are marketed. Are they sold by factory salesmen? Or reps? Or by both? And what percentage is sold by each?

How is the competition marketing its products? Does there seem to be an advantage either way?

Engineers should know the factory price of the equipment on which they are working. Also, the retail price, if applicable.

Engineers should know how much total business is done by the firm—and the percentage profit. They should also know the competitive position of the firm—whether it is first, second—fifth—in its field.

Engineers should know management's objective. For instance, what percentage of the firm's business is military, and how much commercial. If the picture is changing, they should know that, too, and the direction it is taking.

Managements must accept the fact that it is important for their engineers to be informed on these areas. Not just for their personal satisfaction, but because it enables team performance and helps in developing a strong, consistent, outside corporate image.

Of course, when management makes these figures available, it also opens itself to criticism. But a company management that can't stand criticism is probably on borrowed time, anyway.

One very simple device for engineers—become a stockholder in the firm. Even one share of stock entitles the holder to copies of the earnings statements. And frequently, the most important details on company plans and accomplishments are contained in the Annual Report.

Successful business calls for teamwork between management, marketing and engineering.

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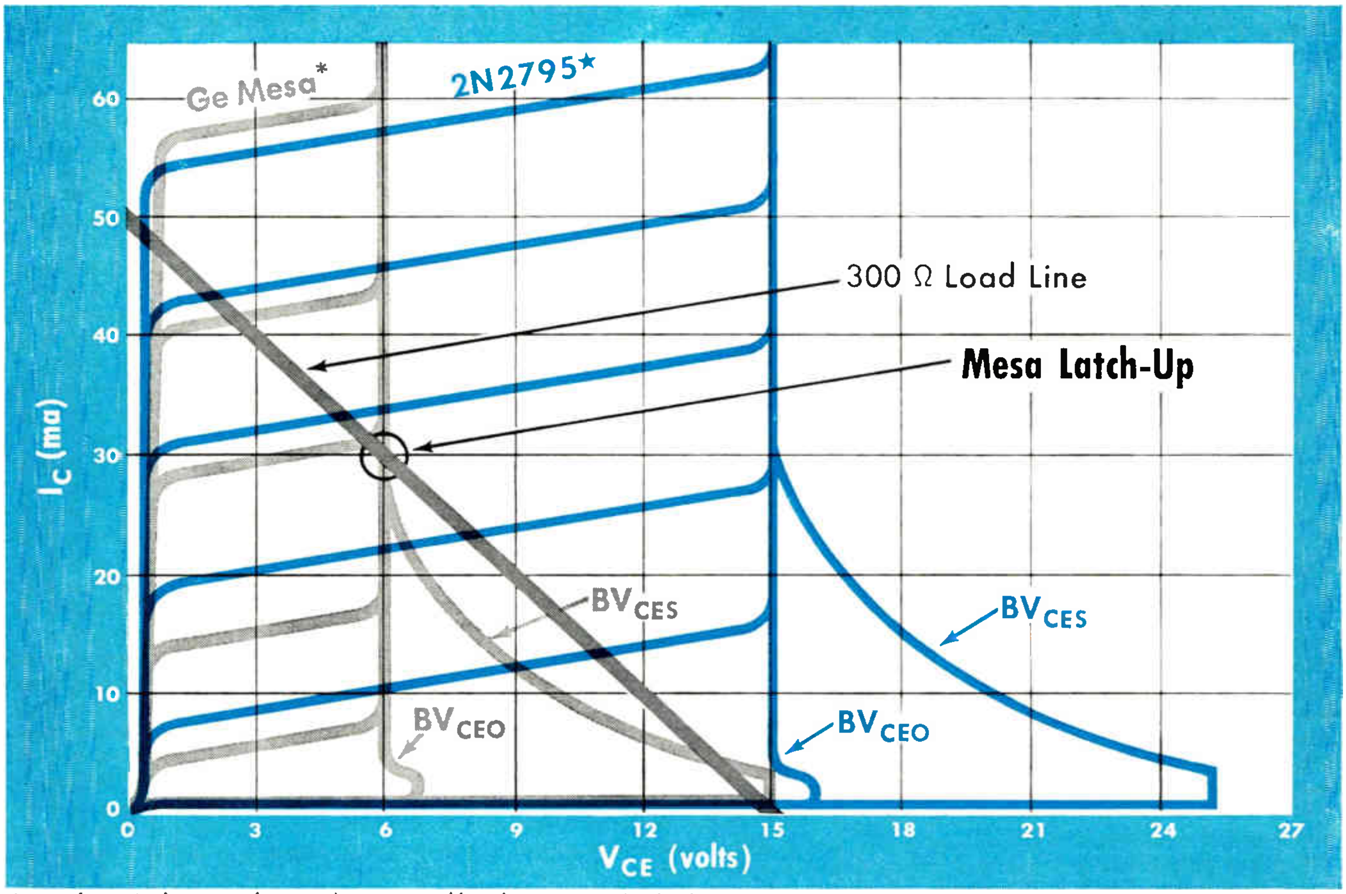

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2N2795	450 mc	25 volts	15 volts
2N2796	450 mc	20 volts	12 volts
2N984	350 mc	15 volts	10 volts
2N979	150 mc	20 volts	15 volts
2N980	150 mc	20 volts	12 volts
2N2048†	250 mc	20 volts	15 volts

(†TO-9 Case)

● For additional information on Sprague High Voltage Logic Transistors, write to the Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Massachusetts.

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ELECTRONIC INDUSTRIES

September 1963
Vol. 22, No. 9

EDITORIAL FEATURES

DEPARTMENTS

ELECTRONIC INDUSTRIES, September, 1963. Vol. 22, No. 9. A monthly publication of Chilton Company. Executive Editorial & Advertising offices at Chestnut & 56th Sts., Phila., Pa. 19139. (Area Code 215) SHerwood 8-2000. Controlled circulation postage paid at Phila., Pa. $1 a copy; Directory issue (June), $5.00 a copy. Subscription rates U. S. and U. S. possessions: 1 yr. $10.00; 2 yrs. $18.00. Canada 1 year, $12.00; 2 yrs. $20.00. All other countries 1 yr. $18.00; 2 yrs. $30.00.

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TYPE 405E, 411E Molded-Case FILMISTOR® deposited-carbon RESISTORS Engineering Bulletin 7000B	TYPE 239E Vitreous-Enamel BLUE JACKET® power wirewound RESISTORS Engineering Bulletin 7410D	TYPE 219E Silicone-Encapsulated ACRASIL® precision power wirewound RESISTORS Engineering Bulletin 7450	TYPE 5000Z CONNECTORS and ISOLATORS ("shorts and opens") Engineering Bulletin 94,000	TYPE 7000Z Shielded Radio Frequency INDUCTORS Engineering Bulletin 41,800

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For complete technical data, write for Engineering Bulletins listed above. Address: Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Massachusetts.

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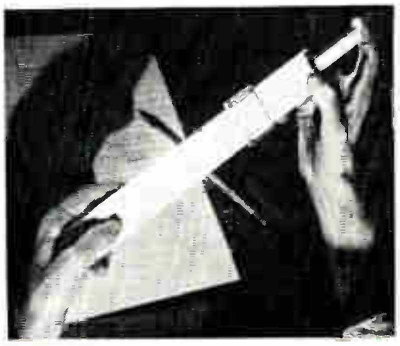
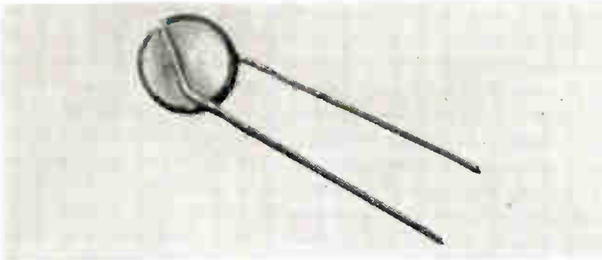
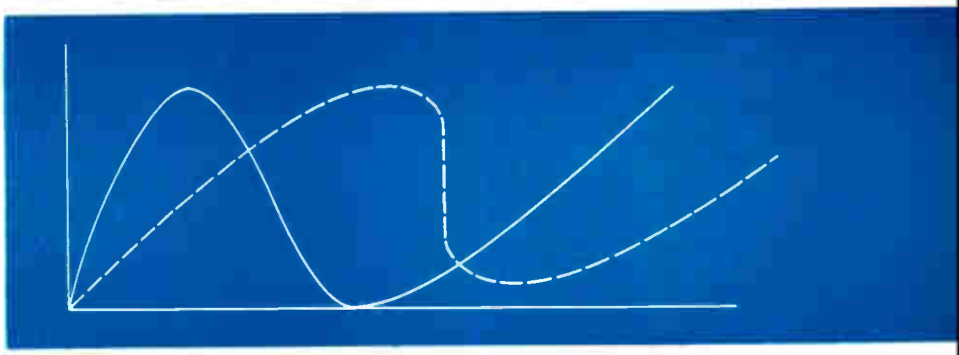
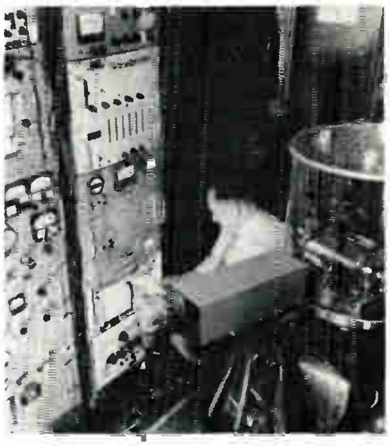
ARTICLE HIGHLIGHTS

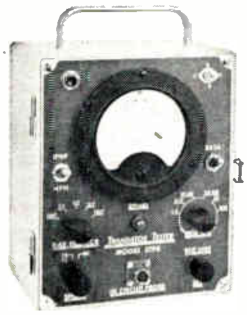
of this issue











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Engineers and other technically-trained men are particularly prone to "drift with the tide" because their starting salaries are reasonably high and promotions come at regular intervals early in their careers. It isn't until later—too much later in many cases—that they discover there is a definite ceiling on their incomes as technicians.

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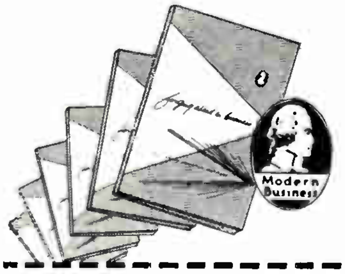

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RADARSCOPE

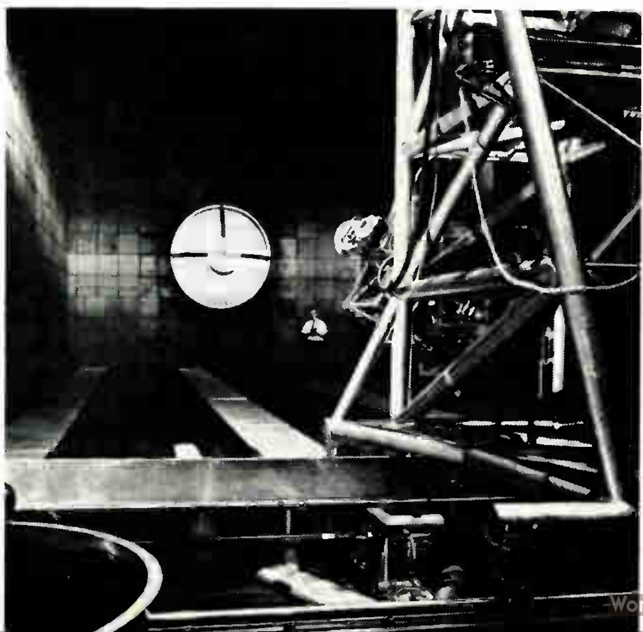
Analyzing current developments and trends throughout the electronic industries that will shape tomorrow's research, manufacturing and operation

LASER SPACE WEAPONS were suggested as an "obvious area of speculation" and development by Sen. Barry Goldwater (R.-Ariz.) at the Ohio Wing Conference of the Air Force Association. He suggested that the Soviet Union is perhaps doing more than just speculate. "We are now six full years into the space age. . . . We have not authorized a single military space weapons system." He declared that Soviet concentration on manned satellites and maneuverability in near space clearly point to military goals and away from abstract science or preoccupation with the moon. The Senator, in effect, has asked the U. S. to de-emphasize the moon and get moving on a military space program.

GOVERNMENT CONTRACTS AWARDED to small firms under the Small Business Administration's set-aside program rose 6.7% in fiscal 1963, SBA deputy Administrator Irving Maness disclosed. During the year, 46,356 Government contracts valued at $1.9 billion went to small businesses as a result of SBA program, which compares with 56,944 contracts valued at $1.8 billion awarded in fiscal 1962. The number of contracts awarded to small firms fell below the 1962 level, but the rise in dollar value indicates a more specialized nature of contract being awarded by U. S. agencies to small firms.

RAYTHEON-MARTIN SPACE TESTS

Raytheon's prototype rendezvous radar installed in Martin-Marietta's terminal rendezvous closure and docking simulator. Martin's full-scale space simulator is being used to test Raytheon's phase-modulated CW space rendezvous, all solid-state radar, planned for use in advance spacecraft systems.



ZERO-VOLTAGE CURRENT and other phenomena in superconductivity in metals near 0°K have been verified, according to Dr. Sidney Shapiro of Arthur Little, Inc., Cambridge, Mass. In 1962, B. D. Josephson, Cambridge University (Eng.) predicted that in addition to single-electron tunneling, new effects in paired-electron tunneling should occur, one being a current entirely free of voltage. Josephson also predicted that on an E-I curve, r-f waves should influence paired tunneling, causing zero-voltage current to appear at regular intervals along the curve depending on frequency. Another Josephson phenomenon, verified by Dr. Shapiro, is the ability of I to reverse itself while E remains unchanged. It happens and no one knows why.

SIGHT BY INFRARED RADIATION has been advanced a big step by Westinghouse scientist T. P. Vogl with a new compact, high-speed, high-resolution lens system for infrared imaging. Although good electronic systems exist for making objects visible in total darkness through their self-radiated IR, a major technical problem has been adequate lenses for collecting and focusing the IR rays. They have been typified by low speed, bulkiness and poor image quality. Vogl's lens system is very fast—f/0.75, four stops faster than a first class lens for a 35-mm camera—f/2.8. Its radiation-gathering ability is, therefore, 16 times better. Past IR lenses were limited to f/1.5.

PHYSICAL PHENOMENA associated with the re-entry of bodies into the earth's atmosphere will be studied by Great Britain, Australia and the U. S. The findings may help in developing new electronic systems for identifying and tracking re-entry bodies. Known as DAZZLE, the project will use Britain's Black Knight research missile. Launchings will be at Woomera Range in Australia. U. S. Advanced Research Projects Agency will provide instruments to observe re-entry. Britain and Australia will check data.

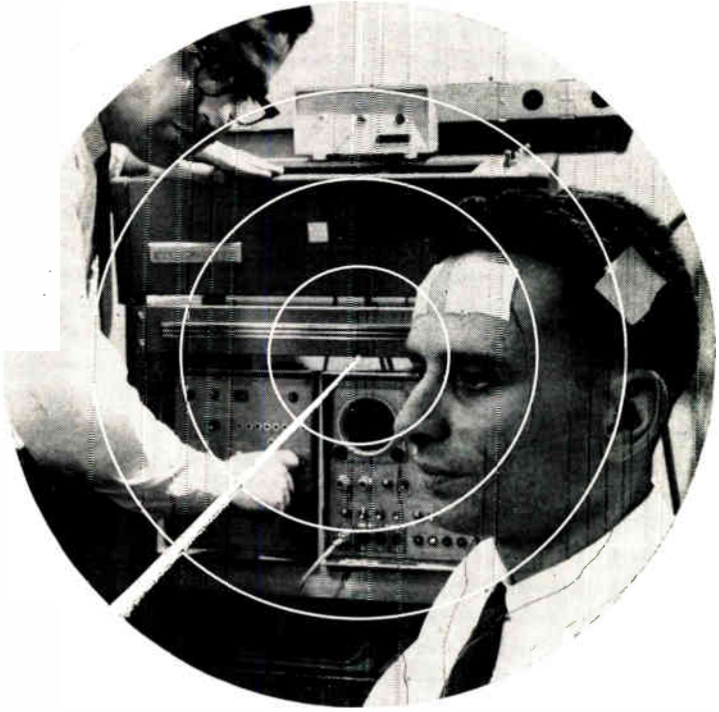
PATENT CATALOG, 1790 TO NOW, is a mammoth publishing project to place all U. S. patents at the fingertips of industry, science and engineering. The project is being handled by Rowan & Littlefield, Inc., of New York City with the cooperation of the U. S. Patent Office. Called "The National Catalog of Patents," the project will draw together in orderly classification the massive patent information from more than 5,000 issues of the Patent Office Gazette. Patents will be grouped by classes and sub-classes. The first four volumes of the Catalog just published list all patents filed in 1961 in the electrical and chemical fields.

THIN FILM DEPOSITING PROCESS, using a new solution-spraying method, has been developed by National Cash Register Co. A means of depositing inorganic thin films, the process is especially good for preparing photoconductors, according to an NCR official. The technique provides deposition over a large area, higher yields, greater reproduction of characteristics, high dark-to-light resistance ratios having rise and fall times measured in milliseconds, and improved spectrum response. The process affords good adhesion of films to substrates. Its advantages, according to NCR, include simplicity in film forming, cheaper cost because no vacuum equipment is needed, and the technique can be used in large-area depositing as well as in continuous depositing on belt-type substrates.

METRIC SYSTEM CONVERSION for American science and industry before the end of the century has been predicted by economists of the Stanford Research Institute. They also forecast a total national bill of about $11 billion for the whole changeover. But—the cost for industry will be more than made up by increased business and productivity. The switch will mean faster calculations for engineers, better understanding between scientists and businessmen, easier and better teaching of the young, and less chance for costly errors. Some 82% of the world's people now use the metric system.

LIGHT BEAMS TO MICROWAVES

Experimental system for converting laser beams to microwaves is adjusted by developer, Kenneth E. Niebuhr, IBM engineer. Ruby laser and quartz crystal are coupled optically to produce an S-band signal from two beam frequencies. This was the first use of electro-optics for microwave conversion.



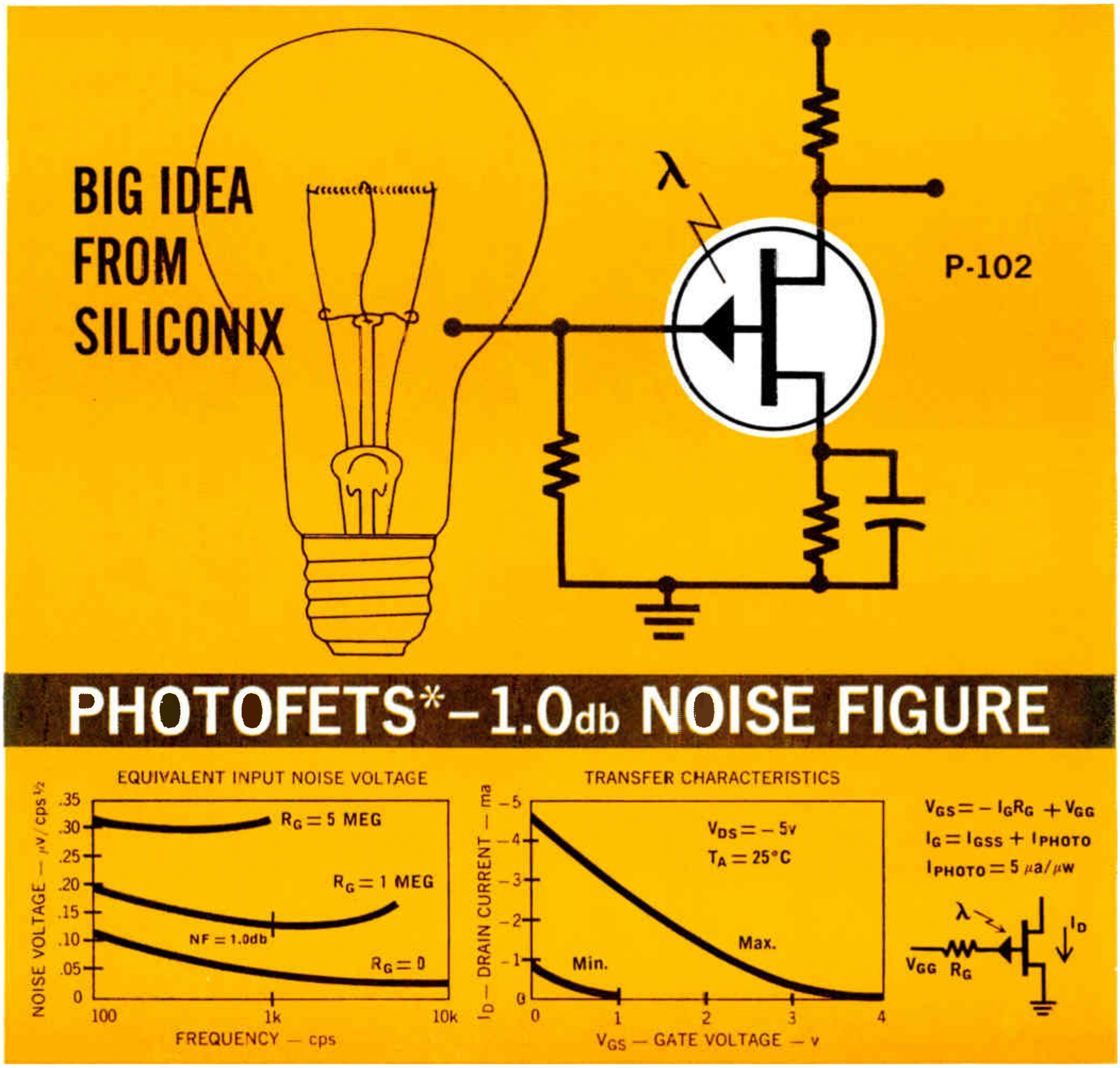
BRAIN WAVE 'DETECTIVES'

Honeywell scientists hope to isolate electrical brain waves which might allow forecast or even control of human behavior over great distance. Scientist Doland Tepas does preliminary test using colleague Roy Jacob as subject. Brain waves are analyzed by a digital Computer of Average Transits (CAT).

MANPOWER TRAINING INCREASE was given a helpful nudge by James Carey, International Electrical Workers Union head, before a House Labor Subcommittee as he cited a "rapid and continuing shift from production to non-production workers" in the electronics industry. He declared, in support of expanding the Manpower Training Act, that change in emphasis from the unskilled and the semi-skilled—hand workers and simple machine operators—continues with their replacement by operators of semi-automatic and automatic operations and the supporting skilled technicians and professional employees. He reported that in 1953 some 23% of electrical workers were non-production, but in 1962 the total was 32%. In electronics alone the figure was 37%.

HOME ELECTRONIC PRODUCT MAKERS and dealers "are courting chaos," reports Roland J. Kalb, vice president of 45-year-old Pilot Radio Corp., an industry pioneer, now in high-fidelity systems. "High pressure selling, low profit merchandising, indiscriminate distribution and over-saturated markets are quickly tightening the noose on the whole industry. We can either take the heavily traveled road to chaos, or we can take the one paved with fair profits, professional salesmanship and protected trading areas," Kalb declared. Pilot management has begun "an intensive campaign to restore fair profits and sanity to the industry."

(More RADARSCOPE on Page 11)



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RADARSCOPE

SEMICONDUCTOR DIODE BEHAVIOR at power switch-on was studied by Yuan Feng Chang, electrical engineer at Purdue, who has come up with an answer to the mystery. Using a pulser for input signals and a scope, he reports that at switch-on a large current or input signal shows an immediate high peak, then a sharp drop in voltage that levels to a steady flow. With a small signal the voltage rises gradually and then levels. A medium current makes the voltage go up like a step instantaneously (10 millionths of a second) and stay there. Semiconductor diode response differs then according to the current. In contrast, vacuum tubes always respond in the same way regardless of signal. Professor Chang's work implies that the most efficient use of semiconductor diodes is from a medium input signal.

LASER-IN-SPACE EXPERIMENTAL DATA are being gathered by scientists at the Air Force Systems Command's Aeronautical Systems Division, Wright-Patterson Air Force Base. Problems of operating lasers in a vacuum, such as space environment, are under investigation in an electro-magnetic radiation analyzer chamber by Avionics Lab scientists. Laser projects at Avionics range from efforts to increase peak and average power of gaseous and solid-state lasers to communications and optical radar. Space-to-space communications links are envisioned with enormous message handling abilities, requiring only small primary power. A multi-channel optical communications transmitter using a CW laser as the signal source has been developed and is being evaluated at ASD.

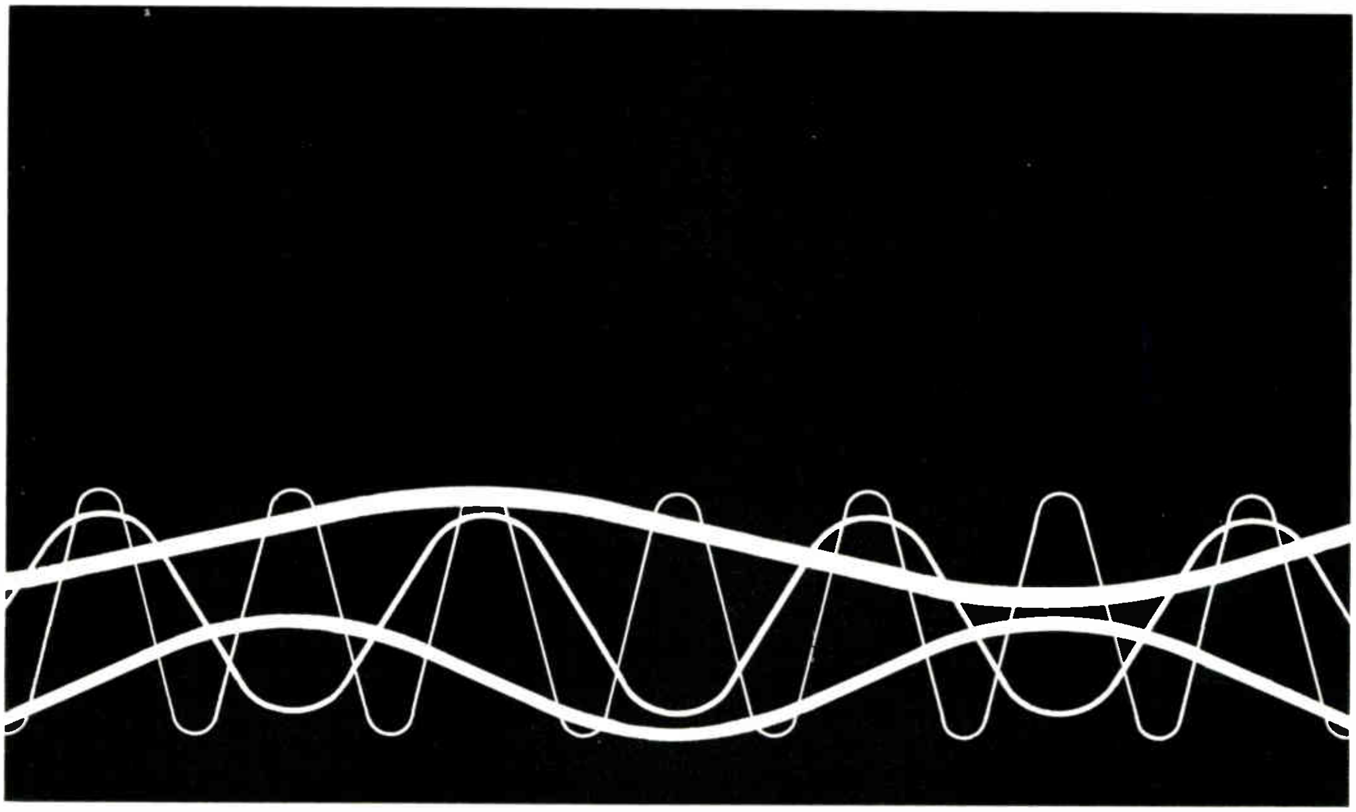
AIR TRAFFIC CONTROL RADARS are substandard in many of our big city airports, according to a survey made by Edward H. Cockerham, executive director of the Air Traffic Control Association. He found that most big city fields still rely on old ten-inch, ASR-2 scopes as compared to more efficient and accurate 16-inch variety with modern circuits. Oddly enough, newer radars are being used by many smaller, less busy fields such as Harrisburg, Pa., and Greensville, N. C. Cockerham feels that the inefficient, out-of-date equipment could not have been commissioned by responsible persons. The survey disclosed that many big fields trying to make the ASR-2 work with modification kits have already run up costs equal to the cost of the new 16-inch units. And, the ASR-2 is still a detriment to air safety as targets fade in and out.

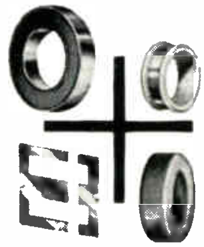
ADDITIONAL VHF STATIONS anywhere in the nation would be contrary to the intent of Congress in its all-channel TV law, effective April 30, 1964, according to James D. Secrest, executive vice president of EIA. It would delay the law's effectivenss and discourage investment in UHF stations. The slowdown of UHF station construction to any degree through FCC approval of VHF "drop-in" stations would retard sales of all-channel sets substantially and with it employment and business for manufacturers, distributors, and dealers—or, many consumers would have to pay as much as $30 or more for UHF tuning they could not use. EIA asked FCC not to reverse its recent decision denying VHF "drop-in" proposals.

COLOR MOVIES OF THE LARYNX, at 9,000 exposures per second, is an Air Force development directed toward realistic electronic and mechanical voice reproduction for advanced speech transmission systems. According to scientists at Cambridge Research Lab, the high-speed, color film clearly shows the onset and end of brief transition vocal sounds that normally occur in speech. Area of larynx opening of cords, as a function of time, will be measured from the film with the aid of a digital computer. Speech synthesis tests may determine the degree of larynx activity needed for natural voice quality, speaker identification and emotional cues.

IMPENETRABLE WINDOW

A germanium window that visible light cannot penetrate was used in a DC-8 flying observatory for the National Geographic Society-Douglas Aircraft eclipse study in July. Reflecting Douglas scientist A. T. Ireland is germanium circle through which instruments recorded IR radiation in the sun's corona.





Optimizing circuit components to frequency? Get more from magnetics

THE CORE: What's the best core for operating at low frequencies? What powder core or flake core is best for a higher frequency? That depends on what you're looking for. Frequency alone does not determine where one type of core should be used in favor of another. There's an overlap of usefulness and many core possibilities within a frequency range. Core choice for optimum performance at a given frequency must be related to core cost, and operating temperature, to name a few. Optimizing comes from a careful analysis of the many variables. The *man from Magnetics Inc.* will re-acquaint you with them and will assist you with your selection.

THE MORE: The 550 mu Permalloy cores permit greater circuit miniaturization, bridging the design selection gap between laminations and powder cores. Or, choosing a laminated core where you may have thought to use a powder core might be just the thing to effect lower costs, size reduction, operating stability, and high efficiency. Because we produce and stock a wide range of sizes and types of high permeability components, we can assist you a little more than most. Just how much more? Ask the *man from Magnetics Inc.* next time he calls . . . or write us on your letterhead giving the details of your problem. Magnetics Inc., Dept. EI-6 Butler, Pa.

TOTAL ASSISTANCE, SERVICE, SELECTION/GET THE MORE FROM MAGNETICS

MAGNETICS inc.

...the symbol of quality in Zener Diodes

. . . Because the Depth of Motorola's Research Group Assures Continuous Zener Diode Breakthroughs

Zener diode innovations never stop at Motorola! Deep in talent and proven experience, Motorola research engineers continually strive for new achievements you can use. *Here are some examples:*

FIRST 50 WATT ZENER DIODE — Motorola's depth of research contributed this first in the industry, and set the pace for high-wattage zener diodes.

SURMETIC* ZENER DIODES — Made by a new low temperature oxidation process, this was the industry's first glass surface passivated zener diode. So effective is this temperature oxidation process, that surface passivated dice with leads attached, and no further protection, passed all standard MIL high temperature-humidity storage tests!

LOW-LEVEL OXIDE PASSIVATED ZENER DIODES — This new Motorola series (1N4099-1N4135) is specifically designed for low power applications, and features low leakage, low knee impedance and low noise.

These are typical achievements you can expect from Motorola's research group. They place the emphasis on results . . . for you . . . *at no extra cost.*

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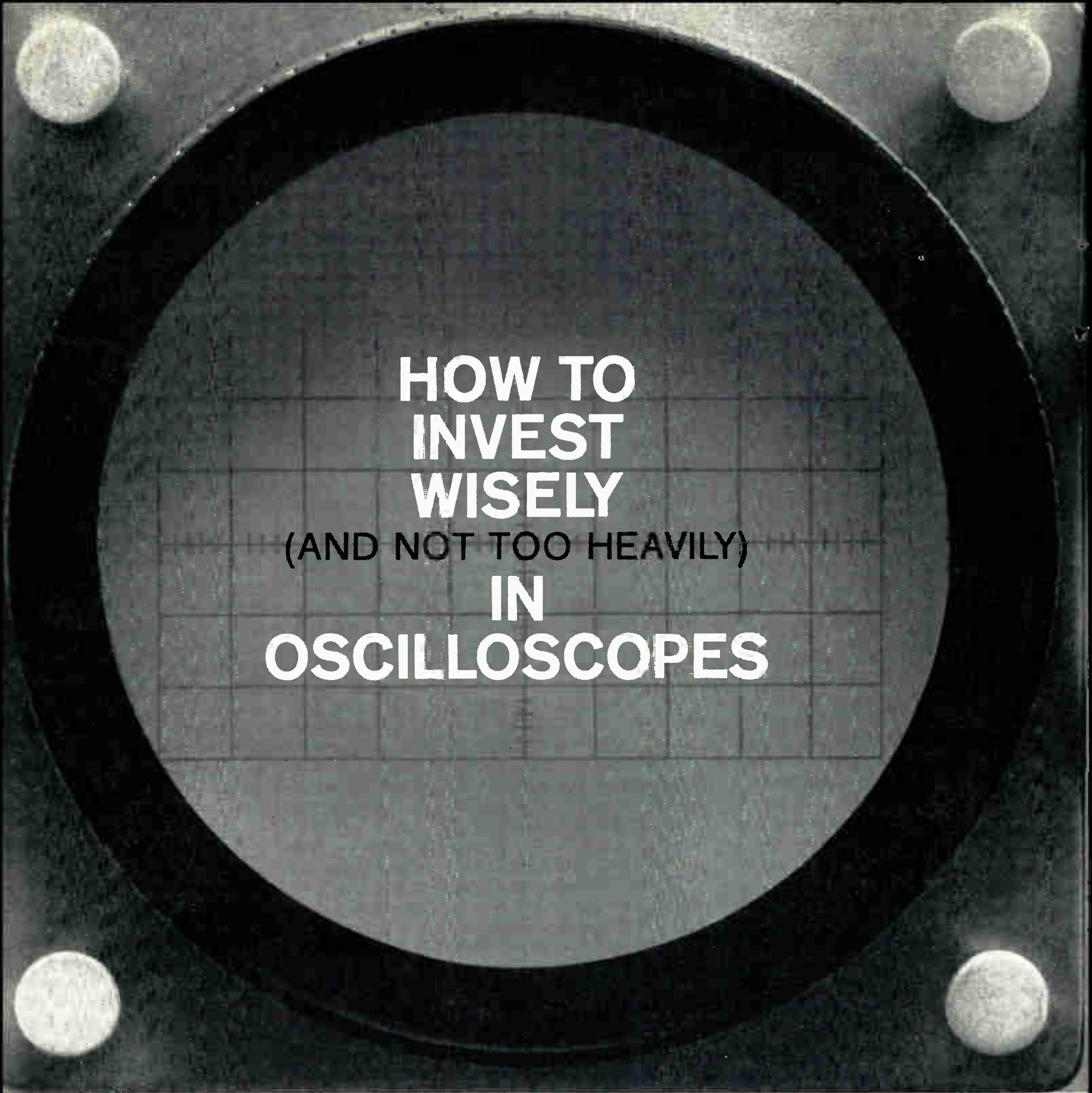


OSCILLOSCOPES aren't necessarily cheaper by the dozen. Not if six will do the work of a dozen. Fairchild's new solid-state line offers you the widest choice of transistorized scopes in the field—so that you can cover all of your requirements with fewer instruments. The versatility is designed in, along with unsurpassed precision.

Consider, too, the advantages of solid-state circuitry. Compactness (the rack model is only 7″ high). Low power requirements (no cooling fans needed). MIL reliability (through advanced engineering and Fairchild silicon semiconductors).

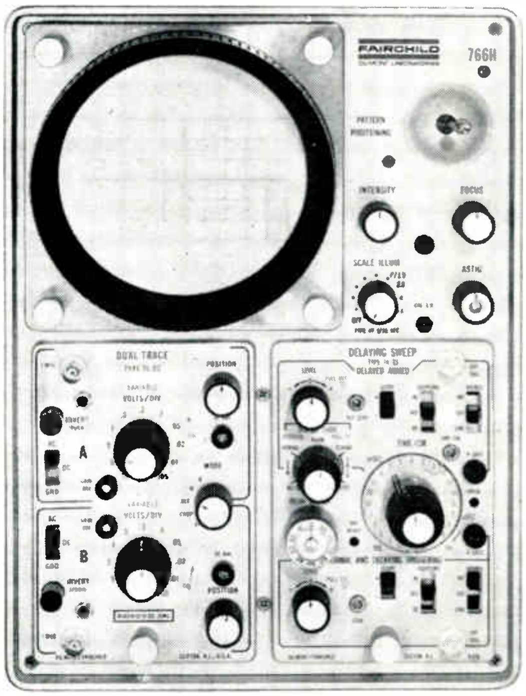
Before you invest in another scope, compare features. Compare performance. Then invest wisely . . . in Fairchild.

NEW FAIRCHILD SOLID-STATE SCOPES GIVE YOU UNMATCHED VERSATILITY WITH MIL RELIABILITY

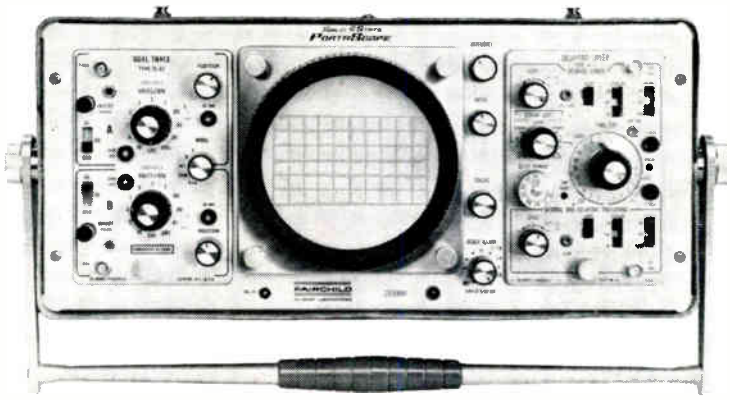
The new 765 Series shown here is made in three basic configurations: bench, rack mounted and truly lightweight portable. The dual interchangeable plug-in units below work into any model in the 765 Series to provide laboratory to production line applications.

Additional versatility is afforded by an option of 5 kv or 13 kv CRT. The higher accelerating potential permits observation or recording of fast transients or pulses with low repetition rates. A no-parallax internal CRT graticule is optional.

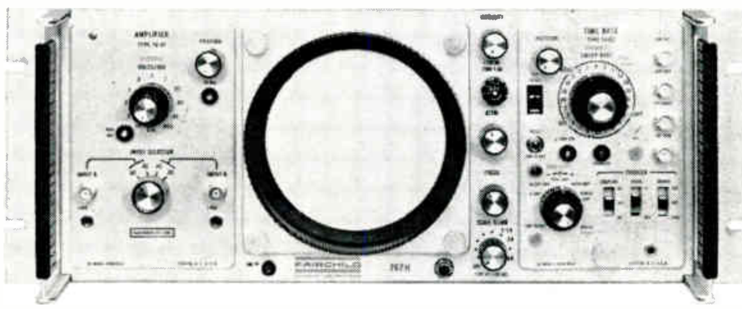
CHECK THESE PERFORMANCE FEATURES • Transistorized for compactness, MIL reliability, low power requirements (185 watts—no cooling fans) • Frequency range: dc-100 mc • Sensitivity: up to 0.5 mv/cm • Rise time: to 0.35 nsec • Sweep rate: 10 nsec/cm—1 min. full scale • 6 x 10 cm display area • No-parallax internal graticule optional • Dual interchangeable plug-ins drive CRT directly for maximum accuracy—no intermediate circuitry



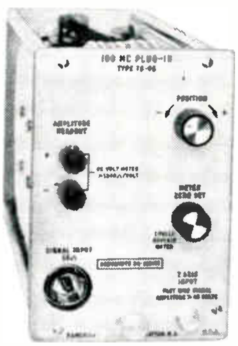
Type 766—Bench model provides high precision measurements in all laboratory or production line applications.



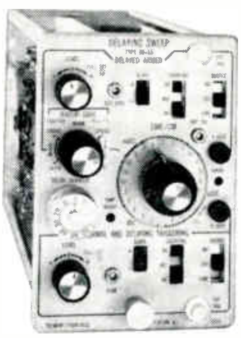
Type 765 "Portascope"®—Fiberglass case is no larger than an overnight bag. Cover of case holds probes, leads, accessories. Weighs only 35 lbs. with case. Also available in militarized version.



Type 767—Rack-mount configuration is standard 19″ in width, only 7″ high.



Type 76-05—100 mc Plug-In



Type 74-13—Dual Time Base Delaying Sweep

NINE PLUG-INS AVAILABLE TODAY...MORE COMING SOON
Dual interchangeable plug-ins give Fairchild Series 765 scopes the widest range of application. With 9 units available now, 3 being readied for production, and still others in development, your investment in a Series 765 scope is insured against obsolescence for years to come.

Write for New Literature
A new catalog with specifications and prices on Fairchild scopes, scope cameras and accessories is waiting for you. Write for it today. Fairchild Scientific Instruments, Dept. 750 Bloomfield Ave., Clifton, N. J.

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COMING EVENTS

SEPTEMBER

Sept. 15-19: Electrical Insulation Conf., IEEE, NEMA; Conrad-Hilton Hotel, Chicago, Ill.

Sept. 16-20: 13th Int'l Mgmt. Cong., Int'l Committee for Scientific Mgmt.; Waldorf Astoria, New York Hilton Hotels, New York, N. Y.

Sept. 18-19: 12th Annual Ind. Electronics Symp., IEEE, ISA; Kellogg Ctr., Mich. St. Univ., E. Lansing, Mich.

Sept. 22-25: Nat'l Power Conf., IEEE, ASME; Netherlands-Hilton Hotel, Cincinnati, Ohio.

Sept. 23-24: Int'l Conf., AIIE; New York, N. Y.

Sept. 25-28: Materials & Eqpt. and White Wares Divs. Fall Mtg., ACS; Bedford Springs Hotel, Bedford, Pa.

Sept. 29-Oct. 2: 51st Nat'l Mtg., Amer. Inst. Chem. Engrs.; Hotel Americana, San Juan, Puerto Rico.

Sept. 29-Oct. 3: Fall Mtg., Electrochemical Soc.; Hotel New Yorker, New York, N. Y.

Sept. 30-Oct. 3: Nat'l Fall Mtg., AWS; Hotel Statler-Hilton, Boston, Mass.

'63-'64 Highlights

NEC, National Electronics Conf., Oct. 28-30, IEEE, McCormick Place, Chicago, Ill.

NEREM, Northeast Research and Eng. Mtg., Nov. 4-6, IEEE; Boston, Mass.

IEEE Int'l. Conv., Mar. 23-26; Coliseum, New York Hilton, New York, N. Y.

WESCON, Western Electronic Show and Conv., Aug. 25-28, IEEE, WEMA, Sports Arena, Los Angeles, Calif.

OCTOBER

Oct. 1-2: Engineering Problems of Manned Interplanetary Exploration Mtg., AIAA; Cabana Motor Hotel, Palo Alto, Calif.

Oct. 4-6: Amer. Radio Relay League Nat'l Conv.; Cleveland, Ohio.

Oct. 15-17: 9th Tri-Service Conf. on Electromagnetic Compatibility, IIT Res. Inst., U. S. Army, Navy and Air Force, IEEE (PTG-RFI); Ill. Inst. of Tech., Chicago, Ill.

Oct. 15-23: Anglo-American Conf., AIAA, Canadian Aeronautics & Space Inst., Royal Aeronautical Soc.; New Ocean House, Swampscott, Mass.

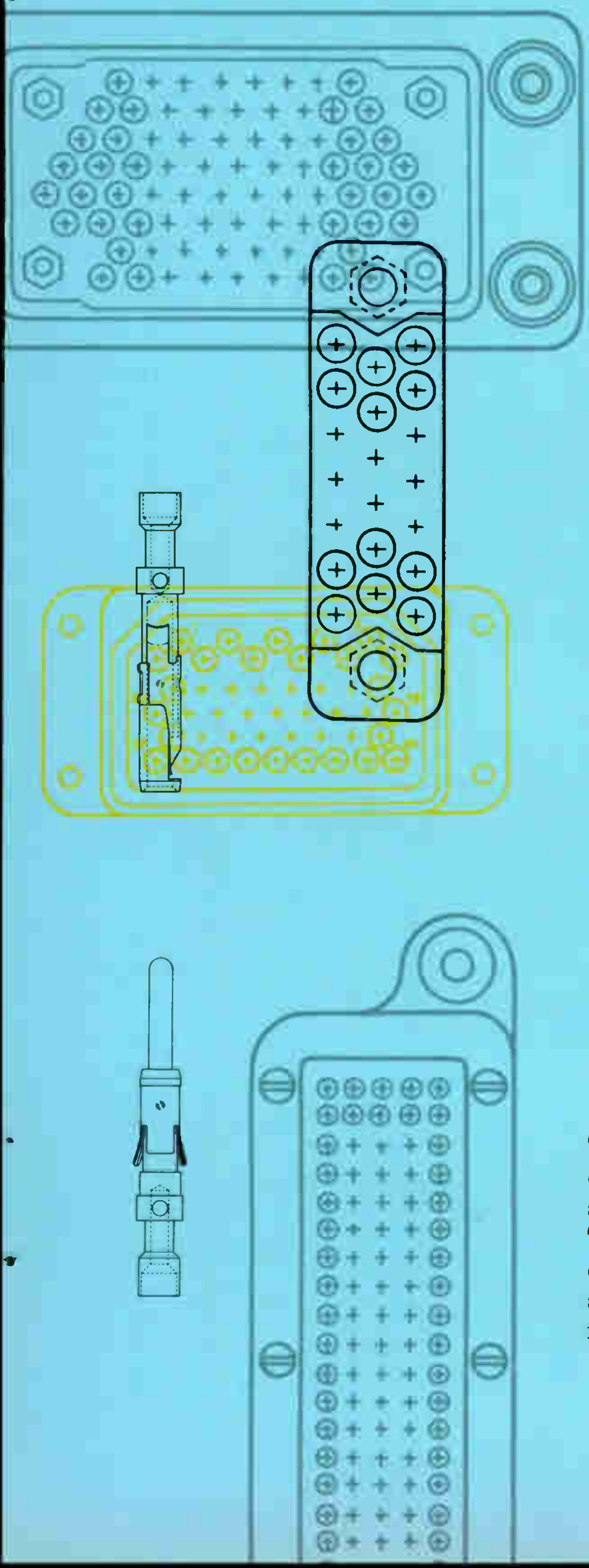
Oct. 16-18: Nat'l Symp. on Vacuum Technology, Amer. Vacuum Soc.; Statler-Hilton Hotel, Boston, Mass.

Oct. 18-19: Mtg., American Physical Soc.; Chicago, Ill.

Oct. 21-25: ASM Metals/Materials Exp. & Cong.; Cleveland-Sheraton Hotel, Cleveland Public Hall; Cleveland, O.

Oct. 23-25: 1963 Annual Mtg. of the Human Factors Soc.; Ricky's Hyatt House, Palo Alto, Calif.

Oct. 31-Nov. 1: 1963 Electron Devices Mtg., IEEE (PTG-ED); Sheraton-Park Hotel, Washington, D. C.



What advantages are offered by crimped, snap-in-type pin and socket contacts?

The steady rise in the volume of crimping (versus soldering) as a method of terminating multiple connector contacts can be traced to the fundamental merits of this technique.

Basically, the AMP method consists in mating the terminal barrel with the wire by means of a hand or automatic crimping tool. In either case the crimping dies fully bottom on the terminal before it can be released. Since the dies in each instance are perfectly matched to the terminal all crimps virtually amount to a "cold weld" and are identical in appearance and performance. With this procedure the variables so persistent in other methods are eliminated.

The AMP termination technique has been adjudged superior to thermal and other bonding methods, particularly in low-level circuitry, for a number of reasons: (1) It is generally easier to crimp individual contacts before they are inserted in the connector block than to solder densely spaced contacts already in position; (2) both insulated wire and stranded wire are more readily crimped than soldered; (3) in most instances crimped joints are more resistant to shock, vibration and other environmental hazards than other types; (4) no special skills are required for crimping; (5) very often with thermal methods the entire connector must be replaced if a single contact is damaged; with crimping (since the contacts are removable), any individual contact can be replaced without removing the connector from its mounting; (6) with crimping there is no danger of insulation burns or the wire becoming brittle; (7) when crimped, the contacts are fully enclosed in the connector housing which forms a natural dielectric barrier between circuits; (8) crimped contacts are placed in the block only where needed, thus saving the cost of extra contacts; (9) simple tooling permits easy removal and re-insertion of snap-in contacts; rearrangement of circuits is costly and time-consuming with solder, weld, or wrap-type connections; (10) little or no set-up time is required whether crimping is done with manual or pneumatic hand tools, or by automatic machines; (11) the crimp, snap-in technique is much faster in assembly and usually results in lowest installed cost; (12) crimping permits extreme flexibility in production procedures. Contacts may be crimped to individual leads or harnesses any time, anywhere; and actual insertion of contacts can be done in any volume or sequence desired. This is particularly helpful in the building of modular electronic systems where each unit must be completely assembled and pre-tested before it is combined with another unit.

In addition: While the AMP crimping method offers such advantages as convenience, ease of assembly, production economies, etc., as noted above, the electrical quality of the crimp, snap-in termination is generally superior to that of thermal or wrap-type terminations. This conclusion has been substantiated by tests for tensile strength, relative immunity to vibration, millivolt drop, and corrosion resistance.

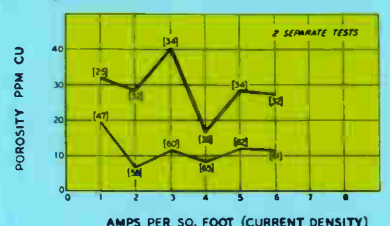
What specific benefits are derived from gold over nickel plating?

In sensitive signal circuits, "dry" circuits —in all critical circuitry—gold or rhodium is mandatory. Since gold is less costly, more readily available, has extremely low electrical resistance and high resistance to corrosion, oxidation and humidity, it is used as standard outer plating for contacts in connectors used in missiles, computers, aircraft and many other applications where extreme reliability is demanded.

But gold alone was not the final answer to the plating problem. Research and testing revealed that gold, even to a thickness of .000100" did not prevent copper from migrating through the gold to form an oxide on its surface. The solution, after lengthy research, was the use of a plating barrier that would offer strength and stability. The sub-plating that proved most successful, and is used as an AMP standard, was nickel. This gold over nickel plating suited both the geometry of the product and periodic removal and insertion of the pins from and into their mating receptacles.

Another factor was electroplate porosity, which is defined by chemical engineers either in terms of the relative amount of "empty" volume in the deposit or in the relative amount of exposed base area.

During a series of porosity experiments, AMP research teams found that different baths produced a measurable difference in porosity and that in some cases even bigger differences occurred with the same gold plating in different locations. A direct linear relationship between porosity and current density was also found. Efficiency decreased above 5 ampere/ft². For this particular bath, the faster the rate of plating, the greater the porosity.



These experiments combined with other experimental work has resulted in a system of controls that produce gold over nickel plating with negligible porosity. Another notable refinement of the AMP method: an exclusive X-ray measuring technique so microscopically accurate that it measures plating thicknesses to the millionth of an inch. These two factors—low porosity and fully controlled plating thickness—have been found to be ideally suited to highly sensitive circuits where voltage drop is measured in millivolts. It has also proved that a similarly high and consistent standard for gold-plating of contacts does not generally exist throughout the industry—an urgent consideration in connection with many space-age applications.

What plastic insulating block materials are needed and why?

Most of the phenolics, alkyds, allyds, (diallyl phthalates) and other thermosetting materials used predominantly in connector insulating blocks vary considerably in their behavior pattern. This is why they should never be chosen by "handbook values", but always with the reputation of the supplier as a prime consideration.

Glass-reinforced diallyl phthalate approved by the military, for example, is used in connectors, switches and various other military as well as critical non-military applications.

With or without glass reinforcement, diallyl phthalates are characterized by high arc resistance, low dielectric loss, high dielectric strength, and excellent mechanical properties, even under high humidity, temperature and other stress conditions. Another plus value is their extremely low post-mold shrinkage which makes close-tolerance applications feasible. Plastic components from which the parts are made are selected to give the best overall physical and electrical characteristics for the intended use of such parts.

High-grade phenolics have been found wholly suitable for less critical uses in more moderate environments.

They are used in more electrical applications than any other insulating material. They possess not just good electrical characteristics, but are also strong, rigid and dimensionally stable. Besides being poor electrical conductors they absorb only minuscule quantities of water, are unaffected by oils, greases, alcohol, weak acids, and most solvents. They do not evidence creep or cold flow, and are extremely resistant to electrical conductivity.

Although the choice of connector block material is dictated by the environmental climate in which a connector operates, the performance of plastics must be backed by the connector manufacturer. Thus AMP has tested and established the proper standards for all plastics used in A-MP★ connectors. The materials must be capable of conforming to all applicable military specification for any given connector and/or be wholly suited to commercial needs.

How much resistance to environment should be built into a connector?

Resistance to environment must be built into every connector, but the amount of such resistance varies with the degree of heat, vibration, corrosion and other hostile environmental factors to which a particular connector is subjected.

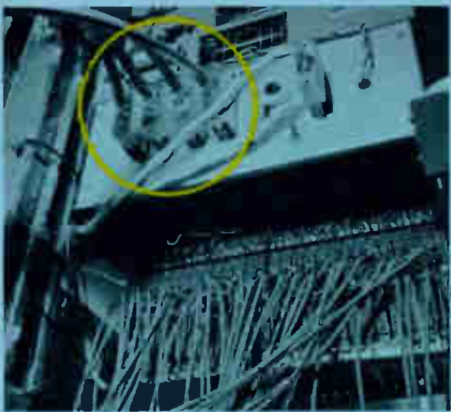
For example, the range of resistance to environment varies greatly between connectors with mated face seals between contact cavities as well as peripheral seals between the shells and inserts, and those with neither shell nor environmental seals. To a lesser degree the same is true of connectors with diallyl phthalate inserts and those with the phenolic type.

These and many other environmental specifics have been determined through actual and simulated conditions in the AMP laboratories, one of the largest and most modernly equipped in the industry. Each connector is designed to operate with maximum reliability in the particular environment for which it is designed. With this in mind, let us briefly examine two contrasting applications:

CONNECTOR FOR TYPICAL AIRBORNE APPLICATION

Here the overall environment is hostile. The connector recommended for this use must withstand ambient temperatures of up to 400° F. and have extremely low and stable electrical resistance. Maximum current is 5 amperes per contact for a total of 100 male and 100 female contacts. Working voltage must not exceed 200 V ac. Gold-over-nickel plating is mandatory on all contacts. As a further safeguard against hostile environments, cadmium-plated aluminum shells, face and peripheral seals, and suitable grommets to act as rear seals for all terminations must be used. In short, the connector must perform its stable electrical function in its own isolated environment despite the fluctuations and varying stresses inherent in its application.

★ Trademark of AMP Incorporated



CONNECTOR FOR TYPICAL BUSINESS MACHINE

This type works satisfactorily without the refinements required for an airborne application. It operates intermittently inside a stationary machine, with little harmful vibration or other environmental detractions. Snap-in type terminations applied with automatic machines are less costly, and low-cost phenolic resin is adequate for the housings. These connectors may or may not require shells or strain-relief hardware. In brief, a general-purpose connector is well suited to this environment.

A number of modifications of these two opposites may be had from AMP to meet every connector need whether its operation is intended for a mild, moderate, or hostile environment. This includes connectors that can withstand a temperature extreme of 1200° F., with corresponding severity of vibration, shock and corrosion-inducing factor.

* * * * * * *

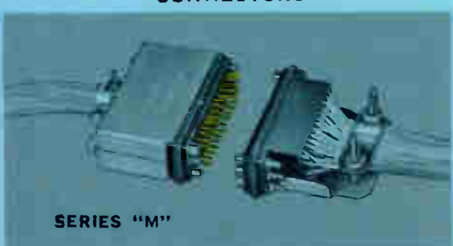
To sum up: AMP's present line of pin and socket connectors is designed to operate faultlessly within the environment for which any particular type is intended. The potential user simply evaluates the conditions under which the connector must operate, and AMP recommends the type or types needed to meet this set of requirements.

The following information is a guide to the classifications and types of A-MP Pin and Socket Connectors:

Types of connectors and contacts

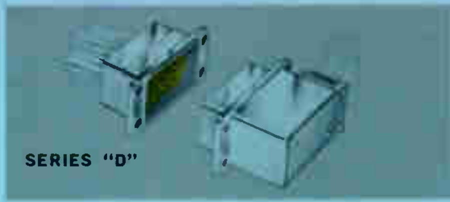
At present AMP manufactures eleven classifications of Pin and Socket Connectors. Connectors range from the Series "M" general-purpose block connectors, without a shell, for relatively non-sensitive applications; to the "D-DE", with full environmental sealing for critical military and commercial use.

SERIES "M", "D", "D-D" AND "W" CONNECTORS



SERIES "M"

The series "M" is available in housings with 14, 20, 21, 26, 34, 41, 50, 75, 104, (and 104 center fastener) positions. These housings can be obtained in molded phenolic resins, or diallyl phthalate. When fully assembled, these connectors have no metallic shell. They do, however, offer a complete line of shields (180° or 90° exit) and strain relief hardware. As a group they are general purpose connectors.



SERIES "D"

SERIES "D-D"

SERIES "W"

The Series "D" has housings with 45 and 78 positions, the Series "D-D" with 90 and 156 positions, and the Series "W" with 26, 40 and 45 positions.

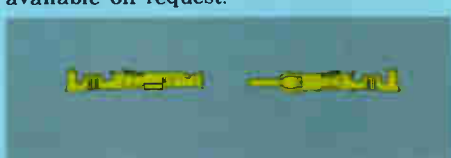
All Series "D" and "D-D" housings have positive polarization and floating bushings for accurate alignment with the receptacle. Plug shell skirts help protect pins against plug-in damage, while float space of pins and sockets also helps prevent misalignment. All inserts (phenolic or diallyl phthalate) are alpha numerically coded—front and rear—and encased in cadmium-plated aluminum shells. For the military, an olive drab finish is available.

Matched accessories include shields, cable-clamps, and strain relief clamps. Also available are polarizing block configurations, and keying pins.

AMP has designated Type II, Type III and Type III (+) pin and socket contacts for use with Series "M", "D", "D-D", and "W" Connectors. Obviously, choice depends on nature of application, installed cost and other modifying factors. Here, therefore, is basic information on the suitability of these contacts for specific needs.

TYPE II CONTACT

This is a highly reliable crimp, snap-in, screw-machine processed contact that meets MIL-C-8384 and MIL-C-5015 specifications. At 7.5 amperes, resistance is less than 25 millivolts after environmental testing, and engagement forces vary from 1 to 12 ounces per line for a #20 contact. External retention spring provides quick assembly and firm seating to the connector block; however, it can be easily removed and re-inserted. Minimum surface wear is assured with the use of cantilever-beam engagement spring. Available in contact sizes 20 and 16 in a wire range of #32 through #14 AWG. May be ordered in loose piece form, or tape-mounted for high-speed application with automachines. Standard AMP plating of gold over nickel. Other platings available on request.



TYPE III CONTACT

This is a crimp, snap-in, formed contact that may be fed in a continuous strip into automatic crimping machines for high-volume application. This contact has bell-mouthed sockets and closed entry for proper pin alignment and protection from probe damage. Cantilever-beam engagement spring provides sustained contact pressure which results in minimum surface wear. Quick assembly and firm seating in the block are assured through the use of an external retention spring. The contact can also be easily removed with an A-MP extraction tool. Contact sizes: 20, 18, 16 for use with wire from #24 through #16 AWG. Also supplied in loose piece form. Standard AMP plating: Gold over nickel. Other platings available on request.

TYPE III(+) CONTACT

This contact is identical to Type III with the exception that, additionally, it features insulation support for greater mechanical strength and is supplied only in contact size 16 which encompasses a wire range of #26 through #16 AWG.

Series "A" connectors

Series "A" Connector is designed for either rack and panel or bulkhead use. It is an environmental connector with high performance ratings, and is available in either 50 or 100 positions. Both configurations are sealed or unsealed, as ordered. In both cases the insert material is diallyl phthalate. In the sealed version the peripheral and interfacial seals are made of fluid resilient silicone rubber. Shells are made of cadmium-plated die-cast aluminum. This connector meets the following performance requirements: dielectric withstanding voltage at sea level —1500 V ac, rms; insulation resistance —5,000 megohms; temperature cycling— —55°C to +125°C; vibration (method 204 and condition C of MIL-STD-202B)—10 to 2,000 CPS; shock (method 202 of MIL-STD-202)— at 15 G's; humidity (method 106 of MIL-STD-202)—5,000 megohms.

TYPE I CONTACT

The Type I Contact is designed for critical circuitry and meets the electrical requirements of MIL-C-26636. It is a crimp, snap-in, precision screw-machine processed type, with resistance of less than 25 millivolts at 7.5 amperes after environmental testing, for a #20 contact. Minimum surface wear is assured through cantilever-beam engagement springs and is available with AMP gold over nickel plating which assures optimum corrosion resistance and long life. Available in sizes 20, 18, 14, 10, and 8 for wire range of #26 through #8 AWG. Loose piece form, or tape-mounted for high-speed application.

Series "D-DE" connectors

This design with 144, 126 and 108 positions is intended primarily for high-altitude, high-temperature applications. It is fully sealed against hazards encountered at temperatures ranging up to 275°F, altitudes of up to 100,000 feet, excessive vibration and other hostile environmental factors.

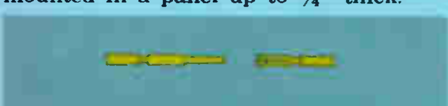
Series "D-DE" connectors are similar in construction to the Series "D-D". It contains all the environmental hardware and seals needed for maximum protection of contacts. Inserts are molded from glass-filled diallyl phthalate; both plug and single-lead grommets are included. For specific test data, refer to Series "A" connectors for bulkhead mounting.

TYPE V CONTACT

This contact is designed for high-temperature, high-altitude application and conforms to MIL-C-26636. Minimum resistance is 15 millivolts, maximum 23 millivolts after environmental testing. For a #20 contact, insertion forces do not exceed 8 ounces per line on a steel pin. Cantilever-beam contact spring insures uniform contact pressures. Plating on Type V is optional. Military specifications call for either rhodium on the pin and socket or rhodium on the pin and gold on the socket. Contact is available in sizes 20, 16, 12, 10 for a wire range of #26 through #10 AWG. It is applied with a hand crimping tool or automatic tape-fed tools.

Sub-miniature connector

The 50-position A-MP sub-miniature connector with force-fit type contacts is no longer than an ordinary book match. Yet the contact area occupies a full 50% of the total area compared to 20% for other makes of sub-miniature connectors. The connector block, which is self-extinguishing, is made of polyurethane, the shell of cadmium-plated brass, and jack screw assemblies and strain relief clamp of stainless steel. The connector is polarized for error-free assembly, and can be mounted in a panel up to ¼" thick.



TYPE VII CONTACT

This is a reliable sub-miniature, screw-machine processed, compression-crimp, snap-in type contact. It is made of bronze with a .000030" gold-over .000030" nickel plating. It accommodates stranded or solid wire in sizes #26 to #32 AWG. This contact makes extreme density possible — .060" center to center spacing in single lines and .050" in clusters.

Series "C-PS" connectors

This connector features three coaxial and 12 pin and socket contacts. It is available in a phenolic or diallyl phthalate block, with 1-piece or 2-piece shields, center-guide assembly, pin hood, fixed or turnable jack screws, and other hardware accessories. It accommodates Type II, Type III, Type III (+), and Type IV miniature coaxial contacts.

TYPE IV CONTACT

Aside from its use in "C-PS" Connectors as a "contact mix", the Type IV contact is suitable for many configurations in the series "M" and series "W" connectors. It is designed to outlast more than 500 insertions and extractions, and permits simultaneous one-crimp terminations of center conductor, outer braid, and cable support — (an exclusive with AMP). Dielectric material separates shells from male and female center contacts. Construction also features closed entry and a cantilever-beam engagement spring which is built into the socket. A special type of retention spring is used to provide firm seating into the connector block and to act as a shield for crimping ports. Operating temperature is —55°C to +85°C, operating voltage 1,000 V ac, flash-over voltage 1,900 V ac, and shock MIL-STD-202B, method 202A. Available in a wide range of cable sizes and applied with extreme reliability with A-MP crimping tools.

Breakaway connector

This single circuit pin-and-socket connector is characterized by high-reliability performance in military, aircraft, missile and commercial applications. Quick connect/disconnect versatility is combined with the reliability features of a permanent splice. It is fully insulated and available in a sealed or unsealed version. The A-MP Breakaway Connector exceeds electrical and mechanical requirements of MIL-T-7928, MIL-C-5015D, MIL-C-8384A and MIL-E-5272.

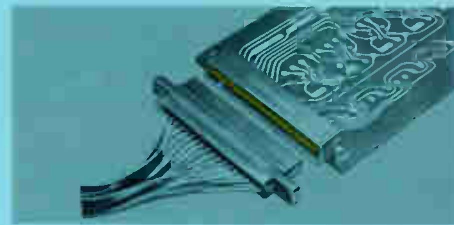
Two types are available. Pullaway force for the 5/15 type is 15 pounds maximum and 5 pounds minimum; for the 5/20 type, 20 ounces maximum and 5 ounces minimum. Both utilize the same size crimp, snap-in contacts and the identical size nylon housing sleeves.

CONTACT FEATURES

At 7.5 amperes, Breakaway Connector Contacts have a minimum resistance of 15 millivolts and a maximum resistance of 20 millivolts after environmental testing. Available with AMP gold over nickel plating. Longer insertion/extraction life is assured with the use of a cantilever-beam contact retention spring while bell-mouthed sockets allow easy pin alignment. Wire size for sealed units is #20 AWG, and for unsealed units the range is #26 to #20 AWG. "Dry circuit" quality and a low-cost, time-saving assembly method is assured with AMP's precision crimping technique.

Special application connectors

Two such connectors in AMP's pin and socket line: (1) Connector for Printed Circuits, (2) Tier Block Connector.



(1) The 19 position printed circuit connector utilizes the pin and socket principle and is used principally for aircraft, missiles and ground support equipment. It is an extremely stable connector, with Type V precision screw-machine processed contacts efficiently sealed against hostile environmental stresses. Pins and sockets are plated to a thickness of .000050" gold over .000030" nickel and satisfy requirements of MIL-C-26636. The female housing of this connector is rigidly staked to the edge of the printed circuit board to prevent warping and misalignment. Connector block is made of diallyl phthalate with retention member built into it.

(2) The Tier Block Pin and Socket Connector consists of 10-position male and female blocks that unite firmly without hardware accessories. Normally, blocks are made of general-purpose phenolic, but are available on order in diallyl phthalate. When stacked, male members are locked into position with #10 screws.

This connector utilizes Type II and Type III contacts rated at 7.5 amperes (size 20), and size 18 Type III contacts rated at 10 amperes.

* * * * * * *

The questions we have asked and answered encompass only the major elements of the AMP story. Much additional material — including detailed specifications — is needed to solidify the interest we hope we have aroused through the publication of this report. Facilities which include research, testing, engineering and product development are available to you, without obligation, to assist with any circuitry problems that may relate, in your mind, to the techniques and components discussed in the report. Your inquiry, addressed to AMP, INCORPORATED, Harrisburg, Pennsylvania will be promptly evaluated and answered.

Printed in U.S.A.

SLIMLINE...the first standard line of lower cost precision potentiometers with all the exclusive advantages of

Markite conductive plastics!*

(8-gang unit, actual size)

Delivered in 3 weeks! Sizes: 1-1/16″ to 3″ diameter. Standard Linearities: ±0.2% and ±0.5%. Fully Gangable...additional cups only 0.200″ thin. Write for SLIMLINE Technical Data Sheet SL-906.

*Infinite resolution • Long useful life (many millions of cycles) • No catastrophic failure • Stability in extreme environments • Consistently low noise in system use...and many more

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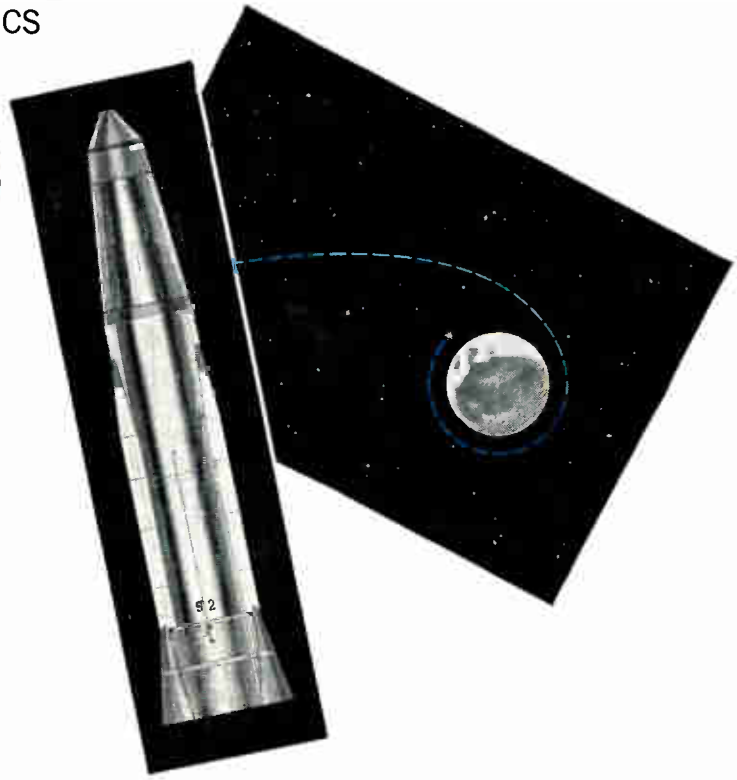
MK-8

Circle 11 on Inquiry Card

IN ELECTRONICS . . . AVIONICS . . . ASTRIONICS

STEMCO THERMOSTATS



RANK FIRST IN PRECISION TEMPERATURE CONTROL

In today's military and commercial projects, you can't afford to overlook any one of these important areas: Reliability, Size, Availability, Economy.

And because Stevens is in production now on the largest number of different types and styles of bimetal thermostats, all these advantages are yours automatically when you specify Stemco thermostats.

1st in Reliability. Proven designs, latest production techniques, most stringent inspection procedures.

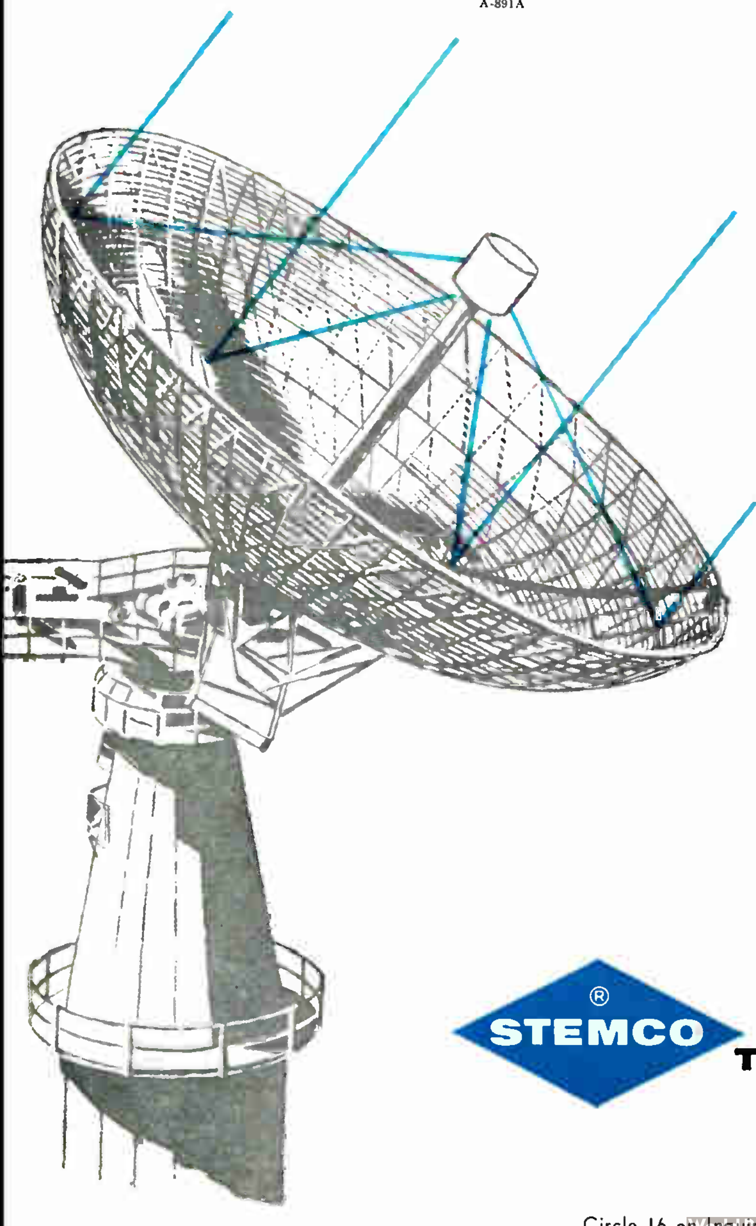
1st in Size. Stemco thermostats score in compactness and lightness without sacrificing performance.

1st in Availability. Tooling for most types is in existence. Flexibility of design cuts lead time on other types.

1st in Economy. Mass production of many standard Stemco types with hundreds of terminal arrangements and mounting brackets cuts your costs.

**Refer to Guide 400EO for U.L. and C.S.A. approved ratings.*

A-891A



TYPE A* semi-enclosed. Bimetal disc type snap action thermostats; give fast response to temperature changes. Can be made to open on rise or close on rise. Single-throw with double make and break contacts. Operation from -20 to 300°F. Lower or higher temperatures on special order. Average non-inductive rating 13.3 amps, 120 VAC; 4 amps, 230 VAC and 28 VDC. Various mountings and terminals available. Bulletin 3000.

TYPE A hermetically sealed. Electrically similar to semi-enclosed Type A. Various mountings, including brackets, available. Bulletin 3000.

TYPE MX hermetically sealed. Snap acting bimetal disc type units to open on temperature rise. 2 to 6°F differentials as standard. 1 to 4°F differentials available on special order. Depending on duty cycle, normal rating 3 amps, 115 VAC and 28 VDC for 250,000 cycles. Various terminals, mountings and brackets available. Bulletin 6100.

TYPE MX semi-enclosed. Construction and rating similar to MX hermetically sealed type. Bulletin 6100.

TYPE M hermetically sealed. Bimetal disc type, snap acting thermostats. Also available in semi-enclosed. Operation from -20 to 300°F. Lower and higher temperatures available on special order. Depending on application, rated non-inductive 10 amps, 120 VAC; 3 amps, 28 VDC. Various terminals, wire leads and brackets available. Bulletin 6000.

TYPE C hermetically sealed. Also semi-enclosed styles. Small, positive acting with electrically independent bimetal strip for operation from -10 to 300°F. Rated at approximately 3 amps, depending on application. Hermetically sealed type can be furnished as double thermostat "alarm" type. Various terminals and mountings. Bulletin 5000.

STEMCO® THERMOSTATS

STEVENS *manufacturing company, inc.*
P.O. Box 1007, Mansfield, Ohio

Circle 16 on Inquiry Card

NASA MUST GET ALONG ON LESS—NASA is going to have fewer dollars than it would like this year. The agency wants $5.7 billion for fiscal 1963-64, but the Senate approved a budget of about $5.5 billion, and the House only about $5.2 billion. Senate-House conferees met to resolve differences. While the trimming will not seriously hurt major NASA programs, it is important to note that the agency's honeymoon with the Congress is over. Congress has silently warned that all NASA projects will have to be justified in detail before money is appropriated.

MOON SHOT WILL GO—Controversial U. S. moon shot will go ahead as planned; however, it's still being heavily criticized. Most critics suggest sending only an instrumentation package to the moon. They would divert the dollars thus saved to other space research. But congressional leaders are convinced that NASA's moon-shot program is worth the time and money. They are prepared to back the moon shot against all critics. Because of their backing, money cutbacks are not foreseen.

MORE GRUMBLING OVER TRADE LAW—Is President Kennedy's foreign trade program coming unstuck? There's increasing evidence it is. Industry after industry is asking Washington to slow volume of imports arriving in U. S. Politicians are now lending sympathetic ears to the complaints, after first having pooh-poohed protests as "isolated instances."

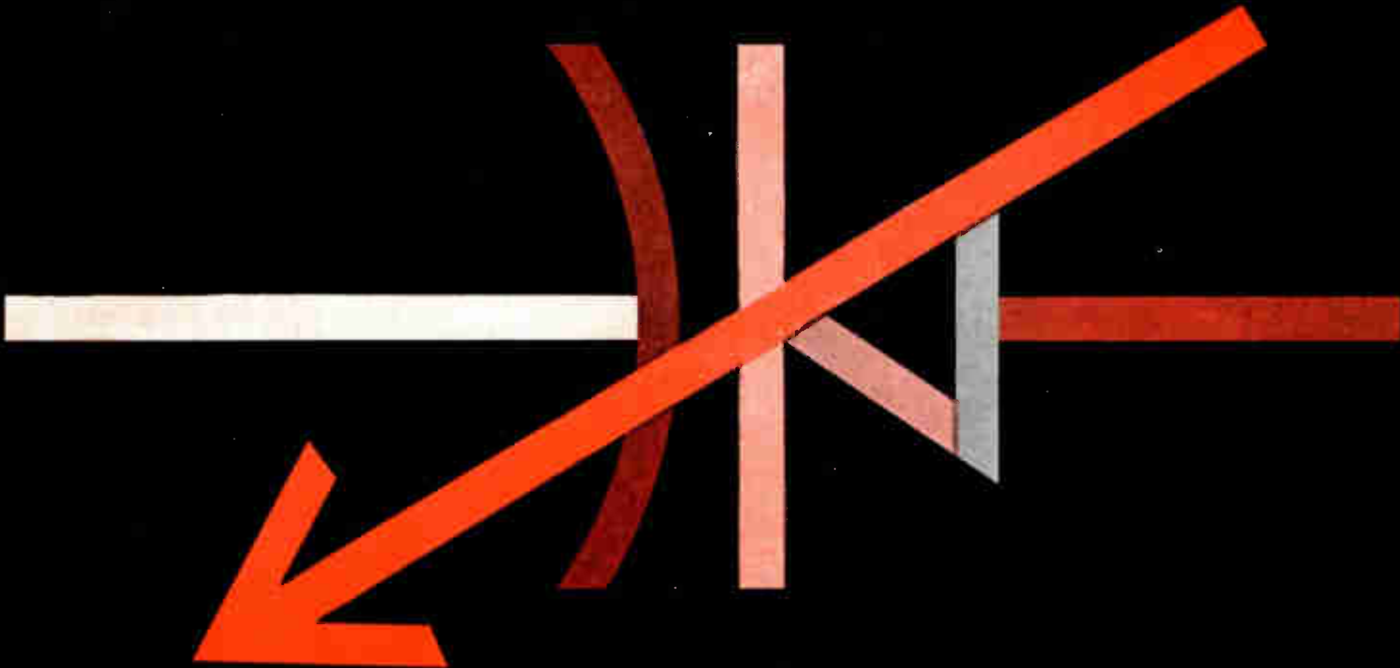
FEWER ITEMS, FEWER CONTRACTS—Set up in January, 1962, as the buying agency for DOD, Defense Supply Agency already reports it has taken control of 1 million common items. It claims a general 10% cut in inventories. Capitol Hill watchdogs note, however, there are still over 3 million defense items not yet under its management. They urge study to determine what can be added to DSA's list. Within a year DSA's Defense Electronics Supply Center took control of some 521,000 of 725,000 items assigned to the class. Goals include elimination of duplicate inventories, a cut in annual supply surpluses, cuts in procurement budgets—all these will mean fewer contracts on many electronic items.

PATENT COSTS MAY RISE—U. S. Patent Office will charge inventors higher fees, if Congress approves. Both private inventors and companies owning patents would pay more, both for filing fees and for maintenance fees.

FM ON THE MOVE AGAIN—FM broadcast is headed for a big leap forward. FCC dissolved freeze it put on issue of new FM licenses last Dec., said it would start grants for new FM commercial stations this month. Freeze ended only in 48 states, however. But it should be removed fairly soon in Hawaii and Alaska, as well as Puerto Rico, the Virgin Islands and Guam.

RCA DISPUTES McNAMARA SAVINGS CLAIMS—Defense Sec. McNamara's claims of procurement cost savings have been disputed by RCA. Pentagon boss says he saved the government more than $1 billion in 1963, and he offers this example: DOD bought 8,570 radio receivers from RCA at $2,278 each under a negotiated contract. Later, under competitive bidding, DOD bought additional receivers from RCA at $843 each. McNamara claims this cost saving ($10,494,312) is due to competition among the suppliers; however, RCA points out factors glossed over by Pentagon: Price of first order included design engineering, tooling, other non-recurring production costs. In bidding on second order, RCA was able to omit these costs. In addition, subsequent contract called for larger quantity of receivers, thereby making possible lower unit prices. Also, prices of transistors and other components bought from RCA suppliers declined, making possible further price cutting.

IS IT DEDUCTIBLE?—Nervousness continues over the 1963 Internal Revenue Service rules regarding expense deductions. Nobody likes them, but there's no immediate sign rules will be changed. IRS, still somewhat sheepish over the uproar it caused by the clampdown on expense-account spending, recently issued a question-and-answer booklet for the businessman to help make clear what can be deducted and what can't. (Samples: If a taxpayer takes a customer to lunch for business goodwill and the customer's wife comes along, will the expense be disallowed if they don't discuss business? Answer: No. What about convention entertaining? OK, if it measures up as ordinary and necessary entertaining.) Hotel and restaurant men have been hit hard by the new rules. All their business is off—up to 10% in the newer and fashionable places; as much as a crushing 50% in older places. Congressmen from convention cities and resort areas want a law to restore the pre-1963 expense-account rules.



NEW PHILCO VOLTACAP*

A new concept in voltage-variable capacitors... and a broad new range of applications

Philco brings a new set of values to voltage-variable capacitor design. Higher reverse bias voltage, higher Q, lower reverse leakage current, *closer tracking* and *larger change ratios*. Result: A new capability for *electronic tuning*.

The new concept — Philco VOLTACAP — is an Epitaxial Silicon Planar Voltage-Variable Capacitance Diode. Epitaxial growth raises Q values. Planar construction reduces I_R, and assures both inherent reliability and product uniformity. Voltacaps are so uniform that maximum tracking error is specified for every type.

Discover how Philco Voltacaps can add to your designs. Get types V2853 and V2854 today from your Philco Distributor. And send for complete data—write Dept. EI963.

PHILCO VOLTACAP RATINGS AND CHARACTERISTICS

ACTUAL SIZE

PARAMETER	TYPE V2853	TYPE V2854
Max Reverse Bias Voltage, V_R	115 v	115 v
Max Storage Temperature, T_S	−65 to +200°C	−65 to +200°C
Max Reverse Leakage Current (@ V_R = 100v, 85°C ambient), I_R	2.5 μa	5.0 μa

PARAMETER	TYPE V2853	TYPE V2854
Capacitance (@ 8v, 1 mc), C_V	47pf ± 20%	150pf ± 20%
Capacitance Change Ratio (@ 4v to 100v), ΔC_V	4:1	4:1
Min Q (@ 8v)	90 @ 50 mc	180 @ 25 mc
Max Tracking Error (@ 4v to 100v)	1.0%	1.0%

Trademark of Philco Corporation for Epitaxial Silicon Planar Voltage-Variable Capacitance Diode.

PHILCO®

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SOLID-STATE CENTER U.S.A.

LANSDALE DIVISION, LANSDALE, PA.

Circle 17 on Inquiry Card

Facts and Figures Round-Up

'U.S. ALL-NUCLEAR BY 1999, ENERGY NEEDS TO TRIPLE'

Resources for the Future, Inc., a nonprofit organization dedicated to conservation and proper use of our resources, thinks that nuclear energy will become the medium for generating all electric power by the end of the century.

The group expects that total U.S. demand for energy may triple by the year 1999. It also believes, however, that at least through the 1970's there will be vigorous and continued use of oil, coal, natural gas and hydro-electric power.

At best, then, electronic instruments and controls will continue to be sold to new nuclear power plants in somewhat small quantities.

Public utilities should then continue to be good markets for computers, microwave systems, radio communications systems plus consumer household goods.

At the moment, commercial nuclear electric power is still in the think, talk, test stages. A controversy raised by the AEC—whether to permit nuclear plants in big cities—may determine whether Consolidated Edison of New York will have the OK to put up a plant in New York City. Its output would exceed combined power of all nuclear plants now operating in the U.S.

Plans are on the board for nuclear plants near Los Angeles and San Francisco. These plants may give California a technological edge over New York, which already has been out-populated by California.

Moreover, locating nuclear power palnts in or near large U.S. cities may help decide whether plants will be built in big cities in other nations.

SEVEN U.S. STATES HOLD 55% IN DEFENSE CONTRACTS

Seven states lead in defense work, accounting for more than 55% of military prime contracts awarded in the first three quarters of the fiscal year, according to Commerce Clearing House.

Firms in California, New York, Ohio and Texas have $7.5 billion in defense contracts out of a total $17.9 billion. California leads with 23.2% of awards, but this represents a 0.7% drop from last year. New York ranks second with 8.9% of awards, but it dropped 1.8% from last year. Ohio with 5.1% and Texas with 5% rank third and fourth.

Among states showing gains, Missouri leads with an increase from 2.2% to 3.3%. Texas also showed a 1% gain. Three other states handling substantial contracts are New Jersey with 4.9%, Washington with 4.6% and Massachusetts, 4.2%.

INDEPENDENT REPS LOSING OUT, FIRMS SELLING DIRECT

Electronic manufacturers' reps seem to be losing ground in high-cost, low-volume equipment and instruments, and in low-cost, high-volume components.

There is a trend among manufacturers to side-step the middleman and sell directly to customers, offering them more sales and engineering assistance.

Early this year, Hewlett-Packard disclosed its own sales force recruited from independent local reps to sell H-P products exclusively. Beckman Instruments began selling directly through its offices in 33 U.S. and Canadian cities to strengthen customer relations.

G.E. Specialty Control reorganized field operations to better sell to and serve users of numerically controlled machine tools. Bendix Industrial Controls reshaped its national sales to give more engineering aid to machine tool builders and customers who use numerical control machines with these tools.

In components, areas once served only by independent reps are now being served more often by regional and national distributors, as well as by central holding companies with a national network of regional reps. Some reps are straddling these functions by becoming "stocking reps," maintaining inventories.

Little money is needed to pay commissions to a free lance rep whose sales orders are filled directly from manufacturers' stocks. However, many large firms feel they can afford to invest more money in their own sales networks and make or save more money by marketing to, and technically serving customers directly.

$1,500,000 NOW AVAILABLE TO BUILD NEW ETV STATIONS

An allocation of $1.5 million is now available to assist in construction of educational TV stations, according to the office of Anthony J. Celebrezze, Secretary of Health, Education and Welfare.

Total expenditures of $32 million are authorized for a five-year life of the Educational Television Facilities Act. The total five-year grant within any one state cannot exceed $1 million.

U.S. SALES ARE PROMISING IN COMMON MARKET NATIONS

Prospects for sales of U.S. electronic equipment in the European Common Market look promising. The market is good for computers and advanced systems for industrial and military use, but is somewhat poor for consumer goods.

Europeans have nearly saturated the consumer market and now export quite heavily. If the Common Market nations are to pay more for their share of NATO expenses, it seems they will want to sell a larger percentage of electronic and military equipment.

Economists and marketing men viewing this world electronics pie, predict a need for the U.S. to export more electronic gear since we have the lowest percentage of exports, although dollar volume is still high.

All the European Economic Community (EEC) nations export twice the dollar volume the U.S. exports. The question is—will EEC exporters manage to export a high volume of consumer goods, yet also absorb higher amounts of Japanese-made electronic goods?

ATOM-DETECTOR FIRMS LOOK FOR EXPANDING CD MARKET

Makers of electronic radiation-detection instruments are still largely marking-time for a full-blown national civil defense program, though many Congressmen still regard CD as a big "boondoggle."

Accordingly, Congress may continue its annual practice of whittling down the CD budget. President Kennedy's request for $300 million for the FY 1964 CD program will probably be considerably slenderized.

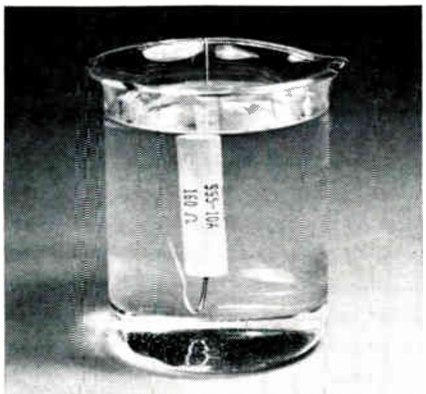
Yet, the Administration has a back door to civil defense funding—the Department of Defense.

COLOR TV SALES MAY YIELD 1 MILLION SETS, $½ BILLION

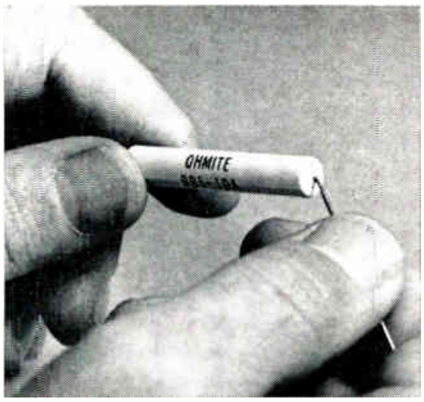
Color TV is making a colorful sales comeback along a road lined with golden optimism. Total industry sales of color TV sets in 1963 "could run from 750,000 to 1 million units, depending on availability of color CRT's," asserts W. Walter Watts, RCA Group Executive Vice President.

At an estimated average price of around $500 per set, this market could soar to about a half billion dollars. Color-pioneer RCA still holds the lion's share of this market.

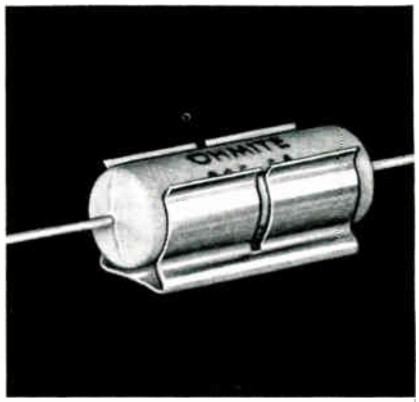
Meanwhile, to break the color CRT bottleneck and to cash in on this rejuvenated market, Zenith's Rauland Corp. and Sylvania have started producing color tubes.



SOAK IT IN SOLVENT! Here's another test you can run quickly. Fill a beaker with the most active of organic solvents used in degreasing and flux removal. Drop in a Series 99 molded resistor. Let it soak. Then try to rub off the markings. They're bright as new, because they're *part* of the ceramic coating. Try this on any other resistor . . . the markings dissolve and can be rubbed off.



BEND THE LEAD where it emerges from the resistor body! You can bend the lead repeatedly at this point without damage. Conventional axial-lead, vitreous-enameled resistors have a dipped coating which forms a meniscus around the lead where it joins the body of the resistor. Bending the lead ruptures the meniscus and damages the coating. Series 99 resistors are molded and there is *no* meniscus.



CLIP IT! Insert a molded Series 99 resistor into a metal clip. Don't baby it; ram it in. There's no danger of cutting, chipping, or scratching the hard coating which provides 1000 VAC insulation. Notice the snug fit, too. The clip mounting shown is resistant to high shock and vibration. When mounted on a metal chassis, it provides a heat sink which may increase the wattage rating as much as 100%.

on any other resistor!

10,964,000 UNIT-HOURS OF TESTING! This new molded construction has been proven in extensive load-life tests shown in the accompanying table.

These test results have been obtained from many experimental lots of resistors representing different constructional materials and manufacturing processes. These resistors were produced, tested, and evaluated for developmental purposes which ultimately determined our present production practices. Hence, the %△R values given should not be specified as design or performance limits.

More typical △R data is presently being collected as part of another test program in which samples are being taken from standard production lots. Data will be available after sufficient time has elapsed.

CYCLIC LOAD-LIFE TEST SUMMARY ON TYPE 995 RESISTORS AT RATED WATTAGE

(GROUPS STARTED AT DIFFERENT TIMES)

TYPE	TOTAL NUMBER OF UNITS	TOTAL UNIT-HOURS "ON-TIME" AS OF 6/4/63	ALL GROUPS 2000 HRS. "ON-TIME"		ATTAINED "ON-TIME" OF DIFFERENT SUBGROUPS AS OF JUNE 4, 1963					
					3000 HRS.		4000 HRS.		5000 HRS.	
			NO. OF UNITS	AV. %△R	NO. OF UNITS	AV. %△R	NO. OF UNITS	AV. %△R	NO. OF UNITS	AV. %△R
995-1A	409	1,304,000	409	0.447	284	0.536	101	1.051		
995-3A	768	3,055,000	768	0.868	155	0.999	373	1.397	206	0.876
995-5A	346	1,131,000	346	0.633	89	0.687	175	0.662		
995-5B	281	1,124,000	281	2.109			281	2.740		
995-10A	438	1,609,000	438	0.733	146	0.780	238	0.891	37	0.974
ALL	2242	8,223,000*	2242	0.712	674	0.715	1168	1.455	243	0.891

*Equal to 10,964,000 total unit-hours of test (cyclic: 1½ hours on, ½ hour off).

"fatal" characteristic F (salt water immersion test) of former MIL-R-26B.

SPECIFICATIONS

Series 99 molded vitreous resistors meet all requirements of MIL-R-26C for insulated units RW69, RW67, and RW68, characteristics V (350° C max hotspot) or G (275° C).

They can also be supplied as RW59, RW57, and RW58 resistors, characteristics G or V.

Standard tolerance is ±5%. Tolerances down to ±0.25% supplied to order.

Low temperature-coefficient requirements of 0 ± 30 ppm/°C for resistances of 10 ohms and greater, and 0±50 ppm/°C for resistances under 10 ohms (up to 350°C) are available on order.

Standard leads are solder-dip coated for soldering; furnished bare for welding, or gold plated on order.

OHMITE STYLE	RATED WATTS AT 25° C	DIMENSIONS (INCHES)		OHMS RANGE (COMM'L)
		DIAM. +.031 −.000	LENGTH ±.015	
995-1A	1	0.125‡	0.422‡	1 to 3,000
995-2A	2	0.188	0.375	1 to 3,000
995-3A*	3	0.203	0.547	1 to 10,000
995-5A§	5	0.313	0.922	1 to 30,000
995-5B	5	0.203	0.938	1 to 25,000
995-10A†	10	0.313	1.781	1 to 51,000

NOTE: Standard lead length is 1½". *Also in MIL style RW69V (991-3). §Also in MIL style RW67V (991-6.5). †Also in MIL style RW68V (991-11). ‡Tolerance, +.015 −.005.

Write for Bulletin 103

OHMITE

OHMITE
MANUFACTURING COMPANY
3662 Howard Street, Skokie, Illinois

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

Circle 18 on Inquiry Card

In space science, where electronic equipment must not fail, we have adopted the habit of leaning on the "approximate" and the "less-than-perfect." Dr. Welsh suggests that we are neither technically nor educationally geared for the unfailing-perfection demands of our space program—though we could be.

U.S. NEEDS ELECTRONIC CAPABILITY FOR SPACE

. . . An Interview with Dr. Edward C. Welsh

THE COST OF SPACE-SHOT FAILURE IS SO GREAT—not only in money but in national prestige, in manpower, in time and in our national product—that the cost of perfection, whatever it may be, is small by comparison.

The fact that we are still a long way from scientific and engineering perfection points up today's challenge to our profession.

". . . college fees are so high that many talented students are discouraged or drop out before reaching maximum potential, and are thus lost to our society . . ."

On a matter of grave concern to everyone in the electronics industry today, a top presidential adviser, Dr. Edward C. Welsh, executive secretary, National Aeronautics and Space Council, speaks of what the industry needs to meet this challenge, in a question and answer interview:

Q.—I understand you said recently that this country does not have an electronic capability to meet our space effort. Is this true?

A.—I would probably not state it as strongly as that, but it is a fact that technological needs brought about so rapidly by our space program have resulted in an inadequacy in what was at one time an adequate electronics capability. Before our space program the industry may have been quite adequate but rapid developments have placed such strain and so many requirements on people and facilities that there is a great lag in electronics in our space effort.

Q.—Are you speaking for the space program in general, or is there specific electronic equipment or a system where we have this lack of capability?

A.—The whole program. Every phase has electronic equipment which must be reliable and function perfectly. The space program is far ahead of industry in its demands for sophisticated electronics.

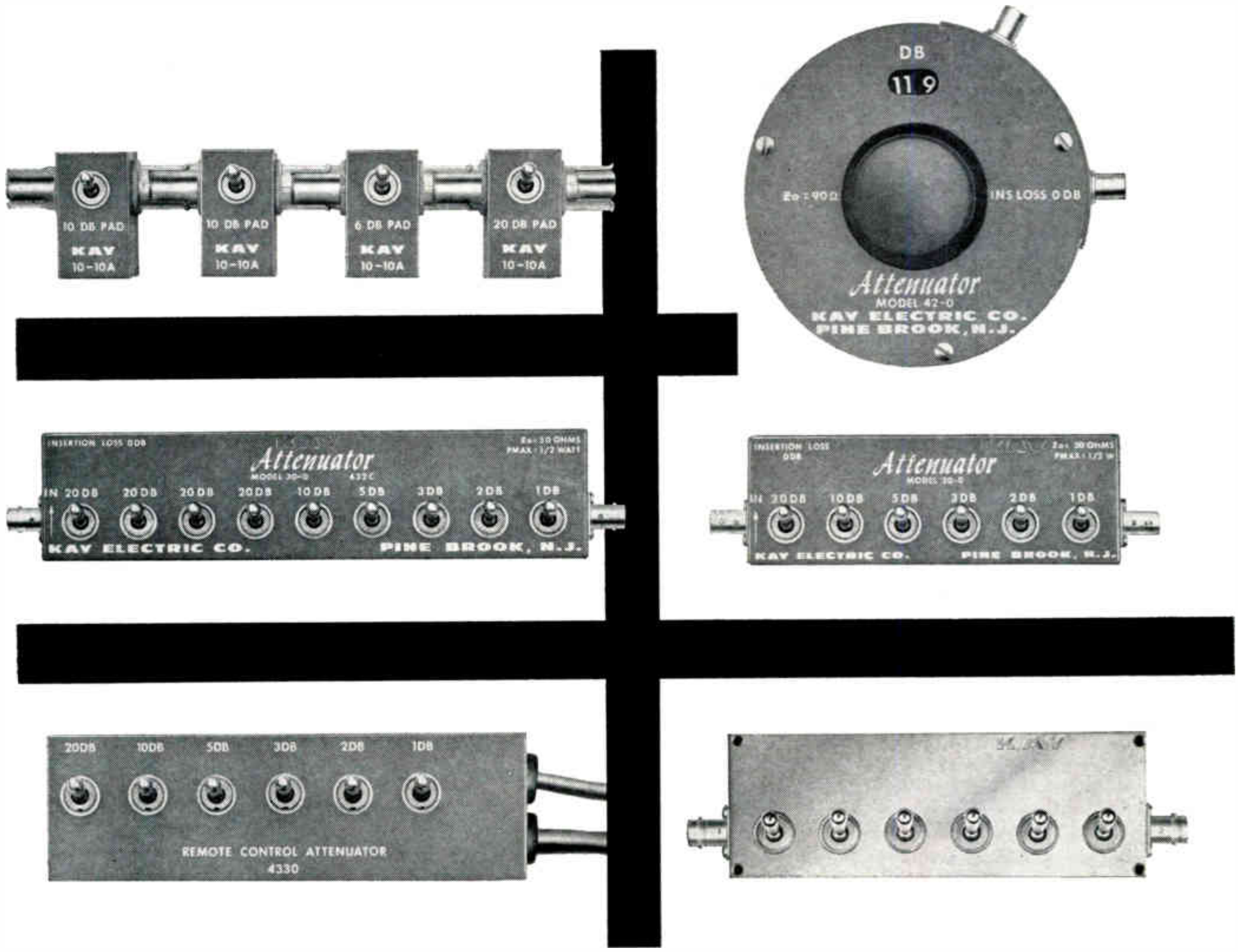
Q.—Would you say that reliability is the problem?

A.—Reliability is definitely a key problem: we can't allow for breakdowns. Yet, reliability is a field in itself. High volume and low cost production in our country have been based on a certain margin for error—something less than perfection—an allowance for repair and maintenance. We just aren't geared for the demands of the space program which requires an entirely different attitude—that only the best is acceptable.

Approximate measurements and approximate tolerances will not do in the space age. Selections of firms for space work, based on reputation for

(*Continued on page* 162)

By ELMER T. EBERSOL
Editor-at-Large
ELECTRONIC INDUSTRIES



PRECISION, HIGH FREQUENCY

ATTENUATORS

DC TO 500 MEGACYCLES

- 50, 70, or 90 ohm impedance
- High-Frequency, Precision Teflon & Silver Switches
- 1% Carbon Film Resistors
- Fully Shielded Units
- Up to 101 db
- Fixed 0 or 10 db insertion loss
- SWR: 1.2:1 max up to 250 mc
  1.4:1 max 250 to 500 mc
- Min. Insertion*: 0.1 db at 250 mc; 0.2 db at 500 mc
- Accuracy: At full Attenuation: 0.5 db at 250 mc, 1.2 db from 250 to 500 mc
- Price: (Model 20) $79. f.o.b. factory. $87. f.a.s. N. Y.

*Zero insertion loss (Model 20-0) $75. f.o.b. factory

NEW!

REMOTE CONTROL
FOR ALL UNITS
(Electrically Operated)
Price: $350.

•

NEW
DC TO 1000 MC
SWITCHED ATTENUATOR PADS

Model 10-10A
Frequency Range: DC to 1000 MC
VSWR: Less than 1.15:1
Insertion Loss: Less than 0.1 db
Accuracy: 0.25 db
Price: $39.
Model 42-0 (Rotary): $250.

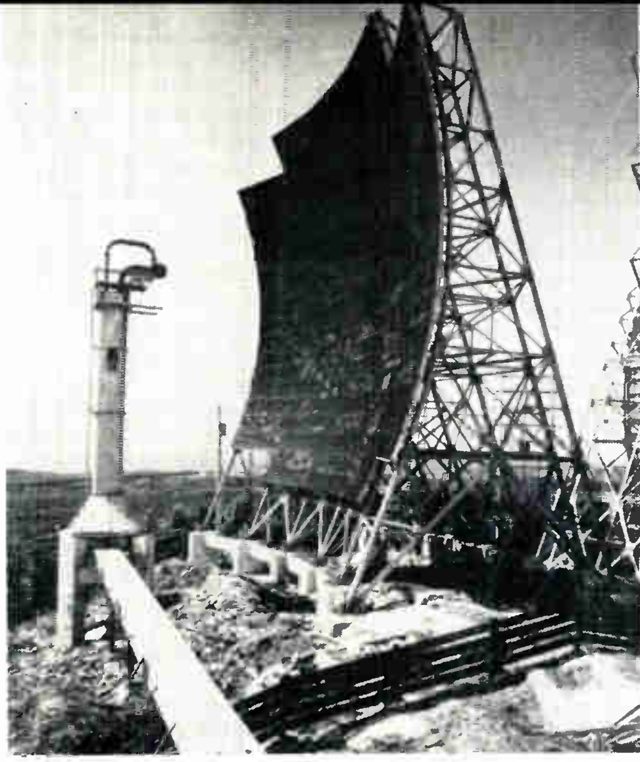
Write for Catalog

KAY ELECTRIC COMPANY

Dept. EI-9, MAPLE AVENUE • PINE BROOK, MORRIS COUNTY, N. J. CApital 6-4000

RELAY STATION

Antenna and feed horn shown at right are part of a relay station located on Trutch Island off the coast of British Columbia. It is part of a tropospheric scatter system between Annette Island, Alaska, and Vancouver Island, B. C. The General Telephone & Electronics Corp. system provides 240 channels for voice communications and data transmission for commercial and defense uses.



SNAPSHOTS... OF THE ELECTRONIC INDUSTRIES

PEAR-SHAPED

Prototype Echo II spheres (1), are shown during inflation. Skin of the space balloons is a plastic film, sandwiched between sheets of ultra-thin aluminum foil, produced by Aluminum Co. of America, Pittsburgh, Pa. Huge 135-ft. diameter spheres were inflated for a series of special tests to determine their value as reflectors of radio and radar signals.

LONG-STEMMED

Sue Huber examines multiplier phototubes as they are processed on a vacuum exhaust pump at RCA's tube plant in Lancaster, Pa. The tubes are used in scintillation counters to detect nuclear radiations. RCA plans a $11.6 million new expansion program for the plant.

STRAIN GAGES

Technicians install Metalfilm™ strain gages on 2 tunnel liners in a new Toronto subway. Ninety-six of the gages—a product of the Instruments Div., The Budd Co., Phoenixville, Pa.—will be used to measure bending and hoop stresses imposed on the tunnel. Wires from the gages will be connected to a terminal board from which readings will be taken.

NEW...ENCAPSULATED INDUCTORS

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Fastest assembly job ever! Unique pin configuration prevents assembly errors. Plug into printed circuit board . . . dip solder . . . the job is done. No wires – no wiring time. These rugged, high quality units provide extra benefits for printed circuit board applications. Solder-coated terminals are located on 0.10″ grid with 0.20″ minimum spacing. Header pads keep the unit off the board, preventing moisture entrapment while permitting easy removal of flux. The encapsulated design assures excellent temperature and moisture characteristics – plus dimensional uniformity. Header layout for up to 8 terminals provides wide choice of tapped inductors or transformers. The price? . . . competitive with molded or dipped units when on the board.

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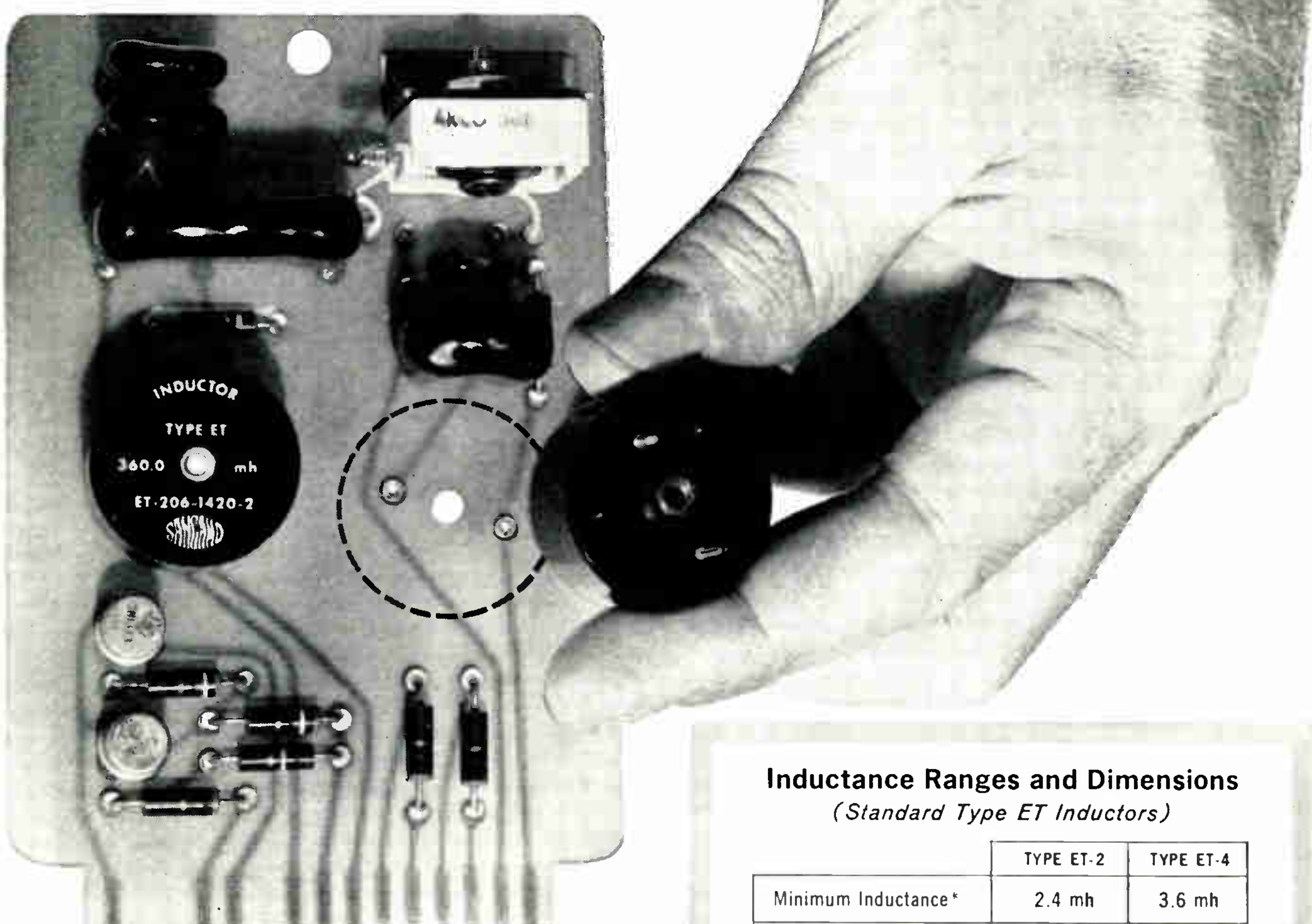


Send us your specifications

Prototype units are shipped within 72 hours. Select your inductance values from the accompanying table. For additional information, write for Bulletin 2721.

Inductance Ranges and Dimensions

(Standard Type ET Inductors)

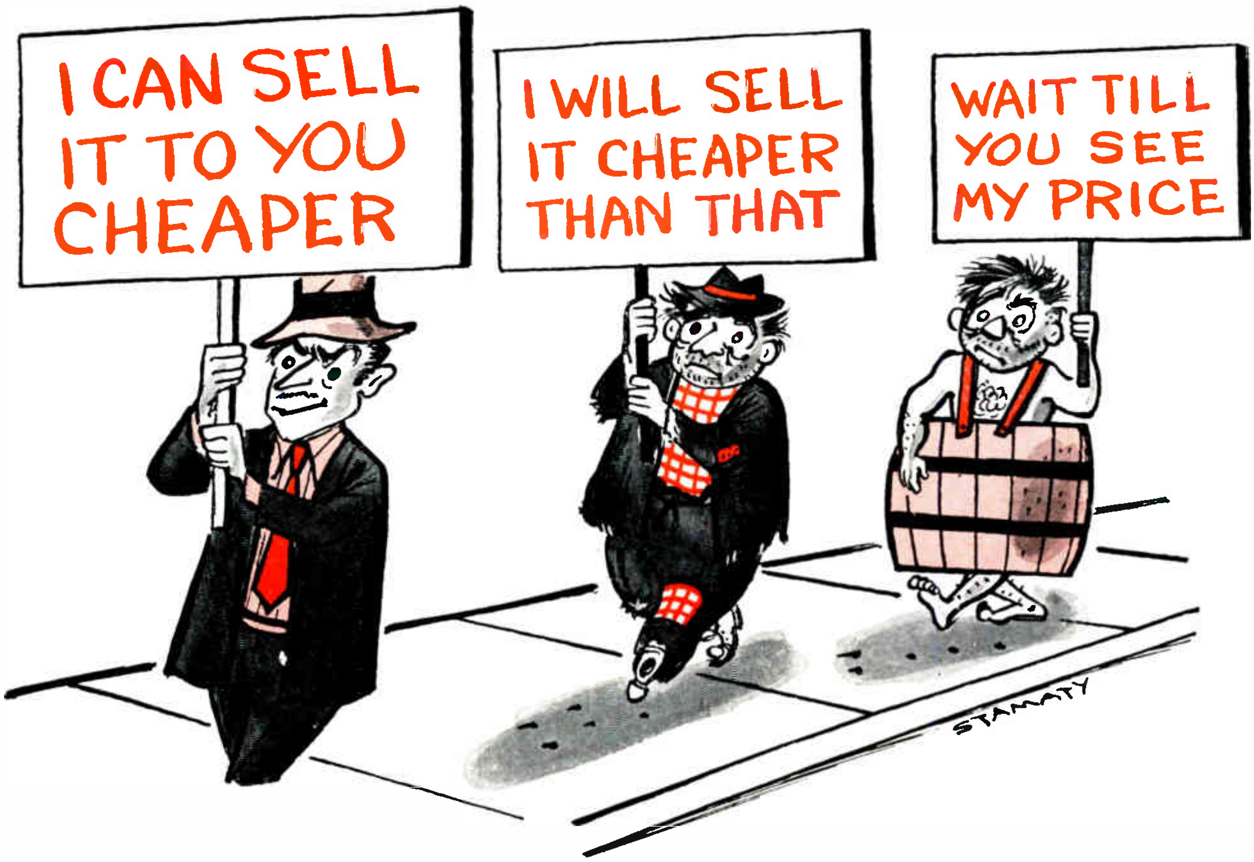
	TYPE ET-2	TYPE ET-4
Minimum Inductance*	2.4 mh	3.6 mh
Maximum Inductance*	3.9 h	30.4 h
Maximum Diameter	1.08″	1.33″
Maximum Height (including header pads)	.66″	.86″

**Inductance is measured at 1 kilocycle per second.*

EC63-12

ELECTRONIC COMPONENTS

SANGAMO ELECTRIC COMPANY • Springfield, Illinois



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- ☐ The Fusite catalog
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Name ____________________ Title ____________________

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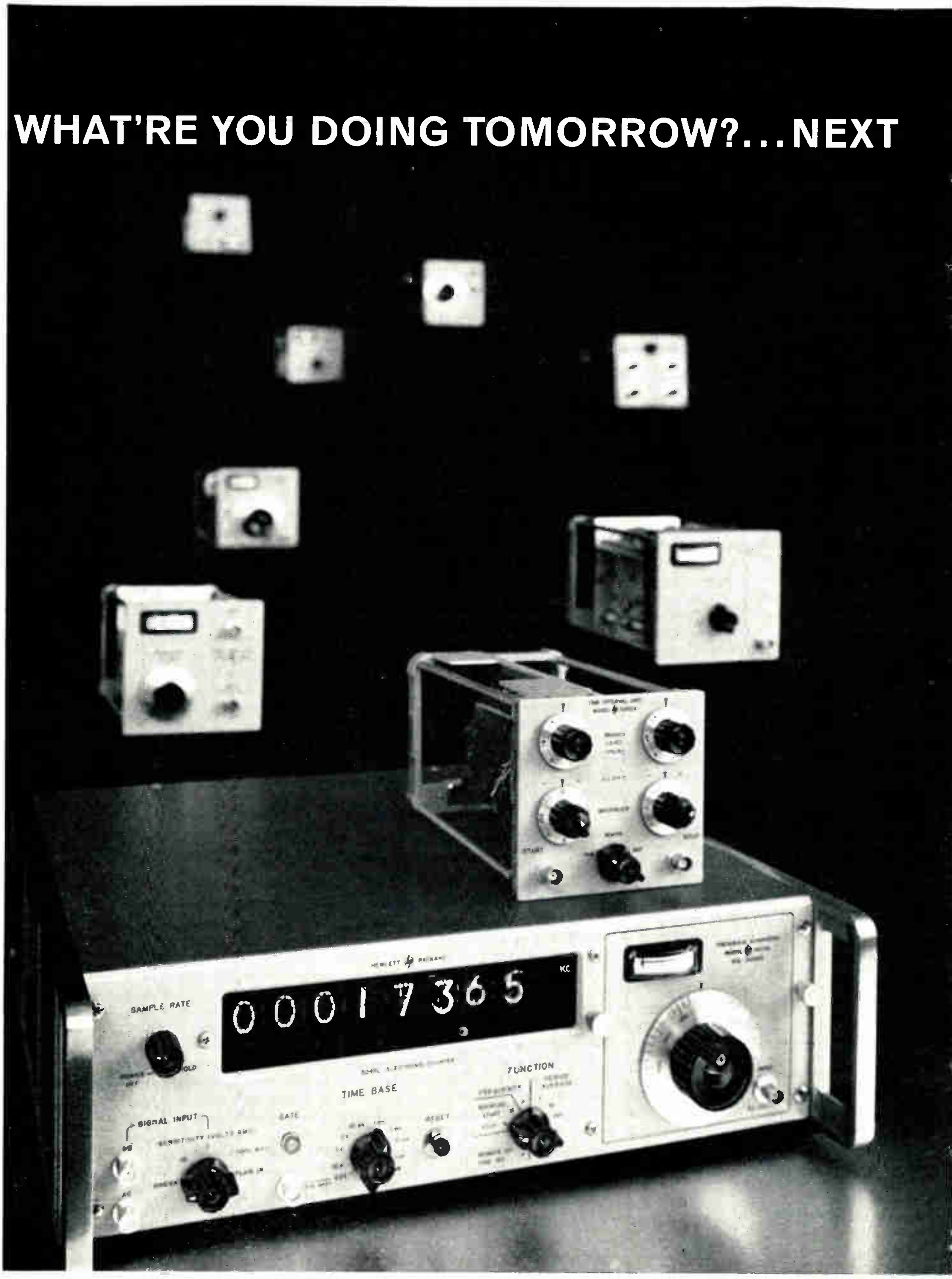
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FUNCTION
SIGNAL INPUT
GATE
RESET
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WEEK?....A YEAR FROM TODAY?....1965?....197(

Make a date with the hp 5245L Universal Electronic Counter...it'll be working for you, whatever your measuring requirement!

MANY PLUG-INS AVAILABLE NOW
MORE TO COME

Measure to 500 mc today, to 2500 mc tomorrow with the versatile hp 5245L and today's widest array of precision counter plug-ins.

The solid state 5245L Counter and its plug-in units let you custom-design the instrument to your specific measuring need by adding plug-ins when, but not until you need them. As your requirements change, you can easily and economically change the 5245L to meet them.

The 5245L measures frequency, period, multiple period average, ratio and multiples of ratio. The basic counter, without plug-ins, offers a maximum counting rate of 50 mc with 8-digit resolution. With just one plug-in you can measure from 50 to 512 mc.

Other plug-ins include a video amplifier which increases the 5245L sensitivity to 1 mv rms and a time interval unit which enables the counter to measure time interval from 1 μsec to 10^8 sec. More plug-ins, including one to extend the capability to 2500 mc, are in final development. All retain the basic accuracy of the counter.

With still more plug-ins on the way, the 5245L will never lose its usefulness . . . in fact will become more useful as your measuring task becomes more demanding and you add plug-ins to the one basic counter.

Beyond this built-in flexibility, the 5245L offers these unparalleled advantages . . . yours to match against any comparable instrument:

- **Direct counting to 50 mc**
- **Time base stability better than 3 parts in 10^9/day**
- **Display storage for continuous readout**
- **Sample rate, independent of gate time, adjustable 0.2 to 5 sec**
- **Readout in close-spaced rectangular Nixie tubes**
- **Four-line BCD output for systems, recorder use**
- **Remote programming capability**
- **Plug-in circuit construction for easy maintenance**
- **Compact, stackable cabinet only 5¼" high**

The specifications tell the story briefly. Check them out for a partial indication of the superior performance offered by the 5245L. Then call your Hewlett-Packard field sales office for a demonstration on your bench.

Start using the 5245L today . . . and you'll be using it for a long time to come.

SPECIFICATIONS

FREQUENCY MEASUREMENTS

Range:	0 to 50 mc
Gate time:	1 μsec to 10 sec in decade steps
Accuracy:	±1 count ± time base accuracy
Reads in:	kc or mc, with positioned decimal

SCALING

Range:	0 to 50 mc
Factor:	by decades up to 10^9

PERIOD AVERAGE MEASUREMENTS

Range:	single period, 0 to 1 mc; multiple period, 0 to 300 kc
Periods averaged:	1 period to 10^5 periods in decade steps
Accuracy:	±1 count ± time base accuracy ± trigger error
Frequency counted:	single period, 10^7 to 1 cps in decade steps; multiple period, 10^7 to 1/10 the number of periods averaged, cps in decade steps
Reads in:	sec, msec, μsec with positioned decimal

RADIO MEASUREMENTS

Displays:	(f_1/f_2) times period multiplier
Range:	f_1, 0 to 50 mc; f_2, 0 to 1 mc in single period, 0 to 300 kc in multiple period; periods averaged 1 to 10^5 in decade steps
Accuracy:	±1 count of f_1 ± trigger error of f_2

TIME BASE

Frequency (internal):	1 mc
Stability:	aging rate: less than ±3 parts in 10^9 per day; as a function of temperature, less than ±2 parts in 10^{10}/°C, —20°C to +55°C; as a function of line voltage, less than ±5 parts in 10^{10} for ±10% change in line voltage
	short term: less than ±5 parts in 10^{10} p-p with measurement averaging time of 1 sec under constant environmental and line voltage conditions

GENERAL

Registration:	8 digits in-line with Nixie tubes
Sample rate:	0.2 sec to 5 sec, independent of gate time
Operating temperature:	—20°C to +65°C
Output:	4-line BCD
Remote operation:	all functions programmable from front panel controls except "sample rate" and sensitivity, may be programmed remotely
Size:	19" x 5¼" x 18⅜" deep
Price:	$3250

PLUS THESE PLUG-INS AVAILABLE NOW:

hp 5253B Frequency Converter:
extends range of 5245L to 512 mc, $500

hp 5261A Video Amplifier:
increases sensitivity of 5245L to 1 mv rms, 10 cps to 50 mc, $325

hp 5262A Time Interval Unit:
converts 5245L to time interval counter with a resolution of 0.1 μsec, $300

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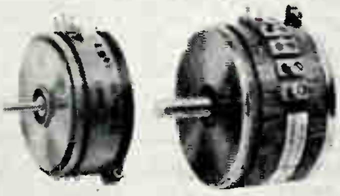
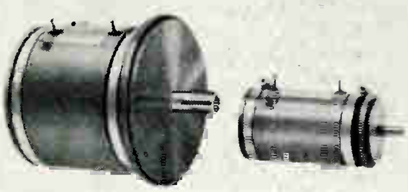


PRECISION WIREWOUND SINGLE-TURN POTENTIOMETERS. Most complete line of linear, non-linear, sine-cosine pots in sizes from ¾" to 5", single cup or ganged. Meet all requirements of MIL-E-5272 and MIL-R-12934 for linearity, resolution, operating life, noise and environmental compatability. Taps, shorted or switching sections, output curves and resistances to meet every requirement.



PRECISION MULTI-TURN POTENTIOMETERS. ⅞" and 1¾" diameter multi-turn pots in 3, 10 and 20 turn sizes. Linearity to ±0.05%. Resistances ranges from 100 to 500Ω. Meet or exceed all applicable MIL specifications for electrical, mechanical and environmental conditions.

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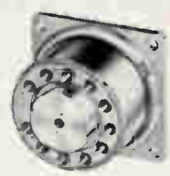
Six different models—gage, absolute and differential—can include regulator, isolator and emitter follower. Adjustable gain amplifier module separately available to suit installation needs.

POTENTIOMETER-TYPE PRESSURE TRANSDUCERS. Fairchild's line of precision transducers include bourdon tube, capsular diaphragm and new bellows types. Linear or non-linear precision potentiometer outputs. Pressure ranges from 1 to 10,000 psi absolute, gage or differential. Sizes from 1" to 3" diameter.



LINEAR ACCELEROMETERS. Ranges ±¼ to ±50 G. Natural frequencies to 175 cps depending upon G range. Excellent shock and vibration characteristics. Miniature size, linear or non-linear outputs, light weight. Accuracy up to ±0.5% in certain ranges.

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3 AXIS GYRO/ACCELEROMETER PACKAGE. Designed to furnish control data for the autopilot in an underwater weapon, this package incorporates 3 gyros and also 2 acceleration-sensing pendulums to measure linear acceleration along the pitch and roll axes. Miniaturization of this package to about ½ the size of previous units—was accomplished by Fairchild engineers without compromising the accuracy, reliability and ruggedness required for such demanding applications.

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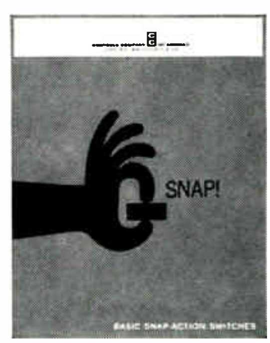

CONTROLS COMPANY OF AMERICA
CONTROL SWITCH DIVISION
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Circle 2 on Inquiry Card

Do you still know how to use the primary tool of your profession—math? Here is the article that will bring you up to date . . . . . it is concise, yet comprehensive, ranging from elementary concepts of algebra to the abstract formalisms of differential equations and theory of a complex variable. Emphasis is placed on applications of this tool.

MATHEMATICAL MODELS FOR ENGINEERS

Cover Story

THE PURPOSE OF THIS ARTICLE is to present a survey of the main mathematical techniques used by engineers today. The scope will be comprehensive, ranging from elementary concepts of algebra and arithmetic manipulations to the abstract formalisms of differential equations and theory of functions of a complex variable.

In all cases our emphasis will be on *application:* what kinds of engineering problems are solved with each mathematical tool. Examples will be given. The specific mathematical tools will be described in a manner consistent with mathematical rigor, but hopefully clearly enough to bring out the potential usefulness readily for the engineer and to indicate the limitations. Key references will be given at the end for extended application details and proofs.

* * *

Algebra is essentially the manipulation of letters and symbols. For engineers such manipulations form a bridge between a conceptual or verbal problem definition and the definitive quantitative computations needed for problem solution.

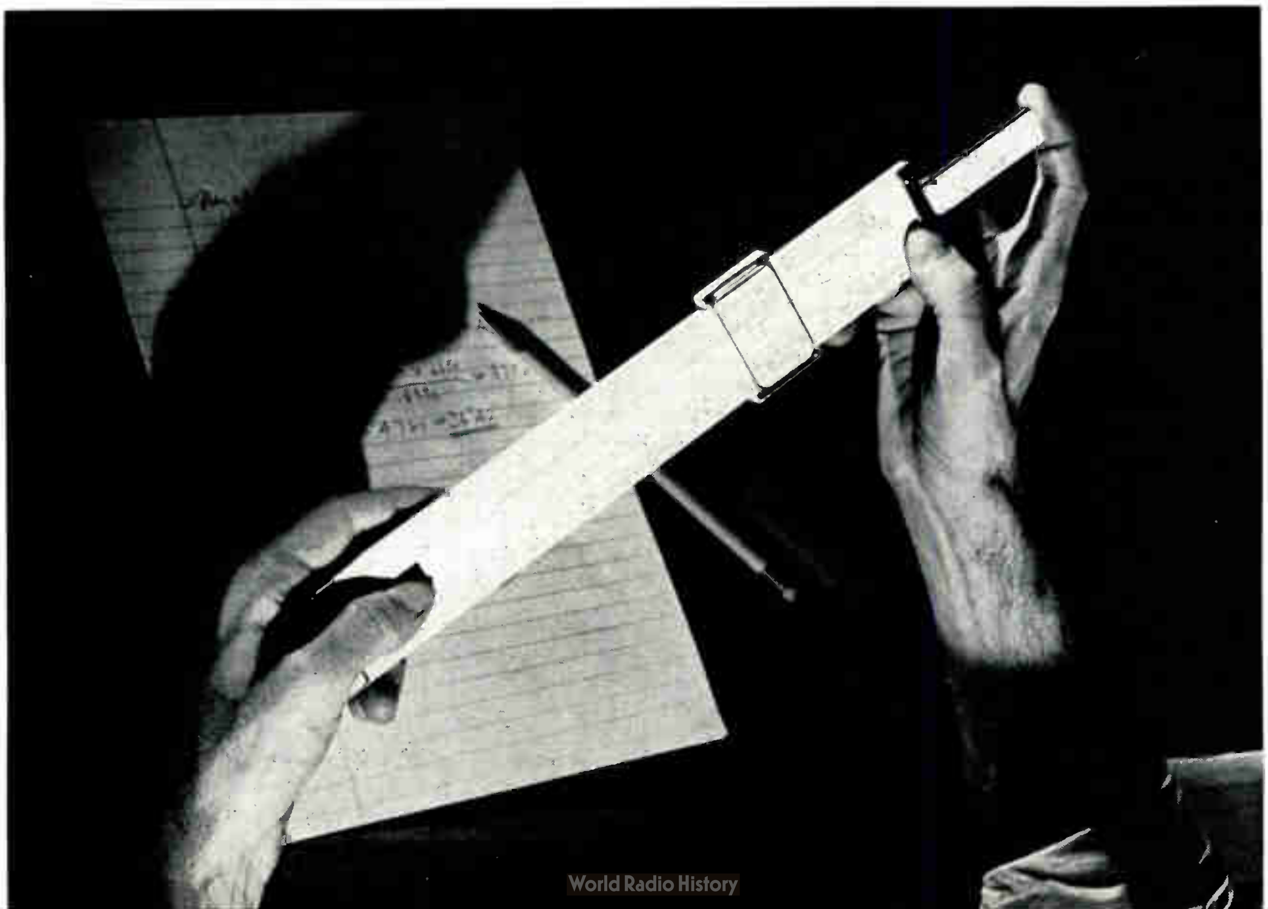
The basic concept is the equation, a statement of equality of two quantities. The laws of nature are expressible in the form of equation; manipulation of equations or sets of equations to *solve* for the desired *unknown* is the pertinent computational task.

It is well to recognize the relationship of the equa-

By Dr. RAYMOND S. BERKOWITZ

Associate Professor
Moore School of E. E.
University of Pennsylvania
200 So. 33rd Street
Philadelphia 4, Pa.

Slide rules, such as the one shown here by Keuffel & Esser Co., are the engineers' primary calculator.



tion concept to that of the formula. While the equation represents a definite quantitative relationship, the formula usually gives only relative proportions of ingredients. Thus, the formula H_2O represents the composition of a water molecule. A corresponding equation would be:

$$m_W = 2m_H + m_O \qquad (1)$$

where m_W = the mass of a water molecule
m_H = the mass of a hydrogen atom
m_O = the mass of an oxygen atom

The above illustrates the logic behind the use of mathematical concepts in solving engineering problems. Eq. 1, together with the following symbol definitions, constitute a *mathematical model* of a physical situation. In this case, of course, the problem of determining any one of the 3 quantities m_W, m_H or m_O from knowledge or measurement of the other two would be readily solved. In general, it is up to the engineer to either find or create a mathematical model applicable to his real-life problem, then solve for the unknowns that can be translated into the required real-life solution to the real-life-problem.

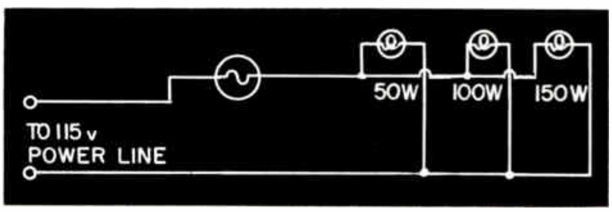
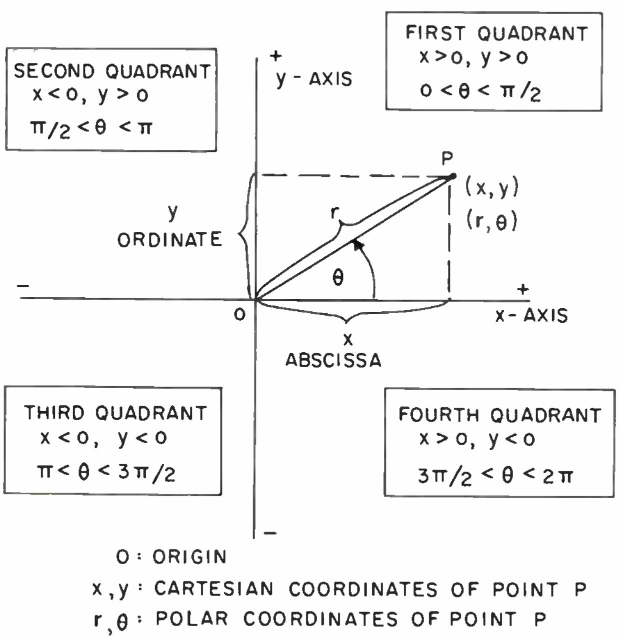


Fig. 1: Elementary circuit theory and mathematics may be used to determine the smallest size fuse that can be used here.

Fig. 2: Cartesian and polar coordinate systems. Such coordinate systems provide a link between algebraic equations and geometrical relationships. Common terminology is also shown here.



Algebraic Problem Solving

A simple illustration of the above general logic is the following simple problem.

Statement of Problem: In the simple circuit shown in Fig. 1, we wish to find the smallest size fuse that can be used.

Mathematical Model: Using elementary circuit theory we set up the following equations:

$$P_1 = EI_1,\ P_2 = EI_2,\ P_3 = EI_3 \qquad (2)$$

$$I = I_1 + I_2 + I_3 \qquad (3)$$

where E = applied voltage = 115 volts
I_1, I_2, I_3 = currents through each bulb
P_1, P_2, P_3 = powers dissipated in each bulb = 50, 100, 150 watts respectively
I = Current through fuse (unknown).

Mathematical Solution:

Solving for I, we have:

$$I = \frac{1}{E}(P_1 + P_2 + P_3) = \frac{300}{115} \cong 2.61 \text{ amps} \qquad (4)$$

Engineering Solution: The smallest size fuse rated at more than 2.61 amps will be satisfactory.

Algebraic equations which arise again and again in engineering can be found in any of the standard handbooks. These equations usually represent "laws" of nature and can be made to fit to the solution of many engineering problems.

Terms, Factors, Units

A word about the structure of algebraic equations. There is always an equal sign (=), separating the "left-hand" side or member from the "right-hand" side. Letter symbols represent numerical quantities, known or unknown variables. Connecting these are operational symbols, designating operations: +, –, × (also • or implied), ÷ (or / or fraction representation), $\sqrt{\ }$, superscripts for raising to a power.

Any parts of an equation connected by + or – are referred to as "terms"; quantities multiplied together are thought of as "factors" of a term.

Different parts of an equation (Eq.) must be "dimensionally consistent." All terms connected by + or – signs must have the same dimensions or units. The dimension or unit of a term is the product of the dimensions of the component factors. The different sides of an Eq. must have the same dimensions. Thus, looking at Eq. 2 above, for example, with E in volts and I in amperes, P must be in volt-amperes or watts.

For more complicated equations, dimensional consistency is often a non-trivial consideration. Frequent checking of expressions is necessary—often dimensional consistency checks can indicate errors in manipulation rapidly.

Equations with One Unknown

In many problems it is possible to set up a mathematical model in which there is only one variable quantity. In such cases the pertinent equation to solve can be written:

$$f(x) = 0 \tag{5}$$

Here $f(x)$ is a "function of x," where x is the unknown variable quantity. Typical such functions are:

$$f_a(x) = \sqrt{2 + x^2} + 3x^3 \sqrt{x}$$

$$f_b(x) = \frac{5 + 2x}{3 + x^3}$$

$$f_c(x) = 2 + 3x + 4x^2$$

Function f_a examplifies an "irrational" function, since it implies other than the "elementary operation": +, −, × and ÷. $f_a(x)$ is called a rational function or fraction and $f_c(x)$ is designated a polynomial.

An important part of algebra is concerned with the "roots" of polynomials, that is, solutions to Eq. 5 when $f(x)$ is a polynomial such as $f_c(x)$ above or a general n-th order polynomial given by:

$$p_n(x) = a_0 + a_1x + a_2x^2 + \cdots a_{n-1}x^{n-1} + a_nx^n \tag{6}$$

or, in more compact form, using the standard "summation" symbol:

$$p_n(x) = \sum_{r=0}^{n} a_rx^r \tag{6a}$$

where the a's (i.e. the "coefficients") are known numbers.

The "Fundamental Theorem of Algebra" states that the equation

$$p_n(x) = 0 \tag{7}$$

has exactly n solution, i.e., $p_n(x)$ has exactly n roots. Knowing the roots of $p_n(x)$, *say* $x_1, x_2, \ldots x_n$, the polynomial can be factored as follows:

$$p_n(x) = a_n (x - x_1)(x - x_2) \cdots (x - x_{n-1})(x - x_n) \tag{8}$$

or, in more compact form, using the standard "product" symbol:

$$p_n(x) = a_n \prod_{r=1}^{n} (x - x_r) \tag{8a}$$

"General closed form" solutions are readily available giving the roots in terms of the coefficients for n = 1, 2, 3 and 4. For higher n's it is necessary to use numerical approximation methods for given specific values of the coefficients. In practice, the closed form solutions are usually only used in the cases n = 1, 2; the approximate solution methods give useful answers faster for 3 and 4.

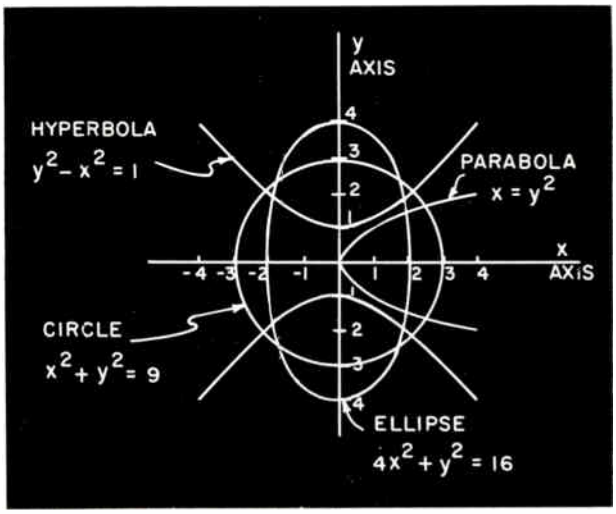


Fig. 3: Equations of conic sections in cartesian coordinates.

Specifically, the solutions for n = 1 and 2 are as follows:

$$n = 1 \qquad x_1 = -a_0/a_1 \tag{9}$$

$$n = 2 \qquad x_1 = \frac{1}{2a_2}\left(-a_1 + \sqrt{a_1^2 - 4a_0a_2}\right)$$

$$x_2 = \frac{1}{2a_2}\left(-a_1 - \sqrt{a_1^2 - 4a_0a_2}\right) \tag{10}$$

The quantity $a_1^2 - 4a_0a_2$ in Eq. 10 is known as the "discriminant." The roots of the quadratic with "real" coefficients (i.e. the case n = 2) will be real-unequal, real-equal, or "complex" when the corresponding value of the discriminant is positive, zero, or negative. The concepts of "real" and "complex" numbers will be described a little later. We close this section with an example.

Statement of problem: The weight in a pile driver is given an upward velocity of 5 ft./sec. one foot above the pile. How long will it take to complete its stroke?

Mathematical model: The pertinent equation describing motion under gravitational attraction is:

$$d = v_0t - \tfrac{1}{2} g\, t^2 \tag{11}$$

where d is the resultant upward distance travelled in time t

v_o = initial velocity (upward)
g = acceleration due to gravity

Solution: Make the following substitutions:

d = −1 ft.
v_o = 5 ft./sec.
g = 32.2 ft./sec./sec.

The following quadratic equation results:

$$16.1\, t^2 - 5\, t - 1 = 0 \tag{12}$$

Solution is given by (10), with $x = t$; $a_0 = -1$, $a_1 = -5$ and $a_2 = 16.1$.

MATHEMATICAL MODELS

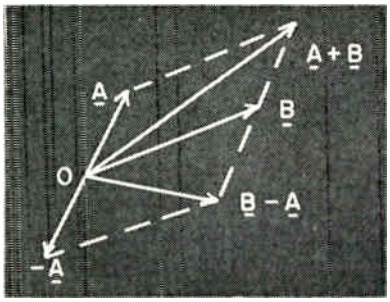


Fig. 4: Vector addition and subtraction parallelogram law.

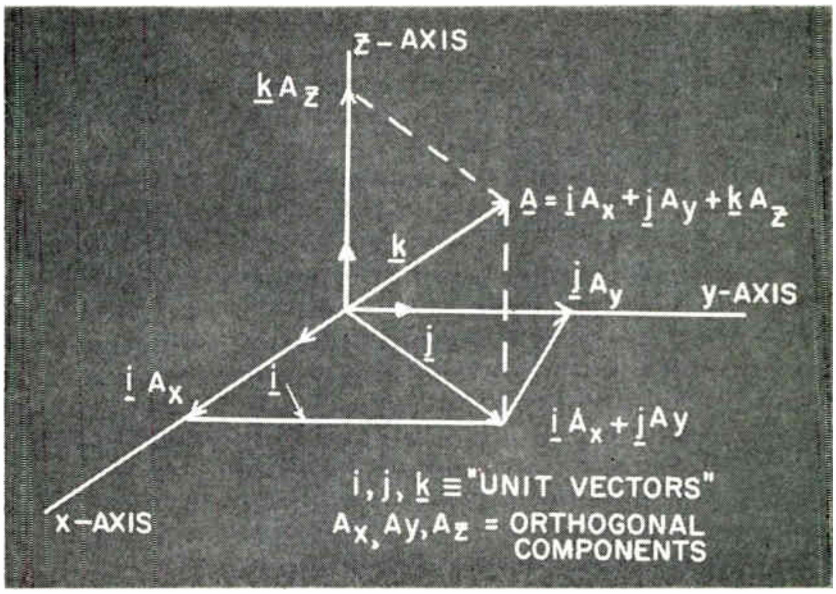


Fig. 5: Vector in Cartesian coordinates.

$$t_1 = \frac{1}{32.2}\left(5 + \sqrt{89.4}\right) = 0.418 \text{ sec.}$$
$$t_2 = \frac{1}{32.2}\left(5 - \sqrt{89.4}\right) = -0.138 \text{ sec.} \qquad (13)$$

Only the first solution, 0.418 sec. is significant, giving the duration of the driver stroke. Since the validity of Eq. 12 for the physical problem only holds for $t>0$, the existence of a root at -0.138 sec. is of no practical interest. Such "selection of roots" to fit the physical situation is a typical standard procedure.

"Number" Classifications

The simplest kind of number is the *integer*, such as 1, 2, 3, 4, −2, −3, etc. Then we have the set of *rational* numbers defined as the ratio of two integers. All numbers which can be written down explicity in fraction or decimal form exactly are rational numbers. Then we can add the class of *irrational* numbers which can only be written down implicitly or can at most be approximated by closed form fractions or decimals. Thus, $\sqrt{2}$, $\sqrt[3]{3}$ are typical examples, usual approximations being:

$$\sqrt{2} \cong 1.414 \qquad \sqrt[3]{3} \cong 1.442$$

Now in finding the roots of polynomials it becomes necessary to admit a further number classification: *real* and *imaginary* numbers. Take, for example the Eq.:

$$x^2 + 4 = 0 \qquad (14)$$

Applying the quadratic formula (Eq. 10 above), the roots are:

$$x_1 = \sqrt{-4}, \; x_2 = -\sqrt{-4} \qquad (15)$$

Now we know that none of the above defined integers, rational, or irrational numbers; positive or negative; will result in "-4" when multiplied by itself; hence what meaning can be ascribed to "$\sqrt{-4}$"? We take care of this simply by *defining* the concepts of *imaginary* and *complex* numbers, to take care of square roots of negative numbers as well as roots of polynomials in general that are not expressible otherwise.

Actually, the *only explicit definition required* is:

$$j \equiv \sqrt{-1} \qquad (16)$$

By convention, all the number types defined above in the first paragraph of this section are called *real* numbers. Any real number multiplied by j as defined formally in Eq. 16 is called an *imaginary* number. We are led naturally to the concept of *complex* numbers as simple combinations of real and imaginary numbers. In general, a complex number c is expressible as:

$$c = a + jb \qquad (17)$$

where a and b are real numbers; a is called the "real part" of c; jb is called the "imaginary part" of c, often written as:

$$a = Re(c); \; jb = Im(c) \qquad (18)$$

In complex notation as given above, the roots of Eq. 14 above are:

$$x_1 = j\sqrt{4} = j2; \; x_2 = -j\sqrt{4} = -j2 \qquad (19)$$

Similarly the roots of:

$$x^2 + 4x + 13 = 0 \qquad (20)$$

are:

$$x_1 = -2 + j3; \; x_2 = -2 - j3 \qquad (21)$$

The roots of any polynomial can be written as complex numbers (note that "real" numbers can be considered as special cases of complex numbers, having zero for imaginary parts). Further representations of complex numbers will be presented later; here we will close with one simple additional definition. For the complex number c defined in (17) above, we define c^*, its corresponding complex conjugate by: $c^* = a - jb$; i.e., just changing the sign of the imaginary part.

Note from Eq. 19 and 21 that in each case x_2 is the conjugate of x_1 and vice-versa. This points out a useful general property of polynomials with *real* coefficients (i.e., a's of Eq. 6 above are real numbers): their roots must either be real or they must occur in complex conjugate *pairs*.

Multivariable Problems

Many problems arise where the mathematical model consists of a number of equations with a number of unknown quantities. Here, the required solution consists of a set of values of the unknowns. Exact solutions are available only for certain *forms* of the set of equations. If there are "n" linear equations with "n" unknowns (n a known integer) the techniques of matrix algebra described later can be used. Otherwise, each problem must be examined separately—there are a number of manipulative tricks that a creative mathematician or engineer can devise to get an answer if one exists. One general statement we can make is that the effective number of equations in the model must be at least as large as the number of unknowns.

In some cases the *substitution* method can give an exact solution. Suppose we have 3 equations with variables x, y, and z. Solve the first equation for x in terms of y and z. Substitute the solution for x in equations 2 and 3: these now constitute two equations in two unknowns. Now solution of 2 for y, substituting in 3, gives a single equation in z. Solving this, we work backwards obtaining corresponding values for y and x. *Example:* solve the set:

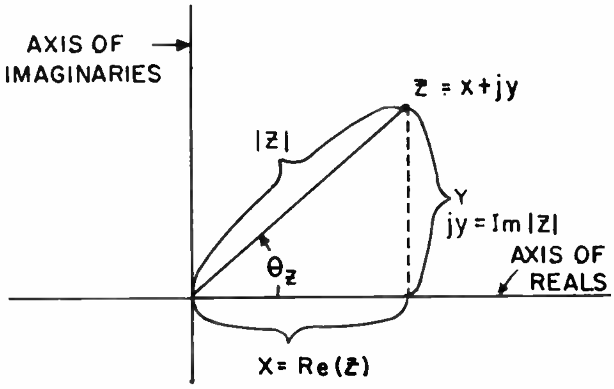


Fig. 6: Argand diagram or "complex plane" representation of complex numbers. These are basic definitions.

$$(1)\quad x\,y\,z^2 = 12 \qquad (22a)$$

$$(2)\quad x^2\,y\,z = 6 \qquad (22b)$$

$$(3)\quad x\,y^2\,z = 18 \qquad (22c)$$

$$\text{Solving (1) for } x:\quad x = \frac{12}{yz^2} \qquad (23a)$$

$$\text{Substituting:}\quad (2')\quad \frac{144}{yz^3} = 6 \text{ or } y\,z^3 = 24 \qquad (23b)$$

$$(3')\quad \frac{12y}{z} = 18 \text{ or } \frac{y}{z} = \frac{3}{2} \qquad (23c)$$

$$\text{Solving (2') for } y:\quad y = \frac{24}{z^3} \qquad (23d)$$

$$\text{Substituting:}\quad (3'')\quad \frac{24}{z^4} = \frac{3}{2} \text{ or } z^4 = 16 \qquad (23e)$$

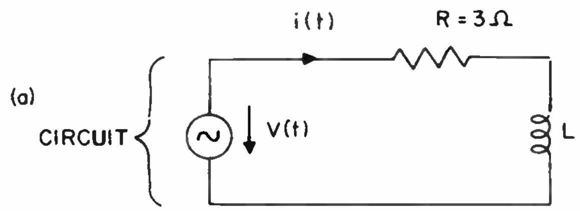
$$\text{Solving } 3'',\ z = 2 \qquad (24)$$

$$\text{Now from (23d), } y = \frac{24}{8} = 3 \qquad (25)$$

$$\text{and finally, from (23a), } x = \frac{12}{(3)\,(4)} = 1 \qquad (26)$$

As seen above, we have taken the liberty of picking a problem with a simple answer; however, it does serve to show the solution procedure.

Fig. 7a: Circuit problem and solution.



GIVEN DATA

$X_L = 2\pi f L = 4\,\Omega$

$V = 110$ VOLTS

$\theta_V = 0$

NUMERICAL SOLUTION

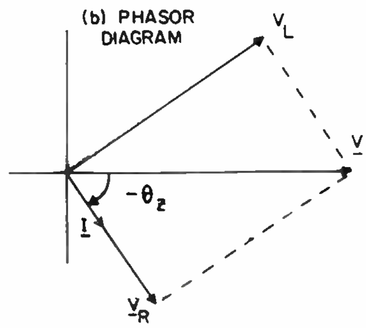
$$\underline{I} = \frac{\underline{V}}{\underline{Z}} = \frac{\sqrt{2}\,110}{3 + j4} = \sqrt{2}\cdot 22\,e^{-j\theta_z}$$

$$\underline{V}_R = R\underline{I} = \sqrt{2}\cdot 66\,e^{-j\theta_z}$$

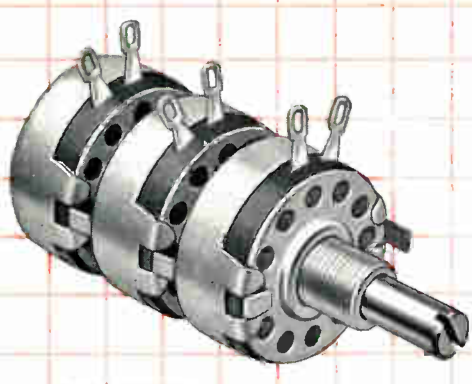
$$\theta_z = \text{TAN}^{-1}\frac{4}{3} = 53.1^\circ = 0.928 \text{ RADIANS}$$

$$\underline{V}_L = jX_L\underline{I} = \sqrt{2}\cdot 88\,e^{j(\frac{\pi}{2} - \theta_z)}$$

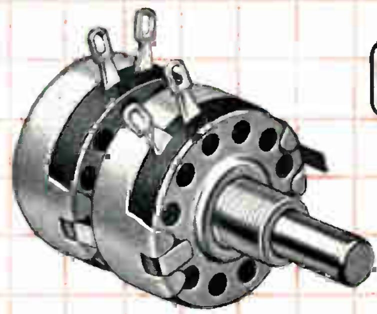
Fig. 7b: Phasor diagram of Figure 7b.



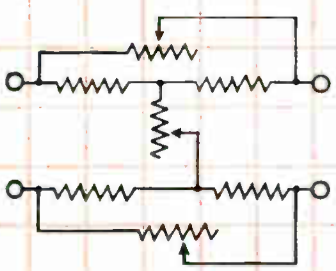
Allen-Bradley Type J Variable Resistors used in constant impedance attenuators provide quiet, smooth control...at low cost!



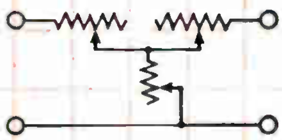
Type JJJ
Actual Size



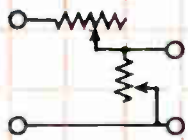
Type JJ
Actual Size



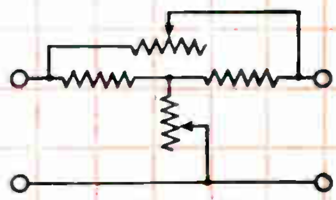
Bridged H



Straight T

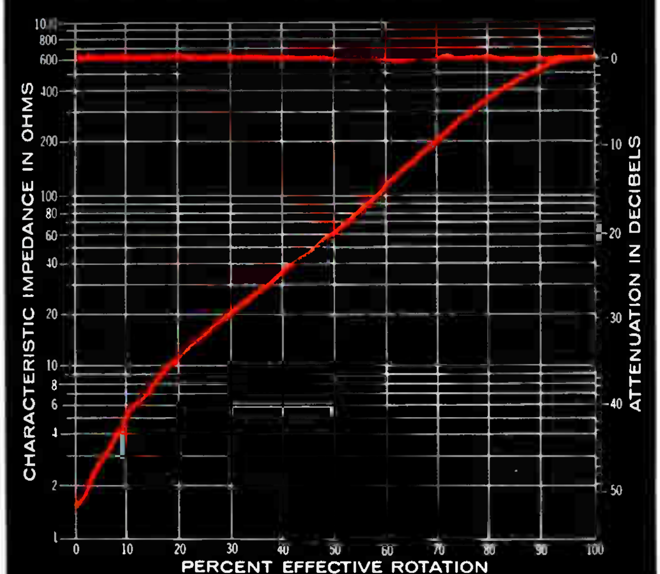


Standard L



Bridged T

Reproduction of actual machine plot of Allen-Bradley 600 ohm Bridged-T attenuator, showing the uniform attenuation and constant characteristic impedance obtainable with such Type J variable resistors.



■ In attenuators, which of these characteristics is most important to you—stability, or smooth control, or constant impedance? Not only will Allen-Bradley Type J variable resistors give you all of these . . . but also long life and a high wattage rating in a remarkably compact structure.

The famous Type J solid resistance element—made by A-B's exclusive hot molding process—provides smooth control at all times—you'll never experience an abrupt change in impedance or attenuation during adjustment.

Allen-Bradley's control of the resistance-rotation characteristics during production assures the desired attenuation—approaching calibration accuracy. And, the characteristic impedance can be held to 10% *throughout* rotation—end to end! The discrete steps inherent in all wire-wound units are eliminated. Don't forget—freedom from inductance insures excellent high-frequency response.

The Allen-Bradley Type J variable resistors are available in dual or triple units for use in attenuators rated up to 5 watts. For more complete information on these Type J controls, please send for Technical Bulletin B5200B. Write: Allen-Bradley Co., 1342 S. Second Street, Milwaukee 4, Wis. In Canada: Allen-Bradley Canada Ltd., Galt, Ontario.

QUALITY ELECTRONIC COMPONENTS **ALLEN-BRADLEY**

MATHEMATICAL MODELS

(*Continued from page 43*)

In many cases the best that can be done is to *approximate* the solution. This is usually done by a *successive approximation* technique: assume a set of values for the unknowns; substitute into the equations; determine magnitude of resultant "errors"; compute modifications to assumed unknown values and repeat, continuing until resultant "errors" are acceptably small. This procedure is related to the *trial and error* method: find (by exhaustion if necessary) values of the "unknowns" which satisfy the equations. With high speed computers such a procedure is sometimes practical.

Numerical Techniques

Up to this point we have presented mathematical models based on simple algebraic equations. However, the engineering logic implied by this discussion carries over to situations involving the more advanced mathematical concepts as well. As seen by the examples given, the last step in the solution of engineering problems consists in the insertion of numerical input values to obtain a numerical result. Here we shall discuss the different methods available for numerical calculations and indicate where they would be useful.

Longhand calculations: We refer here to the elementary number manipulations usually learned initially in elementary school: $+$, $-$, $\times$ and $\div$, also $\sqrt{\ }$. An engineer can expect to have to call on these methods continually, certainly when no refined techniques are available, but also to check the computer or give fast order-of-magnitude results even when more sophisticated methods are at hand.

Methods of checking work are useful, such as "doing it twice" or by "casting out nines."

Slide-rule calculations: These are also a *must* for engineers, both for performing the elementary manipulations and also for trigonometric and "exponential" calculations. In practice a slide rule provides answers usually correct to *three significant figures*. One important feature of slide-rule calculations is the requirement for a rough order-of-magnitude longhand calculation for "fixing the decimal point." This is facilitated by expression of numbers using *"powers of ten."* Thus:

$$\begin{aligned} 247.5 &= 2.475 \times 10^2 \\ 0.00342 &= 3.42 \times 10^{-3} \end{aligned} \quad (27)$$

Desk Calculator: This is a tool for rapid performance of longhand calculations. It is preferable to a slide rule when more than three-significant-figure accuracy is required in intermediate steps of calculations or even in the answer. It is also useful when accuracy may or may not be required, but when a large number of operations must be repeated. Having a calculator available, it is relatively simple to teach a person with very little education to perform a large number of calculations rapidly and accurately.

One job especially suited to the desk calculator is the processing of statistical data: given a set of "observations" determine the mean and standard deviation. A slide rule is almost completely useless here, since to get, say, 3 significant figures in the result, it is usually necessary to carry 5 or 6 significant figures in the separate steps.

Use of Logarithms: This is essentially a manual technique for reducing the time needed for longhand calculations. Also, it enables one to raise numbers to any fractional power. It is a table-look-up method; the accuracy depends on the "size" of the table used. It provides a simplification of manual processes required—for multiplication or division, only addition or subtraction is required.

All operations facilitated by logarithms can be done more rapidly on a slide rule; but, logarithms do provide more accuracy. Note that while a desk calculator does a better job with elementary operations than either a slide rule or logarithms, it is of questionable value for square roots and of no use at all for taking other fractional powers of numbers.

Automatic, general purpose, high-speed Digital Computers: We do not propose to present an exhaustive discourse here on the capabilities of digital computers, just some of the more significant characteristics. In some respects, a modern digital computer is essentially an electronic version of a desk calculator, since the basic operations performed are essentially elementary operations on integers. However, the speed and compactness achievable with electronic components provide many orders of magnitude greater capability and open up whole new classes of problems for which practical solutions can be obtained.

A primary feature of the use of such machines is the control by a "program," a listing of instructions fed into the machine on punched cards, paper tape, or magnetic tape. This program contains information that effectively defines the mathematical model for the given problem, in terms of machine operations and instructs the machine as to specific information required as solution. Using the program, together with any additional input data, the machine then generates the solution which is emitted in the prescribed form (typed or on cards or tape).

For many problems *compiler* languages exist which any engineer can use after a few hours instruction to prepare problem statements. These are then turned

MATHEMATICAL MODELS

(*Continued from page* 45)

over to the computer for direct solution. For more complicated problems it is necessary to use the services of a programmer or coder to translate the engineer's instructions into suitable machine language. Frequently the services of a numerical analyst are needed to decide the "best ways" of using the computer to get the desired results and build up confidence in the accuracy achieved.

Some interesting consequences of the use of high-speed computers have been: a refinement of methods of problem definition as well as a more widespread understanding of the nature of numbers. Concerning the latter item, it is often found useful to use binary, ternary, and/or octal number systems, as well as the usual decimal number systems. (see Table 1). Here, equivalents for numbers from 1 thru 12 are given; also for the single large number 5280. To check the results is easy: e.g. for the octal 12240, we have:

$$1 \times 8^4 + 2 \times 8^3 + 2 \times 8^2 + 4 \times 8 + 0 \times 8^0$$
$$= 4096 + 1024 + 128 + 32 + 0 = 5280 \qquad (28)$$

Understanding of these different number-base systems gives useful insight into the mode of operation of modern computer components.

Some number system equivalents: Table 1

Decimal	Binary	Ternary	Octal
1	1	1	1
2	10	2	2
3	11	10	3
4	100	11	4
5	101	12	5
6	110	20	6
7	111	21	7
8	1000	22	10
9	1001	100	11
10	1010	101	12
11	1011	102	13
12	1100	110	14
5280	1010010100000	21020120	12240

Geometrical Techniques

A fundamental branch of mathematics is geometry, dealing with the relations, properties, and measurements of lines, angles, surfaces and solids. Direct applications to engineering problems are unavoidable for civil and mechanical engineers and arise continually for all engineers. We shall concern ourselves here with some of the more *indirect* types of applications. For purposes of this discussion, we emphasize the related topics of trigonometry and analytical geometry.

Coordinate Systems: A coordinate system is a way of associating unambiguously a pair of numbers with each point in a plane (or a triplet of numbers with a point in three-dimensional space; this discussion will be confined to 2 dimensions for simplicity). Cartesian and polar coordinate systems are illustrated in Fig. 2, showing the common terminology. Simple trigonometric relations between the two systems are the following:

$$x = r \cos \theta \qquad (29a)$$
$$y = r \sin \theta \qquad (29b)$$
$$r = \sqrt{x^2 + y^2} \qquad (30a)$$
$$\theta = \arctan \frac{y}{x} \equiv \tan^{-1} \frac{y}{x} \qquad (30b)$$

Such coordinate systems in themselves provide a link between algebraic equations and geometrical relationships. Useful analogies can proceed in *either direction*. Thus a graph can be drawn for *visual display* of numerical relationships. The cathode-ray-oscilloscope does just this electronically with "waveform voltage" as ordinate and time as abscissa. Conversely, algebraic equations can be set up to describe geometrical forms which occur in nature. Examples are shown in Fig. 3. Further examples provide material for the following.

Vectors: A *Vector* is defined as a generalized type of number having both *magnitude* and *direction* with respect to a 3 dimensionl space. For clarity of discussion, non-vector numbers are called scalars; vector number symbols are usually **bold faced**, scalar number symbols are plane. The basic manipulation law of vectors is addition as shown in Fig. 4.

In many cases it is useful to write vectors in terms of their cartesian coordinate components, Fig. 5. An important relation is immediately apparent: Vector addition is equivalent to scalar addition of corresponding cartesian coordinate components. Thus:

$$\mathbf{A} + \mathbf{B} = \mathbf{i}(A_x + B_x) + \mathbf{j}\,(A_y + B_y) + \mathbf{k}\,(A_z + B_z) \qquad (31)$$

Other relations such as "scalar product" and "vector product" are also useful.

The most obvious use for vectors is for a precise general statement of the laws of mechanics. Forces on a body behave as vectors; motion of a body is readily expressed as a vector function of time. Applications to other problems involving "vector calculus" will be pointed out later.

Graphic representations of complex numbers: Referring back to number classifications above, it is seen that the law for adding complex numbers is very similar to the law for addition of two-dimensional vectors (see Eq. 31).

Thus:

$$\text{if } C_1 = a_1 + j\,b_1 \qquad (32a)$$
$$\text{and } C_2 = a_2 + j\,b_2 \qquad (32b)$$
$$\text{then } C_1 + C_2 = (a_1 + a_2) + j\,(b_1 + b_2) \qquad (32c)$$

Type 8035

COUNTER TUBES

Versatility with minimum circuitry—speeds to 100 Kc

These are versatile components offering many thousands of hours of reliable service, capable of counting and displaying simultaneously with a minimum of circuitry. In addition to counting, the tubes can be used for subtracting, adding, frequency dividing, keying, timing, computing, scaling, coding, modulating, matrixing, indexing, and multiplexing.

Here are just a few of many possible applications:

• Drill press control — tube stops press when transducer sensor signals end of stroke.

• Process control and counting—tube shuts off photo developer when associated timer indicates end of cycle; tube stops paper-stacking machine when selected number of cycles has been reached.

• Radiation detection — tube activates alarm when preset number of pulses has been accumulated from Geiger tube.

• Particle counting — series of tubes indicates number of particles of various sizes, according to amplitude of signal each particle causes.

The Sylvania line of reliable counter tubes consists of two groups:

1. Low-speed types, operate up to 4000 cps.
2. High-speed types, operate up to 50 and 100 Kc.

Circle [illegible] on Inquiry Card

Sylvania special-purpose counting or triggering job

Type SY-1302

COLD CATHODE THYRATRON

New design provides minimum leakage resistance of 10^{12} ohms!

Ideal for use with an ionization chamber to sense smoke, humidity or dust, the Sylvania cold cathode thyratron features a new design with the starter anode at the top. The result is very good insulation, further enhanced by a silicone coating on the bulb to prevent leakage caused by condensation. Compact and equipped with long, flexible leads for ease in mounting, the tube is adaptable to high impedance bridge circuits as a coupling device to lower impedance devices.

Here are some of the many application possibilities:

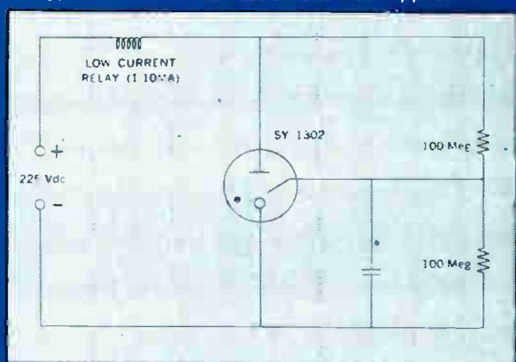
• Detection of light changes, when used with a photocell.

• Detection of smoke, moisture, dust, etc., when used with an ionization chamber.

• Radiation detection.

• Heat, pressure and gas detection.

Typical Circuit for Ionization Chamber Application

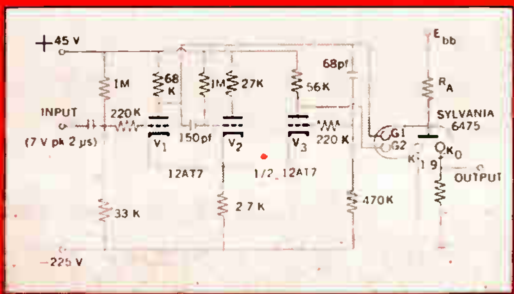


Circle [illegible] on Inquiry Card

In addition, there are several bulb sizes and sockets.

SEND FOR NEW BROCHURE, for complete information and assistance in the use of Sylvania counter tubes. Data sheets and circuits are included.

Short Pulse Driver Circuit



INDICATOR TUBES

Economical direct numerical readout driven by transistors

Here is inexpensive, direct numeric indication for applications up to 1 Kc — solid state computers, scalers and counting devices, for example. Designed for long life, these tubes feature the Sylvania developed integral glass base. As little as 5 volts differential causes a glow behind one of the number cutouts, making this readout tube ideal for use with transistorized circuits. Used as combined counter and indicator, little associated circuitry is required.

Circle 14 on Inquiry Card

Type 8453

tubes may do your better, more economically

TRIGGER TUBES

Deliver 10 amps or greater surge within 1-watt capability

These ruggedized cold cathode trigger tubes (Types 6483 subminiature and OA5 miniature) can handle a minimum of 10 amps surge, within a 1-watt capability. Possible applications include triggering of electronic photoflash units, sonar rescue beacons, flashing airport runway lights, jet ignition systems, spot welders and electric fences.

Circle 15 on Inquiry Card

Type 6483 subminiature

In addition to these special purpose tubes, Sylvania also offers ionization gauges for measuring pressures down to 10^{-7} mm of mercury, and Pirani tubes for measuring pressures down to 1 micron. For information on any of the tubes described here, see your Sylvania sales engineer or write to Electronic Tube Division, Sylvania Electric Products Inc., Box 87, Buffalo, New York.

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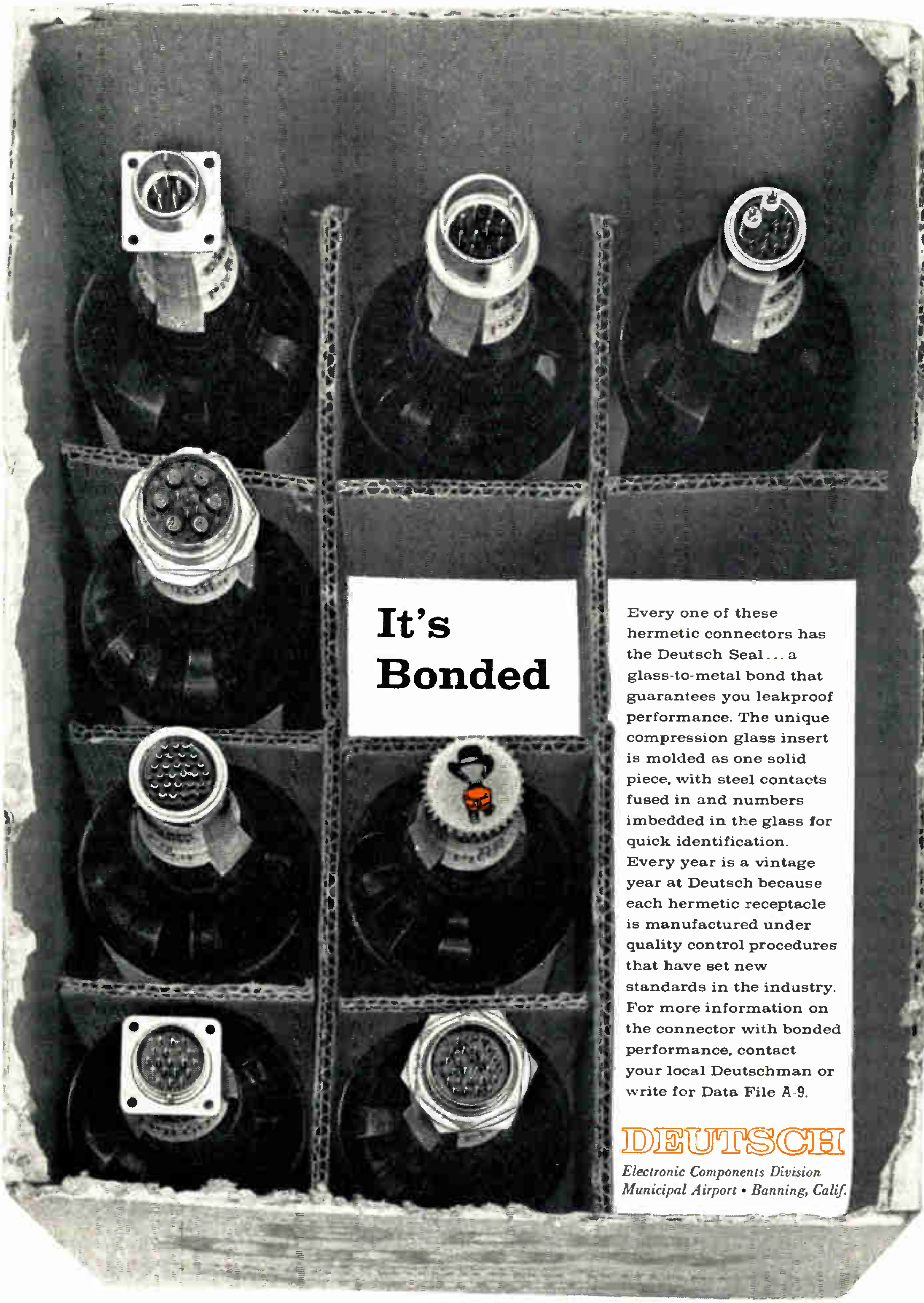


It's Bonded

Every one of these hermetic connectors has the Deutsch Seal . . . a glass-to-metal bond that guarantees you leakproof performance. The unique compression glass insert is molded as one solid piece, with steel contacts fused in and numbers imbedded in the glass for quick identification. Every year is a vintage year at Deutsch because each hermetic receptacle is manufactured under quality control procedures that have set new standards in the industry. For more information on the connector with bonded performance, contact your local Deutschman or write for Data File A-9.

DEUTSCH

Electronic Components Division
Municipal Airport • Banning, Calif.

ADVANCED SPECIFICATION MINIATURE ELECTRICAL CONNECTORS

MATHEMATICAL MODELS

(*Continued from page 47*)

As a result it is convenient to represent complex numbers as points on a plane: see Fig. 6 for the basic definitions. Thus, to find the point corresponding to the "sum" of the complex number for two given points, draw "vectors" from the origin to the given points; the point of the vector sum position will thus represent the sum of the two complex numbers.

At this point it is convenient to introduce the *polar representation* of a complex number. Referring to Fig. 6 and using obvious geometrical relationships we obtain:

$$z = x + j\,y$$
$$= |z|\ (\cos\theta_z + j\sin\theta_z) \qquad (33)$$

or

$$z = |z|\ e^{j\theta_z} \qquad (33a)$$

(the use of $e^{j\theta_z}$ as equivalent to $\cos\theta_z + j\sin\theta_z$ will be discussed below).

Here $|z|$ is known as the "absolute value" or "modulus" of z; the angle θ_z is its "argument." Important relationships include:

a. Product: $|Z_1Z_2| = |Z_1| \cdot |Z_2|$ (34a)

$\theta_{z1\,z2} = \theta_{z1} + \theta_{z2}$ (34b)

b. Quotient: $|z_1/z_2| = |z_1| \,/\, |z_2|$ (35a)

$\theta z_1/z_2 = \theta z_1 - \theta z_2$ (35b)

c. Raise to a power: $(z^n) = |z|^n$ (36a)

$\theta z^n = n\,\theta z$ (36b)

Thus, the *Polar form* of a complex number (Eq. 33a) is most convenient for multiplying, dividing, or raising to a power. On the other hand, for adding or subtracting, the Real-Imaginary form (see Eq. 32, for example) is most convenient.

Phasors: In describing the "steady state" behavior of alternating current electrical networks we must deal with voltages and currents of the form:

$$v\,(t) = \sqrt{2}\ V\cos\,(2\pi f t + \theta_v);$$
$$i\,(t) = \sqrt{2}\ I\cos\,(2\pi f t + \theta_I) \qquad (37)$$

Here, v and i are "instantaneous values" varying with time t (in seconds); f is the "frequency": in cycles per second; V and I are the RMS values that would be read on an "ac" voltmeter or ammeter, θ_V and θ_I are the "phase angles" with respect to a reference ("leads" if > 0; "lags" if < 0). From our complex number definitions, it is apparent that $v(t)$ and $i(t)$ are given by:

$$v\,(t) = Re\left\{\mathrm{V}\, e^{j2\pi f t}\right\} \qquad (38a)$$

$$i(t) = Re\left\{\mathrm{I}\, e^{j2\pi f t}\right\} \qquad (38b)$$

Here V and I are complex numbers given by:

$$\mathrm{V} = \sqrt{2}\ V e^{j\theta_v} \qquad \mathrm{I} = \sqrt{2}\ I\, e^{j\theta_I} \qquad (39)$$

V and I are called the "phasors" corresponding to the voltage and current $v(t)$ and $i(t)$. Solutions can be worked out either algebraically or by using the "argand diagram" which in this case is called the "Phasor diagram."

A sample problem is shown in Fig. 7: 110 v. RMS applied to a series circuit of 3 ohms resistance and 4 ohms reactance. Shown are solutions for current, resistive voltage drop, and reactive voltage drop: e.g. the current has an RMS value of 22 amps and lags the voltage by 0.928 radians or 53.1°.

Sums, Products, Series

In this section we shall start out by giving some standard mathematical notations that are used constantly in mathematical or engineering contexts where "economy of space" or "writer fatigue" are important: e.g. conciseness.

a. Summation notation:

$$\sum_{n=a}^{b} x_n = x_a + x_{a+1} + \cdots + x_{b-1} + x_b \qquad (40)$$

read: "The sum of the x_n from $n = a$ to $n = b$." (a,b integers; n takes consecutive values).

Example:

$$x_n = \frac{1}{n+1},\ a = 1,\ b = 4.$$

$$\sum_{n=1}^{4} \frac{1}{n+1} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} = \frac{77}{60} = 1\,\frac{17}{60} \qquad (41)$$

b. Product notation:

$$\prod_{n=a}^{b} x_n = x_a\, x_{a+1} \cdots x_{b-1}\, x_b \qquad (42)$$

read: "The product of the x_n from $n = a$ to $n = b$."

Example:

$$x_n = \frac{1}{n+1};\ a = 1,\ b = 4.$$

$$\prod_{n=1}^{4} \frac{1}{n+1} = 1/2 \cdot 1/3 \cdot 1/4 \cdot 1/5 = \frac{1}{120} \qquad (43)$$

Another example is the definition of the "factorial" function. Thus, for any positive integer m we define "m factorial" written: $m!$ as follows:

$$m! = \prod_{n=1}^{m} n = 1 \cdot 2 \cdots (m-1)\, m \qquad (44)$$

for example:

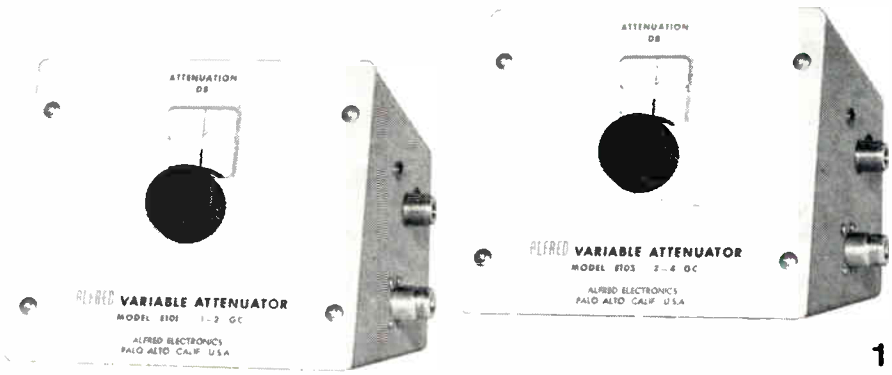
$$1! = 1,\ 2! = 2,\ 3! = 6,\ 4! = 24,\ 5! = 120, \text{ etc.} \qquad (45)$$

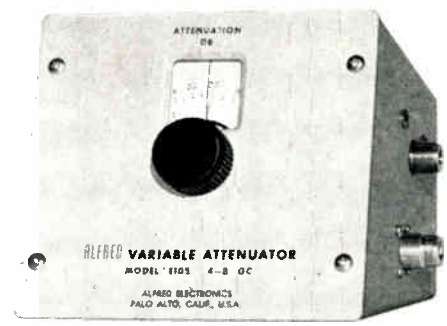
It is convenient to define O! as:

$$0! = 1 \qquad (46)$$

New Attenuator CAPABILITY

...from ALFRED





Coaxial, Variable

1 to 2 Gc, 2 to 4 Gc, 4 to 8 Gc

First to Combine ALL FOUR Attenuator Features!

* LOW INSERTION LOSS

An insertion loss of only 5 db at the zero db setting permits the ALFRED attenuator to be used where limited power is available.

* WIDE RANGE ATTENUATOR

Greater than 60 db continuously variable attenuation in L, S, and C bands.

* FLAT RESPONSE

Frequency sensitivity is less than ±¾ db at minimum attenuation with external terminations having VSWR less than 1.1:1.

* EXPANDED DIAL SCALE

The 8″ calibrated scale length, four times longer than is provided on other coaxial attenuators, gives fine resolution. Accuracy of calibration at mid-band is ±0.2 db or ±2%, whichever is greater.

In addition, good directivity allows the instrument to be used as a directional coupler with high decoupling action or as a variable coupler for mixer applications. Maximum power rating is 100 watts.

SPECIFICATIONS

Model	E101	E103	E105
Frequency Range Gc	1 to 2	2 to 4	4 to 8
Insertion Loss (at 0 db setting)	5 db	5 db	5 db
Frequency Response (at 0 db setting)	±¾ db	±¾ db	±¾ db
Frequency Response (at 60 db setting)	±1½ db	±1½ db	±2 db
Calibration accuracy at center frequency	±0.2 db or ±2%, whichever is greater		
Impedance	50 Ω	50 Ω	50 Ω
Connectors	Type N female		
Price	$400	$450	$480

ALFRED ELECTRONICS

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MATHEMATICAL MODELS

(*Continued from page 51*)

so that a direct analogy to the "Gamma function" of higher mathematics can be stated as:

$$\Gamma(m+1) = m! \qquad (47)$$

The gamma function $\Gamma(x)$ is defined for all real values of x; it satisfies the recurrence relation:

$$\Gamma(x+1) = x\,\Gamma(x); \qquad (48)$$

it is expressible as a factorial when x is a positive integer.

Summation notation is more commonly used in mathematical models of engineering problems than product notation. Certain standard "finite" sums are frequently used in simplifying computations. "Infinite series" often arise (e.g. Eq. 40 with A = 1 or 0 and B = ∞ = infinity) in definitions of useful functions and for approximate calculations. The remainder of this section will cover some examples of both.

Permutations and combinations: The number of arrangements of a set of n objects in a line is given by $n!$ These arrangements are sometimes called "permutations."

Example: Given 4 letters, A, B, C, and D; how many possible "words" can be constructed using each letter once and only once?

Solution: number of letters =4; 4! = 24, which is thus the answer required.

Check: we enumerate the possible words as follows:

ABCD	BACD	CABD	DABC
ABDC	BADC	CADB	DACB
ACBD	BCAD	CBAD	DBAC
ACDB	BCDA	CBDA	DBCA
ADBC	BDAC	CDAB	DCAB
ADCB	BDCA	CDBA	DCBA

Evidently there are just 24 possibilities.

The number of ways of selecting n objects from a set of m objects is given by:

$$\binom{m}{n} = \frac{m!}{n!\,(m-n)!} \qquad (49)$$

The notation $\binom{m}{n}$ is read: "The number of combinations of m things taken n at a time."

Example: How many ways can two resistors be selected from a group of five?

Solution:

$$\binom{5}{2} = \frac{5!}{2!\,3!} = \frac{120}{2\times 6} = 10$$

Answer: 10 selections possible.

Check: numbering them 1, 2, 3, 4, and 5, the possible selections-of-two are:

(1, 2), (1, 3), (1, 4), (1, 5); (2, 3), (2, 4). (2, 5); (3, 4), (3, 5); (4, 5).

Another useful application of the notation of Eq. 49 is the *binomial theorem,* giving the following series expression for raising the sum of two numbers to a power:

$$(a+b)^m = \sum_{n=0}^{m} \binom{m}{n} a^{m-n} b^n \qquad (50)$$

Common Finite Sums:

a. Arithmetic progression:

$$\sum_{n=1}^{m} n = \frac{1}{2} m\,(m+1) \qquad (51)$$

Examples:
$1 + 2 = \tfrac{1}{2} \times 2 \times 3 = 3$
$1 + 2 + 3 + 4 = \tfrac{1}{2} \times 4 \times 5 = 10$
$1 + 2 + 3 + \cdots + 50 = \tfrac{1}{2} \times 50 \times 51$
$= \tfrac{1}{2} \times 2550 = 1275$

b. Geometric progression:

$$\sum_{n=0}^{m} r^n = \frac{1 - r^{m+1}}{1 - r} \qquad (52)$$

where r is any finite number, real or complex.

Example: $r = 0.1$, $m = 5$:

$$1 + .1 + .01 + .001 + .0001 + .00001$$
$$= \frac{1 - .000001}{1 - .1} = \frac{.999999}{.9} = 1.11111$$

c. Sum of squares

$$\sum_{n=1}^{m} n^2 = \frac{1}{6}\, m\,(m+1)\,(2m+1) \qquad (53)$$

Examples:

$$1^2 + 2^2 = \frac{1}{6} \times 2 \times 3 \times 5 = 5$$

$$1^2 + 2^2 + 3^2 + 4^2 + 5^2 = \frac{1}{6} \times 5 \times 6 \times 11 = 55$$

Expressions such as (53) and (51) are especially useful in calculations of statistical parameters of numerical data.

Infinite series: Infinite series usually arise as functions-of-a-variable and are usually defined over a "region of convergence" of the variable. Thus we have *Power Series* of the form:

$$f(z) = \sum_{n=0}^{\infty} a_n z^n \qquad (54)$$

In general, a power series is convergent (i.e. the sum is finite and single-valued) for z anywhere within a "circle of convergence" centered at the origin in the complex plane or Argand diagram.

Example: $a_n = 1$

$$f(z) \sum_{n=0}^{\infty} z^n = 1 + z + z^2 + \cdots \qquad (55)$$

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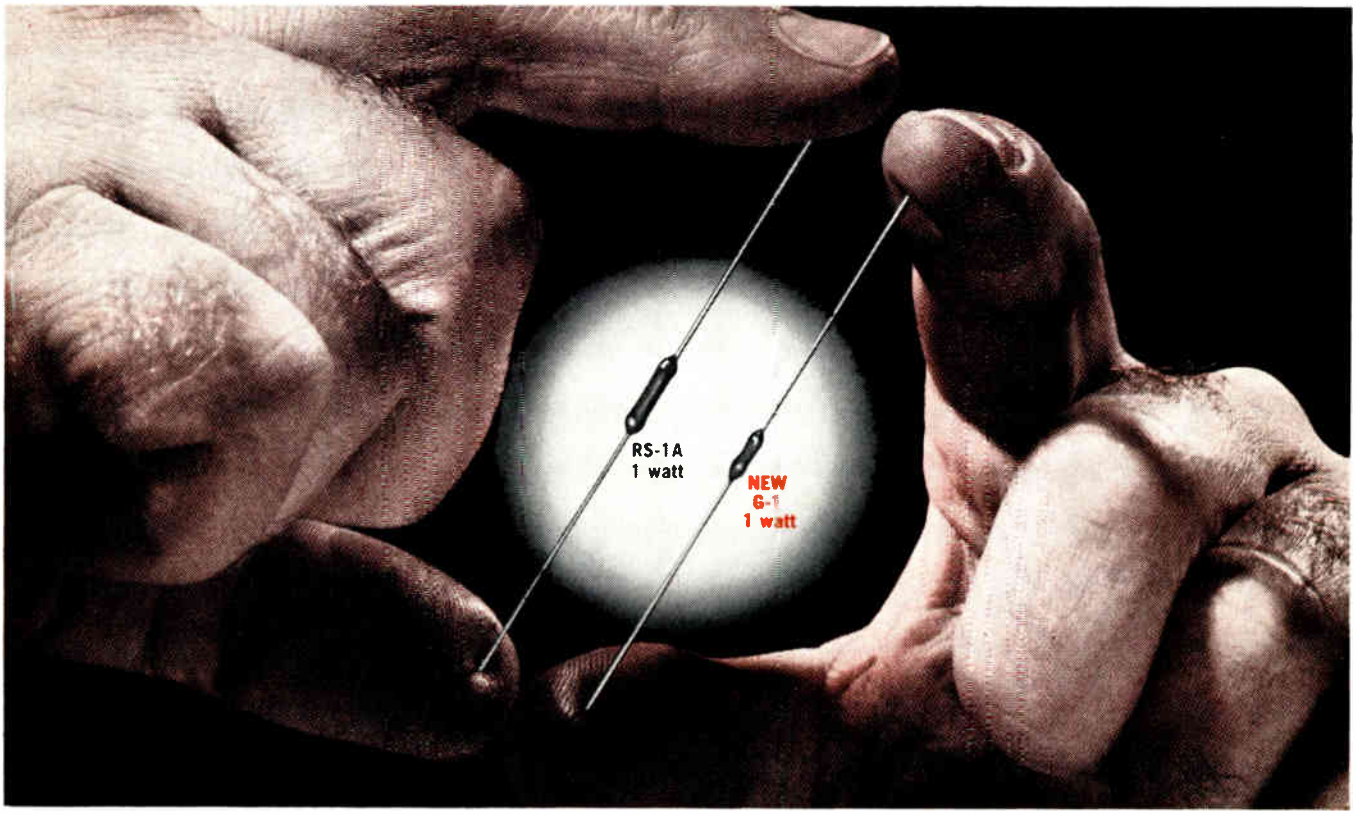
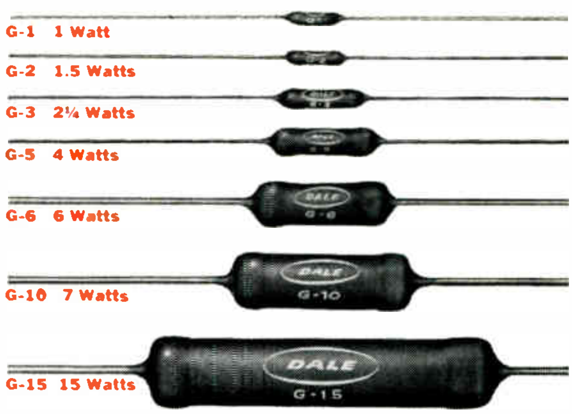
New "G" Series Precision Power Resistors

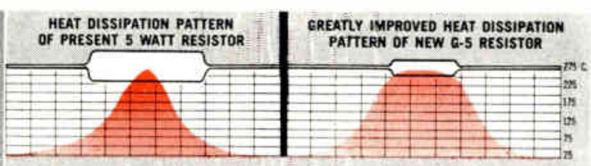


Dale "G" Resistors drastically reduce space requirements

Acclaimed as a major breakthrough in the relation of precision power to size, Dale "G" Series provide a much wider heat dissipation pattern than conventional size wirewound precision resistors—assuring you of inherent stability you expect from Dale. Now available in seven sizes, the "G" Series Resistors are an outstanding example of the new levels of achievement in resistor design and manufacture which have resulted from Dale's participation in the **MINUTEMAN** High Reliability Component Development Program.



DALE TAMES THE HOT SPOT!



The above patterns are typical in a comparison between any G Type resistor and any old style resistor. **NOTE:** If G Type resistors are operated at full power, soldering with low temperature solder is not recommended.

SPECIFICATIONS

- Seven sizes: 1, 1.5, 2.25, 4, 6, 7, 15 watts. Rating based on .001 minimum wire diameter
- Exceed functional requirements of MIL-R-26C
- Resistance Range from 10 to 175K ohms, depending on size and tolerance
- Tolerances: .05%, 0.1%, 0.25%, 0.5%, 1%, 3%
- Temperature Coefficient: 0.00002/degree C.
- Operating Temperature Range: -55° to 275° C.

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MATHEMATICAL MODELS

(*Continued from page* 53)

This series has a radius-of-convergence of unity; so for any value of z for which $/z/ < 1$ the series converges, in this case, to the value of $1/(1\text{-}z)$. For $/z/ > 1$ the series is divergent, i.e., it blows up to infinity.

Common power series with infinite radius-of-convergence are the following trigonometric and exponential functions:

$$\text{cosine:}\quad \cos x = \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n)!} x^{2n} \qquad (56)$$

$$\text{sine:}\quad \sin x = \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n+1)!} x^{2n+1} \qquad (57)$$

$$\text{exponential:}\quad \exp x = e^x = \sum_{n=0}^{\infty} \frac{1}{n!} x^n \qquad (58)$$

Note that the exponential function series satisfies the following relationship:

$$\exp(x_1 + x_2) = (\exp x_1) \cdot (\exp x_2) \quad \text{for any numbers } x_1 \text{ and } x_2 \qquad (59)$$

This accounts for its usually being written "e^x", i.e., the number "e" raised to the power "x" where "e" is given by:

$$e = \exp 1 = \sum_{0}^{\infty} \frac{1}{n!} \cong 2.718 \cdots \qquad (60)$$

The exponential function is of great utility in mathematical analysis because of the property of Eq. 59. The series (58) is reasonably rapidly convergent and thus is useful for numerical calculations. As shown in Complex Numbers and Phasors sections above, it provides a convenient "shorthand" for describing complex numbers through a relation with the trigonometric functions easily proved from Eqs. 56, 57 and 58 above as used in Eq. 33. The number e is the base of the natural logarithm system":

$$\text{natural log } y = ln\, y = \text{that number } x \text{ such that } e^x = y. \qquad (61)$$

Other uses will be pointed out in later sections.

There are many other types of infinite series that are useful in engineering. One particularly useful type is the *Fourier Series:*

$$v(t) = a_o + \sum_{n=1}^{\infty} [a_n \cos(2\pi n f t) + b_n \sin(2\pi n f t)] \qquad (62)$$

In this series t is a real number variable, often designating *time*; the individual terms are sinusoids of frequencies integer multiples of f cycles per second. Properly choosing the coefficients a_n, the series can represent any periodic "waveform functions." "f" is the "fundamental frequency"; multiples of f are called "harmonics"; the period of the waveform is $1/f$ sec. An example is shown in Fig. 8, giving a square wave of period 4 units, fundamental frequency ¼ unit. From its Fourier series expansion, it is seen that only odd-numbered harmonics are present. Letting $t = 0$, we get the following series for numerical evaluation of "π"; (since $v(o) = 2$; $\cos o = 1$)

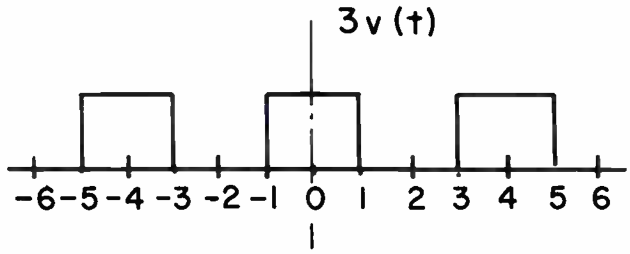


Fig. 8: An example of a Fourier Series is diagrammed.

$$\pi = 4 \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} = 4(1 - 1/3 + 1/5 - 1/7 + 1/9 - \cdots) \qquad (63)$$

$$v(t) = 1 + \frac{4}{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} \cos\left[(2n+1)\frac{\pi t}{2}\right]$$

Partial Fraction Expansion: This is a method for simplifying certain proper algebraic fractions of the form:

$$F(x) = \frac{q_k(x)}{p_m(x)} \qquad (64)$$

where $q_k(x)$ and $p_m(x)$ are polynomials in x as defined in section, Equations of one unknown, above and the "orders" k and m satisfy:

$$k \angle m. \qquad (65)$$

The method requires knowledge of the roots of $p_m(x)$. Let these be designated $r_1, r_2, \ldots, r_m$ (assume for convenience that no two of these roots are equal). The partial fraction expansion is now given by:

$$F(x) = \sum_{n=1}^{m} \frac{A_n}{x - r_n} \qquad (66)$$

where the A_n are constants, given by:

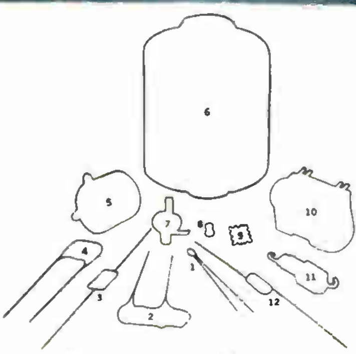
$$A_n = q_k(r_n) \div \left.\frac{p_m(x)}{x - r_n}\right|_{n = r_n} \qquad (67)$$

Example

$$\frac{x+1}{x^3 - 6x^2 + 11x - 6} = \frac{x+1}{(x-1)(x-2)(x-3)} = \frac{A_1}{x-1} + \frac{A_2}{x-2} + \frac{A_3}{x-3} \qquad (68)$$

where

$$A_1 = (1+1) \div (1-2)(1-3) = 1$$
$$A_2 = (2+1) \div (2-1)(2-3) = -3 \qquad (69)$$
$$A_3 = (3+1) \div (3-1)(3-2) = 2$$



1. 3 V, 0.02 mf ULTRA-KAP® micro-miniature capacitor for transistor circuits. Other sizes available in voltages to 20 VDC, capacities to 2.2 mf.

2. 0.3 meg resistor, 470 pf capacitor TUBE-R-KAP® combination (in parallel). Ranges: 100Ω to 4 meg and 100 to 12,400 pf.

3. 500 pf, 500 V FLAT PLATE capacitor for miniaturization applications. Broad range of shapes in capacities to 0.1 mf.

4. .22 mf, 150 VDC, THIN FILM CAPACITOR, for high capacity, intermediate voltage applications. Range: .022–.47 mf.

5. 100 pf ± 1%, 500 V PRECISION capacitor, NPO. Also available ± 5% and N750. Range: 100–2500 pf.

6. 250 pf, 20 KV TRANSMITTING capacitor for high frequency, high RF current circuits. Ranges: 3–1000 pf, 5–20 KV.

7. 5 pf, 500 V DISCOIDAL capacitor with extremely low inductance. Range: 5–1000 pf.

8. 500 pf, 100 V micro-miniature FEED-THRU. 0.16" diameter 0.165" high. Range: 500–800 pf, 100 and 250V. Available with leads.

9. 1.5–5.0 pf, 100 V MICROMINIATURE TRIMMER, for micromodule application. Other styles available, ranges up to 20 pf.

10. 1.5–7.0 pf, 500 V dual ROTARY TRIMMER. 6 styles of rotary trimmers with ranges up to 400 pf are available.

11. 5 pf, 500 V FEED-THRU meets MIL-C-11015. Withstands severe mechanical requirements. Range: 5–1000 pf.

12. 1000 pf, ± 5%, 125 V POLYSTYRENE FOIL capacitor with higher Q, longer life and greater freedom from drift at half the cost of micas. Ranges: 20–600,000 pf, ± .625 to 20%, 63 to 750 V.

Centralab

No matter how unusual your design requirements, there is an excellent chance a standard Centralab type—or an engineered modification—will meet your needs. Centralab offers the industry's most extensive line of ceramic capacitors—almost twice as many types as any other manufacturer. The units shown here are just a few examples of the special—yet standard—Centralab capacitors. For detailed information write for Centralab Capacitor Catalogs.

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MATHEMATICAL MODELS

(Continued from page 55)

These methods are of primary importance in Laplace transform manipulations.

Determinants, Matrices

An important class of problems requires the solution of sets of linear equations with several "unknowns." A simple example from circuit theory is shown in Fig. 9. Here the idea is to learn how many amperes are drawn by the circuit from each battery.

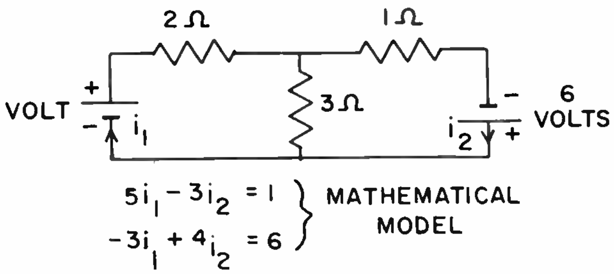


Fig. 9: Simple circuit problem with the mathematical model.

The mathematical model consists of the two (mesh) equations to solve for i_1 and i_2. The solution is readily obtained by the *determinant method*. Thus:

$$i_1 = \frac{\begin{vmatrix} 1 & -3 \\ 6 & 4 \end{vmatrix}}{\begin{vmatrix} 5 & -3 \\ -3 & 4 \end{vmatrix}} = \frac{4 + 18}{20 - 9} = \frac{22}{11} = 2 \text{ amps} \quad (70)$$

$$i_2 = \frac{\begin{vmatrix} 5 & 1 \\ -3 & 6 \end{vmatrix}}{\begin{vmatrix} 5 & -3 \\ -3 & 4 \end{vmatrix}} = \frac{30 + 3}{20 - 9} = \frac{33}{11} = 3 \text{ amps} \quad (71)$$

$$\left.\begin{aligned} 5\,i_1 - 3\,i_2 &= 1 \\ -3\,i_1 + 4\,i_2 &= 6 \end{aligned}\right\} \text{Mathematical Model}$$

While the above demonstrated technique is straightforward, it would take many words and diagrams to explain the general procedures in the general case of n linear equations in n unknowns. We adopt the procedure here of deferring such an explanation till after we have presented some of the concepts of *Matrix Algebra*. Solution of a set of linear equations is equivalent to "inverting a matrix."

In addition to providing a vehicle for concise unequivocal description of methods of solving linear systems of equations, matrices provide a convenient conceptual shorthand for describing mathematical models involving many variables. Besides being useful in circuit analysis, matrix algebra has important applications in physics (e.g. coordinate transformations) and statistics (as in description of the general multivariate Gaussian distribution).

Matrix definitions: We start out with some definitions and notations. These notations differ considerably, depending on which book you look in; the ones used here are due to the late Dr. Harold Pender, at one time Dean of the Moore School of Electrical Engineering of the University of Pennsylvania.

a. A matrix is a rectangular array of scalar quantities, usually numbers or letters representing numbers. Thus a matrix **A** would be given by:

$$\mathbf{A} = \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \end{bmatrix} \quad (72)$$

Note the use of the **bold A** for the complete array, the regular A_{mn} for the "element" in the m-th row and n-th column (Note—when writing longhand use **A**, underlined, to represent **A** bold). While the above is a 3×4 matrix the size can be specified arbitrarily $r \times c$ as required.

b. Equality of matrices:

$\mathbf{A} = \mathbf{B}$ if and only if $r_A = r_B$; $c_A = c_F$; and all $A_{mn} = B_{mn}$

i.e. all corresponding elements equal.

c. The *transpose* of a matrix **A** is that matrix $\mathbf{A}_t$ formed by interchanging the rows and columns of **A**. Symbolically:

$\mathbf{B} = \mathbf{A}_t$ if and only if $B_{mn} = A_{mn}$ for all m and n.

d. Addition of matrices: add all corresponding elements. Symbolically, if $r_A = r_F$, $c_A = c_B$, then:

$\mathbf{D} = \mathbf{A} + \mathbf{B}$ if and only if $D_{mn} = A_{mn} + B_{mn}$ for all m and n.

e. Multiplication by scalar: multiply all elements by the scalar. Symbolically:

$\mathbf{B} = k\mathbf{A}$ if and only if $B_{mn} = kA_{nm}$ for all m and n.

f. Multiplication of matrices: The product of any two matrices A and B for which

$$c_A = r_B \quad (73)$$

is written

$$\mathbf{D} = \mathbf{A}\,\mathbf{B} \quad (74)$$

where, by definition

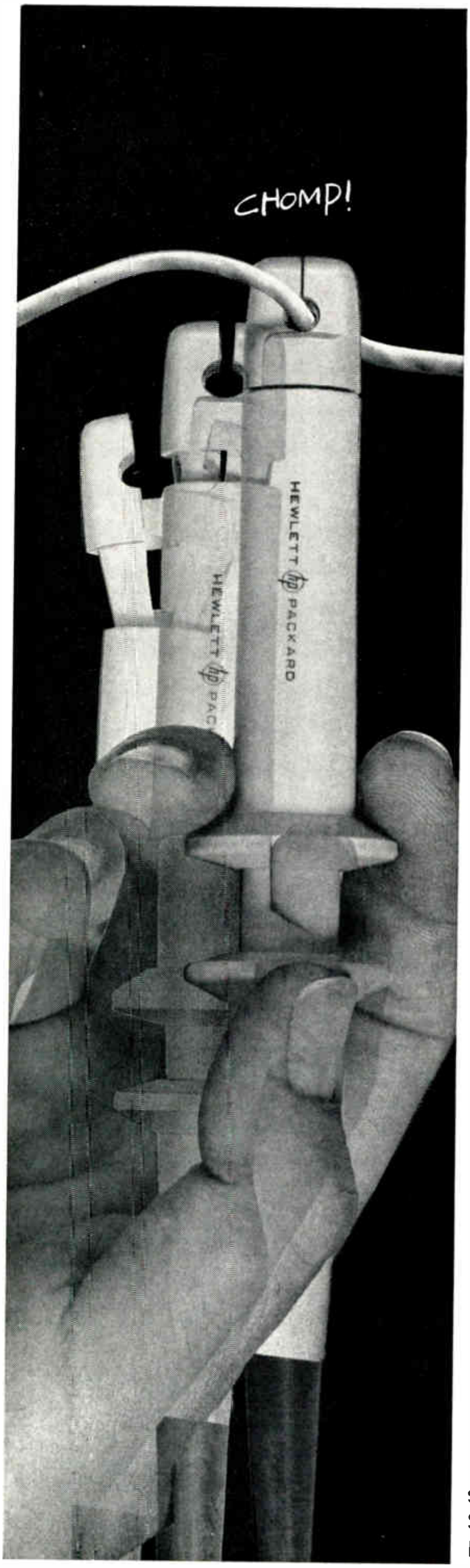
$$D_{mn} = \sum_{i=1}^{r_A} A_{mi}\,B_{in} \quad (75)$$

i.e. multiply m-th **row** elements of **A** by corresponding n-th **column** elements of **B** and add resulting products to get D_{mn}. Note that in (74) it is important to distinguish the **prefactor A** from the **postfactor B** since the multiplication process defined by (75) is not commutative; i.e., in general **AB** ≠ **BA**.

g. "row matrix": only one row: $r = 1$.

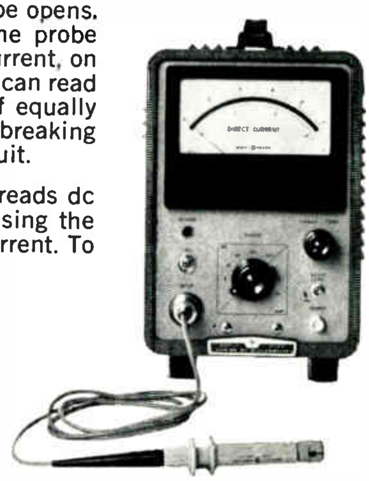
h. "column matrix": only one column.

i. null matrix: **0**: all elements zero.



CLAMP AROUND THE LEAD:

and measure dc current 0.1 ma to 10 amps, without breaking circuit leads, without loading the circuit.



Pull back the probe flange, the probe opens. Aim it at a lead and let loose. The probe closes. Now you can measure dc current, on a bare or insulated wire . . . and you can read it directly, even in the presence of equally strong ac on the same wire, without breaking a lead and without loading the circuit.

The hp 428B Clip-on DC Ammeter reads dc current directly in 9 ranges by sensing the magnetic flux induced by the dc current. To measure the sum or difference of currents flowing through two separate wires, you simply clamp the probe around them both . . . and read. The standard 428B has a range of 0.1 ma to 10 amps and lets you read dc currents on wires up to 5/32" in diameter. A recorder, oscilloscope output is provided on the 428B.

hp 3528A Current Probe

hp 3529A Magnetometer Probe

The hp 3528A Current Probe ($450 with degausser) lets you measure dc current in conductors up to 2½" in their maximum dimensions . . . even pipes, multiconductor cables, lead-sheathed cables, microwave waveguide.

The hp 3529A Magnetometer Probe ($75) is useful in applications ranging from acoustical transducer design to study of the Zeeman effect; it measures the direction or magnitude of any magnetic field with 1 milligauss sensitivity.

Look at the 428B specs, then call your hp field engineer or write direct for a single data sheet which describes all its capabilities.

428B SPECIFICATIONS

Current Range:	1 ma to 10 a full scale in 9 ranges
Accuracy:	±3%, ±0.1 ma
Probe Inductance:	<0.5 μh introduced into measured circuit
Probe Induced-Voltage:	<15 mv peak into measured circuit
AC Rejection:	ac with peak value less than full scale affects meter accuracy less than 2% at frequencies above 5 cps and different from carrier (40 kc) and its harmonics; (on 10 range, ac is limited to 4 a peak)
Recorder/Oscilloscope Output:	app. 1.4 v across 1400 ohms full scale; frequency response dc to 400 cps
Probe Insulation:	300 v maximum
Price:	hp 428B, $600 (cabinet); hp 428BR, $605 (rack mount) (428A also available; same as 428B except range: 3 ma to 1 ampere full scale; no recorder output, $500)

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MATHEMATICAL MODELS

(*Continued from page 57*)

j. square matrix: same number rows and columns: $r = c =$ "order" of square matrix.

k. unit matrix: square matrix with all 1's in the principal diagonal; zeroes elsewhere, e.g.

$r = c = 2$: $\mathbf{1} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ $r = c = 3$: $\mathbf{1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

For any suitable **A**, **B** (not necessarily square)

$$\mathbf{1\,A = A;\quad B\,1 = B} \tag{77}$$

l. Determinant of Square matrix: $A\# \equiv$ determinant of matrix **A**. $A\#$ is a scalar number. Rules for calculating $A\#$ from the square matrix **A** are well known for order = 1, 2, or 3:

$$\text{order} = 1:\ A\# = A_{11} \tag{78}$$

$$\text{order} = 2:\ A\# = A_{11}A_{22} - A_{12}A_{21} \tag{79}$$

$$\text{order} = 3:\ A\# = \text{sum of six terms } (+ \text{ and } -) \tag{80}$$

$$\text{order } Q:\ A\# = \text{sum of } Q! \text{ terms } (+ \text{ and } -) \tag{81}$$

An important relationship that can be proved consistent with the definition of the matrix product is that if A and B are of the same order and square, the determinant of the product is the product of the determinants. Thus:

$$(\mathbf{A\,B})\# = (\mathbf{B\,A})\# = A\#\,B\# \tag{82}$$

m. Adjoint matrix: **A*** is defined as the **adjoint** of square matrix **A** by:

A^*_{mn} is the **cofactor** of A_{mn}, i.e. $(-1)^{m+n}$ times the (83) **determinant** of the square array formed by **deleting** the m-th row and n-th column of A.

A convenient way of computing a determinant as a linear combination of lower order determinants is one of the cofactor expansions:

$$\mathbf{A}\# = \sum_{m=1}^{r} A^*_{mn}\,A_{mn}, \text{ any value of } n \tag{84a}$$

$$= \sum_{n=1}^{r} A^*_{mn}\,A_{mn}, \text{ any value of } m \tag{84b}$$

n. The **inverse** of a square matrix **A**, is that matrix $\mathbf{A}^{-1}$ which when multiplied by A gives the unit matrix. i.e.:

$$\mathbf{A^{-1}\,A = 1;\quad A\,A^{-1} = 1} \tag{85}$$

The value of the inverse is given by:

$$\mathbf{A}^{-1} = \frac{1}{A\#}\mathbf{A}^*{}_t \text{ or } A^{-1}{}_{mn} = \frac{1}{A\#}A^*{}_{nm} \tag{86}$$

Note that if the matrix determinant is **zero** (86) blows up and we must conclude that there is no **inverse to the matrix**. in which case it is said to be a **singular** matrix.

Matrix Equations: A set of n linear (scalar) equations in n unknowns can be written as a single matrix equation and the solution can be obtained by using the inverse matrix.

First, referring to item **b** above we recognize that a single matrix equality is equivalent to rc scalar equalities, one for each set of corresponding matrix elements. With this in mind consider the matrix equation:

$$\mathbf{A\,y = x} \tag{87}$$

Where **A** is a square matrix, order r; and **y** and **x** are column matrices—one column and **r** rows. For the case **r** = 3 this can be written:

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \tag{88}$$

Multiplying (see Eq. 75 above) and equating like elements we get the following set of equations:

$$A_{11}\,y_1 + A_{12}\,y_2 + A_{13}\,y_3 = x_1 \tag{89a}$$

$$A_{21}\,y_1 + A_{22}\,y_2 + A_{23}\,y_3 = x_2 \tag{89b}$$

$$A_{31}\,y_1 + A_{32}\,y_2 + A_{33}\,y_3 = x_3 \tag{89c}$$

The extension to higher orders is evident; also the converse process of converting an arbitrary set of linear equations to a matrix equation is apparent. Once we have the matrix Eq. 88 or 87 we can solve by "matrix algebra"; thus pre-multiplying both sides of (87) by the inverse A^{-1}, using (85) and (77), we get:

$$\mathbf{A^{-1}\,A\,y = A^{-1}\,x} \tag{90a}$$

$$\mathbf{1\,y = A^{-1}\,x} \tag{90b}$$

$$\mathbf{y = A^{-1}\,x} \tag{90c}$$

Computationally, to obtain the "solution" represented by (90c), we need only compute the inverse matrix as defined in (86). Needless to say, this solution must be equivalent to the solution-by-determinants mentioned at the beginning of Determinants. Matrices.

Applying this procedure to the problem given by Fig. 9, we have the matrix equation:

$$\mathbf{z\,i = v} \tag{91}$$

$$\text{where } \mathbf{v} = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 6 \end{bmatrix};\quad \mathbf{i} = \begin{bmatrix} i_1 \\ i_2 \end{bmatrix};$$

$$\mathbf{z} = \begin{bmatrix} 5 & -3 \\ -3 & 4 \end{bmatrix} \tag{92}$$

Proceeding as indicated:

$$z\# = 20 - 9 = 11 \tag{93}$$

$$\mathbf{z}^*{}_t = \begin{bmatrix} 4 & 3 \\ 3 & 5 \end{bmatrix} \tag{94}$$

Assembly

(less than 30 seconds)

Performance

(up to 10Gc.)

Cost

(save up to $1.20)

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(*Continued from page* 59)

$$z^{-1} = \frac{z_t^*}{z\sharp} \quad \begin{vmatrix} 4/11 & 3/11 \\ 3/11 & 5/11 \end{vmatrix} \qquad (95)$$

$$\begin{vmatrix} i_1 \\ i_2 \end{vmatrix} = \mathbf{i} = \mathbf{z}^{-1}\mathbf{v} = \begin{vmatrix} \frac{4}{11} v_1 + \frac{3}{11} v_2 \\ \frac{3}{11} v_1 + \frac{5}{11} v_2 \end{vmatrix}$$

$$= \begin{vmatrix} \frac{4+18}{11} \\ \frac{3+30}{11} \end{vmatrix} = \begin{vmatrix} 2 \\ 3 \end{vmatrix} \qquad (96)$$

Which of course agrees with Eqs. 70 and 71.

The beauty of the matrix method becomes apparent when several sets of transformations are involved. An important relation here is the fact that the inverse of a product of square matrices is the reverse-order product of the inverses of the individual factors:

$$(\mathbf{A}\,\mathbf{B})^{-1} = \mathbf{B}^{-1}\,\mathbf{A}^{-1} \qquad (97)$$

This makes for straightforward solution of problems such as repeated coordinate transformations in missile trajectory calculations, and circuit solutions for "element currents" in terms of "mesh currents" or "node voltages."

Differential Calculus

The derivative of a function $y = f(x)$ is defined as the rate of change of the function y with respect to changes in x. This is illustrated in Fig. 10. We write:

$$\frac{dy}{dx} \equiv f'(x) \equiv \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x} = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} \qquad (98)$$

[Note: the notation "$\lim_{\Delta x \to 0}$ ( )" is read "the limit of ( ) as delta – x approaches zero."]

"Differentiation" is the process of obtaining the derivative of a function; "there are well established rules for differentiating a variety of algebraic, trigonometric, and other expressions; these are well-tabulated in elementary calculus texts and handbooks. For example; if $f(x) = g(x)/h(x)$, we have:

$$f'(x) = \frac{h(x)\,g'(x) - g(x)\,h'(x)}{[h(x)]^2} \qquad (99)$$

Repeated differentiation is often used, such as:

$$\frac{d^2y}{dx^2} \equiv f''(x) \equiv \frac{d}{dx} f'(x) \qquad (100)$$

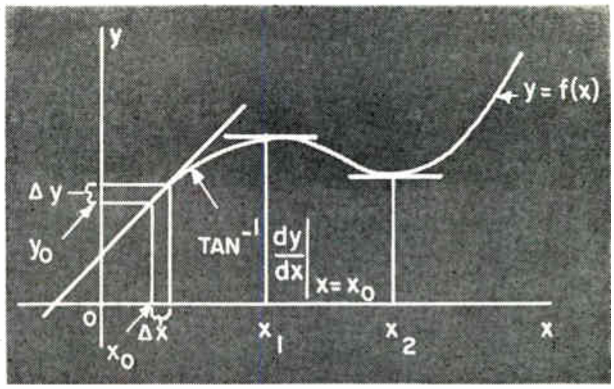


Fig. 10: Derivative of a function is shown graphically.

Similarly $\frac{d^3y}{dx^3}$, etc., give "higher" order derivatives.

A direct application of differentiation is the calculation of the instantaneous voltage drop across an inductor, given by:

$$v(t) = L \frac{di(t)}{dt} \qquad (101)$$

where L is the inductance, or the displacement current in a capacitor:

$$i(t) = C \frac{dv(t)}{dt} \qquad (102)$$

where C is the capacitance.

Another use of differentiation is the determination of maxima and minima. Thus, in Fig. 10, $f(x)$ has a maximum at $x = x_1$ and a minimum at $x = x_2$. The following general rule can be stated:

$$f(x) \text{ is maximum if } f'(x) = 0 \text{ and } f''(x) < 0 \qquad (103)$$

$$f(x) \text{ is minimum if } f'(x) = 0 \text{ and } f''(x) > 0 \qquad (104)$$

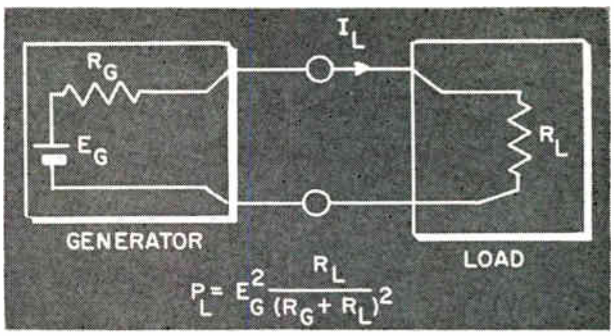


Fig. 11: Matching for maximum power transfer is illustrated.

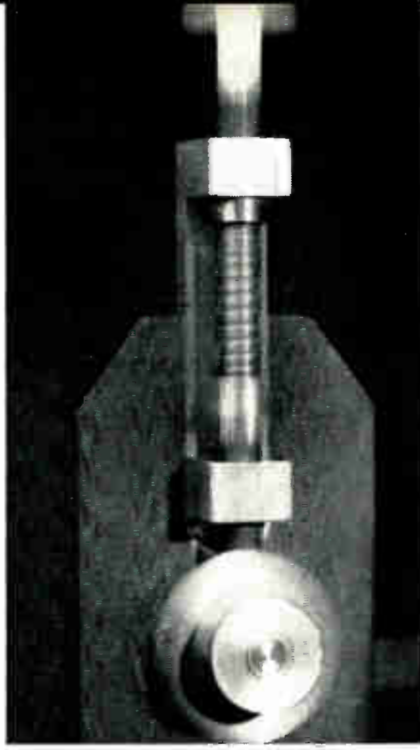
An example of this application is shown in Fig. 11. For the power in the load to be maximum, we must have (using Eq. 99 as well as elementary differentiating rules):

$$0 = \frac{dP_L}{dR_L} = E_g^2 \frac{(R_G + R_L)^2 - R_L \cdot 2(R_G + R_L)}{(R_G + R_L)^4} \qquad (105)$$

Taking out common factors, we get:

$$R_G + R_L - 2R_L = 0 \text{ or } \boxed{R_L = R_G} \qquad (106)$$

What's Going On Here?



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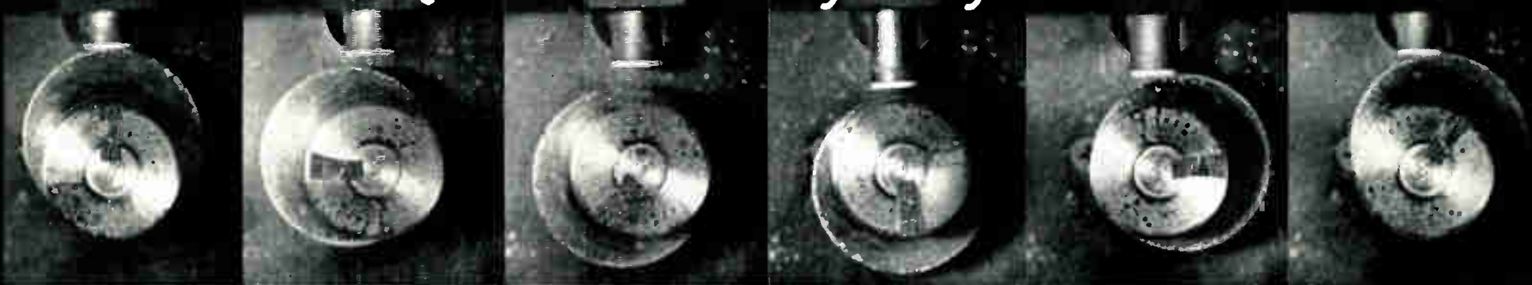

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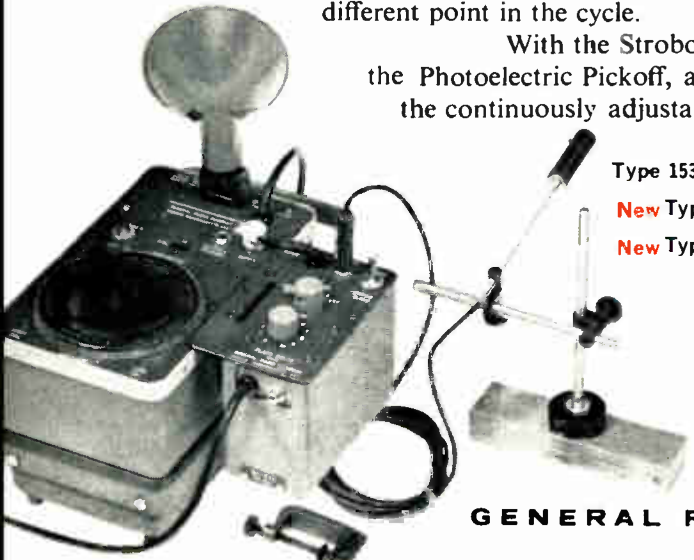

Type 1531-A Strobotac $275

New Type 1536-A Photoelectric Pickoff $65

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The Cam and Follower sequence was photographed at f22 on Polaroid 57 film (ASA 3000)

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MATHEMATICAL MODELS

(*Continued from page* 61)

It is readily shown that this "matched" value of R_L makes P_L maximum, not minimum. The resultant maximum available power from the generator is then given by:

$$P_{L\,max} = \frac{Eg^2}{2\,R_G} \qquad (107)$$

Integral Calculus

"Indefinite integration" is the inverse of differentiation. Thus, if $f(x)$ is the derivative of $g(x)$, then $g(x)$ plus an arbitrary constant is the "indefinite integral" of $f(x)$. Thus, symbolically;

$$f(x) = \frac{d}{dx}\, g\,(x) \longleftrightarrow g\,(x) + c = \int f\,(x)\,dx \qquad (108)$$

Rules and tables are available in any elementary calculus book for calculating the indefinite integral of a wide variety of algebraic, trigonometric and other functions of a variable such as "x".

Practical applications are concerned in most cases with "definite integrals." Fig. 12 shows the definition of a definite integral as the "net area" under the given function between the two limits. Here the stated expression is read: "integral of function $f(x)$ from $x = x_1$ to $x = x_2$". In cases where $f(x)$ has an *indefinite* integral $g(x) + c$, the definite integral has the value:

$$\int_{x = x_1}^{x_2} f\,(x)\,dx = g\,(x_2) - g\,(x_1) \qquad (109)$$

As an example, for $f(x) = 1 - 6x + 3x^2$, the indefinite integral is $x - 3x^2 + x^3$; the definite integral from to 1 to 2 can be written:

$$\int_1^2 (1 - 6x + 3x^2)\,dx = x - 3x^2 + x^3 \Big/_1^2$$

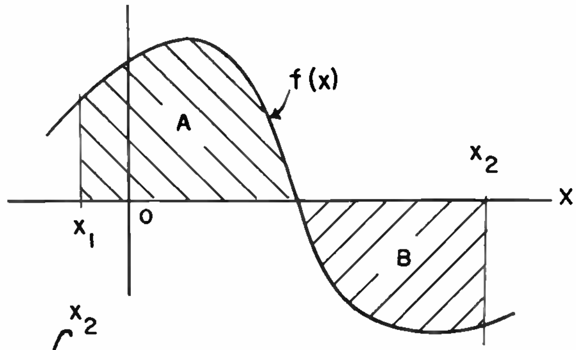
$$= (2 - 12 + 8) - (1 - 3 + 1)$$

$$= -2 + 1 = \boxed{-1} \qquad (110)$$

In many cases the indefinite integral is not available—here approximate solutions may be used (such as replacing the integral by an approximate sum) or in certain special cases techniques of higher mathematics, such as complex variable theory, may lead to an approximate or even exact solution in closed or series form.

A ready extension of the simple "integral" concept presented here is the multiple integral, such as:

$$\int_{x = x_1}^{x^2} \int_{y = y_1}^{y_2} f\,(x,\,y)\,dx\,dy \qquad (111)$$



$$\int_{X=X_1}^{X_2} f\,(x)\,dx = (\text{AREA A}) - (\text{AREA B})$$

Fig. 12: Plot illustrates definite integral—f(x).

representing the *volume* under the surface $z = f(x,\,y)$ in 3-dimensional space, bounded by vertical planes at $x = x_1,\, x_2;\ y = y_1,\, y_2$. Extensions to irregularly bounded volumes and to spaces of more than three dimensions are straightforward and sometimes extremely useful.

An important concept in dealing with definite integrals is the recognition that the argument of the function being integrated has the status of a "dummy variable." A definite integral is strictly a function of its limits, not of its dummy variable. Thus, the charge on a capacitor is related to the displacement current as follows:

$$q\,(t) = q\,(0) + \int_0^t i\,(\tau)\,d\tau \qquad (112)$$

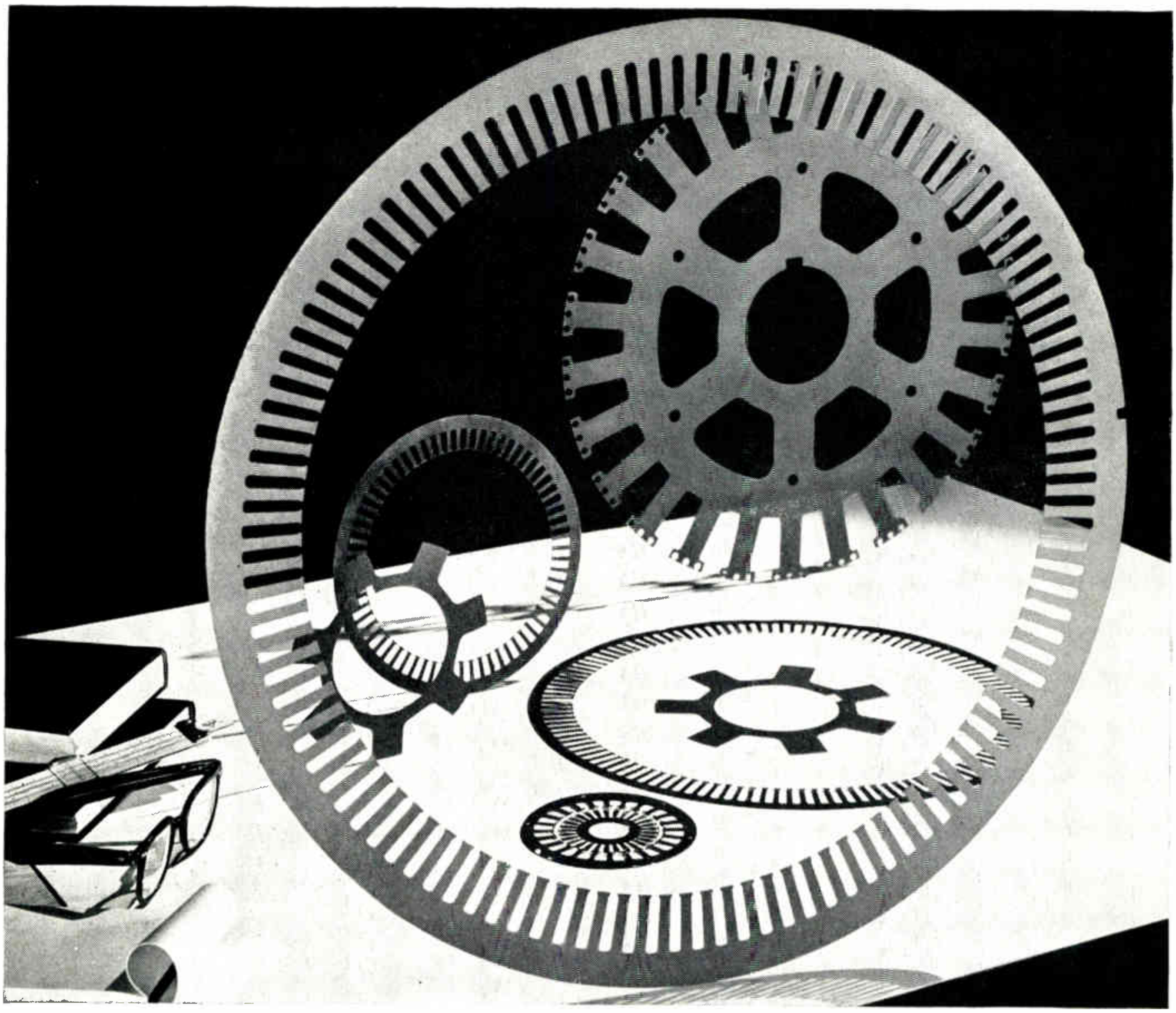
Thus while $i(t)$ is the *current* at time t; the *charge* at time t requires integration to be performed with respect to the "dummy variable" τ varying from 0 to t. Of course, differentiating (112) with respect to t gives the usual:

$$i(t) = \frac{d}{dt}\,q(t) \qquad (113)$$

$$\int_{x = x_1}^{x_2} f(x)\,dx = (\text{Area } A) - (\text{Area } B)$$

Differential Equations

A differential equation represents a generalization of the algebraic equation in which the "unknowns" are not simply numbers but *functions* of one or more independent variables. Further, not only the unknown function or functions appear explicitly in the differential equation, but also the first and possibly higher order derivatives with respect to the independent variable or variables, as the case may be. The present discussion will present the major classifications of types of differential equations showing where they are useful in setting up mathematical models for engineering problems.



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MATHEMATICAL MODELS

(Continued from page 63)

Ordinary vs. partial differential equations: Ordinary differential equations are those where there is *only one* independent variable. The unknowns are functions of this variable, all derivatives in the equations are with respect to this variable.

In most applications, the independent variable is *time;* the unknowns are the variations of physical quantities with time. Outstanding examples are circuit theory: unknowns are currents and/or voltage drops; also mechanics of rigid bodies: unknowns are positions, angles, speeds, etc.

Partial differential equations are those with *more than one* independent variables. Here the independent variables are usually position coordinates (x, y and z) and also time in some cases. Practically all problems in Electromagnetic Field Theory are solved by starting with a set of partial differential equations known as Maxwell's Equations. Additional examples of disciplines having basic mathematical models consisting of sets of partial differential equations are thermodynamics, fluid and gas dynamics, and the modern magnetohydrodynamics.

To facilitate setting up and solving partial-differential-equation mathematical models, formalisms of *vector calculus* have been developed as well as the techniques of *tensor analysis* for some of the more difficult problems in modern physics. To understand these techniques much careful study must be devoted to understanding the details of the symbology. For this reason we shall be satisfied with having *mentioned* the field of partial differential equations and concentrate on the ordinary variety. In many cases the techniques for solving the partial differential equations are simply techniques for reduction to an equivalent set of ordinary differential equations.

Linear differential equations: The general format of this type of equation is a follows:

$$a_2(t)\,f''(t) + a_1(t)\,f'(t) + a_0(t)\,f(t) = g(t) \qquad (114)$$

This is a *second order* linear differential equation. $a_0(t)$, $a_1(t)$, $a_2(t)$ and $g(t)$ are *known* functions of the independent variable t; $f(t)$ is the unknown function. "Solution" consists in obtaining $f(t)$ to satisfy (114) over a specified range of t values. Extension to *higher order* simply consists in adding terms with corresponding higher order derivatives of $f(t)$. Distinction from *non-linear* differential equations lies in the fact that the coefficients a_0, a_1, and a_2 are known functions of t rather than functions of the unknown $f(t)$ or its derivatives.

An important consequence of the form of (114) is the fact that "superposition" with respect to the "driving force" $g(t)$ is satisfied. Thus, if $f_1(t)$ is a solution when $g(t) = g_1(t)$ and $f_2(t)$ is a solution when $g(t) = g_2(t)$, then $f_1(t) + f_2(t)$ will be a solution when $g(t) = g_1(t) + g_2(t)$.

Another consequence is the fact that the general solution to a linear differential equation will be of the form:

$$f(t) = f_p(t) + \sum_{n=1}^{r} c_n\, f_{cn}(t) \qquad (115)$$

Here $f_p(t)$ is called a "particular solution" being any function which satisfies the equation with the given $g(t)$; the sum is designated as the "complementary function" being the most general form of the solution to the "homogeneous equation," i.e., that in which $g(t) = 0$. Here r is equal to the *order* of the differential equation ($r = 2$ for Eq. 114); the functions $f_{cn}(t)$ are the set of r *linearly independent* (i.e., no one of the set can be expressed for all pertinent t as a linear combination of the rest) solutions to the homogeneous equation; the c_n are arbitrary numerical constants.

Thus, the use of linear differential equations as mathematical models of engineering situations requires not only the equation but a set of *boundary conditions* from which the r arbitrary constant values can be found. These can be introduced as specification of $f(t)$ and/or one or more of its derivatives at fixed value or values of time. As an example, consider:

$$f''(t) + 3\,f'(t) + 2\,f(t) = 4 \qquad (116)$$

The general solution is given by:

$$f(t) = 2 + c_1\, e^{-t} + c_2\, e^{-2t} \qquad (117)$$

A possible set of boundary conditions is: $f(o) = f'(_o) = 0$. These give rise to:

$$c_1 + c_2 = -2 \qquad (118a)$$

$$c_1 + 2c_2 = 2 \qquad (118b)$$

Solving (118) for c_1 and c_2 gives:

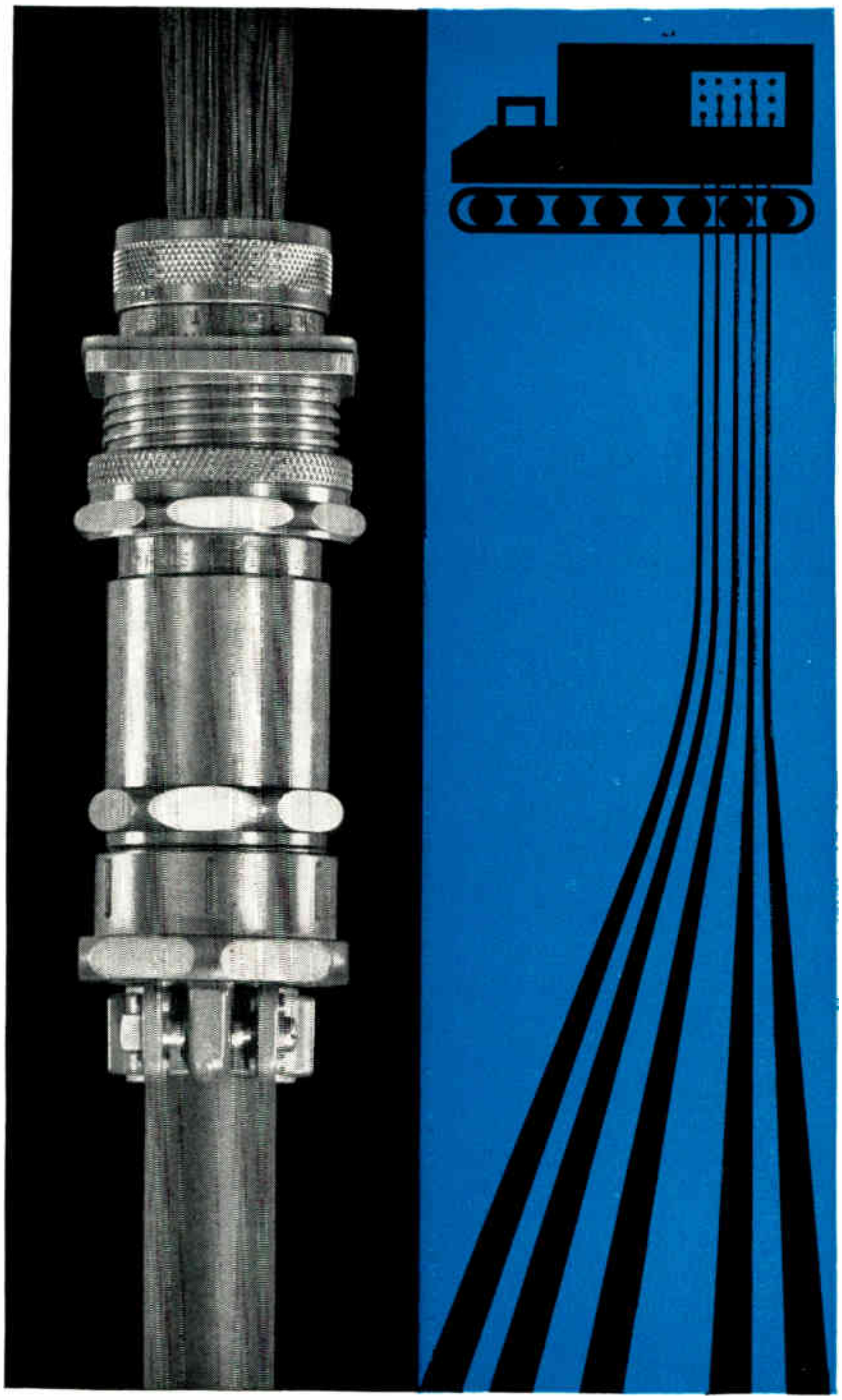
$$c_1 = -6;\ c_2 = 4 \qquad (119)$$

so that the final solution is:

$$f(t) = 2 - 6\,e^{-t} + 4\,e^{-2t} \qquad (120)$$

The reader can prove by substitution that (120) satisfies (116) with the stated boundary conditions at $t = 0$.

General applications: Much of circuit and system theory developed over the last few decades has been concerned with solution methods for *sets of linear differential equations with constant coefficients.* "Constant coefficients" refers to the case exemplified by Eq. 116 or more generally (114) with a_0, a_1 and a_2 *not* varying with time. "Sets of" equations refers to situations in which there are several rather than only



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MATHEMATICAL MODELS

(*Continued from page* 65)

one unknown functions of time: e.g., the voltages and currents at different parts of a network. Matrix methods are frequently used as "bookkeeping" aids—to keep straight the different variables and coefficients.

We close this section by a discussion of non-linear differential equations. Most physical systems require sets of non-linear differential equations for a *complete* description of their behavior. However, the analysis tools for handling such complete mathematical models are rather meager. As a result much analytical effort has been directed toward solving problems where the unknowns are known to vary over *restricted ranges* over which linearity is a valid assumption. Thus the theory of "small-signal" behavior of vacuum tube and transistor amplifiers. In many cases such restricted analyses prove sufficient for practical needs. In cases where it is necessary to go beyond the linear regions it is usual to proceed experimentally, either by building a physical model of the device or by simulating it on an analog or digital computer.

Linear, Time Invariant Systems

We deal here with communication, control, and power systems having mathematical models equivalent to sets of linear differential equations with constant coefficients. The main problems which arise are the pre-determination or "analysis" of "outputs" resulting from given "inputs," knowing what is in the system. (Of course, such techniques must also be understood to solve the design problem of synthesizing a system to have a desired response.) The main solution techniques in use these days are of the following three categories:

a. Steady-state sinusoidal solutions.

b. Solutions via superposition.

c. Operational, Laplace-Transform methods.

Our attempt here will be to point out the main features of each solution method and indicate what kind of problems it is suited for. Of course, in many actual problems, a number of methods may be useful or even a combination of methods.

Steady-state sinusoidal eqs.: These, of course, arise continually in electric power and communication problems. Consider a typical differential equation:

$$a_2\, v''(t) + a_1\, v'(t) + a_o\, v(t) = e(t). \qquad (121)$$

Desired is the response to a sinusoidal applied voltage: $e(t)$ = applied voltage, $v(t)$ = desired response, constants a_2, a_1, a_0 depend on network element values. We have applied:

$$e(t) = E_o \cos(2\pi f t + \theta) \qquad (122)$$

The technique is to solve by phasors. In equation replace $e(t)$, $v(t)$, by $Ee^{j\omega t}$ and $Ve^{j\omega t}$ where $\omega = 2\pi f$ and E, V are complex phasors, simplifying these results

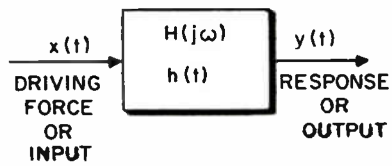
$$[a_2 (j\omega)^2 + a_1 j\omega + a_o]\, V = E \qquad (123)$$

Solving (123) for V, letting $E = E_o e^{j\theta}$, the desired solution for $v(t)$ is then:

$$v(t) = Re\left\{Ve^{j\omega t}\right\} \qquad (124)$$

Note that (123) differs from (121) in two respects: first, the independent variable is ω rather than t; then, it is an algebraic rather than a differential equation.

Fig. 13: Generalized time-invariant linear system.



tion. This latter property enables steady-state ac circuits to be solved by the same basic operations as dc circuits. Thus the "impedance concept":

$$\text{for a resistor:} \quad Z = R \qquad (125a)$$
$$\text{for an inductor:} \quad Z = j\omega L \qquad (125b)$$
$$\text{for a capacitor:} \quad Z = 1/j\omega C \qquad (125c)$$

From here on Kirchhoff's laws give a set of linear algebraic equations which result in the desired steady-state solutions.

Superposition methods: If a driving force to a linear system can be expressed as a suitable sum of "simple" driving forces, then the response to the given driving force will be representable as the sum of the responses to the simple driving forces. The trick is to choose the "simple" driving forces so that the mechanics of solution need be gone through only once. Two such simple types of driving forces are:

a. exponential sinusoid $e^{j\omega t}$

b. unit impulse

First let us examine the exponential sinusoid method. (Refer to general system block diagram of Fig. 13.) A wide class of *input* functions $x(t)$ can be represented by:

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\omega) e^{j\omega t}\, d\omega \qquad (126)$$

This integral can be thought of as the infinite sum of a number of sinusoids $e^{j\omega t}$. Applying superposition, the general response will be:

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MATHEMATICAL MODELS

(*Continued from page 67*)

$$y(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(j\omega)\, H(j\omega) e^{j\omega t}\, d\omega \qquad (127)$$

Where $H(j\omega)$ is the steady state response function of steady-state sinusoidal eq. above based on a system input $e^{j\omega t}$. The integral of (127) gives the desired solution; however we need a method of calculating $x(j\omega)$ to satisfy (126) for the given $x(t)$. It is readily shown that $X(j\omega)$ is the *Fourier Integral* of $x(t)$, given by:

$$X(j\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt \qquad (128)$$

Obviously (127) represents an *Inverse Fourier Transformation.* In many practical cases direct and inverse Fourier transformations can be looked up in a transform table.

Use of *Fourier series* representations of *periodic waveforms* can be considered a special case of this overall technique.

The Fourier Integral technique is usually best suited to problems where the input $x(t)$ is of effectively *finite duration,* so that the integral (128) has a finite value for all real ω. Such problems arise continually in *radar* system studies and frequently in radio communications.

The second method is based on the unit impulse function. Rather than give its rigorous mathematical definition we give a simple graphical representation in Fig. 14. In words, $\delta(t - \tau)$ is "a unit impulse occurring at $t = \tau$", or "a function having *unit area* all confined at the point $t = \tau$".

For a time invariant network we can define a function $h(t)$ as the response of the system to a unit impulse applied at $t = 0$; then the response to $\delta(t - \tau)$ will simply be the time-displaced replica of $h(t)$, namely $h(t - \tau)$.

The final tool required in this method is the decomposition of an arbitrary driving force into an infinite sum of time-displaced impulse functions as shown in Fig. 15. Thus, applying the superposition principle, the response to the arbitrary $x(t)$ is given by:

$$y(t) = \int_{-\infty}^{\infty} x(\tau)\, h(t - \tau)\, d\tau \qquad (129)$$

This is the well-known *"convolution integral"* in which τ is the "dummy variable." It can also be

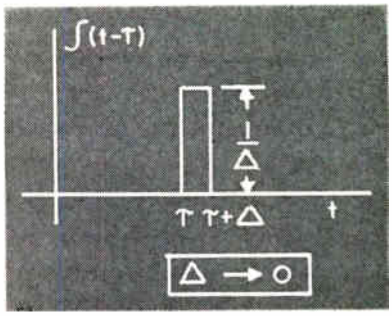

Fig. 14: Graphic representation of unit impulse.

written in the equivalent form:

$$y(t) = \int_{-\infty}^{\infty} h(\tau)\, x(t - \tau)\, d\tau \qquad (130)$$

This integral can be used directly in obtaining responses or in approximating responses. It is the basis of *time-domain synthesis* of electric networks. It is particularly useful for systems which are not simple lumped-parameter electric networks but contain delay elements or possibly unknown elements; in the latter case a single impulse response measurement can serve for predicting response to arbitrary inputs.

It is well to mention that the two superposition methods given above are related in that the system

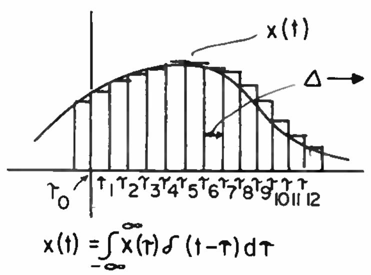

Fig. 15: Unit impulse decomposition of arbitrary driving force.

descriptive functions $H(j\omega)$ and $h(t)$ are "Fourier mates"; that is:

$$H(j\omega) = \int_{-\infty}^{\infty} h(t)\, e^{-j\omega t}\, dt;\; h(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} H(j\omega)\, e^{j\omega t}\, d\omega \qquad (131)$$

Laplace Transform methods: The usual starting point in the application of this technique is a set of linear, constant parameter integro-differential equations, with independent variable t, driving forces $x_1(t)$, $x_2(t)$, etc., and unknowns $y_1(t)$, $y_2(t)$, etc. These equations are then transformed into a set of linear algebraic equations with independent variables parameter s as follows:

The Laplace transform of a function $z(t)$ is given by:

$$L \left\{ z(t) \right\} \equiv Z(s) = \int_0^\infty z(t)\, e^{-st}\, dt \qquad (132)$$

Other useful rules:

$$L \left\{ z'(t) \right\} = s\, Z(s) - z(0) \qquad (133)$$

$$L \left\{ \int_0^t z(t)\, dt \right\} = \frac{1}{s} Z(s) \qquad (134)$$

$$L \left\{ \frac{1}{s+a} \right\} = e^{-at} \quad (t > o)\,. \qquad (135)$$

The solution to the algebraic set of equations gives expressions for the unknown $Y_1(s)$, $Y_2(s)$ .... in terms of s. For lumped parameter networks driven by constant, ramp, exponentially or sinusoidally varying inputs, the $Y(s)$ will be be ratios of polynomials in s. Decomposition by partial fraction expansion (see Partial Fraction Expansion) leads to the usual form of solution (a sum of exponentials) after inversion correspondences are taken account of (see (135) above). The solution so obtained represents the solution to the original set of integro-differential equations with boundary conditions $x(0)$, $x'(0)$, etc., resulting from repeated application of rule 133 above. For the system "initially at rest" a popular case, these quantities may all be zero; however they may also be readily calculated in problems concerned with evaluation of transients caused by open or short circuits in operating systems.

Aside from providing a good basis for transient calculations of power system faults, Laplace transforms are almost universally used in design of control systems with feedback. Behavior of response functions in the s-plane can be closely related to rapidity of time response and is of great importance to system stability.

It should be pointed out that major objectives in engineering mathematics have been the utilization, formalization, and extension of the system analysis techniques presented in this section. An important tool of mathematical analysis in evaluating special inverse Fourier and Laplace transforms is the Theory-of-Functions-of-a-Complex-Variable, especially its concepts of "analytic function" and the "theory of residues." Another type of transform technique that has recently become popular is the method of "z-transforms"—having the same relation to "difference equations" as Laplace transforms have to differential equations (note: in difference equations, the unknowns can change only at discrete values of the independent variable, time).

Conclusions

Up to this point we have covered a considerable segment of the mathematical techniques in use today in engineering analysis and system design. We close by mentioning some concepts not mentioned above and also by giving some key references that we have found useful.

First we have a group of functions usually defined as solutions to certain linear differential equations with variable coefficients, such as Bessel Functions, Modified Bessel Functions, Legendre Functions, Hypergeometric Functions. Such equations frequently arise in Field problems, in situations with specified symmetry, after some preliminary manipulations of Maxwell's equations (e.g. via "Laplace's equation" or the "wave equation"). These functions have been thoroughly studied, solutions in terms of infinite series as functions of complex arguments have found diverse useful applications. Thus Bessel Functions are widely used in signal theory (Spectral decomposition of Frequency-Modulated carriers), iterated filter analysis, as well as study of electromagnetic fields with cylindrical symmetry. Modified Bessel Functions arise in the solution of voltages and currents on a transmission line.

Next we should mention the important fields of *probability and statistics* which are recognized increasingly as having importance in general system analysis and design. To some extent techniques useful in circuit analysis and design have parallel applications here. Important keystones are the higher mathematical functions such as the probability or error function as well as others such as the modified Bessel Function. These disciplines are of importance in engineering problems in evaluation of measurement accuracies and also when effects of "random noise" must be considered.

Concerning references, the earlier portions of this paper are well-covered by standard texts on College Algebra, Differential and Integral Calculus, Analytic Geometry. Other texts found useful to the author covering the later items are:

References

a. H. Margenau and G. M. Murphy—*The Mathematics of Physics and Chemistry*—D. van Nostrand (Good broad coverage of many items).

b. E. Jahnke and F. Emde—*Tables of Functions with Formulae and Curves*—*Dover* (Good numerical tables-higher functions).

c. *Mathematical Tables* from *Handbook of Physics and Chemistry*—Chemical Rubber Publishing Co. (Good numerical tables-basic).

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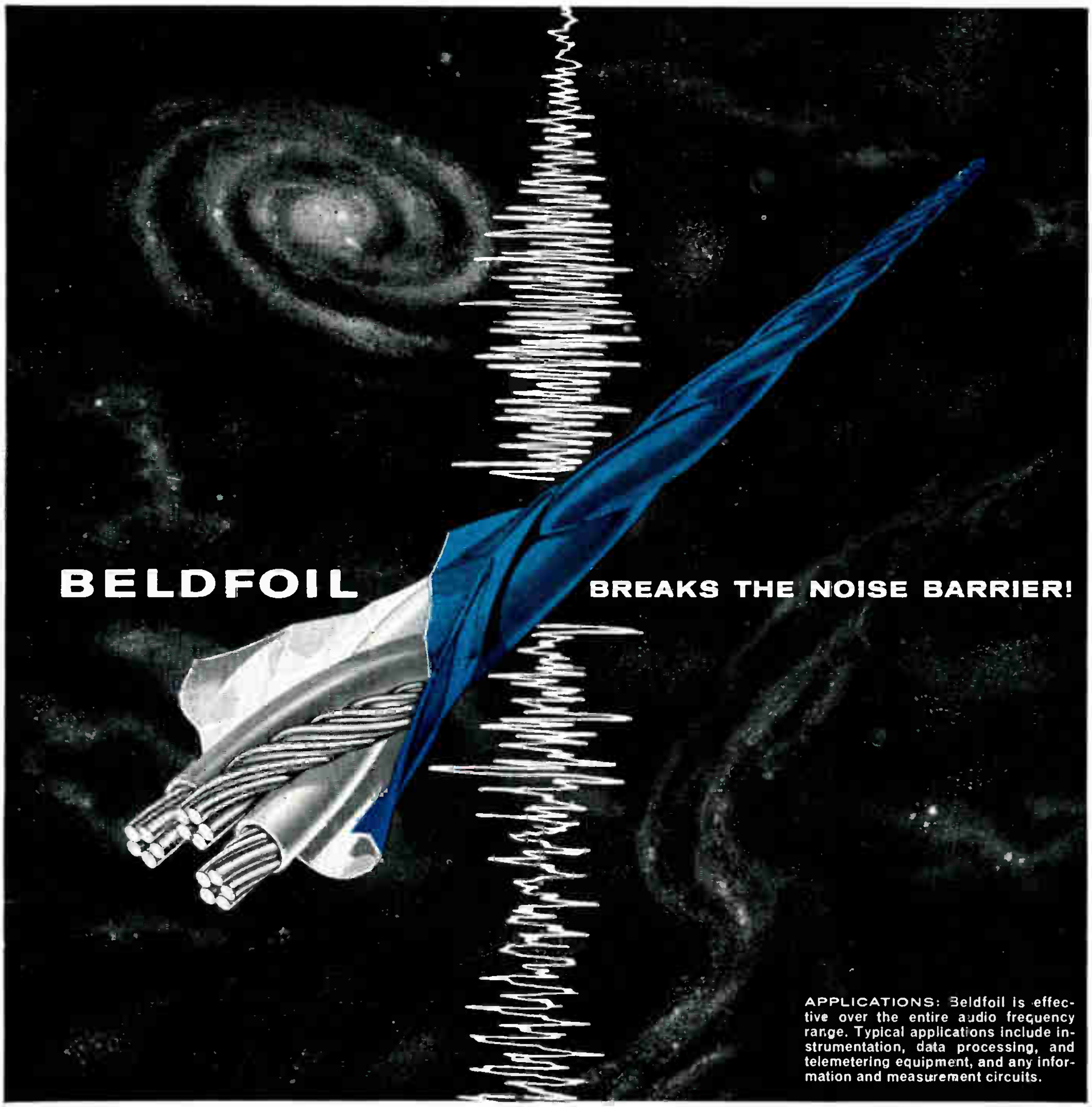
e. A. Papoulis—*The Fourier Integral and its Applications*—McGraw Hill (Good theory).

f. M. F. Gardner and J. L. Barnes—*Transients in Linear Systems*—J. Wiley and Sons (Good study of Laplace transforms—applications to circuit analysis and comprehensive table of mates).

g. J. G. Truxal—*Automatic Feedback Control System Synthesis*—McGraw Hill (Good introduction to modern design concepts).



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8-1-3

WHAT IS BELDFOIL? It's a lamination of aluminum foil with Mylar** that provides a high dielectric insulation. A patented Belden method of folding*** gives definite benefits. An inner fold creates a continuous metallic path around the surface of the cable. This eliminates any possible inductive effects. An outer fold tucks the cut edge of the aluminum under the Mylar. This gives complete isolation from other adjacent shielded cables.

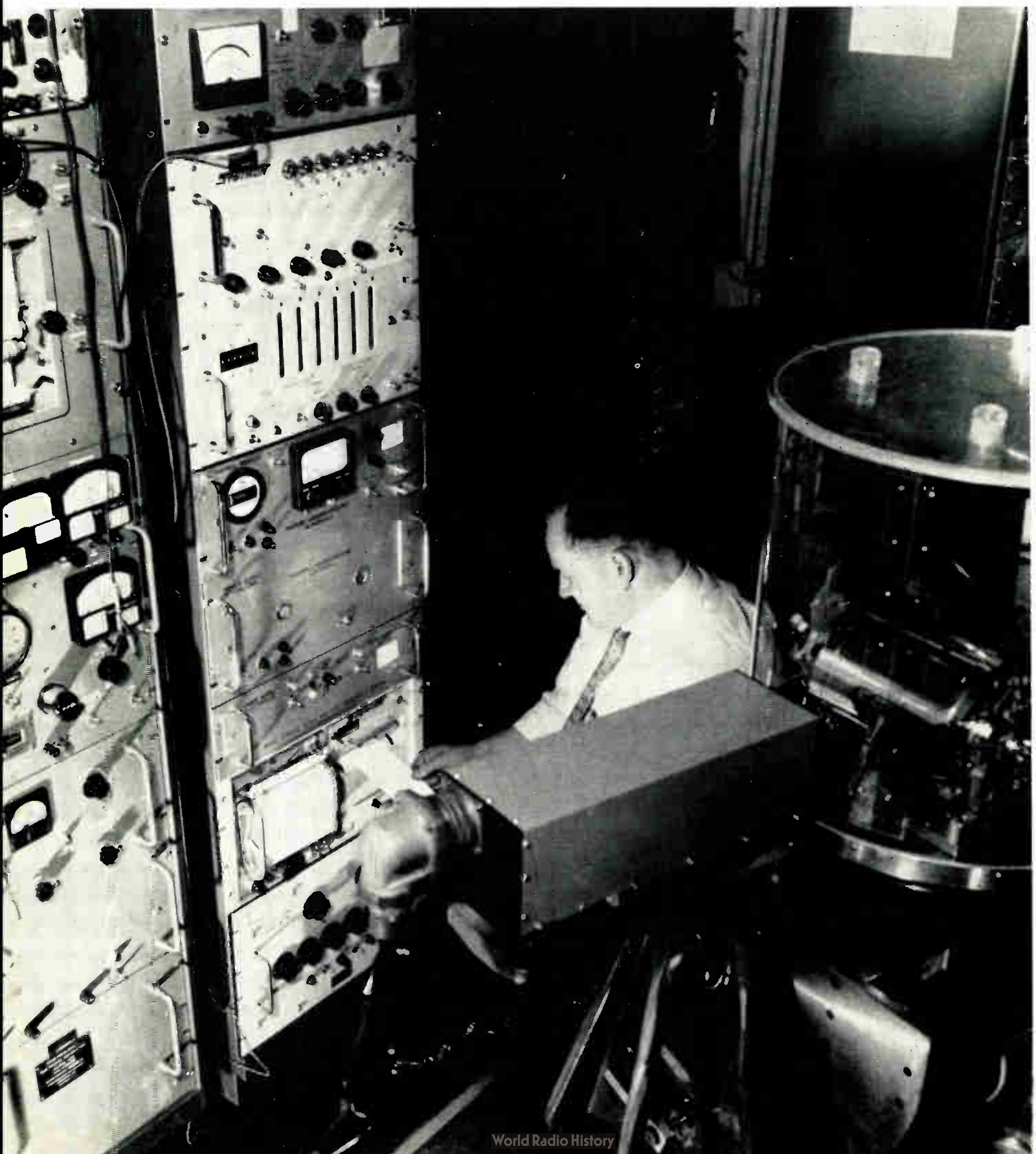
Typical cross section looks like this.

*Belden Trademark Reg. U.S. Patent Office
**du Pont Trademark ***U.S. Patent 3,032,604

Belden
WIREMAKER FOR INDUSTRY
SINCE 1902 — CHICAGO

IMPROVING RATE TABLES FOR GYRO TESTING

Changes for gyro acceptance testing and rate requirements reduce high cost and loss of time from retesting and/or rejections. This article describes equipment which exceeds present specifications and relates the way this is accomplished.



GYROS MUST BE TESTED AFTER THEY ARE BUILT to learn how much they will drift. This drift must not exceed a specified rate or rejection occurs.

New or repaired gyros are tested on a rate table. This rate table cancels the effect of the earth's motion so that actual gyro drift can be found and plotted.

The addition of a device to the rate table will improve its testing ability and will shorten the testing time.

* * *

With the advent of rate table control during periods as small as 20 msec. of time, it is now possible to hold the band-width to better than 0.001 degrees per hr. during intervals as small as 0.36 sec. of arc . . .

In preparing to enter this market, we were interested in learning:

1. The effect of smooth rates on gyros under test.
2. The short-term drift and rate characteristics of sidereal rate tables.
3. Whether advanced instrumentation could overcome the perturbations which are generated by present-day test equipment, with the result that these uncertainties are attributed to poor performance on the part of the gyro.
4. A method to control the speed of the rate tables used in the acceptance testing of gyros to extend their usefulness.

With the above in mind, we applied more than two years experience with MIDARM® (Micro-Dynamic Angle and Rate Monitor) for monitoring table rotation (see Fig. 1) and extended the system to include rate control through a feed-back, closed-loop (rate-control) network.

The MIDARM system is comprised of an optical unit and an electronic unit. (See Fig. 1.) Light from a monochromatic light point source (1) passes through a grid (2), a beamsplitter (3), a collimating lens (4), and strikes a mirror (5) mounted on the rotating specimen to be tested (6). The image is reflected back into the system where it is directed by a beamsplitter (7) to the reference photosensor (8). The image is also reflected by beamsplitter through a second grid (9) to the control photosensor (10).

Rate Table Performance

Today, the gyro to be tested is mounted on a sidereal rate table and its drift characteristics are measured by recording the output of its gimbal position sensors. Its long-term drift, excluding the apparent drift caused by the earth's rotation, usually falls within the specifications. This is true since much of the drift error caused by bearings and pickup drag tend to be random in nature. That is, the drift occurs in either direction about the inertial axis and eventually tends to cancel itself.

During short-term periods, however, drift errors are often found to be excessive and the perturbations —in many cases—exceed the limits. These drift errors, therefore, could cause gross errors in the instantaneous performance of the gyro, even though they tend to cancel themselves over the long-term because of averaging. The gyro manufacturer assumes that the gyro is at fault and rejects it . . . the only safe assumption when a million-dollar missile's success is dependent upon the accuracy of the gyros in the guidance system.

The sidereal rate table, then, is a test device used to develop earth rates, vectorial additions to earth's rate, or to buck-out earth's rate so that only true drift errors remain.

Rate table performance for the testing of advanced gyros requires a long-term drift rate of 0.001°/hr. (or 0.001 arc-sec. per sec. of time, since they are the same rate) so that drift errors can be resolved into

The trademark MIDARM is registered by Razdow Laboratories, Inc., Newark, N. J.

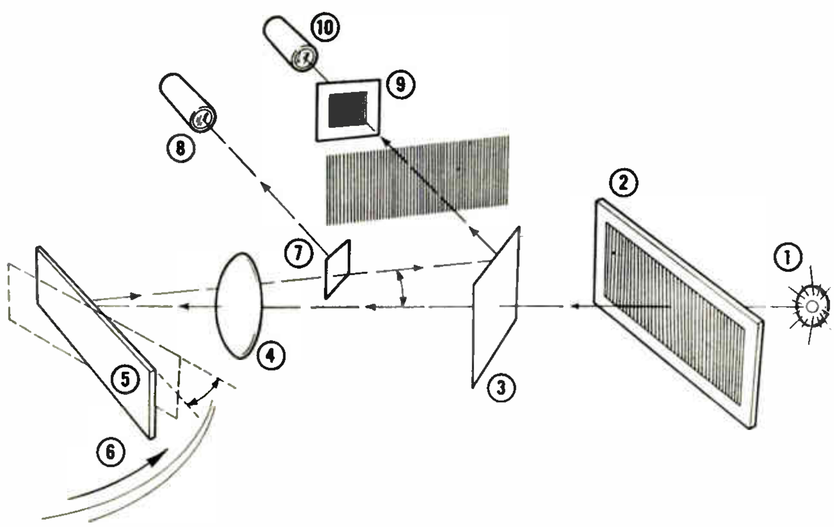


Fig. 1 (right): The MIDARM system is comprised of an optical unit and an electronic unit. The simplified diagram shows how MIDARM operates.

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Supervisor,
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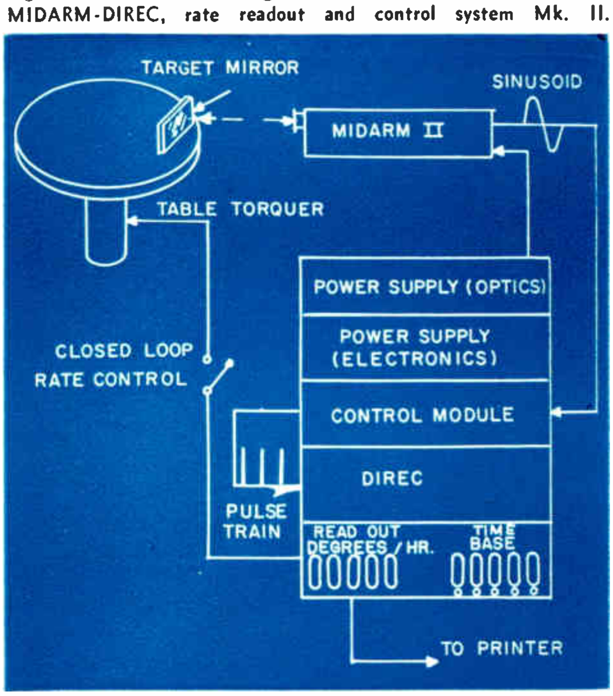
their separate components and analyzed to find their cause.

The usual pickoff or readout devices (either optical or magnetic) are, at best, accurate to within 2 sec. of arc. With this positional accuracy it requires 2000 sec. of time to achieve 0.001 arc-sec. per sec., since: $T=d/R$, where R is the desired rate accuracy, d is the accuracy of the pickoff, and T is the time of measurement.

A second factor must also be introduced to insure proper test conditions, i.e., a smooth, or constant, rate should be held during the period of evaluation. Since the best of the conventional optical and magnetic pickoffs determine table position every 0.1°, they measure table position every 24 sec. of time when the table is turning at one (1) earth rate, which is equal to 15°/hr. or 15 arc-sec. per sec. of time. It, therefore, follows that short-term rate control cannot be done to a drift rate of 0.001 arc-sec. per sec. if a rate control or correctional signal is being developed every 24 sec. of time, when 2000 sec. of time are needed for a system with 2-arc-sec. accuracy.

The above may appear to be a misstatement. But, it is this misunderstanding which can lead to gross errors in drift measurement. The table could wander as much as 0.024 arc-sec. during the 0.1° interval *if* the rate error was constant and did *not* exceed 0.001 arc-sec. per sec. When this condition occurs, the gyro under evaluation reacts to an error which has been

Fig. 2: Schematic drawing of the various sections of the MIDARM-DIREC, rate readout and control system Mk. II.



caused by the control interval of the rate control system being used with the sidereal rate table.

Advanced Table Position Monitor

The first (and perhaps most obvious) conclusion from the above is that a pickoff, or monitor, with a shorter period and higher accuracy should be better able to correct both of the stated causes of error. Here, then, is where Midarm enters the story. With an accuracy of 0.1 arc-sec., the electro-optical sensor reduces the time to achieve 0.001 to 100 sec. of time (since d equals $R \times T$). The Midarm Mark II (see photograph) also satisfies the second condition since its period of 10.4 arc-sec. means that a control or correctional signal is being developed each 0.67 sec. of time at a rate of 15 arc-sec. per sec. of time. This means that the gyro can be held within the specification and that the measurement can be made in 1/20th the time needed by a pickoff with 2 arc-sec. accuracy. It also means that short-term drift measurements can be made to the same accuracy as those required during long-term testing.

An interest was shown in a sensor with a two-phase output and so Midarm Mark IV (see photograph) was developed. Sensor has a 0.1 arc-sec. accuracy so that the time to achieve 0.001°/hr. at one (1) earth rate is still 100 sec. of time. The period is divided by an electronic follower so that it can be used effectively as an interval of 0.36 sec. of arc. Therefore, it lends itself for use with ultra-precise rate control needs since the time period for the generation of the interval is 20 msec.

Rate Control with DIREC and CLEAR

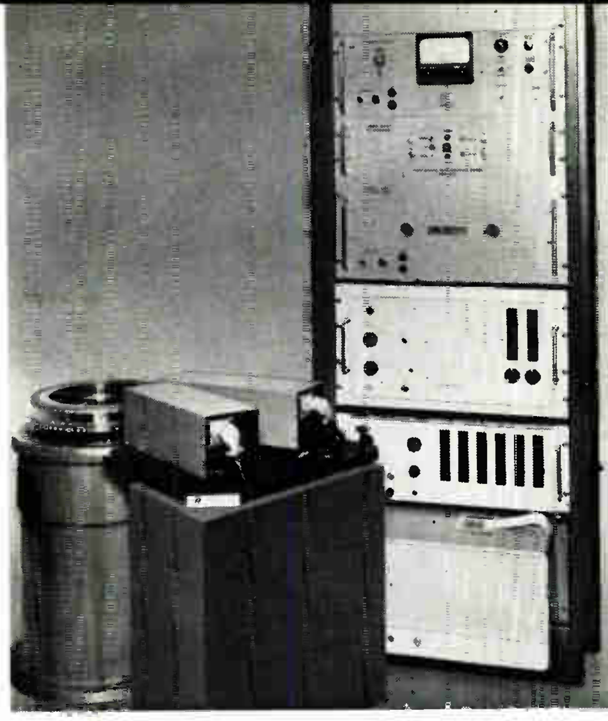
In the conventional rate control systems the average rate can be found but they require longer periods of time than do the Midarm systems. Here, though, we must remind the reader that smooth rates are also necessary and that the system should be able to operate within the band-width or tolerance of the gyro spec. These two are important since widely varying "instantaneous" table rates caused by gearing and bearing inaccuracies, motor lamination slotting effects, and out-of-roundness conditions cause corresponding variations in the drift rate of the gyro under test; and are possible causes for the rejection of advanced gyros. These conditions are most likely to influence the conventional systems with their 0.1° periods and the greater the chance that small, fast perturbations will go uncontrolled.

With the Midarm systems, the rate table moving at 1 earth rate turns less than 0.5° in 100 sec. of time as compared to a rotation of better than 8° in 2000 sec. The smaller test interval is advantageous since the errors from slot effects and inequities in the drive system have less chance to exert their influence as major causes of gyro error. This is important since the rate errors caused by table perturbations show up as drift errors in the output of the gyro. At the same time, genuine drift errors in gyro performance are caused by gyro bearing inequities, pickup drag, air bearing turbine effects, dynamic unbalance, etc. Since both the gyro drift error and the table perturbations occur at the same time they appear as gyro drift errors.

Because the two causes of error cannot be separated and the level of gyro drift errors should not exceed 0.001 arc-sec. per sec. of time, it is clear that the element of high-order control is one of the major needs in an advanced sidereal rate control system. This need can be satisfied by controlling the speed of the table through its servo loop, but only when the error signal being developed is an instantaneous and nearly continuous representation of what is taking place between the actual rate and the desired rate of rotation.

In the Midarm-Direc (Digital Rate Error Computer) system (see Fig. 2), the rate measurement is made each 10.4 sec. of arc. The time base for the desired rate of rotation is "set" into the 5-decade controller which will operate over a range from 0.5 to 100 times earth's rate. The time period between Midarm cycles is compared to a reference period and the difference, if any, is fed to the table torquer. The system is nearly continuous, since it is responding to the slightest change in rate at 1.5 CPS when the rate of rotation is 15 arc-sec. per sec. The signal of the Midarm-Direc is a deviation from the desired rate, which is used to smooth the motion of the table to improve the positional accuracy of the gyro under test. Since the control signal represents a change from the desired rate, it can also be fed into a commercial printer to record the deviations during the period of observation.

Since the response characteristics of the torquer and the table are the limiting factors, the system response is more on the order of 50 msec. The correction signal, however, builds up a bias in the torquer which is, for all practical purposes, continuous, so that the response characteristics of the system are very smooth.



Here is the 360° continuous MIDARM-CLEAR, Mark IV system.

In the Midarm-Clear (Closed-Loop Error of Angular Rate) system, the 2-phase output of the Mark IV sensor is fed into an electronic divide-down circuit so that positional information is produced every 0.36 sec. of arc. The time between these very small periods is compared to the output of an oscillator with the difference, again, representing the rate error of the sidereal rate table. The error signal is amplified and fed to the table torquer during time periods which are as small as 20 msec.

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WHAT'S NEW

DELAY LINES

THESE SUPERCONDUCTIVE DELAY LINES were developed as ready access memory units for logic functions operating at clock rates above 125MC.

As computer clock speeds increase, it becomes increasingly difficult to provide memory capability. But with each increase in speed, the capacity of a transmission line for data storage increases accordingly. For example, at a 125MC clock rate, a line providing a delay of 800nsec. has a 100-bit storage capacity. The delay-line memory is a space saver also. A 1μsec. delay line that stores 125 bits at 125MC occupies a volume of 2⅞ in. diameter by 1-7/16 in. high.

The superconductive delay line is based on propagation delay resulting when a signal travels through a long length of small-diameter coaxial cable. This technique uses low temperatures (4.2°K) to eliminate conductor losses and reduce dielectric losses.

The units give precise delay times from 100 to 2000nsec., with an insertion loss of less than 1db per μsec. with 8nsec. pulses. Rise time is under 0.5nsec. Martin Co., a div. of Martin Marietta Corp., Baltimore 3, Md.

As a result of extended test programs, common ceramic capacitor failure modes and the mechanisms involved are known and understood. A method developed to fluorinate the dielectric material and advanced encapsulation techniques now establish a high degree of reliability in the ceramic capacitor. Their details are presented.

IMPROVEMENTS INCREASE CERAMIC CAPACITOR RELIABILITY

UNDERSTANDING THE RELIABILITY OF CERAMIC CAPACITORS needs a thorough knowledge of all factors which contribute toward the performance of these components. Most significant of these are the nature and characteristic of the dielectric, method of construction, encapsulating materials, failure modes and performance under varying conditions of use. The relationship of each to component reliability is shown and the results of a new approach to high reliability construction are examined here (see Fig. 1).

* * *

The significant feature of any ceramic capacitor is its dielectric. It is possible to manufacture ceramic dielectrics with a dielectric constant (K) as low as 8 to more than 10,000. This wide range can be best appreciated when one considers that air has a K of 1, mica 7 and paper only 4 or 5.

The history of this remarkable dielectric is old and new—old because the art of ceramics is ancient, and new because recent synthetic materials are the main elements of modern compositions. Early synthetic materials, normally steatite, had properties which approached those of mica. Though not superior to mica in all respects, some of the new ceramic dielectrics had features that no other material had.

The use of barium titanate soon followed, and a whole new type of capacitor industry took root. Most of the raw materials presently used are manufactured solely for electronic ceramic devices and are constantly being improved.

Construction of Capacitors

The ceramic dielectric is formed from a carefully blended mixture of raw materials consisting mainly of oxides of the alkaline earths plus additives of other elements, including rare earths. By using set ceramic forming methods, this mixture, or body, can be pressed, extruded, sprayed or cast into almost any convenient shape. See Fig. 2. The green ceramic piece is fired to high temperatures where a solid state reaction or sintering can take place. The chemistry and physics of this reaction are highly complex, but the net result is a nonporous, hard ceramic, suitable for capacitor dielectrics. The most familiar form of the ceramic dielectric has been the disc, or coin shape. However, tubulars, slugs, and rectangular plates are also used.

To form a capacitor, electrodes are fixed to opposite surfaces of the dielectric. The most common electrode material is a glass-filled, silver paste or fluid which is either screened, sprayed or dipped on the ceramic surface. The "electroded" ceramic is then fired at about 1400°F. At this temperature the glass in the silver paste melts and permanently bonds the silver to the ceramic surface. Now, lead wires are attached to the disc, normally by dip-soldering. The capacitor is de-greased, cleaned of soldering flux and encapsulated with a phenolic resin. The phenolic dip contains volatile solvents which evaporate and leave a porous network of capillary voids. This porous matrix is vacuum impregnated with a special wax which protects the capacitor from the rigors of normal humidity environment.

Military and EIA Grouping

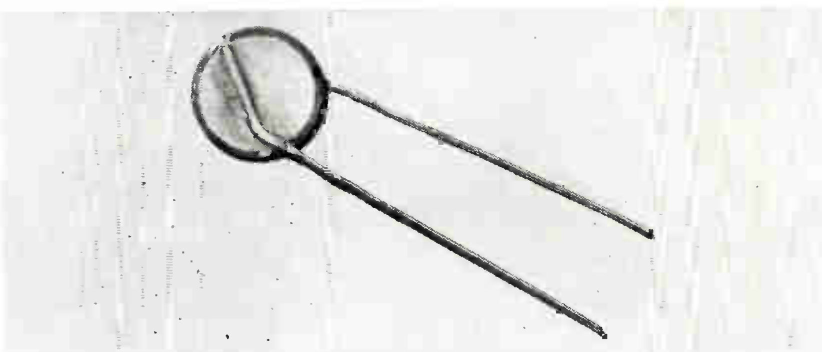
Ceramic capacitors have been divided into two basic groups based on dielectric characteristic and application: Temperature compensating and general purpose fixed ceramic capacitors.

Definition of each group per military and EIA specs is as follows.

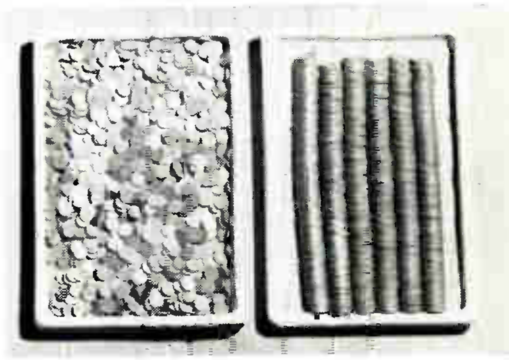
By LARRY NORDQUIST
Ceramic Engineering Mgr.
CDE Div.
Federal Pacific Elec. Co.
50 Paris St.
Newark 1, N.J.

Fluorinated disc ceramic capacitors developed by Cornell-Dubilier when thrust into 1000°F still maintain original characteristics. The hot flame only chars the capacitor's jacket made of rubber.

Of 1000 capacitors life tested at 200°C and 500 vdc, one failed after 763 hours. No other failures after 1.7×10^6 component-hrs.



This is a capacitor that failed. The tiny black spot seen on the side of the unit shows where the dielectric broke down during the extended life test.



For a trip through the fluorination kiln, the once fired ceramic discs are placed in trays called "saggers" made of special ceramic to withstand chemical reaction.

A. MIL-C-20D and EIA RS-198, Class 2—Temperature Compensating and Precision: Capacitors in this group normally are made from rather low dielectric constant materials but show high stability and precision. The dielectric is compounded to provide a controlled change in capacitance with temperature. The temperature coefficient of capacitance normally found in this group ranges from +100 parts per million per degree centigrade, (ppm/°C), to −4700 ppm/°C. Also, the low power factor (or high Q) makes this type of capacitor ideal for tuned circuits where a controlled temperature coefficient is needed to offset the change of other components with temperature.

B. MIL-C-11015 and EIA RS-198, Class 1—General Purpose: This group more truly represents the versatility of ceramic capacitors. The dielectric constant normally ranges from 250 to 10,000. Dielectrics in this class can be compounded to be very stable or unstable with respect to temperature change. For example, available temperature coefficients of these dielectrics can be ±5% in an operating temperature

CERAMIC CAPACITOR (Continued)

range of −55° to +150°C; or, +22, −80 % in an operating range of +10° to +85°C.

Both military and EIA specs have codes to identify temperature characteristic with respect to temperature range. Capacitors in this class can be used for by-pass and coupling.

Failure Modes

Failure modes of ceramic capacitors due to human error and poor workmanship can be greatly minimized through training of personnel, controlled manufacturing procedures and strict supervision. They are readily detected through inspection and testing.

Failure modes from dielectric degradation, poor encapsulation and material deficiencies are more difficult to control, and require a combination of sound design practice and proper selection of compositions and materials.

Degradation: Failure of a ceramic dielectric resulting from degradation is a serious shortcoming of titanate bodies, and leads to electrical breakdown. This is the result of an electro-reduction process under voltage and temperature which changes the crystal from an insulator into a n-type semiconductor. The chemistry of this process can be described as a hydrogen or proton migraton in the lattice, resulting in a valence change of the crystal materials.

Electrical degradation can be improved by adding tri- and pentavalent exides such as Iron (Fe_2O_3), Tantalum (Ta^2O^5) and even rare earths. These additives alone do not completely arrest this degradation. Studies show that fluorides are more effective, since they not only enter into the lattice structure but also react with the crystal matrices of the dielectric.

Encapsulation: The materials and technique of capacitor encapsulation have a pronounced effect on both moisture resistance and degradation. Wax impregnants are used because they seal the capacitor element from moisture. Water on the silver electrodes will cause a migration of silver ions from the anode to the cathode with applied voltage. This migration results in a conducting path forming on the surface of the ceramic. It will cause capacitor failure. Also, the presence of water at the anode provides a source for hydrogen protons which accelerate dielectric degradation.

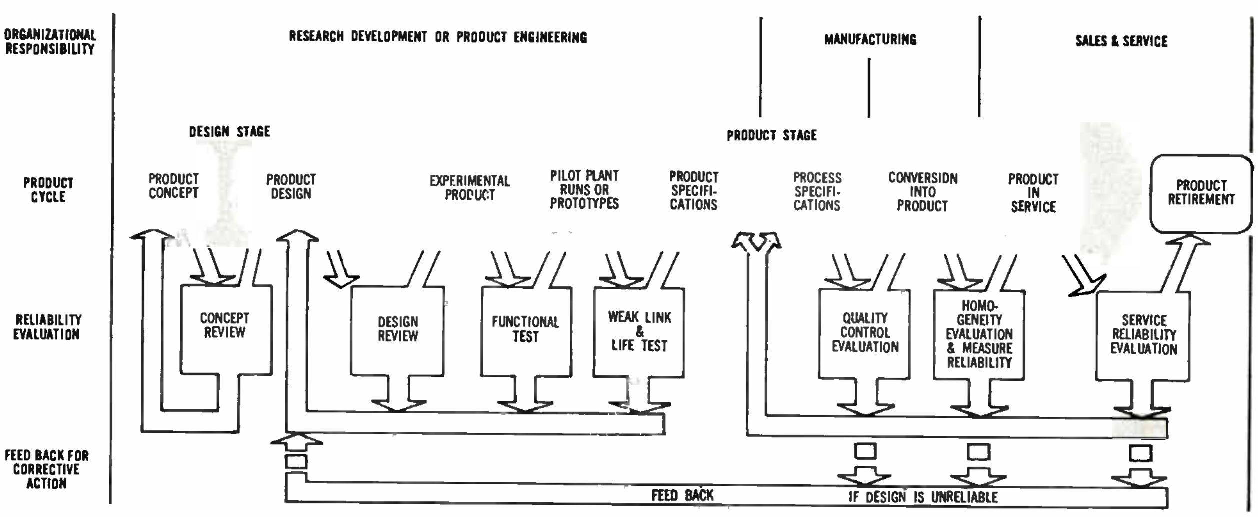
Fluorinated, Glass Encapsulated Capacitors

Under contract to the Signal Corps, a new approach was established for ceramic capacitor manufacture. The contract was to develop and manufacture a fluorinated ceramic capacitor able to operate at 200°C for 2000 hrs. The form factor specified was a CK63 disc capacitor having a capacitance of 10,000 pf. An intensive investigation of fluoride additions to the dielectric barium titanate was started and improvements were noted.

The fluorination of the dielectric was performed in a specially built tunnel kiln capable of close temperature control. A controlled level of volatile fluorides was held in the kiln atmosphere and the dielectrics were cycled through the kiln. This treatment, at elevated temperatures, fully exposed the dielectrics to the permeating fluoride atmosphere, causing a solid state reaction.

The fluoride materials react with both the crystalline structure and matrixes of the barium titanate complexes, altering their chemical composition. This additive acts in a manner similar to the trivalent and pentavalent additions, except that the single valence fluoride ion (F^-) replaces oxygen in the crystal com-

Fig. 1: From product concept to retirement, a component flows through design and production stages to assure reliability.



Courtesy of Roth and Strong, Management Consultants, Boston plex and reduces anion vacancy to a point where ion and proton migration is greatly restricted. As a result, the dielectric has a high resistance to electrochemical reduction and degradation.

This resistance to degradation can be seen in Fig. 3. Note the high resistive value for the fluorinated high *K* dielectric while the value of the standard commercial dielectric falls off rapidly at even moderate temperatures. This comparison was further demonstrated during life tests when unfluorinated dielectrics failed from a few minutes up to 500 hrs., while fluorinated dielectrics had no failures up to 3000 hrs. Both types were tested at 500 v. and 200°C.

Glass Encapsulation: Since the Signal Corps needs a capacitor to operate at 200°C, it became necessary to use encapsulating materials able to withstand this high temperature. Standard organic encapsulating materials and methods which were investigated could not meet the temperature needs of the capacitor. After further study, it was found that glass encapsulation would be the correct approach.

The high-temperature glass-encapsulation method used precluded the use of standard lead materials. We had to employ pure silver wire leads which were fired-on during the electrode firing process.

The glass coated capacitors were given a second coating of silicone rubber for additional protection to the capacitor and glass coating. Finished capacitors (Fig. 4) were then tested per Signal Corps. specs.

Qualifications: Both lots, totaling 100 capacitors, had no failures during the 2000-hr. life test at 500 v. and 200°C. Additional capacitors were continued on to 3000 hrs. with no evidence of degradation. In addition, environmental tests of humidity, shock, temperature immersion and vibration did not produce any failures. Thus, the fluorinated, glass encapsulated capacitor was qualified.

Data Accumulation

An expanded program of evaluation was started to test larger quantities for reliability data. A total of 1000 capacitors, having a fluorinated dielectric, silver leads and glass encapsulation, were made up for life test evaluation. It was necessary to select this large quantity for study because the capacitor embraced new design concepts. Therefore, an accurate understanding of its reliability must be established.

Established Reliability

One failure was noted at 763 hrs.; no additional failures were recorded up to a final check at 1.7 million component hrs. This performance of a high *K* dielectric, normally considered inferior, proved the merits of this new concept. Test conditions for this program were maintained at 200°C and 500 v. to accelerate failure mechanisms. Failure rate calculations based on test conditions resulted in failure rates of 0.229%/M hrs. at 90% confidence level and 0.1189%/M hrs. at 60% confidence level. When considering this capacitor for operation at normal conditions of 250 v. and 85°C by using standard voltage and temperature accelerating factors, failure rates of 0.00000312%/M hrs. at a 90% confidence level and 0.00000161%/M hrs. at a 60% confidence level are established.

Calculation of failure rates at rated voltage and temperature were made as follows:

χ^2 = Chi-Squared Value
N = Number of Units on Test
T = Time in Hours on Test
R = Number of Observed Failures
λ = Failure Rate
10^5 = Constant to reduce λ to %/M hrs.

$$N \times T = 1.7 \times 10^6$$
$$R = 1$$

Where χ^2 is entered with $2(R+1)$ degrees of freedom.

Chi-Squared values for confidence levels are:

R	χ^2 (60% conf. lev.)	χ^2 (90% conf. lev.)
0	1.832	4.610
1	4.044	7.780
2	6.240	10.640
3	8.320	13.360
4	10.500	15.990

$$\lambda = \frac{\chi^2 \times 10^5}{2\,NT}$$

At 90% confidence level,

$$\lambda = \frac{7.78 \times 10^5}{2 \times 1.7 \times 10^6} = 0.229\%/\text{M hrs.}$$

At 60% confidence level,

$$\lambda = \frac{4.044 \times 10^5}{2 \times 1.7 \times 10^6} = 0.1189\%/\text{M hrs.}$$

Voltage Acceleration is based on life expectancy varying inversely with the third power of the ratio of the test voltage to actual voltage. That is, operating a capacitor at one-half rated voltage should increase life expectancy by a factor of 8.

$$K_v = \left(\frac{V_1}{V_2}\right)^3$$

Where:

K_v = Voltage Acceleration Constant.
V_1 = A Given Voltage (500 v.)
V_2 = Another Voltage (250 v.)

$$K_v = \left(\frac{500}{250}\right)^3 = 8$$

Temperature Acceleration is not based on a linear or power law relationship. Graduated temperature ranges are more accurate for ceramic capacitors. Therefore, CDE engineers separated the over-all temperature range into 3 steps, with individual rules of 20°, 10°, and 8°C. Below 85°C, life is doubled for every 20°C decrease in temperature. From 85° to

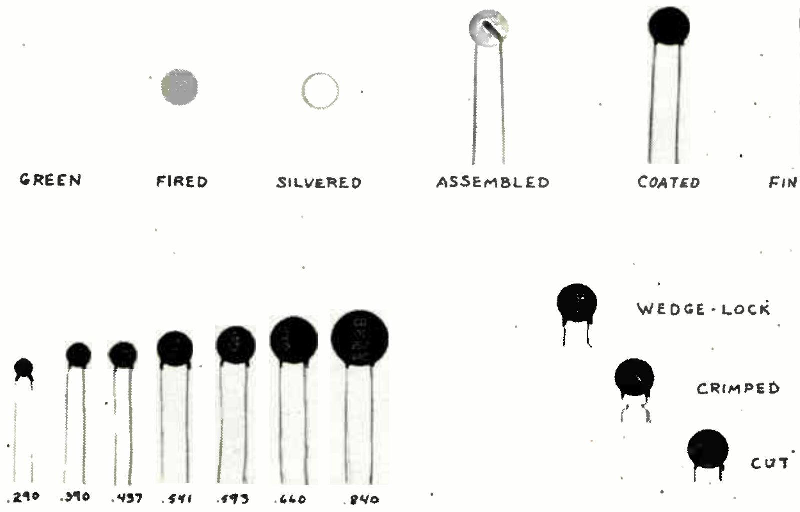


Fig. 2: Typical ceramic capacitor construction. The raw green ceramic piece is made. Then it is fired, silvered, soldered and coated. Available are various leasd.

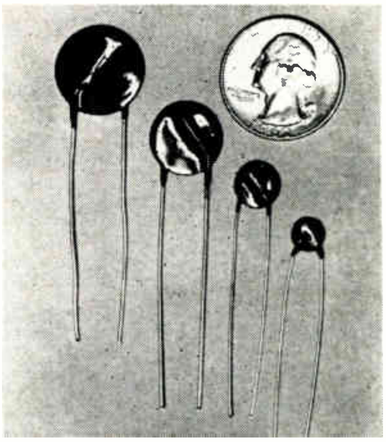


Fig. 4: These fluorinated disc ceramic capacitors operate at 200°C temperature while requiring no voltage derating.

CERAMIC CAPACITOR (Concluded)

125°C, life time is halved for every 10°C rise. Above 125°C, life time is halved for every 8°C rise in temperature.

$$K_T = 2^{(T_1 - T_2)/T_3}$$

Where:

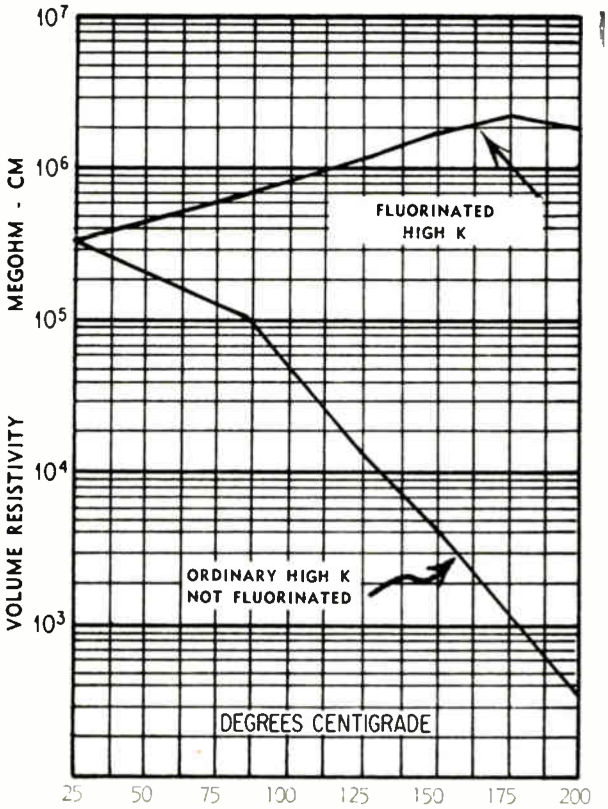
K_T = Temperature Acceleration Constant.

T_1 = A given temperature.

T_2 = Another temperature.

T_3 = Temperature increase or decrease (8°C, 10°C or 20°C).

Fig. 3: In these graphs of typical resistivity vs. temperature high K dielectric with and without fluorination is compared.



$$K_T = 2^{(200-125)/8} \times 2^{(125-85)/10}$$

$$K_T = 2^{9.4} \times 2^4 = 2^{13.4}$$

The product of two temperature acceleration factors is necessary since the temperature varied from 85° to 125°C and from 125° to 200°C. For accuracy, then, the 8°C and 10°C temperature rules are applied.

K_{VT}, or test acceleration factor, is the result of operating conditions of voltage and temperature, and is the product of voltage acceleration and temperature acceleration factors.

These acceleration factors are used to extrapolate actual test data into failure rates expected under normal operating conditions.

$$\lambda_E = \frac{\lambda_{90}}{K_{VT}}$$

Where:

λ_E = Extrapolated Failure Rate.

λ_{90} = Failure Rate at 90% confidence level (0.229%/M hrs.)

$$K_{VT} = K_V \times K_T = 8 \times 2^{13.4} \cong 9192.$$

$$\lambda_E = \frac{0.229}{8 \times 9192} = 0.00000312\%/\text{M hrs.}$$

At 60% confidence level where $\lambda_{60} = 0.1189\%/\text{M hrs.}$

$$\lambda_E = \frac{0.1189}{8 \times 9192} = 0.00000161\%/\text{M hrs.}$$

The Results Applied

The technique and value of fluorination has been established and will be of significant value in these new products.

Advantages of ceramic sealing of the electrodes has also been proven and both features are in a new series of miniaturized ceramic capacitors having very high reliability. These products have very high capacitance to volume ratios. They are available in tubular and rectangular form factors, as well as with weldable and solderable leads.

SMOOTHING-PREDICTING SAMPLED DATA

In military and control systems, techniques which smooth sampled data and predict behavior are widely used. Complexity requires these to be instrumented on a computer. Discussed here is the simplest class of smoothing-predicting including design data and hardware considerations.

TECHNIQUES WHICH SMOOTH SAMPLED DATA and predict the behavior of the phenomenon based on a sampled history of its past performance are being put to more use. Such methods are widely used in military Track-while-scan systems which develop a target's track from search radar data; also in control systems which act on the expected behavior of the processes.

The smoothing-predicting ability is often instrumented on a computer because of the complexity. This article discusses the simplest class of smoothing-predicting techniques (first-order) and presents design data and hardware considerations for exponentially weighted first-order filters with sampled inputs.

* * *

The order of a filter is the order of the differential or difference equation which describes the response of the network. Here, first-order filters are discussed: therefore, the first difference is the highest-order term considered. The output of the filter is assumed constant (clamped) between inputs.

The method used for selecting a final filter configuration is based on a least-mean-squared-error criterion. The input samples are given time-dependent weights, so that any computation of the filter's output yields a value which minimizes the sum of the weighted squared deviations of these input samples from the output value being computed.

To stress the importance of the more recent samples, the output will be fitted to the last k inputs only, and the deviations of these k inputs from the output will be weighted exponentially in time. (The special cases of the equally weighted and the infinite memory filters require only making the weighting function unity and k infinite.)

Derivation of Basic Network Equations

Definitions:

T = sampling period (assumed constant).
nT = time of the most recent input sample.
k = number of samples being smoothed.
$X_{m,i}$ = input at the ith sample.
$X_{c,n}$ = most recent output, the one being computed.
$E_{(n-i)}$ = deviation of the ith input from the latest output.
$W_{(n-i)}$ = weighting function. It represents the weight that the information present at the ith sample has at the time of the latest sample.
b = smoothing constant.
S_n = sum of the weighted squared deviations from the latest output.

In equation form:

$$W_{(n-i)} = b^{n-i} \tag{1}$$

$$E_{(n-i)} = X_{m,i} - X_{c,n} \tag{2}$$

$$S_n = \sum_{i=n-k+1}^{n} W_{(n-i)} \, E^2_{(n-i)} \tag{3}$$

To minimize the sum of the weighted squared deviations, set:

$$\frac{\partial S_n}{\partial X_{c,n}} = 0 \tag{4}$$

This results in the equation:

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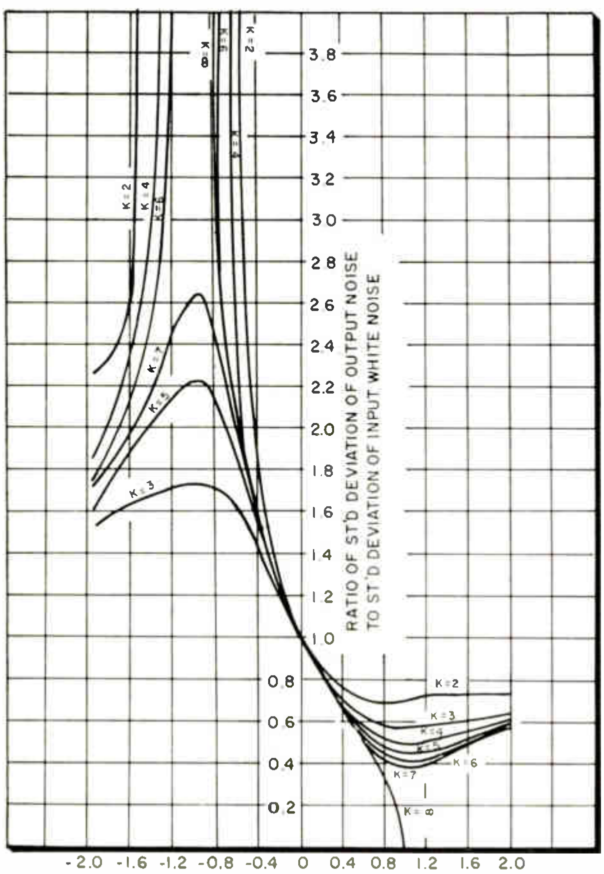
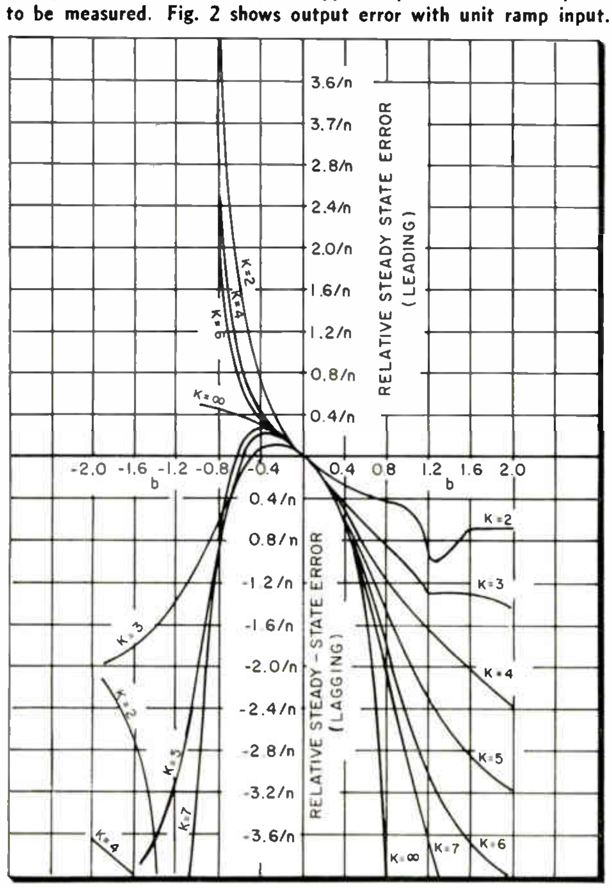
Table 1

		Weighting: Exponential Memory: Finite	Weighting: Exponential Memory: Infinite	Weighting: Equa Memory: Finite
Network Equation		$X_{c,n} = bX_{c,n-1} + \frac{1-b}{1-b^k}[X_{m,n} - b^k X_{m,n-k}]$	$X_{c,n} = X_{c,n-1} + (1-b)(X_{m,n} - X_{c,n-1}$	$X_{c,n} = X_{c,n-1} + \frac{1}{k}[X_{m,n} - X_{m,n-k}]$
Response to a unit step applied when $-1 < n < 0$	$0 \leq n \leq k-1$	$\frac{1-b^{n+1}}{1-b^k}$	$1 - b^{n+1}$	$\frac{n+1}{k}$
	$n > k-1$	1	Not Applicable	1
Response to a unit ramp applied when $n = 0$	$0 \leq n \leq k-1$	$\left[\frac{1}{1-b^k}\right]\left[n - b\frac{1-b^n}{1-b}\right]$	$n - b\frac{1-b^n}{1-b}$	$\frac{n(n+1)}{2k}$
	$n > k-1$	$n - \frac{b}{1-b} + \frac{k\,b^k}{1-b^k}$	Not applicable	$n - \frac{k-1}{2}$
Ratio of the variance of output noise to the variance of input white noise		$\left[\frac{1-b}{1+b}\right]\left[\frac{1+b^k}{1-b^k}\right]$	$\frac{1-b}{1+b}$	$\frac{1}{k}$
Required computer stores		$k+1$	1	$k+1$

Figs. 1 and 2: These design curves aid in synthesis and analysis of first-order networks discussed. Fig. 1 (on left) allows the filter's ability to smooth data (i.e., to suppress spurious random inputs) to be measured. Fig. 2 shows output error with unit ramp input.





$$X_{c,n} = \frac{1-b}{1-b^k} \sum_{i=n-k+1}^{n} b^{n-i} X_{m,i} \quad (5)$$

By writing this one look ahead and changing limits:

$$X_{c,n+1} = \frac{1-b}{1-b^k} b \left[\sum_{i=n-k+1}^{n} b^{n-i} X_{m,i} + b^{-1} X_{m,n+1} - b^{k-1} X_{m,n-k+1} \right] \quad (6)$$

Eq. 5 and 6 yield the network equation for an exponentially weighted finite memory filter:

$$X_{c,n} = b\, X_{c,n-1} + \frac{1-b}{1-b^k} [X_{m,n} - b^k X_{m,n-k}] \quad (7)$$

For stability, Eq. 5 must be finite for all values of n. However, when considering a finite memory filter, b may be any finite number and the system will be absolutely stable. It is possible, of course, to define a relative stability by placing an upper limit on Eq. 5. When considering an infinite memory filter, Eq. 5 becomes an infinite series. For this series to be convergent, and the system hence stable, we must have:

$$-1 < b < +1 \quad (8$$

Under the above condition:

$$\lim_{k \to \infty} b^k = 0 \quad (9)$$

Therefore, from (7) and (9), the network equation for an exponentially weighted infinite memory filter is:

$$X_{c,n} = X_{c,n-1} + (1-b)\,(X_{m,n} - X_{c,n-1}) \quad (10)$$

When $b = 1$, all of the last k inputs have equal weight, and the output of the filter is the average of the last k inputs. To determine the network equation of this filter, use is made of L'Hospital's rule which shows that:

$$\lim_{b \to 1} \frac{1-b}{1-b^k} = \lim_{b \to 1} \frac{1}{k\, b^{k-1}} = 1/k \quad (11)$$

From (7) and (11), the network equation for an equally weighted finite memory filter is:

$$X_{c,n} = X_{c,n-1} + \left(\frac{1}{k}\right) (X_{m,n} - X_{m,n-k}) \quad (12)$$

Note that an equally weighted infinite memory filter is impractical. Eq. 12 shows that as k becomes large, the output does not respond to changes at the input.

Response to White Noise

Equation 5 squared is:

$$X^2_{c,n} = \left[\frac{1-b}{1-b^k}\right]^2 \sum_{i=n-k+1}^{n} b^{n-i} X_{m,i} \sum_{j=n-k+1}^{n} b^{n-j} X_{m,j} \quad (13)$$

If the inputs, $X_{m,i}$ are white noise and expectations are taken of both sides of this equation, the expectations reduce to the following:

$$E\,(X^2_{c,n}) = \sigma^2 X_c$$

$$E\,(X_{m,i} \cdot X_{m,j}) = \begin{cases} \sigma^2 X_m & \text{when } i = j \\ 0 & \text{when } i \neq j \end{cases}$$

Here:

E denotes expectation.

$\sigma^2 X_{c,n}$ denotes the variance of the output.

$\sigma^2 X_m$ denotes the variance of the input.

Therefore for an exponentially weighted finite memory filter:

$$\frac{\sigma^2 X_c}{\sigma^2 X_m} = \left[\frac{1-b}{1-b^k}\right]^2 \sum_{i=n-k+1}^{n} b^{2(n-i)} = \left[\frac{1-b}{1+b}\right] \left[\frac{1+b^k}{1-b^k}\right] \quad (14)$$

This equation is a measure of the network's smoothing ability.

From (9) and (14), the response to white noise of an exponentially weighted infinite memory filter is:

$$\frac{\sigma^2 X_c}{\sigma^2 X_m} = \frac{1-b}{1+b} \quad (15)$$

By utilizing L'Hospital's rule, the response of an equally weighted finite memory filter to white noise is found to be:

$$\frac{\sigma^2 X_c}{\sigma^2 X_m} = 1/k \quad (16)$$

Response to Step and Ramp Inputs

A. Response to a unit step input: Assume that a unit step is applied after $n = -1$ but before $n = 0$ so that:

$$X_{m,n} = \begin{cases} 0 & \text{when } n < 0 \\ 1 & \text{when } n \geq 0 \end{cases}$$

The network response to this step will be different when it "remembers" both the old ($X_{m,n} = 0$) and the new ($X_{m,n} = 1$) inputs (that is, with fewer than k samples of the new input) than when it "remembers" only the new inputs.

Consider first when the network remembers both inputs ($0 \leqslant n \leqslant k-1$). Assume that the particular solution of the difference Eq. 7, hereafter called $X_{c,n}$ (P.S.), is γ.

From (7):

$$\gamma = b\gamma + \frac{1-b}{1-b^k} (1 - 0\, b^k) \quad (17)$$

Therefore:

$$X_{c,n}\ (\text{P.S.}) = \gamma = \frac{1}{1-b^k} \quad (18)$$

Assume that the complementary solution, hereafter called $X_{c,n}$ (C.S.), of equation 7 is Cb^n:

$$X_{c,n} = X_{c,n}\ (\text{P.S.}) + X_{c,n}\ (\text{C.S.}) = \frac{1}{1-b^k} + Cb^n \quad (19)$$

From (7) and (19), at $n = 0$:

$$C = -\frac{b}{1 - b^k} \qquad (20)$$

From (19) and (20), for an exponentially weighed finite memory filter when $0 \leqslant n \leqslant k-1$:

$$X_{c,n} = \frac{1 - b^{n+1}}{1 - b^k} \qquad (21)$$

For an exponentially weighted infinite memory filter the network always "remembers" the old inputs as well as the new. Therefore, for all non-negative values of n, from (9) and (21):

$$X_{c,n} = 1 - b^{n+1} \qquad (22)$$

L'Hospital's rule and (21) show that the response to a unit step of a finite memory equally weighted filter when $0 \leqslant n \leqslant k\text{-}1$ is:

$$X_{c,n} = \frac{n + 1}{k} \qquad (23)$$

2) The network remembers only the new input ($n > k\text{-}1$). Proceeding as before, we find:

$$X_{c,n} \text{ (P.S.)} = \gamma = 1 \qquad (24)$$

and

$$X_{c,n} = Cb^n + 1 \qquad (25)$$

From (7) and (25) at n = k, and from (21) at $n = (k\text{-}1)$, we find that:

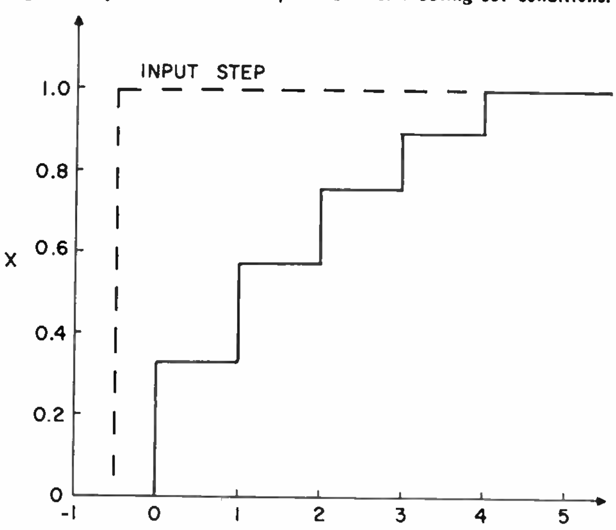
$$C = 0 \qquad (26)$$

Therefore, from (25), the output of a finite memory exponentially weighted filter is, as we would expect:

$$X_{c,n} = 1 \qquad (27)$$

Since $X_{c,n}$ is independent of b when $n > k\text{-}1$, the above equation is also applicable to a finite memory equally weighted filter.

Fig. 3: Response to a unit step for a filter meeting set conditions.



B. Response to a unit ramp input: Assume that a unit ramp is applied at $n = 0$ so that:

$$X_{m,n} = \begin{cases} 0 & \text{when } n < 0 \\ n & \text{when } n \geq 0 \end{cases}$$

Similarly to the case where a step input was applied, the network response will be different when it "remembers" both types of inputs, from when it "remembers" only the ramp input.

Assume:

$$X_{c,n} \text{ (P.S.)} = \beta n + \gamma \qquad (28)$$

$$X_{c,n} \text{ (C.S.)} = Cb^n \qquad (29)$$

These equations can be solved in a manner similar to that used in determining the response to a step input. The network responses to a unit ramp input are given in Table 1. Table 1 summarizes the mathematical results which have been derived in this paper.

Filter Design

Design curves are presented in Figs. 1 and 2, to facilitate the synthesis and analysis of the first-order networks discussed in this paper. Fig. 1 shows the ratio of the standard deviation of output noise to the standard deviation of input white noise; this is a measure of the filter's smoothing capability, or its ability to suppress spurious random inputs. It is clear that, for negative values of the smoothing constant, b, the system is no longer a filter because it amplifies incoming noise. Fig. 2 shows the steady-state output error due to a unit ramp input, long after enough samples have been received to fill the memory store, or after a great many samples have been stored for the infinite memory filter. Here, the important characteristic is not the absolute magnitude of the error, but rather the variation in relative error as b and k are varied. Note that Fig. 2 shows that b and k should be minimized for a filter to accurately follow a first-order input. The equations show that the transient error is small when b is small. However, reductions in b and k are only made at the expense of reducing the importance of the earlier inputs, which, as shown by Fig. 1, is detrimental to the noise suppression capability of the filter. Thus the smoothing constant, b, and the memory capacity, k, should be largely selected by a judicious compromise between transient and tracking error, on the one hand, and noise considerations, on the other, within the limits imposed by the filter specifications.

For example, suppose we must design a digital filter which will reduce the standard deviation of the input noise to less than 50%, and which must have a steady-state error no greater than 1.4% after 100 input samplings. Thus, the initial limits are found by investigating the area below the 0.5 ordinate on Fig. 1; this gives $k_{min}=4$, and $b_{min}=0.6$. Referring to Fig. 2, and dividing the ordinate scale by 100 (the specified value for n), the k_{max} is found to be above $k=7$, using the previous b_{min} value.

Similarly, using the previous k_{min} value and reading along the $-1.4/n$ ordinate, we find $b_{max}=0.96$ for $k=4$, 0.78 for $k=5$, 0.68 for $k=6$, and 0.62 for $k=7$. The acceptable b-k pairs must be chosen from within these limits. Trying first $k=4$, we see from Fig. 1 that there is no point on this curve for $b<0.96$ below the 0.5 ordinate; hence, $k=4$ is not acceptable. Using $k=5$, we find that this curve is below the 0.5 ordinate on Fig. 1 for $b>0.72$; hence, we may choose any pair of $k=5$, and $0.72<b<0.78$. Similarly, for $k=6$ we find that this curve is below the 0.5 ordinate for $b>0.68$; hence, we may choose $k=6$ and $b=0.68$. No $k>6$ is acceptable, because b_{min} would exceed b_{max}. The final choice would be based on such considerations as storage cost and computational ease.

The response to a unit step is shown in Fig. 3 for one of the filters meeting the above conditions. This figure shows the rapid transient response realized by using a finite memory filter.

It can be seen from the basic network equations that a finite memory filter which remembers k requires $k+1$ stores when instrumented on a computer. Since storage space is costly in terms of time, power, weight and volume, it is desirable to keep k as small as possible. It is of considerable significance, however, that when k is made infinite, the basic network equation reduces to the extent that only one store is now required. Therefore, an infinite memory filter is considerably less demanding on computer storage than is a finite memory filter, since it is only necessary to update the single stored output at each sampling time.

A word of caution is in order regarding the evaluation of the filter's response to an input of noise. The assumption was made that the cross-correlation of X_m $[E(X_{m,i} \cdot X_{m,j})$ *when* $i \neq j]$ was zero. This is often valid in practice when a large number of these cross-terms are averaged, but if only a small number of these terms are used, this assumption becomes questionable.

The author gratefully acknowledges the technical assistance provided by Mr. A. DiStefano of the Newark College of Engineering, Newark, N. J., and the editorial contribution of Mr. K. Aldershof, of the Cornell Design Co., E. Rutherford, N. J.

POCKET-SIZE LASER

THIS LILLIPUTIAN-SIZED LASER can be used by distressed boatsmen and downed pilots to signal their position. About the size and shape of a small frozen juice can, the laser emits energy pulses that can be detected by rescuers 30 air-miles away. The device can be fired repeatedly—up to 50 times—before battery recharging is required. The battery charger plugs into any electrical outlet.

In addition to its survival-kit capability, the small size lends itself to other possibilities. Coupled to a microscope, it can punch tiny holes into the specimen being studied. Size of the combined laser head and battery is 2 x 4 x 4 in.; total weight is 14 oz. The laser rod, which replaces the ruby crystal in a conventional solid-state laser, is made of neodymium-doped calcium tungstate. The rechargeable battery consists of nickel-cadmium cells. Raytheon Laser Advanced Development Center, Waltham, Mass.

The rechargeable, battery-powered unit operates without the usual ruby-crystal laser rod.

The development of tunnel diodes and four-layer diodes has placed extra emphasis on the properties of negative immittance as a circuit property. Here is discussed the controversy of two aspects of this property — negative resistance and negative conductance.

ON THE PROPERTIES OF NEGATIVE IMMITTANCE

THE EFFECT OF NEGATIVE RESISTANCE came into importance with the point-contact transistor. When $\alpha_o > 1$, a negative resistance appeared between any pair of its terminals as, for example, between emitter and base in the common-base connection. This meant possible self-oscillation, which proved to be a disadvantage in designing stable amplifiers.

The advent of the junction tetrode enabled junction devices to take over the high-frequency field. In this component, as well as in the Esaki tunnel diode, the property of negative-immittance took on increased importance.

There are growing misconceptions regarding the differences between negative resistance and negative conductance. These are clarified here, in their theoretical aspects and practical uses to which these components, e.g., the tunnel diode, can be put.

* * *

The current-voltage relations for a negative-conductance device are shown in Fig. 1. This is a curve commonly associated with a tunnel diode. If the voltage axis is taken horizontal, an "N-shaped" curve results (the Russians call this an "n-type" negative immittance) and the function is a single-valued function of applied voltage. Similarly, the current-voltage relations for a negative resistance are shown in Fig. 2. Here, an "S-shaped" curve is formed which is single-valued in applied current.

Discussion

The slope of the negative-immittance section of Fig. 1 varies from zero at the ends A-A to a finite maximum value in the middle, whereas the slope of the corresponding section of Fig. 2 ranges from a minimum value to an infinite slope. In other words, whereas the negative-slope section of Fig. 1 has a maximum magnitude of slope in the mid-range, the corresponding section of Fig. 2 has a minimum magnitude of slope in the mid-range.

Since the slopes of both contours correspond to dI/dV, or conductances, the properties of these two types of devices of necessity must be widely divergent. The range of negative conductance for Fig. 1 is from zero to a fixed magnitude, but the corresponding range of negative resistance is from a fixed magnitude to infinity. The range of negative resistance for Fig. 2 is from zero to a fixed magnitude.

If a negative immittance device is used to subtract out part of the positive immittance of an associated circuit element or combination, it is essential that it be used in the manner in which the negative immittance has an upper bound, as otherwise controlled cancellation is not possible. For this reason, amplifiers using devices like tunnel diodes are limited to shunt configuration with respect to the associated circuitry. The arrangement must provide completely stable operation at all frequencies but the desired operating frequency, and must possess the needed gain stability margin even at that frequency.

The negative-immittance phenomenon can be understood more fully from an examination of the behavior of a fictional device with typical loads. For example, in Fig. 3, an expanded view of the negative-conductance area for a tunnel diode is shown along with 3 typical load lines. The line A corresponds to a resistance for which stable operation occurs, line B corresponds to the critical impedance at the inflection point of the curve, and line C to an unstable condition. The triple intersections at 3 independent points with line C have reduced to a triple-point with line B and to a single point for the completely-stable case.

If resistances are combined with a tunnel diode in a series configuration and then in a parallel configuration, the significance of the difference between the two types of negative immittance can be clarified. When resistances are paralleled, the currents in them are summed. Consequently, as the value of parallel resistance is decreased (conductance increased) and its current increases more and more rapidly, the slope of the combination in the area of interest changes from negative to zero and then to positive through the full length of the curve. If, on the other hand, the resistances are connected in series with the diode,

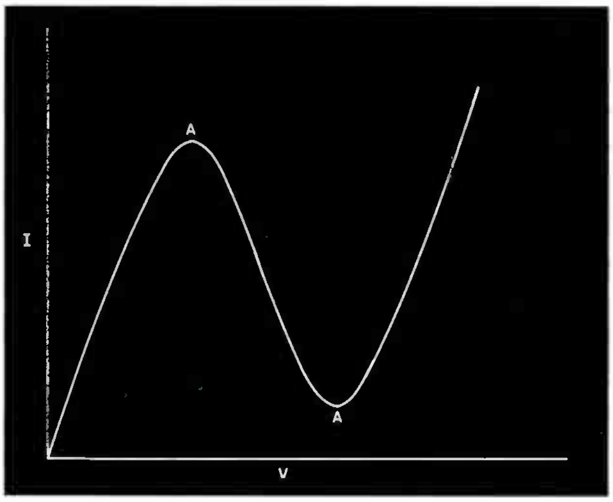


Fig. 1: Curve of a current-voltage relationship of a negative-conductance device

a curious situation develops. The slope of the negative-conductance region gets greater and greater until finally it becomes positive by passing through infinite slope. In the process, however, two corners are left which have negative slopes covering the full range from zero to negative infinity, Fig. 4

This positive resistance region bracketed by two negative-immittance corners is important practically, since the negative immittances on the corners make it impossible to obtain stable operation in the positive region between. Or, the stabilization of a negative conductance can only be achieved by the use of a shunt positive resistance, but not by the use of a series positive resistance.

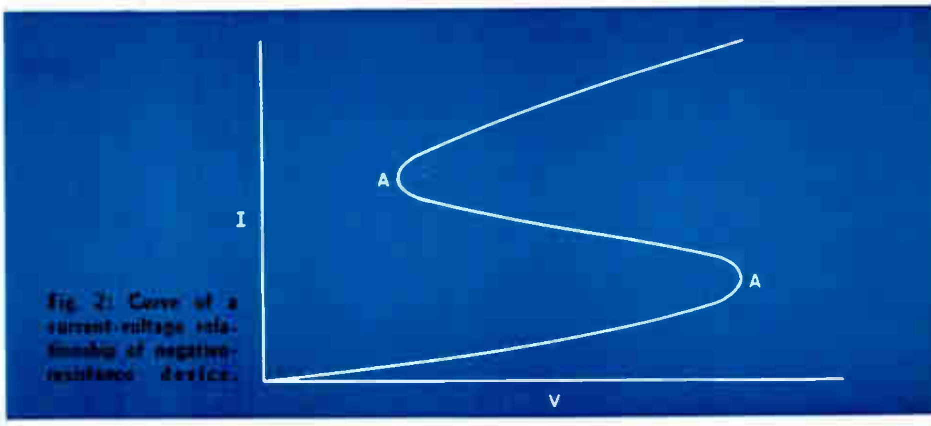


Fig. 2: Curve of a current-voltage relationship of negative-resistance device.

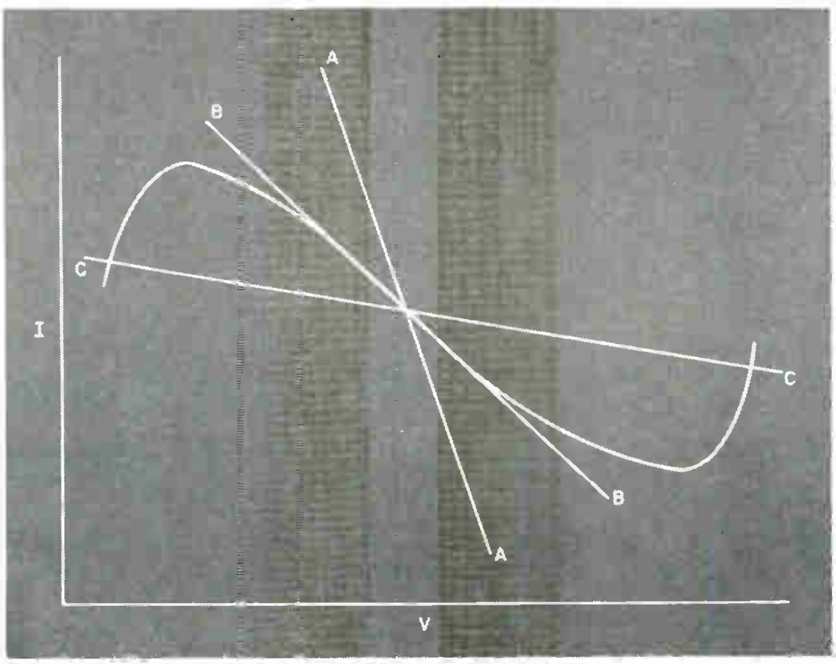


Fig. 3: Curves of the operation of a fictional device with typical loads.

By Dr. KEATS A. PULLEN, JR.
Ballistic Research Labs
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Practical Circuit

That this is physically a fact is readily observeable by testing a tunnel diode in the circuit shown in Fig. 5. The negative portion of the trace can be observed only if the series-metering resistance, R_m,

NEGATIVE IMMITANCE (Concluded)

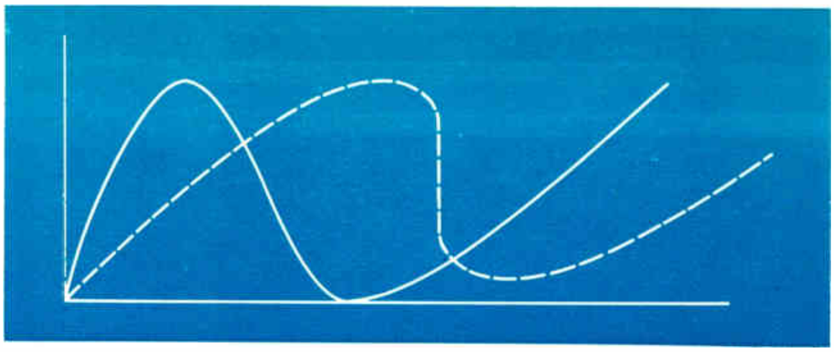


Fig. 4: Curves show the difference between uses of a tunnel diode with resistance combined with it in parallel (solid line) and in series (broken).

is appreciably less than a specified value, typically $1/2|g|$, and the source admittance G is greater than $2|g|$. When the sum $G + (1/R_m) < |g|$, the net conductance of the complete circuit, the value of $(G + g + 1/R_m)$, will be positive throughout the operating range of the device, and the full trace can be seen on a cathode-ray oscilloscope connected as indicated. Otherwise, switching always occurs, and the negative region cannot be observed.

The behavior along load-line C in Fig. 3 has considerable similarity to the build-up curve of a dc generator in that a small change in voltage introduced from the center intersection causes a larger change in device current than is needed to maintain the voltage change. As a result, run-away action, carrying the operation to one of the outer intersections, occurs. The kind of slope rotation needed to shift the triple-point for line B to 3 separate points on line C measures the immittance properties of the device that cause it to behave as either a negative conductance or a negative resistance.

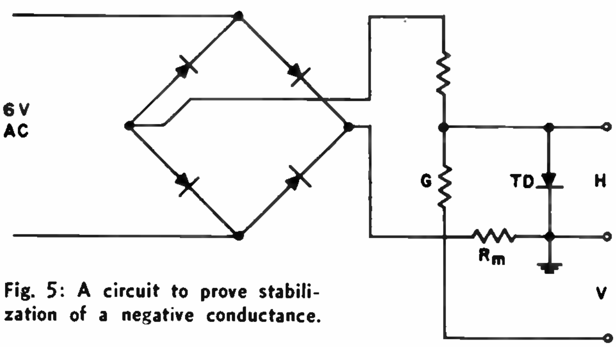


Fig. 5: A circuit to prove stabilization of a negative conductance.

TRANSISTOR "AND" CIRCUITS

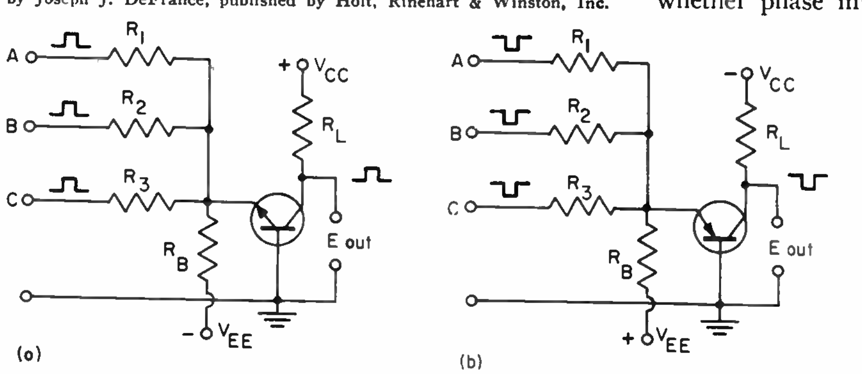
Two "AND" CIRCUITS using transistors are shown in figure. Notice that the grounded-base configuration is used. In either case, the basic principle is the same as with diode circuits. The transistor conducts heavily in the absence of coinciding input signals, and the output is clamped at ground level. However, when a proper input signal is applied to *all* inputs, the emitter-base junction is reverse biased; the transistor is driven into cutoff; and the output rises to the full collector supply value. Isolation resistors R_1, R_2, and R_3 are required to prevent interaction among the 3 signal sources. Their values are chosen in relation to R_B, so that reverse bias is obtained only when pulses are applied to all inputs simultaneously.

Based on material from a new book, *General Electronics Circuits*, by Joseph J. DeFrance, published by Holt, Rinehart & Winston, Inc.

Since these circuits use a combination of resistors (for isolation), and a transistor for the AND action, they are known as *transistor-resistor logic* or *TRL circuits.*

In the above logic circuits, the output pulse polarity was the same as the input pulse polarity. For computer service, the pulse polarity is quite important. However, there are other applications of these circuits wherein the polarity of the output has no special significance. In such cases, the transistor of the TRL circuit can be connected in the common-emitter connection, and the output will be inverted with respect to the input signals.

When better isolation between signal sources is needed, each signal is fed through a separate transistor to a common load. The transistors can be interconnected in parallel or in series, and depending on whether phase inversion between input and output can or cannot be allowed, the transistors can be connected in a common-emitter or a common-base configuration. Also depending on the input pulse polarity, the transistors used could be NPN or PNP type.



The basic principle of the two AND circuits is the same as in diode types.

ENGINEER'S NOTEBOOK

#68 USEFUL MATHEMATICAL APPROXIMATIONS

MANY OF THESE EQUATIONS WERE USED IN the VLF transmission. They play an important role in calculations involving refraction and absorption of such waves in the ionosphere. Of course the trigonometric identities are useful in ac circuit analysis, sampling and modulation techniques, etc. Many of the relationships are useful in statistical studies.

1. $n! \cong n^n e^{-n} \sqrt{2 \pi n}$

This relation is known as Stirling's formula. The error for n greater than 10 is less than 1%.

In the following relations delta Δ is a very small quantity and gamma Γ a very large quantity. Both Δ and Γ being small or large in comparison.

2. $\sin (x \pm \Delta) \cong \sin x \pm \Delta \cos x$
3. $\cos (x \pm \Delta) \cong \cos x \pm \Delta \sin x$
4. $\tan (x \pm \Delta) \cong \tan x \pm \dfrac{\Delta}{\cos^2 x}$
5. $\sin \Delta \cong \Delta$
6. $\cos \Delta \cong 1$
7. $\tan \Delta \cong \Delta$
8. $\sin^{-1} \Delta \cong \Delta$
9. $\tan^{-1} \Delta \cong \Delta$
10. $\sinh \Delta \cong \Delta$
11. $\cosh \Delta \cong 1$
12. $\tanh \Delta \cong \Delta$
13. $\sinh^{-1} \Delta \cong \Delta$
14. $\tanh^{-1} \Delta \cong \Delta$
15. $\sinh (x \pm \Delta) \cong \sinh x \pm \Delta \cosh x$
16. $\cosh (x \pm \Delta) \cong \cosh x \pm \Delta \sinh x$
17. $\tanh (x \pm \Delta) \cong \dfrac{\tanh x}{1 \pm \Delta \tanh x}$
18. $\sinh \Gamma \cong \cosh \Gamma \cong \dfrac{1}{2} e^{\Gamma}$
19. $\tanh \Gamma \cong 1$
20. $\sin (\Delta \pm j A) \cong \Delta \cosh A \pm j \sinh A$
21. $\cos (\Delta \pm j A) \cong \cosh A \pm j \Delta \sinh A$
22. $\tan (\Delta \pm j A) \cong \dfrac{2 \Delta \pm j \sinh 2A}{1 + \cosh 2A}$
23. $(1 \pm \Delta)^x \cong 1 \pm x \Delta$, if $x > 1$
24. $\dfrac{1}{(1 \pm \Delta)^x} \cong 1 \pm x \Delta$, if $x > 1$
25. $e^{\Delta} \cong 1 + \Delta$
26. $e^{-\Delta} \cong 1 - \Delta$
27. $\sqrt{A (A + \Delta)} \cong A + \dfrac{\Delta}{2}$
28. $\sqrt{A \pm \Delta} \cong \sqrt{A} \pm \dfrac{\Delta}{2\sqrt{A}}$
29. $\ln (x \pm \Delta) \cong \ln x \pm \dfrac{\Delta}{x} - \dfrac{1}{2} \left(\dfrac{\Delta}{x} \right)^2$
30. $\ln (1 \pm \Delta) \cong \pm \Delta - \dfrac{1}{2} \Delta^2$
31. $\sinh (A \pm j \Delta) \cong \sinh A \pm j \Delta \cosh A$
32. $\cosh (A \pm j \Delta) \cong \cosh A \pm j \Delta \sinh A$
33. $\tanh (A \pm j \Delta) \cong \dfrac{\tanh A \pm j \Delta}{1 \pm j \Delta \tanh A}$
34. $\tanh (\Gamma \pm j A) \cong 1$
35. $\sin (A \pm j \Gamma)$

$$\cong \cosh \Gamma \, \angle \pm \tan^{-1} (\cot A) \cong \frac{1}{2} e^{\Gamma} \, \angle \pm \left(\frac{\pi}{2} - A \right)$$

36. $\cos (A \pm j \Gamma)$

$$\cong \cosh \Gamma \, \angle \pm \tan^{-1} (\tan A) \cong \frac{1}{2} e^{\Gamma} \, \angle \pm A$$

37. $\tan (A \pm j \Gamma) \cong \tanh 2 \Gamma \, \angle \pm 90°$

$$$ for Circuit Designs

Have you come up with any simple or unique circuit designs lately? Do you think that they would be useful to fellow engineers? If so, why not send them to us for possible publication? We pay our usual space rates for those accepted. Please keep them as concise as possible and send to: Circuit Design Editor, ELECTRONIC INDUSTRIES, 56th & Chestnut Sts., Philadelphia 39, Pa.

By ARTHUR L. PLEVY

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A SPEEDY METHOD OF COMPUTING DIELECTRIC PROPERTIES

The search for specific dielectric materials has been speeded up by using a computer in conjunction with the Newton-Raphson method. This supplies the dielectric constants and losses quickly and accurately.

AN INCREASING NUMBER OF NEW DIELECTRIC MATERIALS are available for microwave use. This has created a need for a fast, accurate method of determining the dielectric constant and attenuation. A method which can perform the data reduction has been adapted in a FORTRAN program. It is a variation of the shorted waveguide method of Bowie and Kelleher. The expression tan $(x)/x = c$ is solved rapidly and accurately by applying the Newton-Raphson iterative procedure to a related expression.

Dielectric constant and loss tangent are obtained algebraically without use of graphs and without regard to preset dimensions.

* * *

The standing-wave ratio and the dielectric and attenuation constants are related by an expression derived by S. Roberts and A. von Hipple[3]:

$$\frac{\dfrac{E_{min}}{E_{max}} - i \tan \dfrac{2\pi X_o}{\lambda_g}}{1 - i \dfrac{E_{min}}{E_{max}} \tan \dfrac{2\pi X_o}{\lambda_g}} \cdot \frac{\lambda_g}{i\, 2\pi d} = \frac{\tan h\gamma d}{\gamma d}. \tag{1}$$

In this equation E_{min}/E_{max} is the standing-wave ratio, X_o is the distance from the sample face to an electric field strength minimum, λ_g is the guide wavelength, d is the thickness of the sample, and $\gamma = \alpha + i\beta$ is the complex propagation constant of the sample.

By restricting attention to materials with dissipation factor less than 0.1, T. W. Dakin and C. N. Works[4] reduce Eq. 1 to

$$\frac{\tan \beta d}{\beta d} = -\frac{\lambda_g}{2\pi d} \tan \frac{2\pi X_o}{\lambda_g}. \tag{2}$$

The expression for dielectric constant, E, becomes

$$E = \frac{\dfrac{1}{\lambda^2_c} + \left(\dfrac{\beta d}{2\pi d}\right)^2}{\dfrac{1}{\lambda^2_c} + \dfrac{1}{\lambda^2_g}}; \tag{3}$$

the dissipation factor is obtained from

$$\text{loss} \tan \delta = \frac{\Delta X}{d} \cdot F_1 \cdot F_2, \tag{4}$$

where

$$F_1 = \frac{\dfrac{1}{\lambda^2_c} + \dfrac{1}{\lambda^2_g} - \dfrac{1}{\lambda^2_c} \cdot \dfrac{1}{E}}{\dfrac{1}{\lambda^2_c} + \dfrac{1}{\lambda^2_g}} \text{ and}$$

$$F_2 = \frac{\beta d \left(1 + \tan^2 \dfrac{2\pi X_o}{\lambda_g}\right)}{\beta d\,(1 + \tan^2 \beta d) - \tan \beta d} \tag{5}$$

In these expressions λ_c is the cut-off wavelength, ΔX is the width of the standing wave, and E is the "uncorrected" dielectric constant[1].

Introducing substitutions

$$P = \left(\frac{\lambda}{\lambda_c}\right)^2$$

$$x = \beta d, \tag{6}$$

where λ is the free-space wavelength, permits a compact presentation of Eq. 2 through 5:

$$\frac{\tan (x)}{x} = C_1,\ C_1 = -\frac{\lambda_g}{2\pi d} \tan \frac{2\pi X_o}{\lambda_g}$$

$$E = P + (1 - P)\left(\frac{\lambda_g}{2\pi d}\right)^2 x^2 \tag{7}$$

$$\text{loss} \tan \delta = \frac{\Delta X}{d}\left(1 - \frac{P}{E}\right)\left(\frac{x + x \tan^2 \dfrac{2\pi X_o}{\lambda_g}}{x + x \tan^2 x - \tan x}\right).$$

The parameters are easily determined. The difficulty is to obtain the quantity x. Table look-up,

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graphical [2, 6], and linear iterative[5] procedures, and combinations of these[1], have been used to cope with this problem. By applying the Newton-Raphson method to an expression to be derived, a more efficient procedure is obtained whose convergence properties can be well established.

Mathematical Analysis

Denote by R_n the open interval, or region, defined by

$$R_n = \left(\frac{2n-1}{2}\pi, \frac{2n+1}{2}\pi\right), n \geq 1$$
$$R_o = \left(0, \frac{\pi}{2}\right). \tag{8}$$

Within any region R_n, $n \geqslant 1$, the function

$$g_n(x) = \frac{\tan(x)}{x}, x \epsilon R_n. \tag{9}$$

is continuous, has an inflection point at $n\pi$, and diverges to $-\infty$ and $+\infty$ at the respective end-points of the region. $G_n(x)$ is almost periodic with period π; its graph resembles that of the tangent function. For R_o

$$\lim_{x \to 0} g_o(x) = 1. \tag{10}$$

Since in

$$g_n(x) - C_1 = 0 \tag{11}$$

the variable x appears both explicitly and as the argument of a transcendental function, there is no tractable analytical inverse in terms of which x can be found directly. An iterative solution is a natural alternative. However, periodicity and the presence of inflection points can introduce serious difficulties, although with an accurate first estimate of the root by a search method it is possible to use, for example, the Newton-Raphson method for later refinement. This approach wastes time and is unreliable. This is due largely to a lack of knowledge as to the accuracy required of the first estimate. This estimate must be accurate to assure convergence of the iterative procedure.

Another approach circumvents many of these difficulties. Set

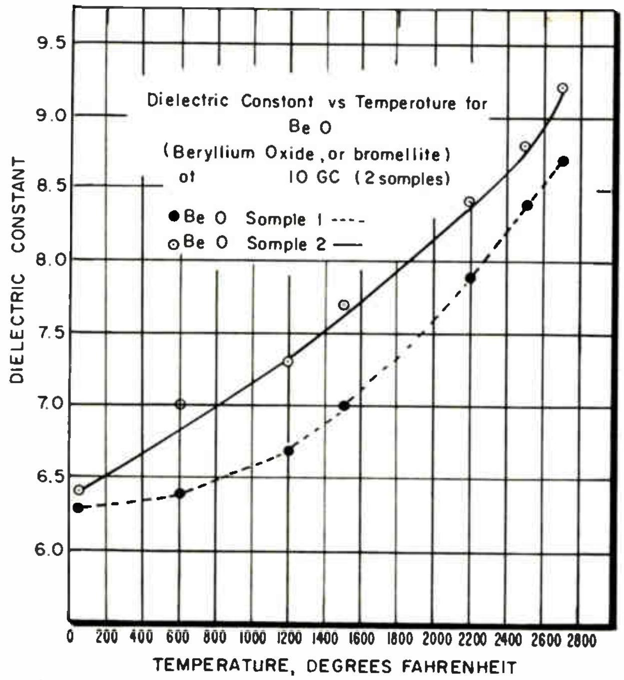
$$y = \tan(x - n\pi) \tag{12}$$

whence

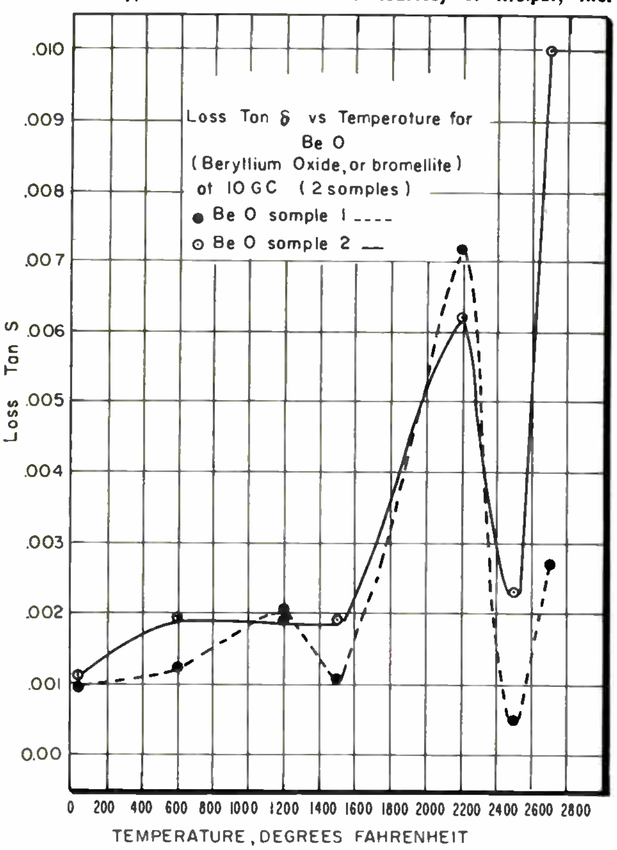
$$x = \tan^{-1} y + n\pi. \tag{13}$$

Define $f_n(y)$ by substitution for x according to Eq. (13) in the reciprocal of $g_n(x)$:

Equipment used for dielectric determinations at test frequencies from 8.5 to 11 GC and temperatures to 1650 degrees Centigrade.



Each chart shows results for two samples of beryllium oxide. These are typical cases. Charts are courtesy of Melpar, Inc.



$$f_n(y) = \frac{\tan^{-1}(y)}{y} + \frac{n\pi}{y}. \qquad (14)$$

The expression whose root is sought is

$$f_n(y) - c = 0, \; c = \frac{1}{C_1}. \qquad (15)$$

From Eq. (14) it is clear that

$$f_o(y) = f_o(-y)$$
$$\lim_{y \to 0} f_o(y) = 1 \qquad (16)$$
$$\lim_{y \to \pm\infty} f_o(y) = +0$$

whence, for $n>0$,

$$\lim_{y \to \pm 0} f_n(y) = \pm\infty$$
$$\lim_{y \to \pm\infty} f_n(y) = \pm 0. \qquad (17)$$

A simple FORTRAN code of Eq. 14 run on an IBM 7090 reveals that the graph of $f_o(y)$ resembles a witch, whereas for $n>0$, the graph of $f_n(y)$ resembles the hyperbola xy=constant. The latter suggests a number of characteristics of the derivatives of $f_n(y)$:

$$f'_n(y) \angle 0, \; y \neq 0$$
$$f'_n(y) \cdot f''_n(y) \neq 0, \; y \neq 0. \qquad (18)$$

Furthermore, for y "near" 0,

$$f_n(y) \cdot f''_n(y) > 0, \; y \to 0. \qquad (19)$$

The Newton-Raphson method is especially well suited to solving Eq. 15. Most importantly, it can be proven analytically that where conditions such as Eq. 18 and 19 prevail, the method converges. Furthermore, this occurs quadratically, i.e., the number of significant figures obtained with each iteration increases geometrically. The initial point is easily obtained with reference to Eq. 19.

The case $n = 0$ must be handled as a special one, due to the presence of an inflection point for $f_o(y)$. However, the rapidity of table look-up can be used to advantage, with later refinement by the Newton-Raphson method.

The Code

In practice, an estimated dielectric constant is provided as input from which an approximate x is calculated. This x is used to find n, thus establishing the region R_n within which the correct x probably lies. However, in order to accommodate large errors in these estimates, the first solution is actually found in R_{n-2}. The solution in R_{n-1} is then found starting with the point obtained by adding π to the solution found in R_{n-2}. Solutions are similarly found in R_n, R_{n+1} and R_{n+2}. Dielectric and attenuation constants appropriate to the x values obtained in each of the 5 regions are listed as found. For each batch of data a final report is also produced listing only that dielectric constant actually computed that agrees best with the input estimate. (*Continued on page 94*)

DIELECTRIC PROPERTIES (Concluded)

Five significant figures are preserved throughout the computations, with double-precision used in places as a precaution. Fifteen input parameters are needed; they are listed along with the results. Seven sets of data, with dielectric constant estimates ranging from 5 to 3000, and with the additional output of the results of each iteration, were processed by an IBM 7090 in less than 0.01 hours. The iterative procedure usually provides 5 significant figures in 4 iterations.

Summary

Use of the Newton-Raphson iterative method to solve Eq. 15 provides a rapid, accurate, and assured method of finding x to satisfy Eq. 11. This permits an accurate algebraic determination of the dielectric constant and loss tangent according to Eq. 7.

The work described here was performed under contracts with Melpar, Inc., Falls Church, Va.

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WHAT'S NEW

THREE-MODE SWEEP OSCILLATORS

Model 691A (1-2GC) and Model 692A (2-4GC) have three sweep-operation modes. In the normal sweep mode, the output frequency is swept in either direction between two continuously adjustable limits. In the Δ F mode, frequency is swept about an adjustable center frequency. Two independently adjustable frequency markers amplitude modulate the output in both the normal or Δ F modes, an especially useful feature when making an X-Y recording or observing an oscilloscope sweep. The frequency-marker controls can also be used to establish sweep limits for a third operating mode which is similar to the normal mode. Pushbutton mode selection makes it easy to first sweep the entire pass band of a filter (for example), and then make an expanded sweep of the filter's rejection region—without having to re-adjust sweep limits. (*Continued on page* 98)

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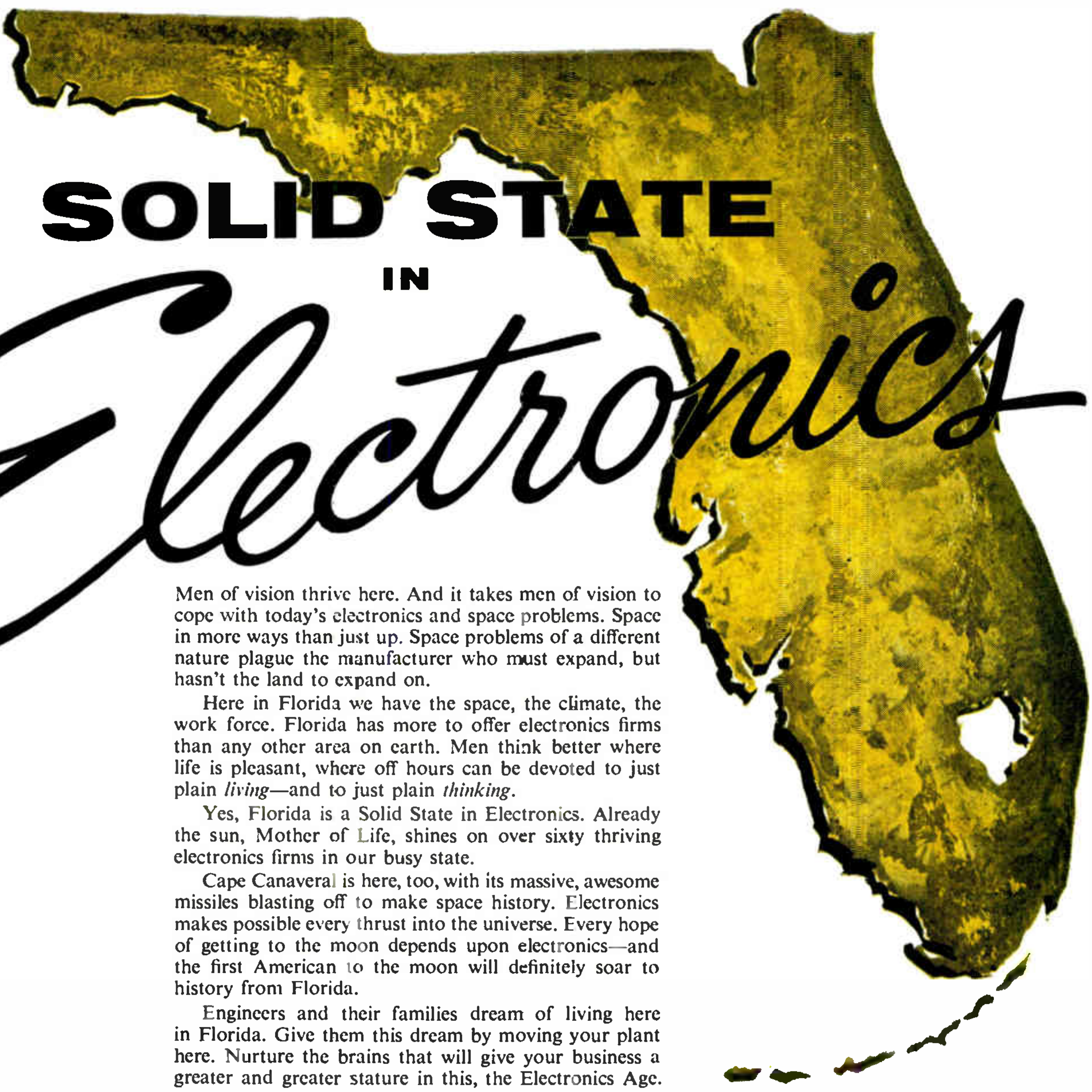

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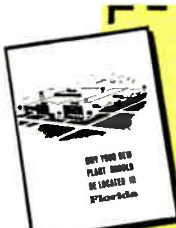

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THREE-MODE SWEEP OSCILLATORS (Continued)

Both oscillators use electrically-controlled PIN diodes for modulation and attenuation, making it possible to remotely-control output amplitude (for leveling, as an example), as well as output frequency. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.

The output freq. can sweep in either direction between an adjustable center freq. The AM output is useful in X-Y recording.

NUMERICAL CONTROL

AUTOMATIC TAPE PUNCH allows machinists to generate a control tape while making the original part.

Working from a blueprint, the operator dials in the information needed to produce the part. Since the part and tape are made simultaneously, the possibility of dialing incorrect information is reduced. After the tape is cut, it can be used to make additional tapes.

The tape unit and associated mill should find use in model shops where its flexibility will reduce time in making and modifying precision parts. Hydra-Point Div., Moog Servocontrols, Inc., Proner Airport, East Aurora, N. Y.

Using the tape unit (right) the operator dials in part information. The tape produced is used to make subsequent parts.

FISHBOWL HEIGHT IS 10½ INCHES. VOLUME IS 471 CUBIC INCHES.

Guess how many Honeywell Meters in this fishbowl. Win a baby shark.

Imagine the fun of having your very own shark! Imagine the delighted laughter of neighbors when they discover it in your swimming pool! All you do is guess how many Honeywell miniature meters are in that fishbowl. Come closest, and the shark is yours for life! (Why the contest? To dramatize how many different miniature meters we make—most in the business—and just how miniature our miniatures are. Like the HS-1 Ruggedized that shrugs off vibration, is immune to dust and moisture; the MCE-1 Edgewise; the stylish MM-1 Medalist meter; and the new, square-shaped MS-1.) Entries must be postmarked before midnight, Nov. 15, 1963. In case of tie, earliest postmark wins. People who work for Honeywell may compete but we warn them: they won't win. Send your guess to Honeywell, Precision Meter Division, Manchester, N.H. While you're at it, ask for our latest catalog. Fascinating poolside reading.

Honeywell

Circle 109 on Inquiry Card

NEW TRICKS WITH STROBES

By synchronizing the light flash of a stroboscope with a cyclic motion, engineers can examine every detail of a machine's behavior at tens of thousands rpm.

Three new accessories extend the use and versatility of the strobe. They are a photoelectric pickoff, a flash delay and linear speed wheel.

Photoelectric Pickoff

Developed by General Radio Co., the photoelectric pickoff consists of a small lamp, a photocell, an optical system—all in a cylindrical housing—plus an output cable and a flexible, multiple-joint linkage system. Usually, this accessory is clamped near the observed object, and the lamp is pointed. A strip of reflecting tape placed on the object reflects light to the photocell during each revolution, then sends a trigger pulse to the strobe.

The photocell must be placed within an inch or so of the rotating object—depending on ambient light, speed, and tape or object reflectivity. High speeds around 100,000 rpm are no problem for the pickoff-strobe combination.

The human eye is unable to hold an image for more than a fraction of a second at very low speeds. Then we get flicker. To get around this, three tapes spaced around the observed object will make the strobe flash three times faster. The multiple image may be preferable to flicker.

If the photoelectric pickoff is used with an electronic counter for speed measure, six tapes and a 10-second counting time produce an rpm readout (as would 60 tapes and a one-second count).

Flash Delay

A flash should be producible at

Photoelectric pickoff (right) senses light reflecting from moving object, and sends trigger pulse to strobe (left) via flash delay. Flash delay powers pickoff, amplifies pulse, and introduces adjustable time delay for phase control of flash. User can observe moving object at any point.

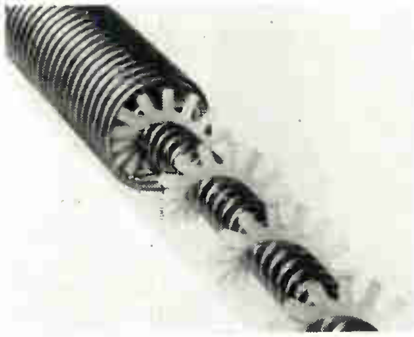
STROBE TRICKS (Concluded)

any point in the cycle. For this, another accessory—the flash delay—is connected to the pickoff output, to delay the trigger pulse. Delay is widely adjustable, and the user can easily phase the flash to show the moving object at any point in its motion.

The flash delay, in addition to delaying the trigger pulse, also amplifies the pulse, which otherwise would not be strong enough to fire the strobe. It also furnishes power to the pickoff.

Linear Speed Wheel

Another gadget—the linear speed wheel—extends the strobe's use as a tachometer. Flash rate is adjusted manually until flash and motion are in synch; rpm is read from the strobe dial. Linear speed in feet-per-minute is sometimes required. The wheel, a black nylon disk with a white radial stripe, converts rpm to fpm. When in contact with a moving surface, the disk turns at a rate related to the linear speed of the surface. Wheel circumference allows quick conversion.



H9 Heliax cable has a 5 in. dia. and a power handling capability of 826 kw.

AIR DIELECTRIC CABLE

A NEW AIR DIELECTRIC CABLE (Type H9 Heliax) which can be used for high power communication systems up to 950 MC has been announced by the Andrew Corp., Chicago, Ill. It is the largest known flexible, air dielectric cable available for high power installations. It has a 5 in. diameter and a power handling capability of 826 kw.

The convoluted conductors permit easy bending around obstructions, simplifying installation and eliminating discontinuities found in broken length installations. Produced in continuous lengths, Type H9 is available in lengths up to 1,000 ft. (shipping reel capacity). It may be readily formed to a radius of 50 in.

Pressure tight flanged end fittings for Type H9 are designed and produced to assure maximum peak power service and low attenuation.

Type H9 Heliax may be ordered with a polyethylene outer jacket for extreme environmental protection or direct burial. End fittings may be factory attached or readily assembled to the Heliax in the field.

AUTOMATIC RELAY TEST SET

A CONSOLE TYPE RELAY TEST SET for automatically checking up to 6 relays with one program setting has been developed by Associated Research, Inc., Chicago, Ill.

The new unit (Model 8555) handles relays with contact arrangements from SPDT through 6-pole double throw. Relays may be single coil non-polarized, single coil polarized, double coil polarized, latching or non-latching.

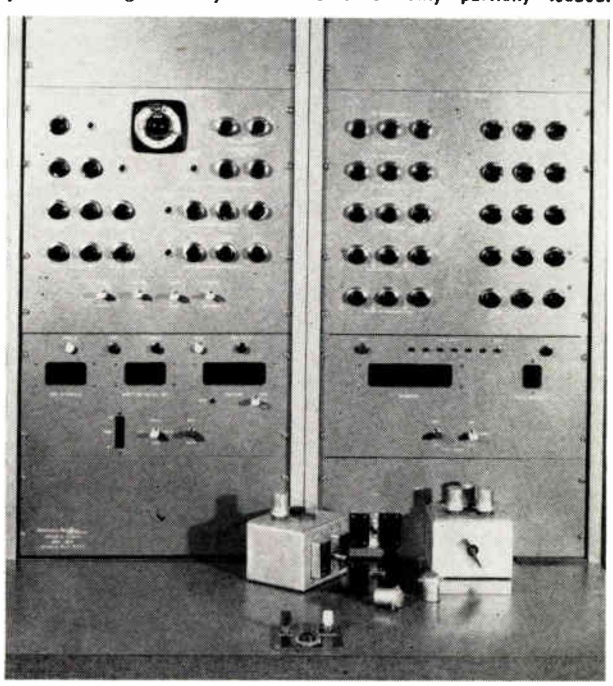
The Model 8555 will measure pull-in voltage or current, release voltage or current, operate time, release time, coil resistance, insulation resistance, dielectric strength, contact resistance, contact bounce on operate and contact bounce on release.

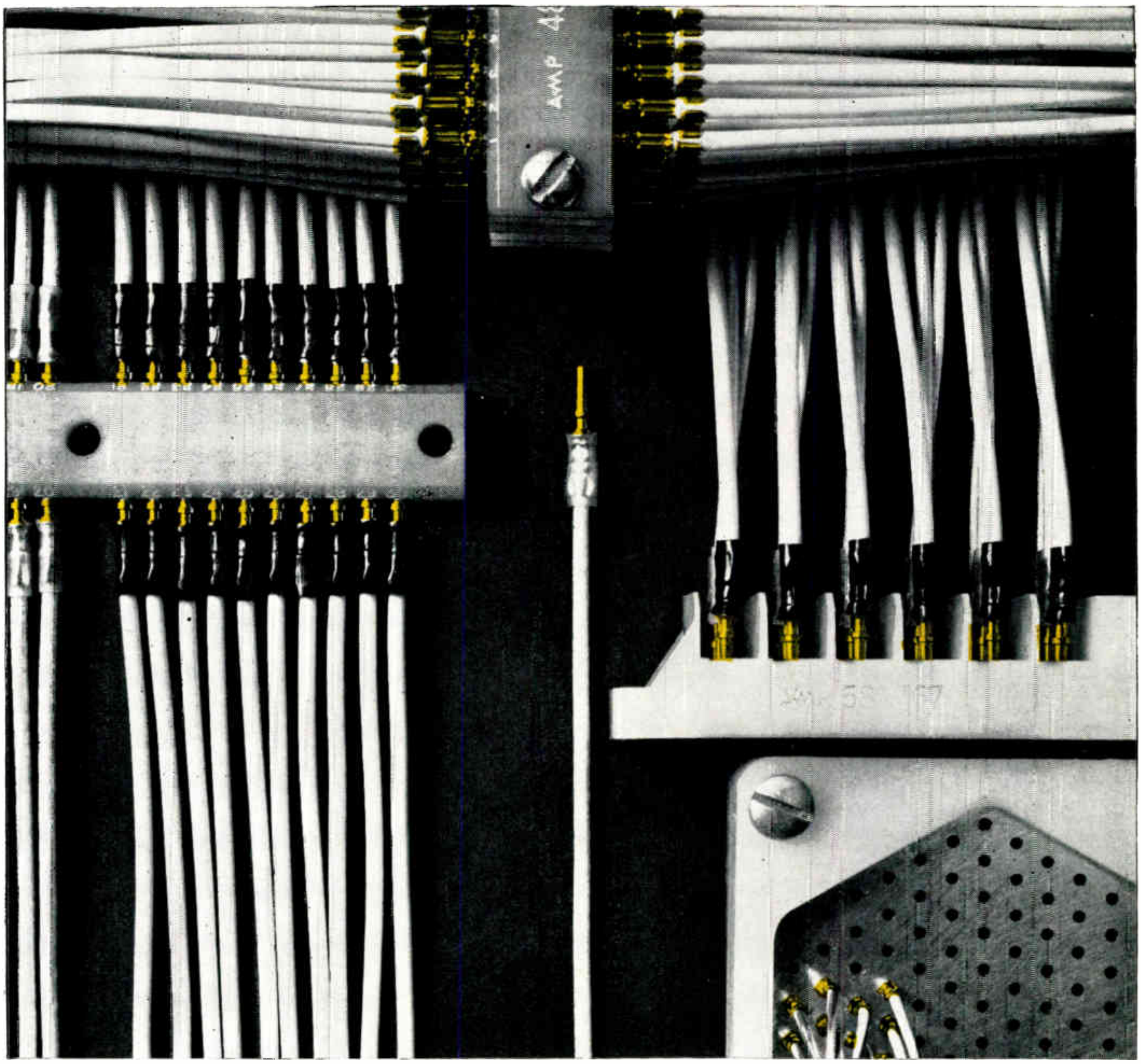
It will operate completely unattended and supply a printed or punch record giving the serial number of the relay, the test identification, measured value and pass or fail information.

To speed the testing of a large number of relays, the tester provides for the connection of 6 relays at a time through a scanner to the input of the tester. Tester and scanner operate so that one relay is completely tested before the scanner moves to the next position.

The set is of modular design. Each module is a self-contained integrated package, a complete functional unit, which is mounted on pull-out slides and plugged into the appropriate input and output channels.

Data regarding type of relay to be tested and the operating parameters are programmed with digital dials on left panel. Independent pass-fail limits for each test are set on the digital dials on the right panel. Photo shows one fixture in place holding 3 relays and the other only partially loaded.





1,000,000,000 Why's

In data processing machines, in radar installations, in missile guidance systems—in well over 1 billion electrical-electronic circuits, A-MP* Taper products rate first choice. And with good reason.

Maximum Density–An A-MP termination, just slightly thicker than the wire insulation diameter, permits maximum circuit concentration. Provides greater space freedom for design requirements of other vital components.

Front-end Fitness-AMP's precision taper creates peak mechanical and electrical characteristics. It makes the pins self-cleaning and self-locking. Makes sure they stay put under the most gruelling operating conditions.

Compression-crimp Consistency–Quick, precise attachment by matching crimping tools eliminates oxide creep, burnt and brittle insulation, cold solder joints. Assures uniformity throughout the connections, and at a lower total installed cost than any other method.

Broadest Selection–With AMP you choose from the most complete line of taper products in the industry. All types of pins—stamped and formed, uninsulated and insulation piercing types, screw machine with insulation support and pre-insulated Diamond Grip. One and two piece stackable taper blocks in standard configurations of 10, 20 and 30 cavities. Plus a long list of companion items, such as vertical entrance blocks, taper bus bar and taper tab blocks.

For all maximum density, high reliability circuits, choose A-MP Taper products. Complete information available on request.

*Trademark of AMP INCORPORATED.

AMP
INCORPORATED
Harrisburg, Pennsylvania

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • Mexico • West Germany

Circle 43 on Inquiry Card

NEW TECH DATA

for Engineers.

Film Resistor

The DC series of precision film resistors have tolerances to 0.01% and temp. coefficients standardized at 20 ppm. They are also available at 15, 10, and 5 ppm, meeting applicable specs. of Mil-R-10509D. Nominal TC can be selected, and values of 0 ppm or a wide variety of values from −100 to +1000 ppm/°C are available. Resistance range is 100Ω to 100KΩ. Angstrohm Precision Inc., 7341 Greenbush Ave., N. Hollywood, Calif.

Circle 130 on Inquiry Card

Piezo Accelerometer

The capabilities of Type 4-280 piezoelectric accelerometer, which combines integral impedance-matching electronics and the sensing element into a single miniature package, are described in bulletin 4-280 from Consolidated Electrodynamics Corp., a subs. of Bell & Howell, 360 Sierra Madre Villa, Pasadena, Calif. The instrument permits direct readout and recording of the output signal without intervening electronic equipment.

Circle 131 on Inquiry Card

Tape Reader

Specs. and operating information on model 52 perforated-tape reader with continuous tape-loop cartridge are given in this brochure. Continuous tape-loop cartridge allows tape to be drawn from the inside surface of a reel and rewound on the outside. Reader is suited to computer programming and control and checkout uses. Logic circuits detect malfunctions. Cook Electric Co., Data-stor Div., 8100 N. Monticello Ave., Skokie, Ill.

Circle 132 on Inquiry Card

SSB Transmitter

Tech. data is available on a new 50kw. h-f, SSB transmitter. Featuring reduced size and weight, the type MST transmitter is based on the design of proven transmitters and linear power amplifiers. Completely housed in 3 standard cabinets, the unit is air cooled, provides automatic tuning over 10 pre-set channels, and has low distortion. Silicon-controlled rectifiers and transistors are used in all power supplies. Marketing Dept., Westinghouse Electronics Div., Box 1897, Baltimore 3, Md.

Circle 133 on Inquiry Card

Thermoelectric Modules

Thermoelectric modules consisting of several couples arranged electrically in series and thermally in parallel are described in this 2-page publication. Tech. Data 54-768 gives data on uses, dimensions, plus typical characteristics. Special Products Dept., Semiconductor Div., Westinghouse Electric Corp., Youngwood, Pa.

Circle 134 on Inquiry Card

Photoelectric Components

The 32-page Catalog A describes photoelectric and automation components, including miniature tubular scanners, proximity sensors, miniature scanners, explosion-proof scanners, long-range systems, scanner relay systems, electronic timers, rototimers, and electronic relays. Complete data includes detailed description of each item, dimension drawings, photograph, electrical specs., installation methods, adjustments, weight and prices. Farmer Electric Products Co., Tech. Circle, Natick, Mass.

Circle 135 on Inquiry Card

Connector Slide Rule

The connector selector circular slide rule enables the circuit designer to choose from 40 parts when designing crimp-type connectors. Over 120 combinations of wire size, mating, and mounting styles are available. Also offered are data sheets giving specs., dimensional outline drawings, and other features of Microcrimp coaxial connectors. Microdot Inc., 220 Pasadena Ave., So. Pasadena, Calif.

Circle 136 on Inquiry Card

Magnet Charger

Tech. information and application data on a low-voltage magnet charger are given in this bulletin. The RFL Model 2470 is capable of saturating all the Alnico as well as the newer barium-ferrite compounds. Output emf is adjustable in 7 steps from 35 to 150v. Test & Service Products Div., Radio Frequency Laboratories, Inc., Boonton, N. J.

Circle 137 on Inquiry Card

Solid-State Counter

Information is available on a solid-state freq. counter, Model 4EX15A, produced by General Electric Co. and Computer Measurements Co. It is fully transistorized, covers all freqs. from 10cps to 500MC continuously without extra heads, plug-ins or modules. Highly accurate. Communication Products Dept., General Electric Co., Lynchburg, Va.

Circle 138 on Inquiry Card

Commutator and Motor Upkeep

Commutator and motor maintenance products, designed for in-place use, is the subject of this 8-page color brochure. It describes artificial abrasives, commutator resurfacers, brush seaters and flexible abrasives designed for copper removal, seating of brushes, cleaning and burnishing. Information on selecting grade and size is given. Also included are data and specs. on precision grinders, mica undercutting equipment, and other small tools. Ideal Industries, Inc., 5180 Becker Pl., Sycamore, Ill.

Circle 139 on Inquiry Card

Microwave Diode

Data Sheet 4000 on ceramic cartridge diodes lists many new mixer and video detector diodes in high burnout, hermetically sealed and high temp. ratings. Data Sheet No. 4100 lists many newer and higher burnout types in addition to the established 1N830 and 1N831 series. Microwave procurement and engineering personnel should find this literature valuable. Alpha Microwave, Inc., 381 Elliot St., Newton Upper Falls 64, Mass.

Circle 140 on Inquiry Card

Gaussmeter Adapter

Model MMA-1 is a gaussmeter adapter for a dc VTVM. It consists of a magnetic sensor, power supply, and control system. The device is calibrated to have an output of 1mv/100 gauss. Provision is made for increasing this sensitivity to 3mv/100 gauss. Readout is accomplished by connecting the unit to any high-impedance dc VTVM. The accuracy of the unit is ±3% and it is useful to 30 kilogauss. Data available from Scientific Columbus, Inc., 840 Kinnear Rd., Columbus 12, Ohio.

Circle 141 on Inquiry Card

Research Laser

Model 3166 is composed of: an optical pumping head complete with ruby laser crystal and matching xenon flash lamp; a basic 10,000 Joule capacitor module, variable in 100 Joule increments, or a 12,000 Joule module with 1000 Joule increments; a 5kv, 0.5a. charge and control unit; and a trigger generator. Additional 10,000 J and 12,000 J capacitor modules can be added. With minor adjustments, the pumping cavity will accept ruby, glass, fluoride and oxide rods from ¼ to ¾ in. dia. and in 1-8 in. lengths. Additional information from Radiation Inc., Melbourne, Fla.

Circle 142 on Inquiry Card

VHF Accelerometers

Specs. and detailed performance characteristics of the latest models in a series of high sensitivity, VHF micro-miniature accelerometers are included in data sheet T-133. Diagrams and photos and a 1 to 50 unit price list are given. Columbia Research Laboratories, Inc., MacDade Blvd. & Bullens Lane, Woodlyn, Pa.

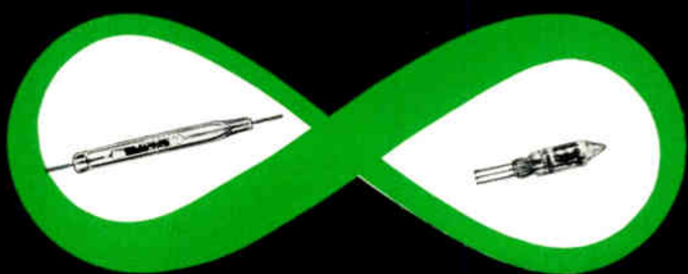
Circle 143 on Inquiry Card

Driving Motors

Data sheet describes standard Slo-Syn driving motors with a 72 RPM ±10% shaft speed from either dc or high-freq. power sources. The new 50 and 150 oz.-in. dc Slo-Syn Motors are operated from a 28vdc ±5% input or from a 120v., 200-1000 CPS source. Superior Electric Co., Bristol, Conn.

Circle 144 on Inquiry Card

resistance = ∞ - 1?

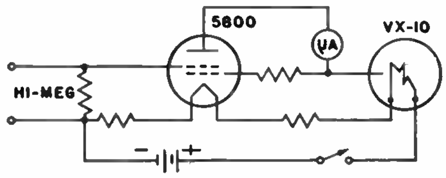


Not quite. But it's no trick at all to get values as high as 10^{14} ohms with famous Victoreen Hi-Meg Resistors, and input resistances to 10^{15} ohms with Victoreen Electrometer Tubes. They belong in your circuit if you demand exotic performance at a realistic price.

VICTOREEN

THE VICTOREEN INSTRUMENT COMPANY
5806 HOUGH AVENUE • CLEVELAND 3, OHIO, U.S.A.
Victoreen European Office: P. O. Box 654, The Hague

INSTABILITY OF THE DC LEVEL of electrometer tubes, particularly in a direct-coupled amplifier, has long been a disconcerting problem for design engineers. One factor contributing to this instability is the result of simultaneous application of plate voltage and filament voltage. Even the 10 mA filaments commonly used in these tubes require up to 1 second to come to full emission temperature. During this time the tube is operating in an emission-limited mode. Resulting instability may require from a few seconds to several hours for correction.

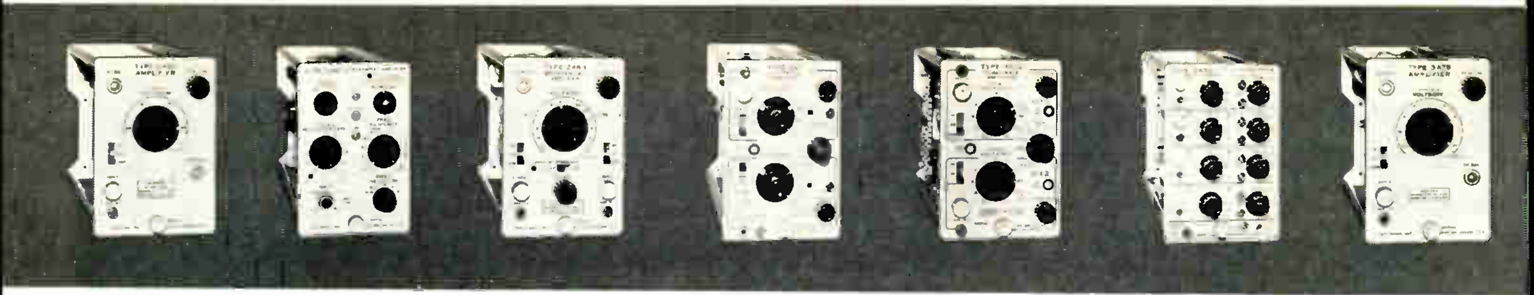


Victoreen has produced two Thermal Time Delay Relays to prevent this destabilization: The VX-10 and VX-69, each of which automatically provides approximately 1 second delay in the application of plate voltages.

Due to the high leakage resistance (10^{15} ohms) of the open contacts, these Thermal Time Delay Relays provide excellent means for remote switching of Hi-Meg Resistors and other high resistance circuits. This is particularly useful when a multi-range radiation detector must be located in a high radiation field precluding the possibility of manually adjusting zero or changing ranges. VX-69 provides isolation between thermal element and relay contacts, permits the switching of circuits which have no common electrical connection. VX-10 has control circuit and contact circuits electrically connected, making them particularly suitable for series operation with electrometer tubes. Filament reading for these tubes is nominally 1.25 volts at 10 mA.

Full details on request to
Applications Engineering Department
THE VICTOREEN INSTRUMENT COMPANY
5806 Hough Ave., Cleveland 3, Ohio, U.S.A.

 Circle 44 on Inquiry Card



EASY ADAPTABILITY TO PARTICULAR NEEDS

WIDE OPERATING VERSATILITY, AVAILABLE THROUGH 2-SERIES AND 3-SERIES PLUG-INS

AMPLIFIER UNITS

Type	Passband (3-db down)	Calibrated Deflection Factor †	Input (ac or dc coupled)	Price
2A60 Single Trace	dc — 1 Mc.	50 mv/cm—50 v/cm in 4 steps.	1 megohm, 47 pf, 600 volts max.	$105
2A61 Low-Level Differential	.06 cps—300 kc.	10 µv/cm—20 mv/cm, 1-2-5 sequence.	10 megohms, 50 pf, ±5 volts, ac-coupled	$385
2A63 Differential 50:1 rejection ratio	dc — 300 kc.	1 mv/cm—20 v/cm, 1-2-5 sequence.	1 megohm, 47 pf, 600 volts max.	$130
***3A1 Dual-Trace** (Identical Channels)	dc — 10 Mc. (each channel).	10 mv/cm—10 v/cm, 1-2-5 sequence.		$410
3A72 Dual-Trace (Identical Channels)	dc — 650 kc (each channel).	10 mv/cm—20 v/cm, 1-2-5 sequence.		$250
3A74 Four-Trace (Identical Channels)	dc — 2 Mc. (each channel).	20 mv/cm—10 v/cm, 1-2-5 sequence.		$550
3A75 Single Trace	dc — 4 Mc.	50 mv/cm—20 v/cm, 1-2-5 sequence.		$175
3C66 Carrier Amplifier	dc—5 kc (70-µsec risetime)	10 µstrain/div—10,000 µstrain/div, 1-2-5 sequence	input via 4-arm bridge with 25-kc excitation	$400
3S3 Dual-Trace Sampling (use with 3T77)	equivalent dc—1 Gc. (0.35-nsec risetime)	5 mv/div—200 mv/div, 1-2-5 sequence	100 K—2 pf ±3 volts max.	$1500 (with probes)
3S76 Dual-Trace Sampling (use with 3T77)	equivalent dc—875 Mc (0.4-nsec risetime)	2 mv/cm—200 mv/cm, 1-2-5 sequence.	50 ohms, 2 volts pk-to-pk max. dc-coupled	$1100

TIME-BASE UNITS

Type	Sweep Rate †	Magnifier	Triggering	Price
2B67 Single Sweep	1 µsec/cm to 5 sec/cm, 1-2-5 sequence.	5X	Internal, External, Line; amplitude-level selection; ac or dc-coupled; automatic or free run; ± slope.	$175
3B1 Sweep Delay	0.5 µsec/cm to 1 sec/cm, 1-2-5 sequence (for both normal and delayed sweeps).		Internal, External; amplitude-level selection; ac or dc-coupled; automatic (normal sweep only) or free-run; ± slope.	$475
3B3 Calibrated Sweep Delay Single Sweep	0.5 µsec/cm to 1 sec/cm, 1-2-5 sequence (for both normal and delayed sweeps). Continuously variable calibrated delay from 0.5 µsec to 10 sec.		Internal, External; amplitude-level selection, ac or dc coupled, ± slope. Normal sweep has in addition: automatic and line plus single sweep.	$525
3T77 Sampling Sweep (use with 3S3 or 3S76)	Equivalent sweep rates 0.2 nsec/cm to 10 µsec/cm, 1-2-5 sequence.	10X	Internal or External, ± slope.	$650

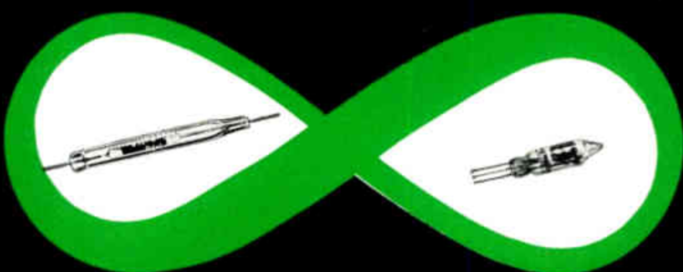
† Deflection factor and Sweep Rate are variable between steps, uncalibrated. * Provides 6-cm linear scan.

FOR MORE INFORMATION ON EITHER MODEL OF THIS NEW OSCILLOSCOPE AND ANY COMBINATION OF PLUG-IN UNITS, PLEASE CALL YOUR TEKTRONIX FIELD ENGINEER.

Tektronix, Inc. / *P. O. BOX 500 · BEAVERTON, OREGON 97005 · Phone (Area Code 503) Mitchell 4-0161 · Telex: 036-691 · TWX: 503-291-6805 · Cable: TEKTRONIX · OVERSEAS DISTRIBUTORS IN 27 COUNTRIES*

Tektronix Field Offices: in principal cities in the United States. Consult Telephone Directory • Tektronix Limited, Guernsey, Channel Islands
Tektronix Canada Ltd.: Montreal, Quebec • Toronto (Willowdale), Ontario • Tektronix Australia Pty. Limited, Sydney, New South Wales

resistance = ∞ -1?



Not quite. But it's no trick at all to get values as high as 10^{14} ohms with famous Victoreen Hi-Meg Resistors, and input resistances to 10^{15} ohms with Victoreen Electrometer Tubes. They belong in your circuit if you demand exotic performance at a realistic price.

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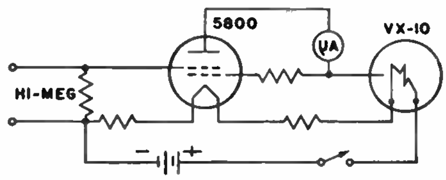

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NEW TECH DATA

Switch Catalog

A 2-color switch catalog is available from Tech Laboratories, Inc., 52 E. Edsall St., Palisades Park, N. J. This 24-page catalog provides complete engineering specs. on the full standard line switches. It defines industrial terminology and proper switch maintenance.

Circle 157 on Inquiry Card

Nuvistor Triode

Noise figure and gain characteristics for the RCA-8056 nuvistor triode operating at 200MC under noise-matched conditions are presented in note AN-195. It includes practical curves for constant noise figure and constant gain. Design examples and measuring-circuit used are given. Commercial Engineering, Electron Tube Div., Radio Corp. of America, Harrison, N. J.

Circle 158 on Inquiry Card

Multiplier Phototube

Type No. C70129B is ½ in. dia. multiplier phototube. It is expected to have wide usage in missiles, satellite applications, spectrophotometric measurements, and instrumentation. It is a 9-stage side-on type having S-4 spectral response, and is a scaled-down version of the RCA-1P21. It has survived 30g for 11msec. Additional data from RCA Industrial Tube and Semiconductor Div., Lancaster, Pa.

Circle 159 on Inquiry Card

Detector Module

This tech. data sheet highlights features and operation of a freq. detector module used in FM detection for telemetry dc readout of input freq. and automatic freq. or speed control. The 1¼ x 4 in. transistorized cylinderical module produces a dc output voltage proportional to freq. of the input sq.-wave signal. A preamp. of 0.25v. RMS sensitivity is also available for use with inputs having other than sq.-wave form. Daystrom, Inc., Manchester Rd., Poughkeepsie, N. Y.

Circle 160 on Inquiry Card

Rubberized Abrasives

This catalog describes 17 new rubberized abrasives for deburring, smoothing and polishing. It also suggests many cost-cutting uses for these abrasives, which are available in wheels, points, sticks, blocks and cones in 4 grit textures and in a wide range of sizes. Included are operation instructions, application data, speed tables, graphs, photos, and other tech. information. Cratex Mfg. Co., Inc., 1600 Rollins Rd., Burlingame, Calif.

Circle 161 on Inquiry Card

Timer Terminology

This glossary of timer terminology is offered to reduce the use of several different terms to describe the same function. Copies available from Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle 162 on Inquiry Card

The CLARE Type JDP Relay assembly provides for direct plug-in mounting of the CLARE Type J Relay with the contact springs and coil terminals serving as plug pins. This complete assembly of relay, mounting socket and clear plastic dust cover is available at much lower cost than comparable relay assemblies. Part numbers and prices include complete assembly at one low price.

And that's not all. The Clare JDP Relay assembly provides a simple, economical plug-in relay with all the advantages of the stable operation and adjustment, the consistent performance and the optimum reliability which have made the CLARE Type J Relay so widely accepted as the ideal component for critical control applications.

Direct plug-in mounting eliminates costly internal wiring, and makes possible cost savings with no sacrifice of Type J Relay quality. There is space-saving, too. Overall height of the JDP assembly when mounted is 20% less than the height of relays with the conventional octal plug.

Type JDP assemblies are available in two sizes. A 28-pin assembly for 24 contact springs and four coil terminals, and a 16-pin assembly for 12 contact springs and four coil terminals. Relay terminals are slotted so relays intended for JDP assembly can also be wired directly into chassis.

All standard Type J Relay features are available in the Type JDP assembly. These include: contact forms A, B, C, D, and E; contacts for low level to 5 ampere switching; double-wound coils; slow operate; slow release; and a-c coil operation.

ELECTRICAL AND MECHANICAL CHARACTERISTICS OF CLARE TYPE J RELAYS

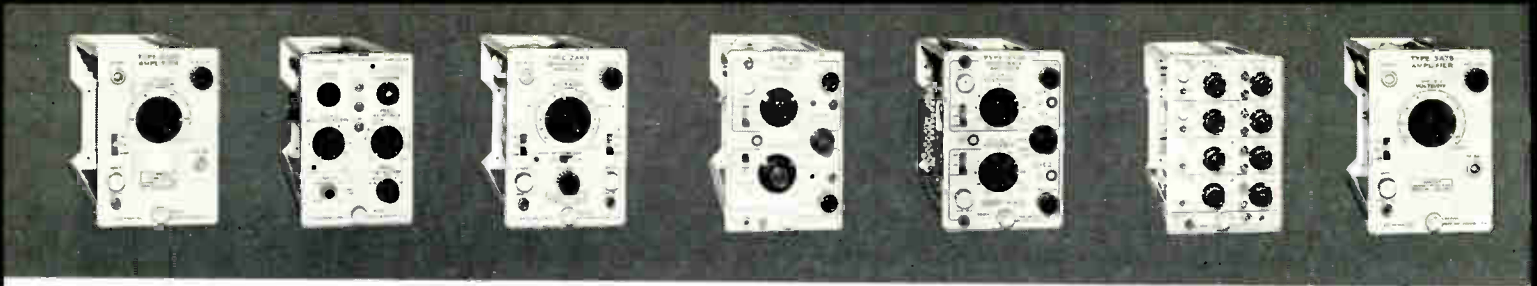
Contact Arrangements	Contact Ratings	Coil Resistance	Nominal Operating Voltages	Operate Time	Release Time
Forms A, B, C, D, E, up to 24 contact springs max	Low level to 5 amps, 500 watts	Up to 21,000 ohms	Up to 300 vdc Up to 220 vac, 50-60 cps	Fast operate: 5 ms min Delayed operate: 60 ms max	Fast release: 5 ms min Delayed release: 125 ms max

GET COMPLETE INFORMATION

including prices, detailed specifications, and standard part numbers. Circle Reader Service Number below, or write C. P. Clare & Co., Group 9D5, 3101 Pratt Blvd., Chicago 45, Illinois.

CLARE® Relays and related control components

Circle 47 on Inquiry Card



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3A72 Dual-Trace (Identical Channels)	dc — 650 kc (each channel).	10 mv/cm—20 v/cm, 1-2-5 sequence.		$250
3A74 Four-Trace (Identical Channels)	dc — 2 Mc. (each channel).	20 mv/cm—10 v/cm, 1-2-5 sequence.		$550
3A75 Single Trace	dc — 4 Mc.	50 mv/cm—20 v/cm, 1-2-5 sequence.		$175
3C66 Carrier Amplifier	dc—5 kc (70-μsec risetime)	10 μstrain/div—10,000 μstrain/div, 1-2-5 sequence	input via 4-arm bridge with 25-kc excitation	$400
3S3 Dual-Trace Sampling (use with 3T77)	equivalent dc—1 Gc. (0.35-nsec risetime)	5 mv/div—200 mv/div, 1-2-5 sequence	100 K—2 pf ±3 volts max.	$1500 (with probes)
3S76 Dual-Trace Sampling (use with 3T77)	equivalent dc—875 Mc (0.4-nsec risetime)	2 mv/cm—200 mv/cm, 1-2-5 sequence.	50 ohms, 2 volts pk-to-pk max. dc-coupled	$1100

TIME-BASE UNITS

Type	Sweep Rate †	Magnifier	Triggering	Price
2B67 Single Sweep	1 μsec/cm to 5 sec/cm, 1-2-5 sequence.	5X	Internal, External, Line; amplitude-level selection; ac or dc-coupled; automatic or free run; ± slope.	$175
3B1 Sweep Delay	0.5 μsec/cm to 1 sec/cm, 1-2-5 sequence (for both normal and delayed sweeps).		Internal, External; amplitude-level selection; ac or dc-coupled; automatic (normal sweep only) or free-run; ± slope.	$475
3B3 Calibrated Sweep Delay Single Sweep	0.5 μsec/cm to 1 sec/cm, 1-2-5 sequence (for both normal and delayed sweeps). Continuously variable calibrated delay from 0.5 μsec to 10 sec.		Internal, External; amplitude-level selection, ac or dc coupled, ± slope. Normal sweep has in addition: automatic and line plus single sweep.	$525
3T77 Sampling Sweep (use with 3S3 or 3S76)	Equivalent sweep rates 0.2 nsec/cm to 10 μsec/cm, 1-2-5 sequence.	10X	Internal or External, ± slope.	$650

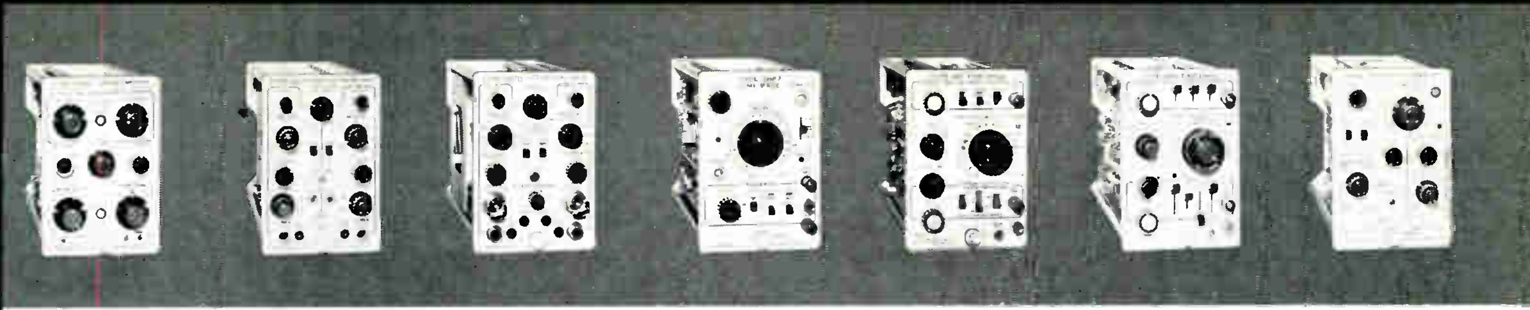
† Deflection factor and Sweep Rate are variable between steps, uncalibrated. * Provides 6-cm linear scan.

FOR MORE INFORMATION ON EITHER MODEL OF THIS NEW OSCILLOSCOPE AND ANY COMBINATION OF PLUG-IN UNITS, PLEASE CALL YOUR TEKTRONIX FIELD ENGINEER.

Tektronix, Inc. / P. O. BOX 500 · BEAVERTON, OREGON 97005 · Phone (Area Code 503) Mitchell 4-0161 · Telex: 036-691 · TWX: 503-291-6805 · Cable: TEKTRONIX · OVERSEAS DISTRIBUTORS IN 27 COUNTRIES

Tektronix Field Offices: in principal cities in the United States. Consult Telephone Directory • Tektronix Limited, Guernsey, Channel Islands

Tektronix Canada Ltd.: Montreal, Quebec • Toronto (Willowdale), Ontario • Tektronix Australia Pty. Limited, Sydney, New South Wales

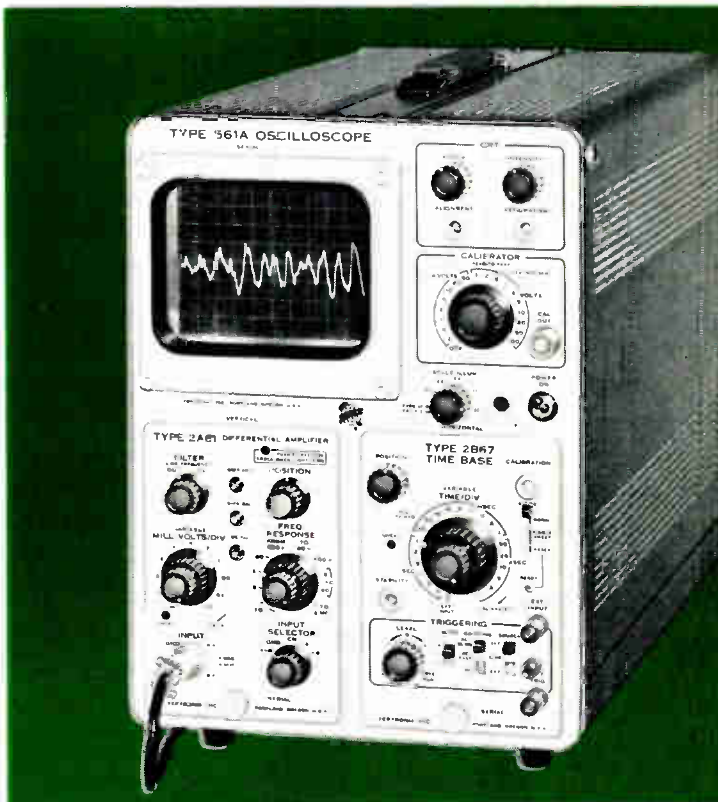


IN COMPACT NEW TEKTRONIX OSCILLOSCOPE

Here's a high-performance oscilloscope featuring operational simplicity and versatility through a new series of plug-in units. Presently, you can select from 10 amplifier units and 4 time-base units.

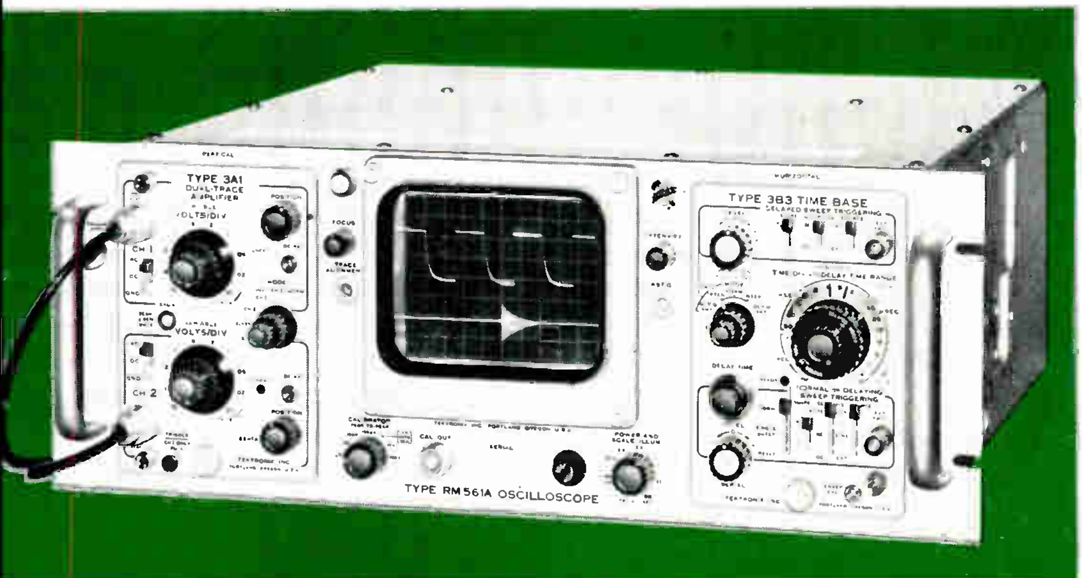
Knowing your application area, you select those units that fit your needs. Some of the general-purpose plug-in unit combinations available include those for low-level applications, differential applications, multi-trace applications, wide-band applications, sweep-delay applications, among other presentations. A special-purpose plug-in combination equips the oscilloscope for sampling applications, in which the instrument becomes a low-drift sampling system as easy to operate as a conventional oscilloscope, but with sensitivity and bandwidth possible only through sampling.

With any combination of plug-in units in the oscilloscope—including the same type amplifier units in both channels for X-Y displays—this new value package provides you with "no-parallax" displays and sharp trace photography.



The 2A63/2B67 Plug-In Unit combination—illustrated with Type 561A—equips the oscilloscope for *low-level differential applications.*

Circle 48 on Inquiry Card



The 3A1/3B3 Plug-In Unit combination—illustrated with the rack-mount model, Type RM561A—equips the oscilloscope for *high-sensitivity, wide-band, dual-trace operation and sweep-delay applications.*

The rack-mount model occupies only 7 inches of standard rack height.

OSCILLOSCOPE FEATURES

NEW RECTANGULAR CRT . . . with an internal graticule and controllable edge lighting . . . regulated power supplies . . . regulated dc heater supply . . . Z-axis input . . . 3.5-kv accelerating potential . . . amplitude calibrator . . . and operation from 105 v to 125 v or 210 v to 250 v. (The Type 561A operates from 50-400 cps and the Type RM561A operates from 50-60 cps.)

Type 561A (shown in low level application) $470

Type RM561A (shown in sweep delay application) . 525

Oscilloscope prices without plug-in units.

U. S. Sales Prices, f.o.b. Beaverton, Oregon

NEW TECH DATA

Industrial Parts Catalog

The 1963-1964 edition of the Cramer industrial electronics catalog lists over 45,000 separate items in 458 pages. This buyers' guide is profusely illustrated and provides complete descriptions, latest product data, and factory OEM pricing. Featured are the newest microminiature devices, semiconductors, electronic components and equipment for use in industrial, research, and aerospace. Cramer Electronics, Inc. Newton, Mass.

Circle 163 on Inquiry Card

Laminated Plastic

Tech. data bulletin No. 3.1.22.3 describes grade XXXP-733, a paper-base, phenolic-resin laminated plastic which can be punched at room temp. It has high-insulation resistance under high-humidity conditions, excellent electrical properties and good dimensional stability. Insulation resistance under condition C—96/35/90 is 500,000 megohms for sheets 1/32, 1/16, and ⅛ in. thick. Taylor Corp, Valley Forge, Pa.

Circle 164 on Inquiry Card

Soldering Stands

Bulletin #633 describes the model SS series soldering stands that permit max. freedom of movement and eliminate the handling of soldering irons. Viewing window makes it easy for the operator to focus attention on soldered joint. Lost motion is eliminated and the pace of soldering is accelerated. Photomation, Inc., Box 460, Mountain View, Calif.

Circle 165 on Inquiry Card

VHF Pentode

In this bulletin the Type 8149 VHF pentode, a single-ended T-12 compactron design, is described in depth, with complete sets of mechanical and electrical specs., as well as detailed outline and basing diagrams. Includes a chart showing Intermittent Commercial and Amateur Service (ICAS) ratings, and 3 characteristic curve performance charts. Freq. limit is 175mc, with a max. plate dissipation of 35w. (ICAS). Tung-Sol Electric Inc., One Summer Ave., Newark 4, N. J.

Circle 166 on Inquiry Card

Transistor Application

This booklet contains graph, tables, schematics, and equations applicable to the design of circuits using field-effect transistors. Temp. effects, dc biasing, freq. and switching, limitations, and circuits are discussed. Amelco Semiconductor, Div. of Teledyne, Inc., 1300 Terra Bella Ave., Mountain View, Calif.

Circle 167 on Inquiry Card

Nickel Plating Solution

Technical information is available on a new nickel plating formula which improves the stress and ductility of nickel sulfamate plating. Called SULFAMEX, the solution is available in ready-to-plate form. The Meaker Co., subs. of Sel-Rex Corp., Nutley, N. J.

Circle 168 on Inquiry Card

NEW TECH DATA

Freq. Control Handbook

A 44-page, letterhead-size handbook and catalog lists standardized crystals, filters and freq. sources. The handbook, with illustrated design parameters, is divided into 3 major sections: crystals ranging from 400 cycles to 100MC; filters ranging in center freq. from below 1KC to over 20MC, and freq. sources ranging from 1CPS to over 250MC. Hill Electronics, Inc., Mechanicsburg, Pa.

Circle 169 on Inquiry Card

Semiconductor Catalog

This catalog, in full color, presents complete information on a line of transistors, diodes, micrologic, custom microcircuits, test equipment, and special products. The parameters of each transistor and diode are presented in tabular form, along with a brief description of the design and manufacturing processes. Photos and schematics illustrate the 6 units needed to fabricate an entire logic system. Custom microcircuit design are pictorially shown from schematic to finished product. Fairchild Semiconductor, 545 Whisman Rd., Mountain View, Calif.

Circle 170 on Inquiry Card

Nsec Interval Counter

Information is available on the Model 783G 10nsec. time interval counter that counts 100MC pulses obtained from either an internal or external 1MC standard. Readings are in μsec. with fixed decimal point; unit is available with 3 to 9 digits. Levels to ±40v. will not damage inputs. Eldorado Electronics, 1832 Second St., Berkeley 10, Calif.

Circle 171 on Inquiry Card

Impact Melamine

Design engineers and plastic molders will be interested in this tech. data report on medium impact melamine molding compound published by the Plastics Div., Allied Chemical Corp., Box 365, Morristown, N. J. Melamine molding compound —MFG-33—provides 25% to 100% more impact strength than standard cellulose-filled melamine. Tech. data report M1-3 presents electrical, physical, mechanical and chemical properties, as well as molding properties.

Circle 172 on Inquiry Card

Laminated-Edge Connectors

Product Bulletin No. PBM-21 on low-cost laminated edge connectors gives dimensional data and electrical specs. on 6 styles with up to 56 contacts/connector. The 8 types of contact tails available are described. Cinch Mfg. Co., 1026 S. Homan Ave., Chicago 24, Ill.

Circle 173 on Inquiry Card

ECDC Transistors

The use of Type 2N2095 and 2N2098 ECDC transistors as VHF amplifiers and oscillators at freqs. up to 160MC are described in Semiconductor Application Note No. 38016 available upon letterhead request to the Technical Literature Service, Sprague Electric Co., Marshall St., N. Adams, Mass.

NEW TECH DATA

Racks and Consoles

Catalog 63 contains 44 pages of illustrations, detailed engineering drawings, tech. specs., descriptions and prices of modular cabinet racks and consoles, together with appropriate standard accessories. Illustrations give examples of how these cabinets and consoles can be used singly as well as in multiple assemblies. Par-Metal Products Corp., 32-62 49th St., Long Island City 3, N. Y.

Circle 174 on Inquiry Card

Insulating Materials

Information on 19 insulating materials — varnishes, impregnating resins and enamels—are on individual loose-leaf tech. data sheets. Materials include new Doryl Class H varnishes, modified polyester base Class F varnishes, varnishes for high-speed rotating equipment, epoxy varnish for chemical uses, and a variety of other Micarta liquid insulating materials. Westinghouse Electric Corp., Micarta Div., Trafford, Pa.

Circle 175 on Inquiry Card

Directional Couplers

This bulletin covers 8 coax. directional couplers which provide overlapping of freqs. from 1 to 1200MC at power levels up to 1000w. Wideband characteristics of the couplers allow transmission-line measurements over a freq. range of more than an octave. Sierra Electronic Operations, Philco Corp., 3885 Bohannon Dr., Menlo Park, Calif.

Circle 176 on Inquiry Card

Irradiated Polyolefin Dielectric

Tech. data is available on a low-loss dielectric called Rexolene P. An irradiated polyolefin, Rexolene P is photo-etchable with standard methods and can be precision-machined. Its uses include phased arrays, strip lines, directional couplers, duplexers, and electronic drive components. Brand Rex Div., American Enka Corp., 31 Sudbury Rd., Concord, Mass.

Circle 177 on Inquiry Card

Plain Foil Capacitor

This tech. bulletin describes high-voltage tantalum plain-foil capacitors that conform to Mil-C-3965. They are described as polar and nonpolar units with 200, 250 and 300v. ratings. The higher dc working voltages eliminate the need for series circuit connections to obtain comparable voltage ratings. Operating temp. is $-55°$ to $+85°$C without voltage derating. Capacitance ratings are said to range from 0.015 to 15μf ($\pm 15\%$). Standard Pressed Steel Co., Box 899, Jenkintown, Pa.

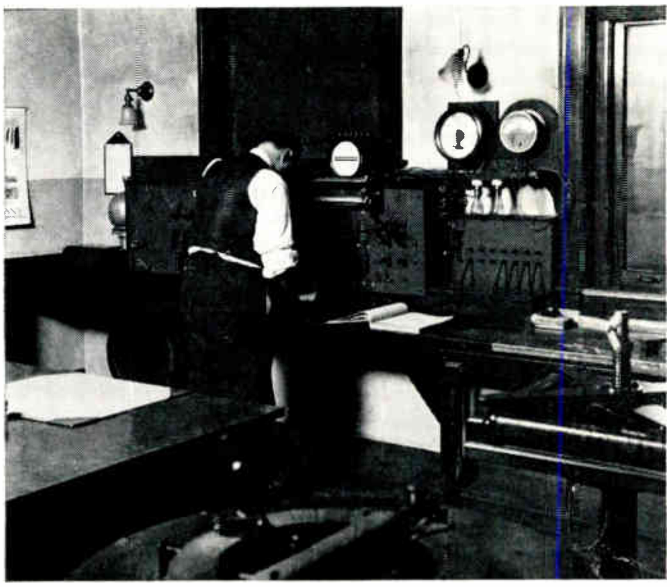
Circle 178 on Inquiry Card

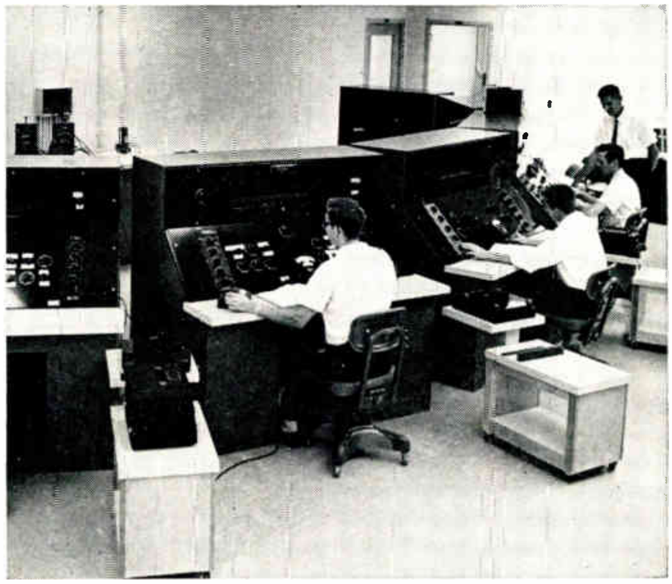
Paints & Washers

Data sheet details series of pressure-sensitive paints and washers for transducers. Washers are described as "a molecular engineering development in force or pressure resistivity." Clark Electronic Laboratories, P. O. Box 165, Palm Springs, Calif.

Circle 179 on Inquiry Card

Profit from Armco's 60 Years' experience with magnetic materials





This year marks Armco's 60th year of continuous research and commercial production of special steels for the electrical industry.

Armco's long experience in the production and application of electrical steels and other magnetic alloys is directed to supplying you with materials that best meet your specific needs. Supplemented by continuing research, this valuable experience has enabled Armco to pioneer in significant achievements such as the development of grain-oriented silicon grades, thin gage electrical steels and nickel-iron magnetic alloys.

In addition to these progressive accomplishments, Armco is aggressively working in both plant and Research Center to achieve even more. Widespread use of Armco Electrical Steels and Magnetic Alloys throughout the industry also has broadened our knowledge of your design and fabrication problems.

We would like to make this 60 years' of varied experience available to you for use in creating better products at lower cost. Just write us for more information. **Armco Division, Armco Steel Corporation, Department A-3603, P. O. Box 600, Middletown, Ohio.**

ARMCO **Armco Division**

Circle 55 on Inquiry Card

NEW TECH DATA

Coaxial Cables

Complete data on line of coax. cables, including physical dimensions, engineering evaluations and closest equivalents, where applicable, is available in a 2-color, standard-size form. Design engineers and purchasing agents using this data sheet will save time and effort when searching for standard, high-temp. insulated coax. cables. Boston Insulated Wire & Cable Co., 25 Bay St., Boston 25, Mass.

Circle 180 on Inquiry Card

Modular Packaging

This 16-page illustrated catalog, No. E-63, describes modular packaging system of reusable aluminum shipping and storage containers for systems and instrument packaging. Includes a summary of benefits and advantages of the system; typical applications; pallet and shroud packaging system; modular container facilities; shock/vibration isolation; design and specs.; accessories; and information on how to order. Zero Mfg. Co., 1121 Chestnut St., Burbank, Calif.

Circle 181 on Inquiry Card

Temperature Converter

This 4-scale table, in color, for Fahrenheit, Centigrade, Kelvin and Rankine gives over 400 conversions for each temp. scale. It includes quick reference conversions every 10°. Table was prepared with basic temp. conversion formulas. It is laid out in columns with each scale distinguished by color shadings. The table can be hung as an 11 x 25½ in. wall chart. Dept. SK, Air Products and Chemicals, Inc., Allentown, Pa.

Circle 182 on Inquiry Card

Sensitive Thermistors

This 2-page data sheet, "Veco Micro-Bead (TM) Thermistors," describes thermistors which are 0.005 in. in dia., with lead wires 0.0007 in. in dia. These thermistors, highly sensitive to power, are very useful in gas chromatography, high altitude temp. measurement, microwave power measurement, medical and biological uses and many others. They are hermetically sealed in glass, protected from contamination, safe for use with explosive gases, and feature high stability and fast time response. Victory Engineering Corp., 124-28 Springfield Ave., Springfield, N. J.

Circle 183 on Inquiry Card

Heat Dissipators

This short-form catalog lists components for cooling and retention of electron tubes and semiconductor devices. It contains part numbers, description, and photos for over 200 standard heat-dissipating electron tube shields. Accessories and a complete line of heat dissipators for transistor and diode thermal control are included. Heat dissipators listed are designed for all types of semiconductors and meet milliwatt-to-high-power dissipation needs. IERC Div., International Electronic Research Corp., 135 W. Magnolia Blvd., Burbank, Calif.

Circle 184 on Inquiry Card

NEW TECH DATA

for Engineers.

Output Transformer Chart

An output transformer chart listing the proper transformer to use for audio amplifier construction or for replacement purposes with 260 different audio tubes is available. The chart is arranged by tube number and lists applicable operating characteristics. Stancor Electronics, Inc., 3501 W. Addison St., Chicago 18, Ill.

Circle 202 on Inquiry Card

Precision Tools

This 16-page catalog includes a complete line of precision special microminiature and miniature tools. It includes a special line for servicing and adjusting relays of every type. Jonard Int'l Corp., Precision Tools Div., 3733 Riverdale Ave., Bronx 63, N. Y.

Circle 203 on Inquiry Card

Min. Magnetic Shields

Data Sheet 162 shows and describes space-saving, sectional miniature precision magnetic shields for small-space gyro and other retrofit uses where available space does not permit a completely conformal shield. Magnetic Shield Div., Perfection Mica Co., 1322 No. Elston Ave., Chicago 22, Ill.

Circle 204 on Inquiry Card

Components Catalog

Catalog '63 offers information on integrated mixer-preamplifiers, strip-type components, including filters, dividers, mixers and modulators; laboratory receivers, i-f and r-f amplifiers; and other special-purpose receiving equipment. This 72-page catalog gives tech. information, photos, dimension drawings, curves, tables, electrical and mechanical characteristics. Lel, Inc., 75 Akron St., Copiague, N. Y.

Circle 205 on Inquiry Card

Bench Top

The Sturdilite copper top is a 2 in. thick, 6-ply laminated and self edged on all sides. It is used where shielding or r-f interference problems are present. A copper screen is laminated between the surface material and a balanced wood core. Cooper discs are used in 2 contact holes that expose the screen. Measurements conducted on a 30 x 72 in. top showed a capacity of 1710pf/sq. ft., and insulation resistance greater than 50,000 megohms/sq. ft. Sturdilite Products, Inc., 3001 Palmolive Bldg., Chicago 11, Ill.

Circle 206 on Inquiry Card

Test Instrument Catalog

This well illustrated, 16-page catalog, AAE 14, presents a comprehensive product line of volt-ohm-ammeters, recorders and high-intensity lamps. Also included are prices, specs., other descriptions and a complete explanation of Amprobe's trade-in programs. Amprobe Instrument Corp., 630 Merrick Rd., Lynbrook, N. Y.

Circle 207 on Inquiry Card

Card Tester

Data sheet 37 describes the Model 110 plug-in tester that tests the circuits of plug-in card modules. These include standard 17-pin cards, 20-pin cards, and 64-transistor matrix cards. Complete specs. are provided. Telemetrics, Inc., 12927 So. Budlong Ave., Gardena, Calif.

Circle 208 on Inquiry Card

Shockproof Resistors

Bulletin 104 describes wire-wound, vitreous enameled resistors designed to meet Mil-R-15109B. Listed are mounting and insulating hardware that satisfy all requirements. Ohmite Mfg. Co., 3671 Howard St., Skokie, Ill.

Circle 209 on Inquiry Card

Circle 57 on Inquiry Card

NEW TECH DATA

Gearless Torque Motor

Information is available on a dc operated torque motor featuring a 4 in. bore. The motor, designed both for torque and for servo uses, is direct driven and uses no gears, thus providing increased resolution without backlash and a high ratio of torque to inertia. Parameters: low flux leakage; min. motor inductance for use of pulsed power input; and max. torque/lb. of motor weight. Permanent magnets produce a high level of magnetic-circuit saturation and eliminate any fixed-phase or field winding excitation. Magnetic Technology, Inc., 13735 Saticoy St., Van Nuys, Calif.

Circle 185 on Inquiry Card

Compact AC Motor

Brochure 107 describes the type MC motor which operates on 60 or 400 cycles in 2, 4 and 6 pole types. Hysteresis or induction rotors are standard in this military qualified motor, with options of spur-gear reducers and odd ratio planetary gear reducers in 129 total reductions. Motor is 1¼ in. dia. x 2¼ in. long and gear reducers add up to 2 in. max. for largest gear reduction. Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.

Circle 186 on Inquiry Card

Pin Catalog

This 2-color, 12-page catalog gives complete product listings for all standard spring pins, their dia. and lengths in zinc-plated, cadmium-plated, plain carbon steel and 420 corrosion resistant steel. In addition, it carries list prices as well as minimum order quantities and quantity discounts. Atlantic Spring Pin Corp., 45 Haddon Ave., Shrewsbury, N. J.

Circle 187 on Inquiry Card

Plastics Bulletin

A 26-page bulletin, NVF Laminated Plastics, describes a complete line of phenolic, melamine, polyester, epoxy and silicone units. Grades, modification ranges, electrical qualities, insulation resistance, flame retardant characteristics, and punching grades are discussed in detail. National Vulcanized Fibre Co., 1063 Beech St., Wilmington 99, Del.

Circle 188 on Inquiry Card

Test Console Catalogs

Described in this 28-page, 2-color catalog, "Components for Test Consoles," are panel-mounted dial assemblies, ac voltmeters, phase-sensitive voltmeters, and phase shifters. Uses, specs., and other data are given. Theta Instrument Corp., Saddle Brook, N. J.

Circle 189 on Inquiry Card

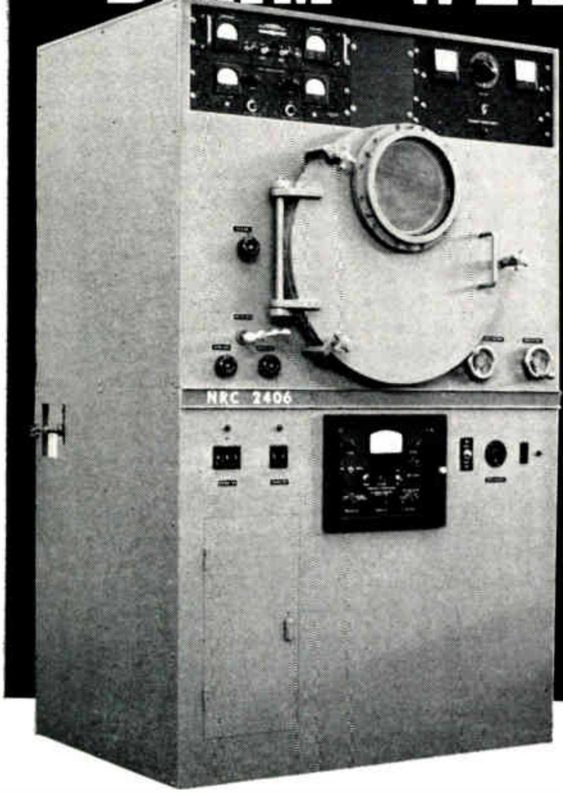
Heating Tubes

KT silicon carbide radiant heating tubes are described and shown in this 3-color folder. Impermeability, high thermal conductivity and good thermal shock resistance are featured. The Carborundum Co., P. O. Box 337, Niagara Falls, N. Y.

Circle 190 on Inquiry Card

Circle 59 on Inquiry Card →

VACUUM ELECTRON BEAM WELDING



for space age metals

The new NRC Model 2406 Vacuum Electron Beam Welder is a compact production facility for precision welds in reactive and super alloy metals. It makes possible fusion welding of "hard-to-weld" metals ranging from aluminum through tungsten. Additional applications include button melting, annealing, outgassing, sintering and brazing of small parts as well as evaporating any known material.

Advantages . . . ■ Externally adjustable gun electrodes speed production by providing proper spacing at any desired beam current without shutting down equipment. ■ Straight line, undisturbed beam path makes pinpoint precision possible. Electron path is unaffected by shape or position of workpiece. ■ Insulated micrometer adjustments enable the filament to be centered and positioned vertically while watching for smallest spot and highest energy density. ■ Spot can be varied from ½″ to more than 10″ below coil to provide clearance for vertical projections and internal welds. ■ Maximum production capability is provided by NRC's high speed pumping system — welder can re-cycle to operating pressure in less than 5 minutes. ■ Low voltage electron gun features economy and simplicity with low X-ray emission, eliminating operator hazards.

The Model 2406 is available now for your research or production requirements. Write or call for data sheet SW-1.

NRC EQUIPMENT CORPORATION
A Subsidiary of National Research Corporation
160 Charlemont Street
Newton 61, Massachusetts
Area Code 617 DEcatur 2-5800

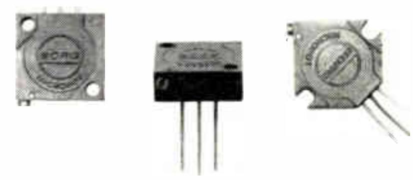
MANUFACTURING PLANTS IN NEWTON, MASSACHUSETTS AND PALO ALTO, CALIFORNIA

Circle 60 on Inquiry Card

NEW PRODUCTS

SUBMINIATURE TRIMMERS

Derated to 0w. at 175°C; resolution of adjustment is 1.0% to 0.084%.

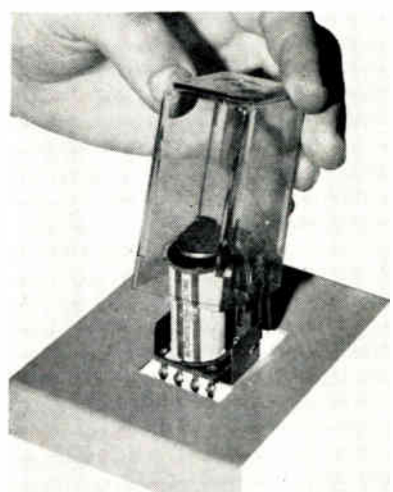


These ⅜ and ½ in. sq. wirewound trimming potentiometers are humidity-proof, dust proof, and shock-proof to 100g. They operate from −65°C to +175°C. The ½ in. model meets all requirements of Mil-R-27208A, Style RT-22. Resistance ranges for ½ in. is 10 to 100KΩ (±5%) and 10 to 50KΩ (±5%) for the ⅜ in. trimmer. Power rating is 1w. at 70°C for ½ in., and the ⅜ in. is 1w. at 50°C. Borg Equipment Div., Amphenol-Borg Electronics Corp., Janesville, Wisc.

Circle 191 on Inquiry Card

RELAY COVERS

The conversion does not require unsoldering or rewiring.



Relays with taper-tabs or solder terminals may be readily enclosed by assembling a metal bracket and clear-plastic dust cover to the relay mounting. The corrosion-resistant nickel-silver bracket is simply sandwiched between the chassis and the relay and held down by the relay mounting screws. Dimples on the bracket hold down the removable plastic cover. The dust covers are available in 2 sizes to enclose relays with up to 12 and 24 springs. Industrial Products Div., Automatic Electric, Northlake, Ill.

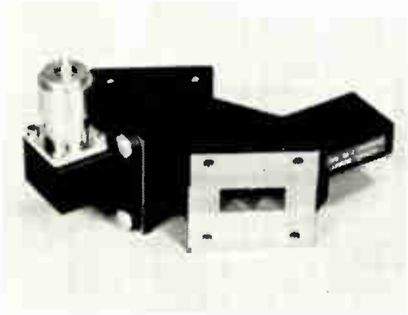
Circle 192 on Inquiry Card

Circle 104 on Inquiry Card

NEW PRODUCTS

TUNNEL-DIODE AMPLIFIER

Min. gain is 25db with an r-f bandwidth of 1GC centered at 9GC.

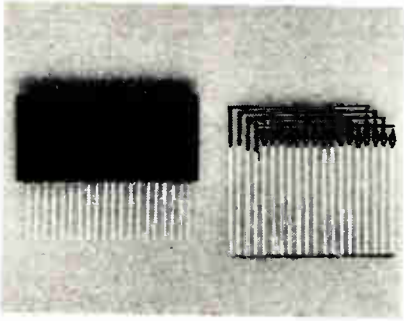


This wide-band, high-gain, X-band tunnel-diode amplifier is for microwave uses in the 8.5 - 9.5GC freq. range. The gain is flat within ±1db over the 1GC pass band. The max. gain variation is ±1db over a temp. range of −30° to +60°C. The noise is 5.5db max. The total weight is 1.3 lbs. with overall dimensions of 2 3/8 x 4 5/8 x 6 in. The max. power drain is 10ma. with 10-15vdc applied. International Microwave Corp., 105 River Rd., Cos Cob, Conn.

Circle 151 on Inquiry Card

MICRODIODE ASSEMBLIES

Pulse current of 1.5a. and recovery times of 0.002 μsec.



These silicon microdiode assemblies are for core driver and other high-current computer uses. Inverse operating voltages are exceptionally high. Junction capacity is as low as 2pf. The assemblies are available in encapsulated models. They meet or exceed Mil-S-19500C and Mil-STD-750. Versatility in packaging dimensions and circuit variations permit ready insertion into memory planes and stacks. MicroSemiconductor Corp., 11250 Playa Court, Culver City, Calif.

Circle 153 on Inquiry Card

WIREWOUND RESISTORS

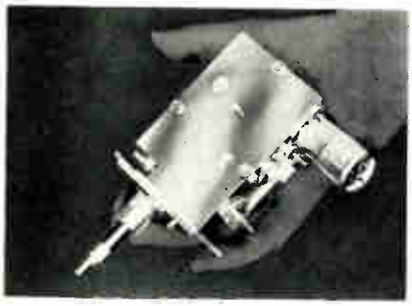
Temp. coefficient is 30ppm/°C; units available to 1.5meg.

This full-line of silicone-coated HL resistors meet the electrical, environmental and dimensional needs of Mil-R-26C and are interchangeable with the major types of vitreous enamel resistors. Offered are 13 tubular models, ranging in size from 5 to 210w. and 5 flat models ranging in size from 21 to 91w. Resistance capabilities range from 0.1Ω to 1.5 megohms (±5%). Tolerances from 0.05% to 10% are available. Dale Electronics, Inc., P. O. Box 488, Columbus, Nebr.

Circle 155 on Inquiry Card

UHF TV TUNERS

Tube type tuners with direct and planetary drive features.

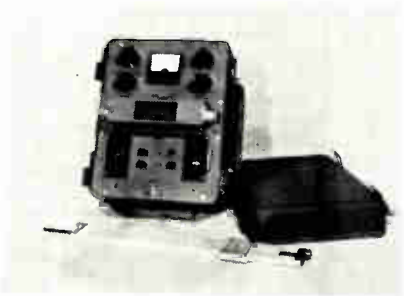


Series U are UHF TV tuners for use as original equipment in receivers. Average noise is 9db; low drift, low microphonics, ease of mounting, compactness, and long life are featured. They will fit all receivers using standard 43MC i-f. It uses a 6DZ4 oscillator tube and silicon diode mixer. For UHF converter manufacturers a model UC is available. Standard Kollsman Industries, Inc., Melrose Park, Ill.

Circle 152 on Inquiry Card

H-F IMPEDANCE BRIDGE

Inserted directly into an h-f antenna systems with little insertion effect.



The OIB-2 measures the operating impedance of individual radiators, network inputs, transmission line terminals, etc., under power. The transmitter, or a high-power signal generator may be used as a signal source. The power rating of the bridge is 1kw. The insertion effect of the bridge is equal to 5 in. of 150Ω transmission line. It operates between 2 and 30MC. Delta Electronics, Inc., 4206 Wheeler Ave., Alexandria, Va.

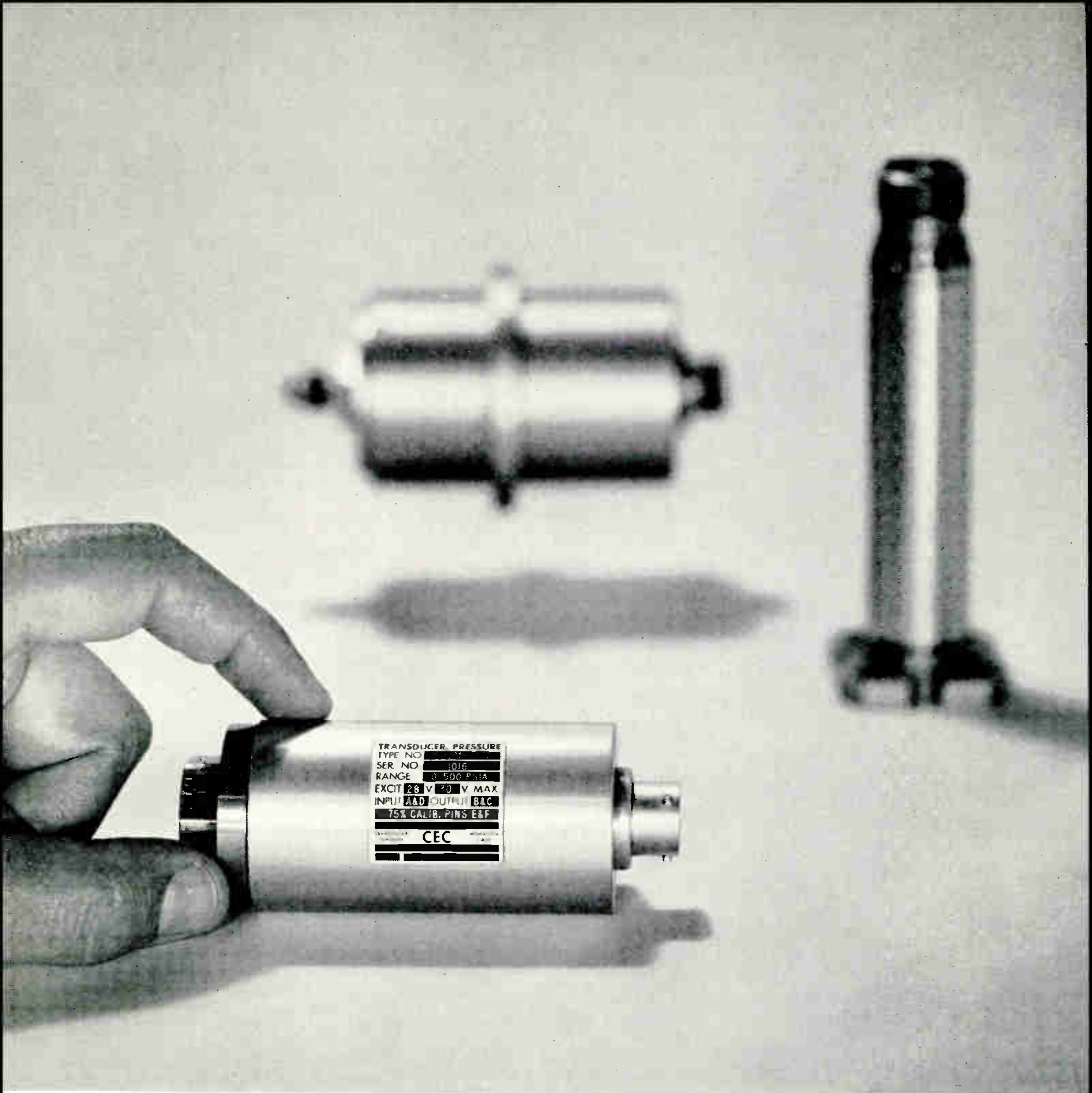
Circle 154 on Inquiry Card

DIGITAL READOUT

Self-contained transistorized digital readout mounts on 1 in. centers.

The Tec-Lite TNR-30 series is available in 8 models to handle 8-wire or 4-wire B.C.D. input in 1, 2, 4, 8 code. Supply voltage of +180vdc (±10vdc) @ 2 to 6ma. is confined to the panel area. Elements of the rectangular neon readout tube are controlled by internal all-transistor decoder components. Numerals are 0.610 high. Life expectancy is 100,000 to 200,000 hrs. Transistor Electronics Corp., P. O. Box 6191, Minneapolis 24, Minn.

Circle 156 on Inquiry Card



Over 1000 delivered

CEC's High Output Pressure Transducer

The CEC 4-390 is a high-output, unbonded strain gage pressure transducer with integral, solid state power supply and amplifier, providing a 5 volt DC output signal. This is a chamber-type instrument designed for absolute and gage measurements of fluids and gasses in pressure ranges of 0-100 psi and 0-5000 psi. Its excitation circuit isolation is 100 megohms minimum between output and primary power ground at 50 volts DC.

Major aerospace contractors have proven this instrument capable of maintaining superior performance characteristics in extreme acceleration, vibration, and shock environments.

The 4-390 is a standard item, being produced in quantity. There are variations for specialized environments or unusual structural application requirements.

If you're in the market for high-output pressure transducers, study the specifications of CEC's 4-390. Those specifications and this instrument are the result of CEC's 27 years of design, engineering, and manufacturing experience; experience that ensures that the 4-390's you order will perform to your specifications — when the pressure's on.

Call or write for Bulletin CEC 4390-X2.

CEC
Transducer Division
CONSOLIDATED ELECTRODYNAMICS
A Subsidiary of **Bell & Howell** • Pasadena, Calif. 91109

NEW PRODUCTS

PORTABLE RECORDERS

Units offer pushbutton selection of 4 chart speeds: 1, 5, 20 and 100mm/sec.

The 290 series consist of single two- and three-channel units. Plug-in amplifiers (Models 292 and 293 multiple-channel units) have a sensitivity range from 5mv-5v./chart div. Input impedance: 2.5 megohms, either side to ground. Power: 115v. ±10%, 60cps, 125w. Weight: 20 lbs. (single-channel) and 40 lbs. (multiple-channels). Americal Optical Co., Instrument Div., Buffalo 15, N. Y.

Circle 193 on Inquiry Card

FIXED POWER SUPPLIES

Load regulation less than 1% to 4%; output ±1% for ±15% of input variation.

Powerguard solid-state fixed dc voltage power supplies offer good load regulation for open-loop devices. Power ratings from 50 to 300w. Output voltages range from 6vdc to 250vdc, with nominal 117vac inputs. Stancor Electronics, Inc., 3501 Addison St., Chicago 18, Ill.

Circle 194 on Inquiry Card

RECTANGULAR CONNECTOR

Expendable tool enables contacts to be inserted and extracted from rear.

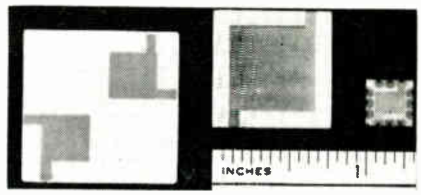
This rack and panel connector features collect-retained, rear-entry and rear-release contacts. The design permits crimped contacts to be snapped-in or removed from terminating side of the miniature connector. The Pyle-National Co., 1334 N. Kostner Ave., Chicago 51, Ill.

Circle 195 on Inquiry Card

NEW PRODUCTS

SCREENED CAPACITOR

For micro or thin-film circuits on flat alumina substrates.



The Cerafer™ capacitor has a capacitance range up to 8000pf/single layer. It has constant capacitance and high Q into the MC range. Voltage breakdown exceeds 250vdc and temp. coefficient is less than 300ppm/°C. Rating is 75vdcw; insulation resistance exceeds 100K megohms at 50vdc. Max. capacitance change is 3% in 1000 hrs. life test @ 85°C and 75vdc continuous. Temp. —65° to +125°C. CTS Corp., Elkhart, Ind.

Circle 196 on Inquiry Card

DRY REED RELAY

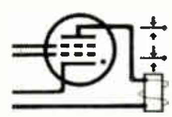
Contact resistance is 50 milliohms and insulation resistance is 1000 megohms.

Series FRP is a plug-in type, 8 or 11 pin header dry-reed relay. Life is 100 million operations at a rated load or 200 million operations under dry-circuit conditions. It operates in the msec. range. Max. current is 0.5a.; max. voltage is 110v. Line Electric Co., 249 River St., Orange, N. J.

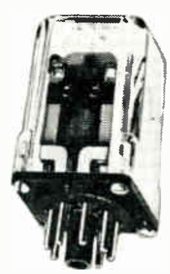
Circle 197 on Inquiry Card

THYRATRON PLATE RELAYS

Contact types: silver rated 5a. at 115vac or 32vdc, or silver/cadmium-rated at 10a.



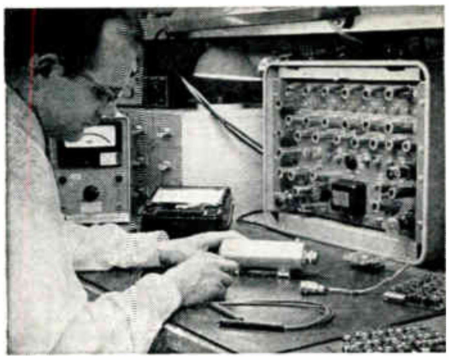
UNENCLOSED (GPR) 3PDT



ENCLOSED PLUG-BASE (GPRTP)

Type GPR relays work without parallel capacitors or fine adjustments. They hold without chatter during half-wave conduction of the thyratron. They work with 2050 and 2D21 thyratrons with 115vac supply. Coil resistance is 1600Ω. Ohmite Mfg. Co., 3672 Howard St., Skokie, Ill.

Circle 198 on Inquiry Card



Here, at Lockheed Missiles & Space Company's Space Communications Laboratory, scientists are re-investigating the possibility of using the moon to facilitate earth communications. Possibilities for the use of the moon as a relay station for earth-to-earth communications have been largely neglected because the moon's shape and rugged surface greatly distorted a return signal. But Lockheed research into the extension of communications on difficult communication channels, using techniques applicable to dispersive time variant channels, is making significant inroads into this problem.

Another area receiving intense study at Lockheed is satellite tracking of deep space probes. Since tracking accuracy depends greatly on stations being as far from each other as possible, while retaining line-of-sight communications, Lockheed is studying the use of two earth-orbiting satellite tracking stations, 8000 miles apart. Not only would great accuracy be gained by the separation, but it would be further enhanced by the positioning of the stations above the earth's atmosphere, thus eliminating atmospheric distortion.

Examples of other research projects being pursued by Lockheed in the communications area include: Random multiplexing, satellite readout techniques, scatter communications, radar mapping, submarine tracking, modulation of optical energy, communications over multipath channels, and learning systems.

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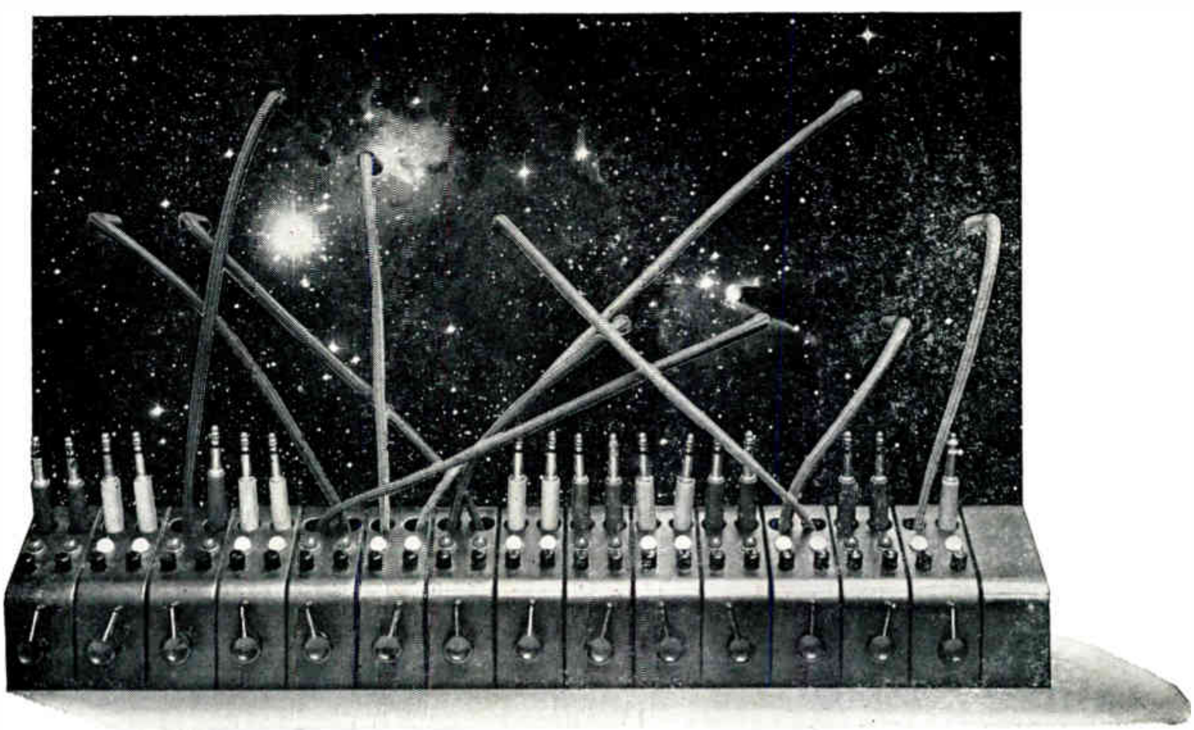
LOOK AT LOCKHEED IN SPACE COMMUNICATIONS:

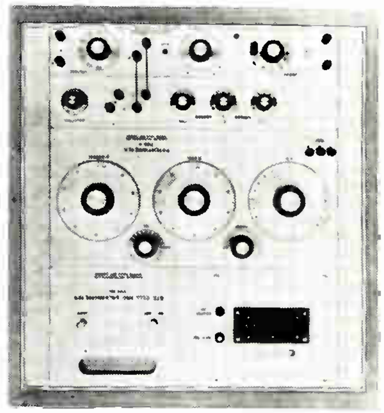
Where outstanding successes have created aerospace leadership



NEW PRODUCTS

POTENTIOMETER SYSTEM

The system consists of 3 modules; each module may be used independently.



Commander Type M, dc potentiometer system is modularized for bench or standard 19 in. rack mounting. One module is a 5-figure, 3-dial, shielded potentiometer with measuring ranges of $-10\mu v$ to 2v. Another module is a current/voltage range extension containing seven 0.01% standard resistors enabling measurements from 0-10a. The last module is a ±10ppm voltage reference. Singer Metrics Div., The Singer Co., 915 Pembroke St., Bridgeport, Conn.

Circle 199 on Inquiry Card

PLASTIC POTENTIOMETER

Combines long life units of different dia. and linearities on common shaft.

In Type 3P56 each section is single-turn and exhibits infinite resolution; multi-million cycle life in continuous system use; low noise; stable operation in extreme environments, etc. It combines a 1 5/16 in. dia. potentiometer having ±0.05% linearity with a 5 in. dia. unit of ±0.01% linearity. Markite Corp., 155 Waverly Place, New York 14, N. Y.

Circle 200 on Inquiry Card

PREAMPLIFIER

Freq. response is 7 to 3000cps; input impedance is 5 megohms.

With the input loaded by a ½ megohm resistance, input noise over a 1 cps band-pass centered at 13 cps is $0.1\mu v$. Model GBA-1 has self-contained mercury cells that power the unit for over 400 hrs. continuous use. Output impedance is 200Ω nominal. Max. gain is X1000 and is adjustable. Texas Instruments Incorporated, P. O. Box 66027, Houston 6, Tex.

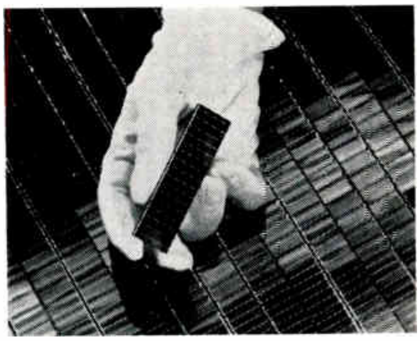
Circle 201 on Inquiry Card

← Circle 65 on Inquiry Card

NEW PRODUCTS

SOLAR PANELS

Parallel connection assures current flow if one cell is damaged.



These silicon solar cell panels are capable of optimum operation in environments encountered in space satellites. They incorporate gridded N-on-P or P-on-N cells and use printed circuits to assure optimum conduction from all cells. Flat-mounting replaces shingling of solar cells, making for more rugged panels. International Rectifier Corp., 233 Kansas St., El Segundo, Calif.

Circle 210 on Inquiry Card

PULSE MODULATOR

Negative or positive pulses have rise and fall times of 30nsec. max.

Model 751 pulse modulator has outputs from 0.2kv to 3kv peak and is continuously variable. It is used in the development and test of low-power beacon type magnetrons with pulse widths as short as 0.05msec. Peak pulse current may be as great as 3a. Pulse characteristics are obtained with a 1KΩ resistive load across the pulse output terminals shunted with a 20pf capacitor. Manson Laboratories, Inc., a sub. of Hallicrafters Co., Stamford, Conn.

Circle 211 on Inquiry Card

DIFFERENTIAL AMPLIFIER

The fixed bandwidth can be changed by the addition of the capacitor.

The Model 361400 is a self-contained solid-state dc differential amplifier that does not require a module for rack mounting or a bench case for portable use. It is available with an output of ±10v., ±10ma. A ±10v., ±100ma unit is also available. Specs: gain is 10 to 1000 in 4 steps; accuracy is ±0.02% @ dc; linearity is ±0.01% @ dc; common mode rejection is 1000 x gain. Redcor Corp., 7760 Deering Ave., Canoga Park, Calif.

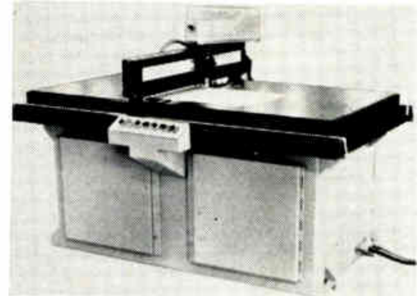
Circle 212 on Inquiry Card

Circle 66 on Inquiry Card

NEW PRODUCTS

TRACER SYSTEM

The system works off layout drawings with ratios from 1 to 20.



By optically scanning a pencil-line tool path layout drawing, practically any shape that can be drawn with standard drafting instruments can be produced in metal in 2 dimensions (X & Y) with this Masterline Tracer system and method. It is provided with a large vertical special mill equipped with 2 zero-backlash ball-bearing table movement lead screws. Any 2 dimensional contour can be machined to a high degree of accuracy. Andrew Engineering Co., Minneapolis 26, Minn.

Circle 213 on Inquiry Card

AC/DC AMPLIFIER

After 500% overload, the unit recovers to 0.05% in 200μsec.

Model 144 is a general-purpose, wide-band amplifier which has a common mode rejection of 120db at 60 cycles with 1KΩ unbalance, and 150db at dc. Gain accuracy, linearity, and stability are ±0.01%. It has 7 fixed gain settings; continuous gain control variable from 1.0 to 1200. Non-Linear Systems, Inc., Del Mar, Calif.

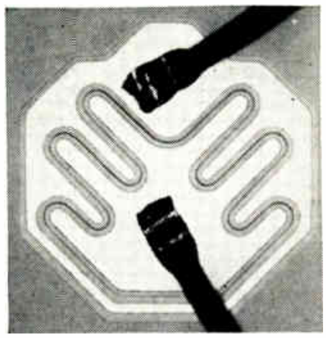
Circle 214 on Inquiry Card

REFERENCE AMPLIFIER

Functions as voltage reference and error-voltage amplifier in power supplies

The integrated reference amplifiers which comprise the RA 1 series have a temp. range from 0°C to +70°C; ref. voltage is 7v. (±10%). Temp. coefficient is 0.02%/°C, 0.005%/°C, and 0.002%/°C. The RA 1 series has an additional device with the temp. coefficient of 0.001%/°C. Series RA 1 and RA 2 operate with no zener bias current. RA 1 and RA 2 have a max. collector-to-emitter voltage of 45v. Max. collector-to-emitter voltage for RA 3 is 60v. Max. power is 300mw. Used in regulated power supplies. General Electric Semiconductor Products Dept., Bldg. 7, Electronics Park, Syracuse, N. Y.

Circle 215 on Inquiry Card



We've never had purple plague!

Why?

We use aluminum alloy leads; not gold. Without the gold, you just don't get the purple plague $AuAl_2$ compound that forms on conventional silicon planar transistors.

Purple plague will usually begin to show up around 50 hours—and almost always by 500 hours—at elevated temperatures. After 5000 hours at 300°C, Bendix® silicon planars are unchanged electrically and mechanically.

Why doesn't everybody use aluminum leads? Eventually, they probably will, but bonding the Al lead to the Al metalized contact area is tricky and takes some rather advanced techniques. As proof of our bonding superiority, Bendix planar transistors have been tested in excess of 37,000 g's centrifuge and 5,000 g's shock without a failure. Our Al-Al bonding technique gives us a pull factor at least three times greater than any reported yet.

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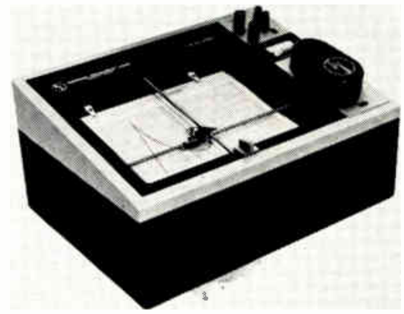
NEW PRODUCTS

T-Y SERVO RECORDER

Plots variable vs. time on standard graph paper; scale range from 10 sec. to 15 min.



Models HR-80 and HR-87 T-Y recorders replace conventional strip-chart and circular-chart recorders for chart lengths of 10 in. or 15 in. Both have a null-seeking servo which moves an ink pen on the vertical axis in proportion to a low level dc input signal. Houston Instrument Corp., 4950 Terminal Ave., Bellaire 101, Tex.

Circle 216 on Inquiry Card

TIME-DELAY RELAY

Delay adjustable from 0.2 to 45 sec; 10a., 15a., and 50a. contact ratings.

In this timing relay the switching mechanism remains undisturbed during the timing cycle; thus it is free from any tendency to vibrate or chatter. Timing repeat accuracy is ±10%. Approx. overall dimensions, open type: 3 13/16 x 1 7/16 x 1 15/16 in. Magnecraft Electric Co., 5577 N. Lynch Ave., Chicago 30, Ill.

Circle 217 on Inquiry Card

THREE CHANNEL AMPLIFIER

Spans 15cps - 180mc; gains to 100. Response flat ±0.5db between 25cps-150mc.

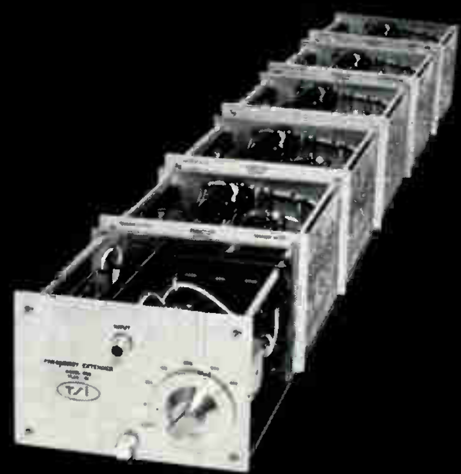
Model 104 consists of 3 separate amplifiers which can be used individually or in cascade for an overall gain of 100 (40db). Two amplifiers are identical, with gains of 10 (20db), 50Ω input impedances, and max. outputs of 1.4v (P to P) into a 50Ω load. The third amplifier is a unity-gain (0db) impedance-matching unit with a 1 megohm, 10pf input impedance. It reduces loading and matches other impedance systems to a 50Ω coaxial system with no loss. Rise time less than 3nsec.; delay time less than 5nsec. Keithley Instruments, Inc., 12415 Euclid Ave., Cleveland 6, Ohio.

Circle 218 on Inquiry Card

NEW TSI 500 MC MODULAR ELECTRONIC COUNTERS

Model 500 Basic Counter ($2,870) with 511 plug-in $3,180
Direct count capability to 100 MC

Model 500L Basic Counter ($2,520) with 515 plug-in $2,800
Direct count capability to 20 MC*



Model 520 Heterodyne Frequency Extender ($680)
Turret-tunes in 6 fixed steps to 500 MC
5 other plug-ins available

Match a TSI Counter To Your Needs—Select From 6 Standard Plug-Ins

TSI's TRANSISTORIZED MODULAR COUNTERS FACILITATE:
• Precise Frequency measurement from DC to 500 MC • Frequency Ratio measurements from 0-20 MC, measured over 1 to 10^5 periods for greater resolution • Time Interval measurements from 0.1 micro sec. to 10 sec.

The eight digit, direct reading Nixie® display provides storage or count-display operation. Decimal point is automatically positioned and units as KC or MC are Nixie indicated.

Sensitivity is 100 MV for AC or DC signals, with stability better than ±2 parts in 10^8 per week. Packaged in an engineered enclosure, the TSI 500 or 500L counter with plug-in weighs less than 45 pounds.

*Factory conversion to 100 MC capability available for $480

Plug-in	"A" input DC-20MC	"B" input DC-20MC	"C" input 1MC-100 MC	"D" input 10 MC-500 MC	Function †	used with Model 500	used with Model 500L	price
510	x	x	x		F, FR, P, TI, E	x		420
511	x		x		F, P, E	x		310
512			x		F	x		200
515	x	x			F, FR, P, TI, E	x	x	280
516	x				F, P, E	x	x	170
520				x	F	x		680

†F=Frequency • FR=Frequency Ratio • P=Period and Multiple period average • TI=Time Interval • E=Total Events

WRITE FOR COMPLETE SPECIFICATIONS

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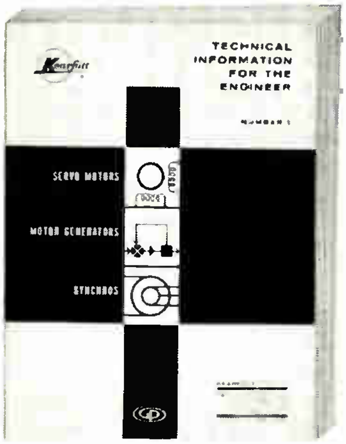
SERVO



Our publication "Technical Information for the Engineer" Number 1 was written and published for two major reasons. First, as the nation's leading innovator and producer of precision components, we wanted to sell more of them and secondly, some time ago we recognized that although textbooks on servomechanisms were very complete, the field suffered through a lack of uniform terminology and tests methods.
We attempted to cover the theory lightly in our book with major emphasis on terms, applications and component behavior from the user's point of view. You may obtain a copy of this 60 page booklet simply by writing to us.

ComPac 8 SERVO ASSEMBLIES. Kearfott's advanced Size 8 component designs have made possible the most complete variety of in-line servo assemblies available. The ComPac 8 units, ¾" in diameter, provide high performance "closed end" devices incorporating a wide range of driving and driven elements coupled through precision single or dual speed gear reducers.

System designs based on the ComPac configurations benefit from high packaging density, and elimination of provisions for the multiple mounting of independent elements and geartrains. A typical ComPac consisting of a servomotor—gear reducer resolver and potentiometer combination measures only 3 inches long and weighs 3 ounces.

Size 8 components available for ComPac assemblies:

- ☐ Motors – Servo, Stepper, Braked, Inertial and Viscous Damped.
- ☐ Motor Generators and Tachometers.
- ☐ Synchros and Resolvers – Transmitters, Transformers, Differential Transmitters, Resolvers, Linear Synchros, 4 wire Synchros.

SIZE 8 COMPENSATED RESOLVERS. Winding compensated Size 8 and 11 resolvers and matching Size 11 buffer amplifier are also available from Kearfott for high precision computing resolver chains. Trimmed for unity transformation ratio, the resolver-amplifier combinations provide TR of 1.0000 ± 0.0017 over the temperature range of −55 to +125°C, frequency variation of 400 ±20 cps and voltage variations from 0.5 to 20 volts or simultaneous combinations of these variations. When used with size 8 resolvers, the servo mounted size 11 buffer can be installed adjacent to the resolver. A "Piggy-Back" tandem assembly of the Size 11 resolver and buffer amplifier is available as well as separate Size 11 resolver and servomounted Size 11 buffer. Additional characteristics of the combined buffer-amplifier assemblies are as follows:

Size 8 Resolver Phase Shift* (Rotor/Amp in.)	Function Error	Rotor Amp in.
0.00° ± 30′	±0.1%	0.5 — 9.0v
Size 11 Resolver		
0.00° ± 12′	±0.1%	0.5 — 20.0v

*This value constant over wide temperature, frequency and voltage range.

COMPONENTS

4 WIRE SYNCHROS. High system accuracy using Size 8 components is made possible through Kearfott's 4 wire synchros. Wound as resolvers, but with appropriate electrical characteristics to permit their use as transmitters, differentials or control transformers, these components can be directly applied in feedback loops without the use of special buffer amplifiers. Features individual component accuracy of 3 minutes of arc from electrical zero, when these components are used in a typical 3 component string, overall accuracy will be approximately 5.2 minutes of arc from EZ. Designated RX, RDX and RC corresponding to transmitter, differential and control transformer respectively, the application of these components to your analog computation devices will contribute to increased accuracy, while reducing volume and weight. Units for high vibration (2000 cps 20 g's) and high temperature (200°C) environments can be provided on special order.

STEPPER MOTORS. Size 8 stepper motors provide non-ambiguous shaft position corresponding to a sequentially pulsed digital input. Positive positioning of shaft through a magnetic detent rather than mechanical devices contributes to the reliability and performance of these motors by eliminating shock loading and mechanical wear. Accurate and positive shaft position makes this unit ideal for application in counting, positioning and switching mechanisms and in applications involving the use of two motors in a self-synchronizing manner. The latter application permits a form of closed loop servo operational from a digital input.

Typical characteristics include: 400 pulses/sec response rate; 0.80 in. oz. holding torque; 0.30 gm cm² rotor moment of inertia; 28V excitation, other values available. Overall dimensions; ¾" diam x 0.875" long; weight 1.5 oz.

Compatible welded electronic switching assemblies can be provided for driving these stepper motors. Other motors in various frame sizes are also available.

AND ELECTRONICS. Complimenting Kearfott's wide range of wound components, a complete family of high density, transistorized servo and buffer amplifiers, pre-amplifiers and power supplies can be provided featuring welded or soldered construction. Servo amplifier voltage gain is variable through the use of external resistors. Phase shift networks matched to some of our servo motors have been included in the amplifier assembly. One representative amplifier, C70 3146 001 is an all-welded unit occupying one cubic inch, provides a 5 watt output.. This amplifier is suitable for driving any size 5, 10 or 11 motor manufactured by Kearfott. Also available: Single and dual channel buffer amplifiers matched to larger diameter compensated resolvers; pre-amplifiers and quadrature rejection circuits for use in high performance tachometer integrating loops.

GP GENERAL PRECISION AEROSPACE

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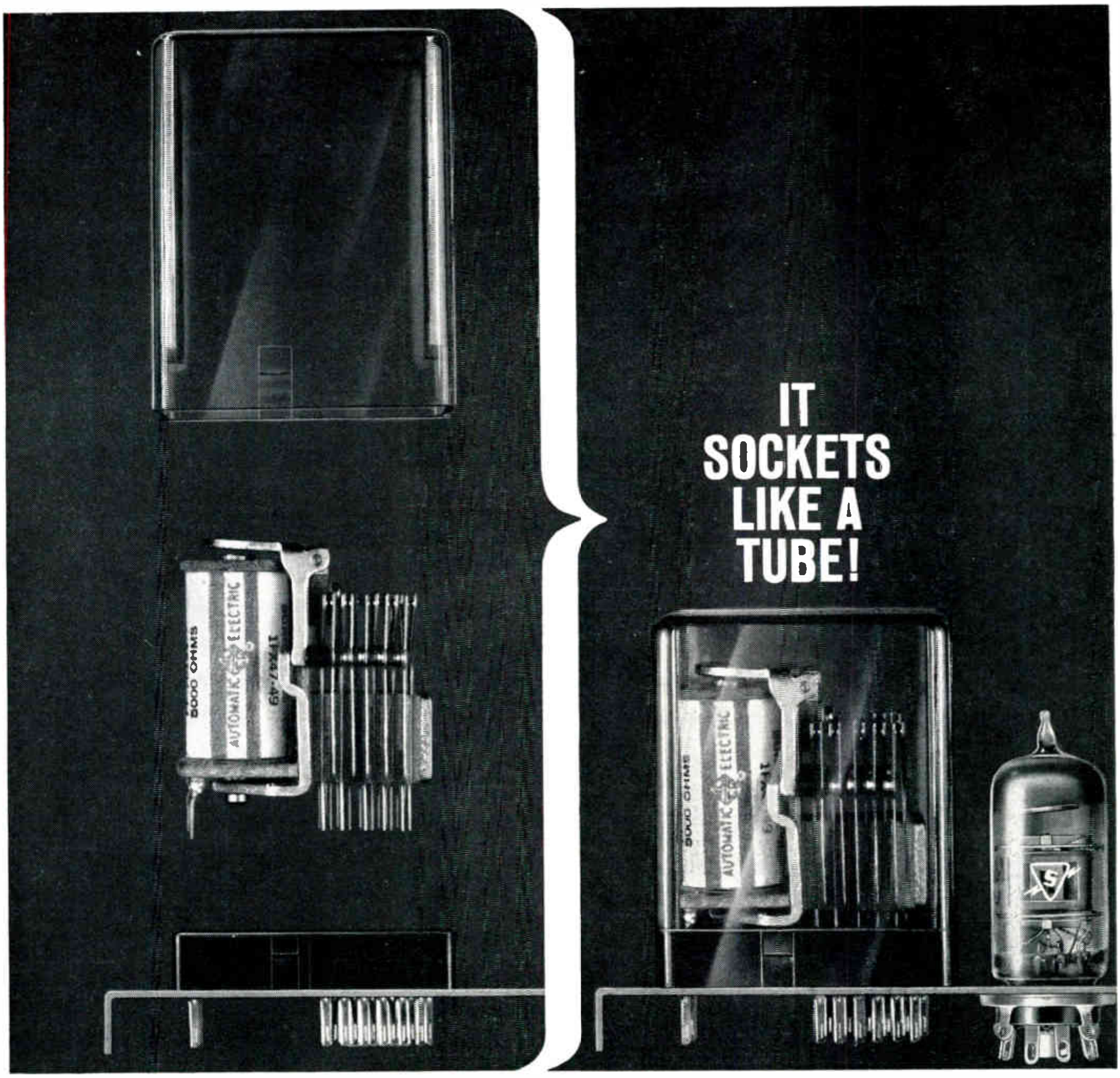


This new relay concept saves you time, stocking and money

AE's new Series EIN relay, that plugs in like a tube, has taken the field by storm—and no wonder:

It's the first telephone quality relay having all the conveniences of octal-type plug mounting, with savings of $1.93 *or more* per relay!

The special sockets are available separately from AE stock. You can order the number you need for a complete production run, and buy the relays and plastic covers "off the shelf" to meet delivery schedules. There's no need to maintain large relay inventories.

The EIN's modern, low silhouette design improves the appearance of your product and cuts space requirements up to 20%.

EIN relays are available in various spring combinations to meet most design requirements. Sockets are available for taper tab, solder, or printed circuit board terminations.

In initial cost and versatility, the EIN can solve many of your design, production and inventory problems.

• • •

For full information, write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

NEW PRODUCTS

SERVO AMPLIFIER

Input impedance is 50KΩ (±5%) and output impedance is less than 25Ω.

Model 1801-3800 is an 8¼ cu. in. servo amplifier which produces 40w. output. Voltage gain is variable from 1 to 1000 through an external resistor in series with the input, and gain stability is ±½db over the full temp. range. Output voltage is 36v. RMS. M. Ten Bosch, Inc., Pleasantville, N. Y.

Circle 219 on Inquiry Card

GAGING TRANSDUCER

Measures to millionths of an in. with very good repeatability.

Miniature LVDT displacement transducers are mechanically interchangeable with dial indicators. The Model GT dimensional gaging transducer has a differential transformer with zero hysteresis and high resolution. The transformer core is integral with the gage spindle, which in turn is mounted on precision bearings and protected by a neoprene boot. A standard replaceable AGD contact point is used at the tip. Full scale output is 70mv/Vex with a 20° phase angle. Transducer Div., Sanborn Co., 175 Wyman St., Waltham 54, Mass.

Circle 220 on Inquiry Card

DC VOLTAGE REGULATOR

Rating is 1a. (28w); fully encapsulated in an epoxy-filled aluminum case.

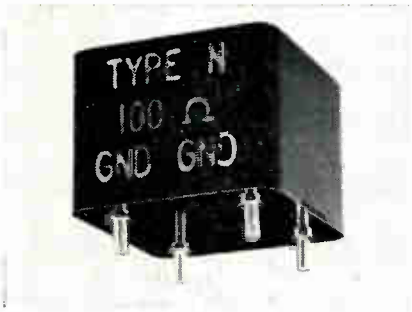
Model SHX-43 accepts inputs from 25 - 29vdc. At a 28 (±0.5) vdc output, regulation is continuous against ½ to full load changes, 25 to 29vdc line changes, and temp. changes from —55° to 71°C. Output is transient-free from line voltage spikes of up to 30v. amplitude for 100msec. Designed to Mil-E-5272D. Arnold Magnetics Corp., 6050 W. Jefferson Blvd., Los Angeles, Calif.

Circle 221 on Inquiry Card

NEW PRODUCTS

DELAY LINES

Time delays are: 20, 30, 40, 50, 60, 70, 80, 90, 100nsec; impedance is 100Ω.

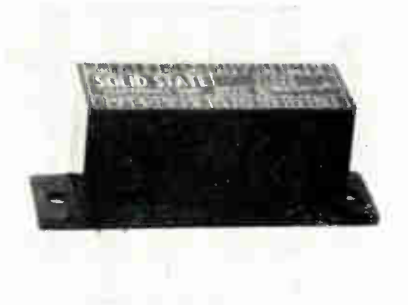


The Series N nsec. lumped constant delay lines are constructed using mica capacitors and iron toroids. Size is ⅝ x ⅝ x 0.450 in. and it may be mounted on printed-circuit boards. Attenuation is 2% max.; temp. coefficient is 50 parts/million/°C. DC working is 300v.; time delay to rise time ratio is 3.5/1 for 1 unit. Allen Avionics, Inc., 255 E. 2nd St., Mineola, N. Y.

Circle 222 on Inquiry Card

SLAVE CLOCK

Adjusted according to the number of loads to be driven.

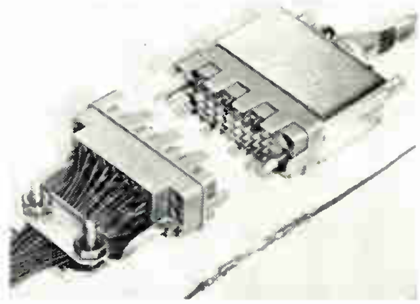


The Model DBSC1151 slave clock consists of a 4-stage high-gain diode-clamped amplifier and is useful in applications requiring increased clock fanout capability. The input circuit is a direct-coupled gate which minimizes driver-circuit loading and increases gate response time. Each stage uses silicon transistors and diodes. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif.

Circle 223 on Inquiry Card

CONNECTOR

Contacts are available for wire range sizes #40 to #18 AWG.



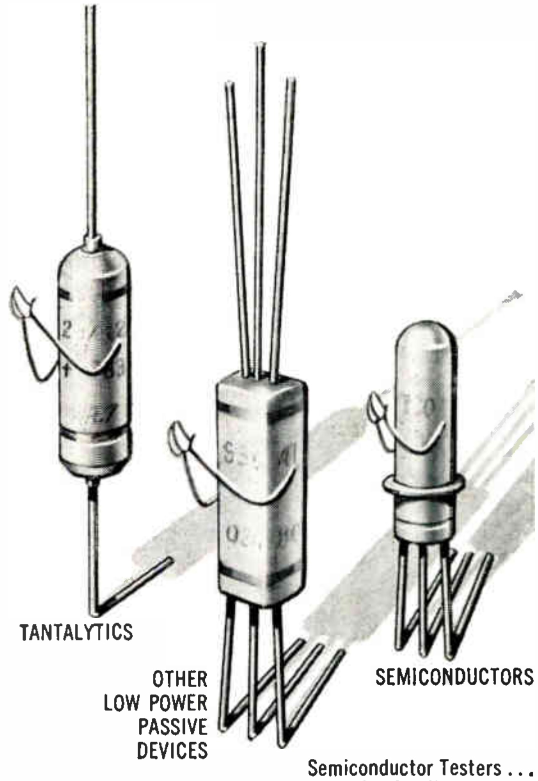
The miniature Dualatch® hermaphroditic connector is composed of both conventional and modular-type 4-position connectors, which permit the max. grouping of 28 units to form a single connecting unit. The conventional model is available in 40-, 60- and 132-position sizes. Standard A-MP® gold-plating assures max. conductivity. AMP Inc., Harrisburg, Pa.

Circle 224 on Inquiry Card

test us . . . but PLEASE!!! DON'T CREMATE US!

use an AEL in-circuit SEMICONDUCTOR TESTER†

the first completely safe, fool-proof, line of semiconductor testers ever developed . . . positively will not damage semiconductors, tantalytics and other low power passive devices



Semiconductor Testers . . .
- In-circuit
- Out-of-circuit
- Circuit

NEWEST ADDITIONS

MEASURES BETA ACROSS 50 Ω

Model 245 In-Circuit SEMICONOUCTOR TESTER*

. . . for quantitative trouble shooting of transistors, diodes and rectifiers . . . with 6-inch meter readout

In-circuit or Out-of-circuit Tests

- Measures Beta (low and high power transistors) with as low as 50 ohms emitter-to-base loading . . . with accuracy of ± 10%. Range: 1-1000.
- Measures resistance between semiconductor electrodes (power limited to one microwatt) independent of semiconductor loading . . . with accuracy of ± 5%.
- Measures diodes and rectifiers for shorts and opens with resistive loading as low as 20 ohms.
- Measures I_{CBO} of transistors and I_R of diodes (out-of-circuit only).

A REALLY SAFE MULTIMETER

Model 250 SEMICONDUCTOR CIRCUIT TESTER

. . . for quantitative trouble shooting of semiconductor circuitry . . . with 6-inch meter readout

- Only known multimeter SAFE for testing semiconductor circuitry.
- Checks front-back ratio of diodes.
- Measures correct value of resistors at semiconductor terminals.
- Conventional multimeters can cause costly self-made failures. The AEL Model 250 delivers a maximum of 150 microwatts in any resistance range — eliminates any possibility of self-made failures.
- 6 DC voltage ranges; 5 AC voltage ranges; 5 DC current ranges; 5 DC resistance ranges.

NO LEADS TO SELECT

Model 240 Automatic In-Circuit TRANSISTOR TESTER*

. . . for qualitative, in-circuit trouble shooting of transistors on "GO" . . . "NO-GO" basis

- Automatically detects shorts, opens and low gain units.
- No previous knowledge required of transistor type or lead configuration.
- Checks transistors both in-circuit and out-of-circuit.
- Each test completed within two seconds.
- "GO" . . . "NO-GO" immediately indicated by lights.
- Power requirements: 115 Volts, 60 cycles, approximately 30 watts.

ALSO AVAILABLE . . . a punched card programmed, fully automatic semiconductor tester with digital readout . . . Model 236.

*Available with in-circuit test probe
†Patents pending

For more information on the complete line . . . or a demonstration of AEL's SEMICONDUCTOR TESTERS, contact your nearest AEL Product Sales Representative . . . or write direct to AEL.

AEL

American Electronic Laboratories, Inc.

1313 RICHARDSON ROAD, COLMAR, PENNSYLVANIA • (215) 822-2929
suburban Philadelphia

CONTACT MODULATORS

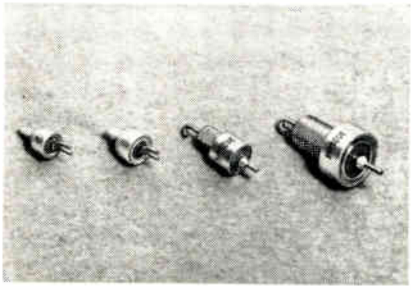
Chopping efficiency is 99% at 60 CPS with a phase angle lag of 5°.

The Model 42 features the advantages offered by contact modulators along with the following features: life is more than 25,000 hrs. with negligible change in noise and phase angle; self-generated current is less than 10^{-12}a.; current is 10^{-14}a. RMS. Operating voltage is 80 - 130v. RMS with an average current of 2ma with a freq. range of 30 - 400 CPS. It may be mounted directly on PC boards. Instrumentation Laboratory Inc., 9 Galen St., Watertown 72, Mass.

Circle 225 on Inquiry Card

CERAMIC CAPACITORS

Both stud mounting standoff and feed-thru designs are available.



These buttonhead ceramic capacitors have glass-to-metal seals. Max. capacitances in the stud mounting bypass capacitors range up to 1800pf at 500v.; capacitance in feed-thru designs is 12,000pf at 500v. They operate at voltages up to 85°C, with special units available operating up to 125°C. Capacitors meet Mil-C-11015C. Sprague Electric Co., Marshall St., N. Adams, Mass.

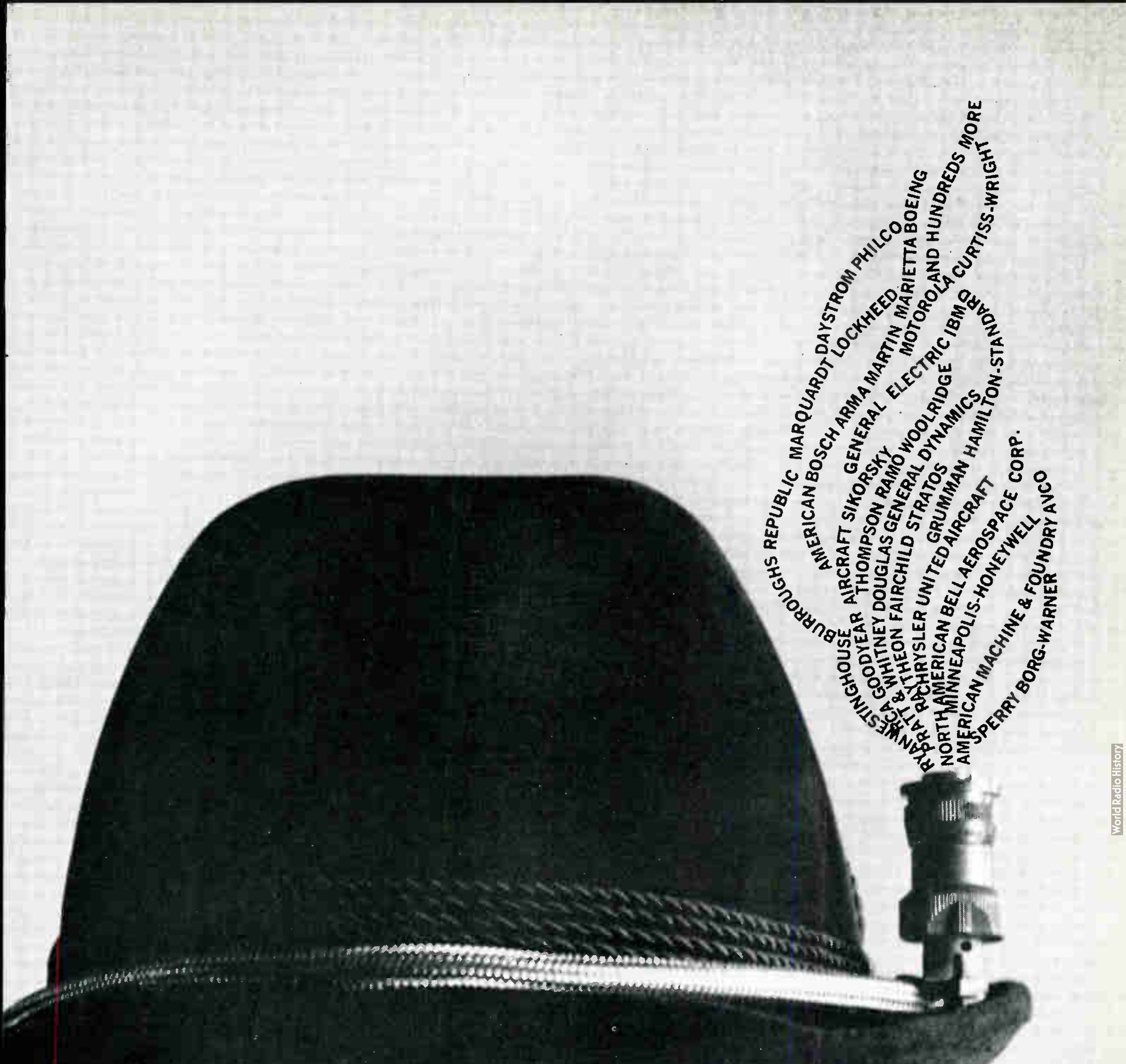
Circle 226 on Inquiry Card

SNAP-ACTION SWITCHES

Rated at 3a. sealed inductive load, 5a. resistive load at 28vdc.

Miniature 6pdt snap-action switches contain switch mechanism, actuator, and light circuits in a single, sealed package. Metal body provides complete RFI seal. Model A has a back panel depth of 0.590 in., and O.D. of 0.937 in. and requires a 15/32 in. mounting hole. Weight is approx. ½ oz.; actuator travel is 0.094 in., and lamp current is 1a. Unit can be adapted to any lens configuration. Precision Electrical Products, Inc., 2080 Placentia Ave., Costa Mesa, Calif.

Circle 227 on Inquiry Card



EACH OF OUR CABLE AND CONNECTOR CUSTOMERS IS A FEATHER IN OUR HAT.

Scintilla Division
Sidney, New York

THE Bendix CORPORATION

Circle 83 on Inquiry Card

NEW PRODUCTS

FEED-THRU TERMINAL

Overall height is 0.351 in.; minor dia. of bushing is 0.148 in.

The FT-SM-74 L5 tubular Press-Fit Teflon® feed-thru terminal has a brass lug with a 0.062 in. dia. thru-hole. The brass lug above the bushing shoulder has 2 turrets 0.125 in. dia.; the solderable portion between the tunnels is 0.100 in dia. Sealectro Corp., 139 Hoyt St., Mamaroneck, N. Y.

Circle 228 on Inquiry Card

SOCKET & SHIELD

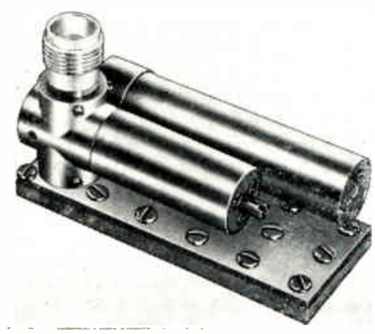
Heat dissipating tube shield reduces bulb temp 40 to 50%.

This electron-tube shield, designed for use with JAN sockets, meets characteristic B of Mil-S-19786C (Navy). Installation does not require twisting and turning. The shield is pushed down over the JAN socket and locks in place with the socket detents. Atlee Corp., 2 Lowell Ave., Winchester, Mass.

Circle 229 on Inquiry Card

MICROWAVE SOURCE DOUBLER

Freq. range of 8.45 to 9.55GC; power output 2.5mw (min.).



Type 9189, part No. 9189-1000, is an X-band CW microwave oscillator and doubler used as a local oscillator for beacons, altimeters and system ground check-out equipment. Power input requirement 140v. @ 20ma, 6.3v. @ 290ma. The unit weighs 4 oz. and is 2½ x 1 x 1¼ in. It can be modified to other freqs. Trak Microwave Corp., Tampa, Fla.

Circle 230 on Inquiry Card

POWER RESISTOR DECADES

They supply required resistance values in one ohm steps.

These power-resistor decades handle up to 225w. at 1000v. and permit dial-in resistance values from 1 to 999,999Ω in 1Ω increments. Decades are made in bench and rack mounted models. A design in the switching arrangement places a constant load across the circuit at all times, with no discontinuity during switch stepping. Clarostat Mfg. Co., Inc., Dover, N. H.

Circle 231 on Inquiry Card

TWO-GUN CRT

Tube has aluminized screen and electrostatic focus and deflection.

SC-3525 is a 2-gun, spiral accelerator CRT is designed for max. display in high-altitude, fighter-plane, fire-control radar. It has a 3 x 5 in. display face and features good pattern and tracking linearity. Sylvania Electric Products Inc., 1100 Main St., Buffalo 9, N. Y.

Circle 232 on Inquiry Card

so what makes one a better buy than the other?

The one on the left (our connector) is far and away your best buy. The reasons are simple: *quality* and immediate *delivery*. □ Every LIONEL connector has been developed and produced by top-notch technical experts. Each element is made from the best, most reliable material we can make or buy. The result? Consistent on-the-job performance. □ You'll never have to worry about slipping schedules when you order from LIONEL. We have a complete inventory of connector types, sizes and configurations. In other words, we begin delivery the hour we get your order. □ By the way, have you sent for our new catalog? We deliver them as quickly as connectors.

LIONEL ELECTRONICS LABORATORIES, INC.
1226 Flushing Avenue, Brooklyn 37, New York • Area Code 212 • EV 6-5715

NEW PRODUCTS

CURRENT LIMITERS KIT

Allows a wide selection of current cut-off levels for experimental work.

Kits using Currector current-limiting diodes aid the designer in selecting various units for breadboarding or prototypes. Limiters are available in germanium and silicon types, and are rated as high as 100v. and 205ma. CircuitDyne Corp., 480 Mermaid St., Laguna Beach, Calif.

Circle 233 on Inquiry Card

DIGITAL VOM

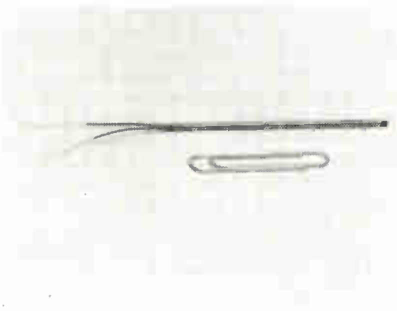
Features: fully automatic polarity switching and indicating.

The Reporter has a sensitivity of 1mv; accuracy is ±0.1% full scale. A regenerative voltage comparator combines the function of a precision ramp generator, voltage comparator, and memory circuits into a single circuit. Automatic ohm indication, tracking illuminated decimal point, and high-voltage protection are also features. Harman-Kardon, Inc., Plainview, L. I., N. Y.

Circle 234 on Inquiry Card

AXIAL FIELD PROBE

Uses Hall effect for sensing magnitude, polarity, and field direction.



Probe Type SBV-555 has an outer dia. of 0.10 in. which permits magnetic field measurements within small deep bores. They use the basic Hall-effect principle to permit sensing of the magnitude, polarity and direction of magnetic fields. Instrument Systems Corp., 111 Cantiague Rd., Westbury, L. I., N. Y.

Circle 235 on Inquiry Card

SIGNATURE MONITOR

Dispersion range and sensitivity is limited only by the receiver used.

The DM-1 spectrum signature monitor converts a receiver or RI/FI meter into a complete spectrum analyzer, providing spectral displays in accordance with Mil-I-11748B. It can be used with any microwave receiver having a 140 to 160MC i-f. Polarad Electronic Instruments, 34-02 Queens Blvd., Long Island City 1, N. Y.

Circle 236 on Inquiry Card

MAGNETIC PICKUP

The 0.250 x 0.500 in. unit generates 3vac. Weight is less than 0.1 oz.

Shell construction in the microminiature 3053 pickup is stainless steel. It can withstand temps. ranging from −100°F up to +225°F. Two 6 in. long vinyl insulated leads eliminate the need for a connector. Electro Products Laboratories, Inc., 6120 W. Howard St., Chicago 48, Ill.

Circle 237 on Inquiry Card

We even put a hat on our drum to avoid contamination

This is only one of the ways we protect GENESOLV® D "Electronic Grade," the purest precision cleaning solvent you can buy.

We do everything possible to protect the purity of our precision cleaning solvent.

Even to using this film cover to keep dirt and moisture from settling on the drum top and possibly contaminating the solvent when you open the drum.

Precautions like this help keep Genesolv D "Electronic Grade" *the purest solvent available*. Residue is less than 1 part per million.

Genesolv D fluorocarbon solvent for critical cleaning cuts rejects due to contamination. It penetrates into even the smallest surface openings for easy, fast cleaning. The solvent has little or no effect on plastics, elastomers, paints and varnishes. There are no additives and it's compatible with any cleaning method.

It offers an outstanding combination of dielectric properties, exceptionally high resistivity with low dielectric constant.

Genesolv D "Electronic Grade" is safer to use than other solvents because it's nonflammable, nonexplosive and virtually nontoxic.

It's easy to recover for reuse. This helps keep your cleaning costs down. And our technical people will be glad to advise you on the best recovery set-up for your particular operation and on proper equipment and solvent storage and handling procedures.

Genesolv D "Electronic Grade" is available in non-returnable drums of 65-, 200- and 690-pound capacity, and in tank trucks of 3800 gallons.

Call on us for answers to any cleaning problems you have. Our years of experience and leadership in supplying high-purity chemicals can help you.

Allied Chemical

GENERAL CHEMICAL DIVISION
P. O. Box 353, Morristown, N. J.

Circle 89 on Inquiry Card

NEW PRODUCTS

AC VOLTAGE REGULATOR

Senses voltage changes and correct voltage to within 0.1% in 100μsec.

Model 760 regulates, stabilizes, and conditions a 60CPS, ac voltage source. Designed to condition a 95 to 135vac, 60CPS line, it handles power to 1kva. The instrument provides 40db (100 to 1) transient rejection and harmonic attenuation, and 100db isolation. Beckman Instruments, Inc., 2200 Wright Ave., Richmond, Calif.

Circle 238 on Inquiry Card

POWER MODULE

DC outputs from 10 to 60v. at 120w. and are adjustable up or down 5%.

Model T12D small-size, regulated power module converts 115v. 400 cycle to dc use. Measures 3 x 5½ x 3¼ in. and weighs 5 lbs. It is hermetically sealed and meets all environmental needs of Mil-E-5272C. Temp. range is from −65°F to +160°F. Abbott Transistor Laboratories, Inc., 3055 Buckingham Rd., Los Angeles 16, Calif.

Circle 239 on Inquiry Card

COMPONENT OVEN

Capacity sufficient for one 1⅛ x 3⅛ in. circuit board.

Dimensions of 1⅞ x 1⅞ x 4 in., excluding studs and header. Operating temp. is 75°C (±2°C). Stability is ±4°C over an amb. temp. range of −55°C to 65°C. Power requirements: 20w at 110vac. Reeves-Hoffman Div. of Dynamics Corp. of America, Cherry and North Streets, Carlisle, Pa.

Circle 240 on Inquiry Card

MAGNETIC TRANSDUCER

Controls fluid flow and determines mechanical speed and movement.

Applications of the commercial types indicate speed, motion, freq., and vibration. They operate from −100°F to +300°F. The military types are fabricated stainless steel and hermetically sealed to pass helium mass-spectrometer leak tests. Produces an ac voltage if there is a variation in external magnetic field. Nova-Netics Corp., 232 Glasgow Ave., Inglewood 1, Calif.

Circle 241 on Inquiry Card

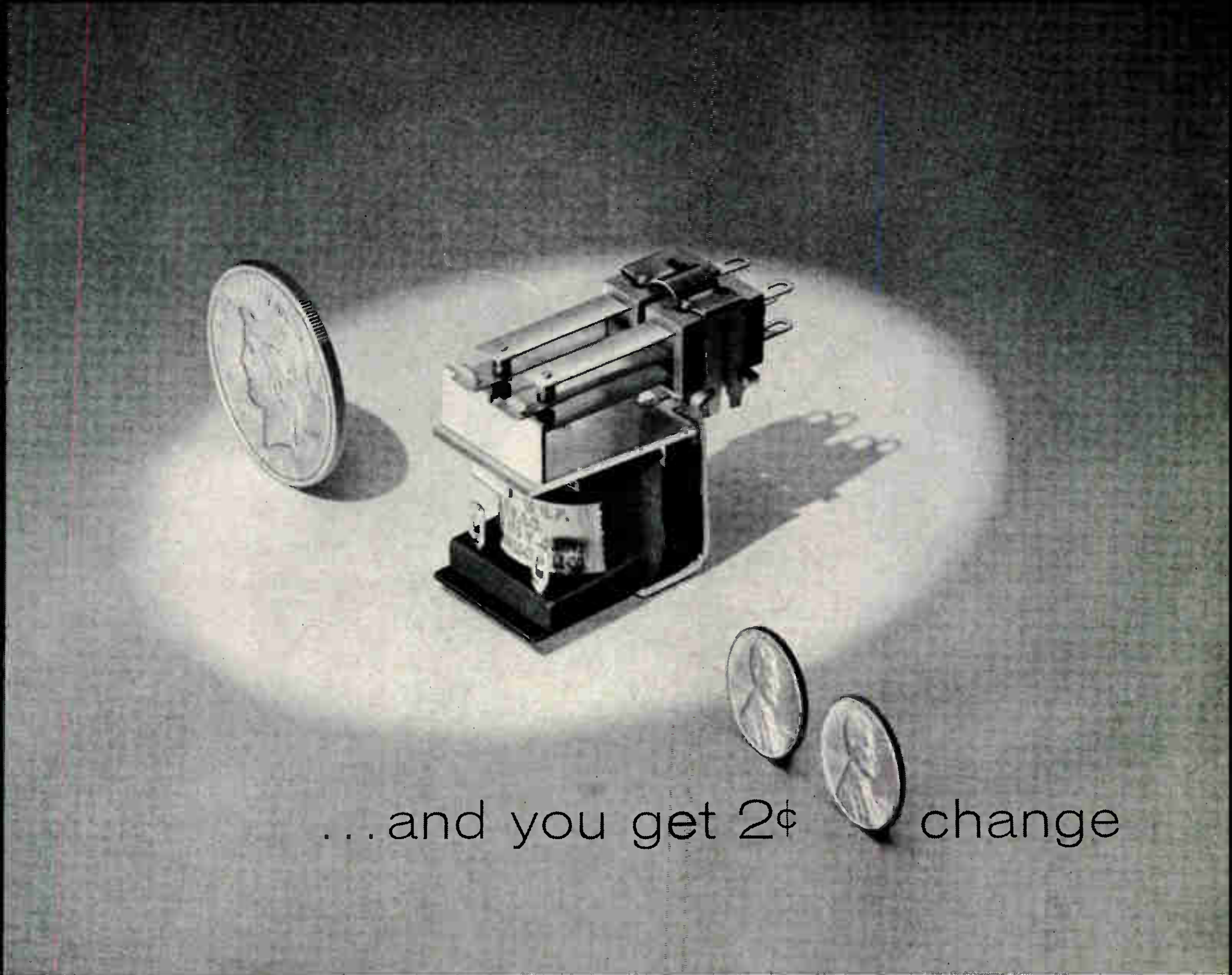
WAVEGUIDE TRANSITIONS

Frequency range is 3.95 to 40.0GC. Max. VSWR is 1.05.

This complete series of standard waveguide taper transitions allow one size waveguide system to connect another waveguide of different size. Optimum transition is accomplished with a minimum of reflected power. Waveline Inc., Caldwell, N. J.

Circle 242 on Inquiry Card

Circle 92 on Inquiry Card →



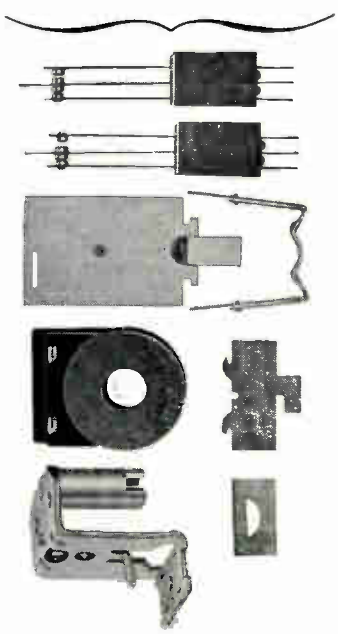
NEW DESIGN AND PRODUCTION TECHNIQUES PRODUCE SUPERIOR RELIABILITY AT A NEW LOW COST (98¢)

A dramatic engineering break-through has made possible a revolutionary price break-through in the production of the Guardian Series "900" Relay. ■ New design and production techniques actually reduce the number of parts 50%, and assembly operations 60%. The new *U.L. approved 115v. AC* "900" relay now features a *one-pi*ece field and core, capsulated coil with cover, *one-pi*ece molded switches, *one-pi*ece mounting clip and return spring, and other simplified parts. With fewer parts, and precision engineering, you're bound to get exceptional dependability and longer life. The Guardian "900" actually out-performs relays selling at many times the low price. All you pay is 98c in quantities of 200 or more. Sure you can pay more—but why? ■ CONTACTS: D.P.D.T. combination with rating of 10 amperes at 115 V.A.C. resistive load. ■ COIL: Voltages 24, 115, 230 V.A.C. or 6, 12, or 24 V.D.C.

NEW "FORM-FITTED" TRAY—Special assembly-line packaging speeds your operation, at no extra cost.

WRITE TODAY—The "900" Relay is carried in stock for immediate delivery. Write today for complete information.

These 8 parts now replace 22 parts



GUARDIAN ELECTRIC

GUARDIAN ELECTRIC MANUFACTURING COMPANY
1550 W. CARROLL AVE., DEPT. E139, CHICAGO 7, ILL.

LIGHTED SWITCH

Available in alternate, magnetic holding, or momentary types.

The Series 4 lighted switch fills the need for an illuminated indicator with control action. Light-tight legend divisions are available in quadrants, halves, or in combination configurations. Colored actuation barriers may be ordered for switch and indicator coding or isolation. Switches rated at 5a., 30vdc; or 5a., 115/250vac/pole. They can be supplied in 1, 2, 3, or 4pdt contact arrangements. Lynn-Western, Inc., 2525 W. 8th St., Los Angeles 57, Calif.

Circle 243 on Inquiry Card

SSB CRYSTAL

Passband flat to 1db from 200 cycles to 6KC from carrier.

Miniature 100KC SSB filter measures 16 cu. in. in volume. Specs: 2db from 100CPS to 6.2KC; opposite sideband rejection greater than 60db; 50db at 120 cycles from carrier. Upper and lower SB available. Burnell & Co., Inc., 10 Pelham Pkwy., Pelham, N. Y.

Circle 244 on Inquiry Card

NAND GATE

Typical propagation delay is 8nsec.; min. fanout is 5 over —55° +125°C.

This epitaxial-planer component is a 0.25 in. sq. single-chip microcircuit which effectively replaces 4 diodes, a transistor, and a resistor. The epitaxial NAND gate consists of a 3-input AND gate followed by an inverting stage. The package is a modified TO-5, but other configurations are available. Sylvania Electric Products Inc., 100 Sylvan Rd., Woburn, Mass.

Circle 245 on Inquiry Card

SERVOAMPLIFIERS

Units available in 60 and 400 cycles; two have 90° phase shifts.

Models 951, 952, and 953 amplifiers drive 33-40v 60-cycle and 400-cycle servomotors. They come in 5, 8 and 11 sizes. Model 951, 400-cycles, weighs less than 2 oz.; Model 952, 400-cycles features built-in 90° phase shift; Model 953, 60-cycles, has a 90° phase shift. Models are fully transistorized and conform with the temp., vibration, and shock requirements of Mil-E-5400D. Helipot Technical Information Service, 2500 Harbor Blvd., Fullerton, Calif

Circle 246 on Inquiry Card

POWER SOURCE

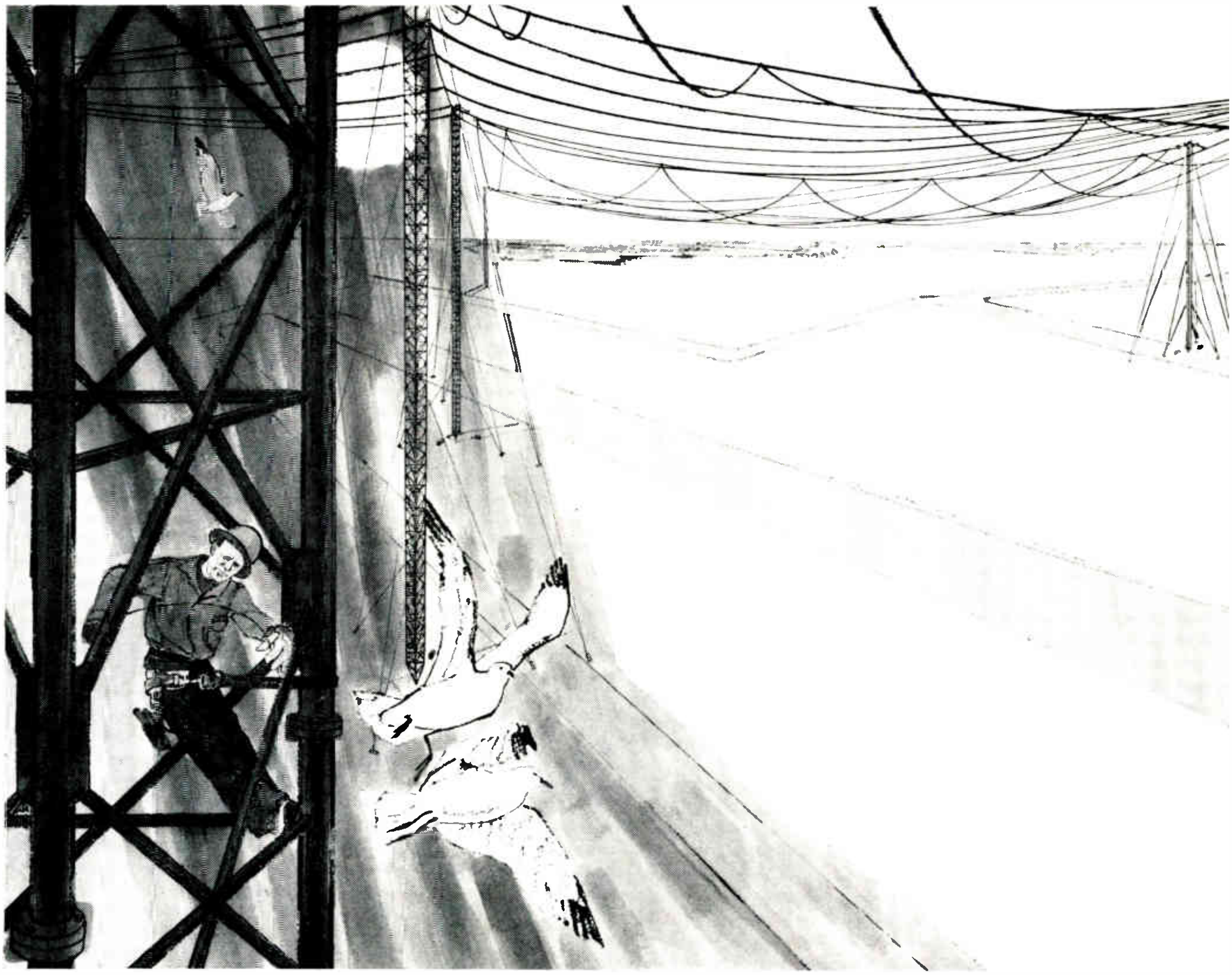
Output power from 0.1 to 50w. in the freq. range of 23 to 74GC.

Model 258 is a portable r-f power source which provides CW or pulsed power. Input power for the manually-tuned unit is 1800w. nominal, 115 or 220v. Pulse modulation duty is rated up to 100%. Litton Industries, Electron Tube Div., San Carlos, Calif.

Circle 247 on Inquiry Card

Circle 93 on Inquiry Card

Circle 94 on Inquiry Card



Anthorn — NATO voice of command...

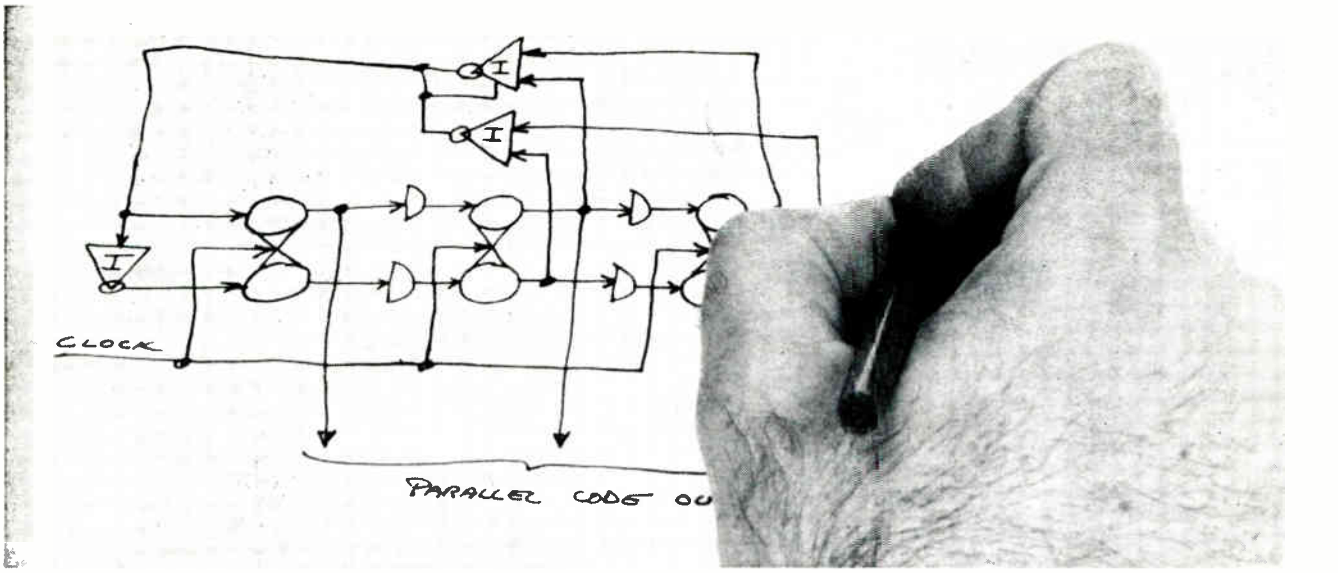
During World War II, the air over Anthorn, England, crackled with control-tower chatter typical of B-17 bases everywhere. Soon, that air will be charged again — this time with the big voice of NATO's new Very-Low-Frequency radio transmitter. With a power of 550-kw, it will feed a six-point-star antenna array stretching 4300 ft. over the old runways.

Like the U. S. Navy's staggering 2-megawatt VLF facility at Cutler, Maine, and VLF Pacific in Australia, the transmitting equipment for this new NATO command communication system is being designed and produced by LTV's Continental Electronics. VLF operation in the 16 - 20-kc range was selected for its immunity to ionospheric disturbances and because VLF propagation follows the curvature of the earth, thus giving added range to the station. Continental is associated with Redifon, Ltd. of London on the Anthorn project.

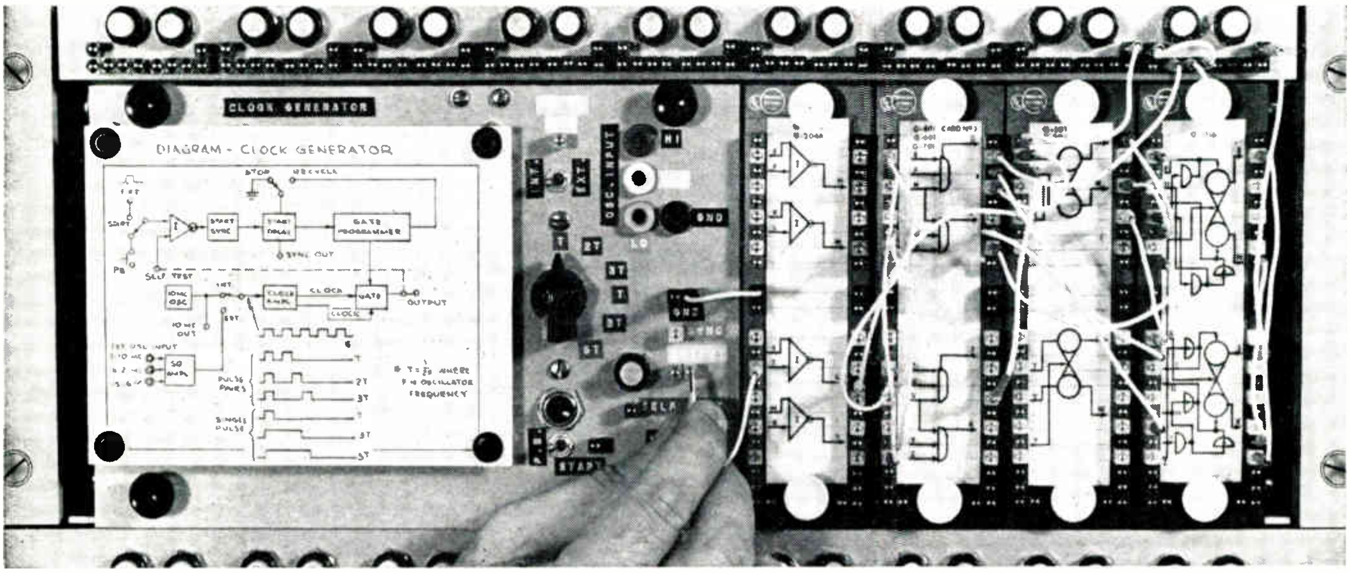
Long recognized as the producer of the world's most powerful transmitters, Continental produced the megawatt Voice of America transmitters, the BMEWS multimegawatt radar transmitters, and Nike-Zeus acquisition radar. Combined with Continental's activity in the fields of standard broadcast AM, HF, UHF, Single Sideband and microwave transmitters, these projects reflect another facet of LTV versatility. Continental Electronics Manufacturing Company, 4212 South Buckner Blvd., Dallas 27, Texas, a subsidiary of Ling-Temco-Vought, Inc.

LTV LEADERSHIP THROUGH VERSATILITY

Circle 95 on Inquiry Card



WILL IT WORK AT 10 MC?



FIND OUT FAST WITH AN EECo HIGH-SPEED DIGITAL SYSTEM BREADBOARD

It looks good on paper. Now—what will be the effect of clock duty cycle? Wiring? Propagation delay?

You can get the answers *fast* with EECo system breadboard equipment—an exceptionally simple means of formulating and testing digital electronic circuits at clock speeds to 10 Mpps.

This versatile transistor equipment lets you patch up trial circuit combinations with the same catalog modules that go into the final system, perform tests at operating frequencies by pushing a button on the control panel, and get a "stop-action" look at the over-all logic flow.

The built-in clock generator permits fast set-up of a wide range of test conditions, and indicators give you an immediate reading on any part of the circuit. Plastic symbol cards further speed your work by giving you a road map of the system as you put it together.

You may operate the system slowly to check individual operations or at end-system speeds, introducing high-speed pulses either singly or in pairs. If you want to try an alternative design idea, a few minutes of patching will make your brainstorm a reality.

Discover for yourself this speedy route from paper to prototype. Write for our new breadboard brochure today.

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- ☐ Mfr. of non-military electronic instruments, measuring, control and test equipment.
- ☐ Mfr. of non-military electronic computers, data processing, analysers, business machines.
- ☐ Mfr. of Guided Missiles and Accessories; Aircraft and Accessories, All Types of Military Products and Equipment.
- ☐ Mfr. of electronic components, parts, tubes and like products.
- ☐ Mfg. Co. (non electronic) using any of the above equip. In mfr., research or development work.
- ☐ Broadcasting or telecasting station.
- ☐ Commercial communication user (Tel & Tel, Police, Airports, Recording Studio, Etc.).
- ☐ Independent research, test, design laboratories and independent consultants—not part of a mfg. Co.
- ☐ Gov't Bureaus, Gov't laboratories, Gov't research center, military installation.
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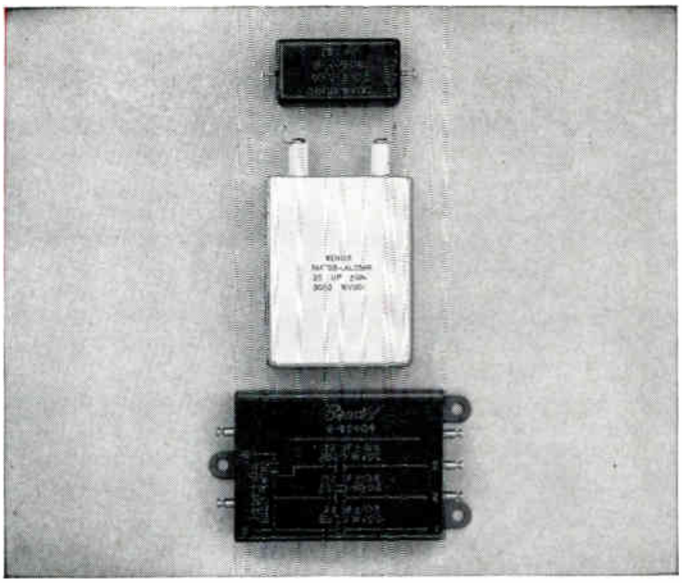
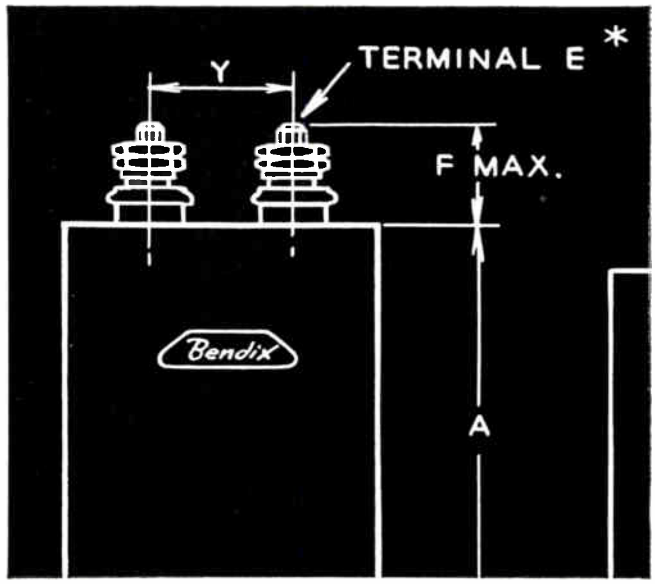
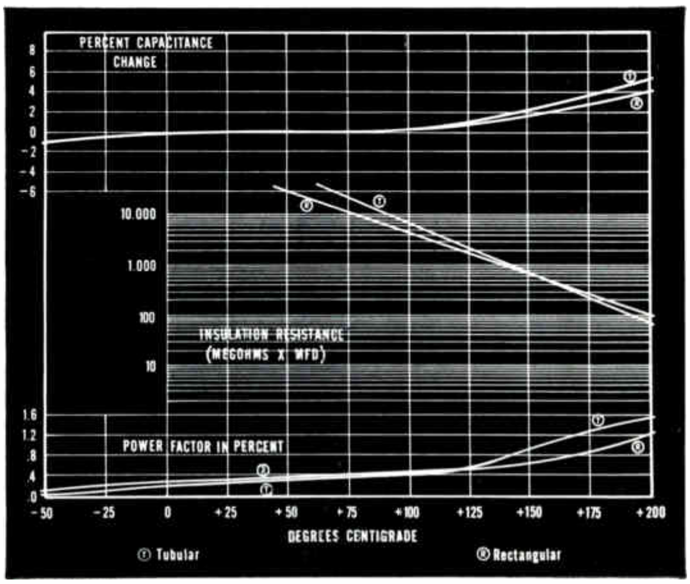


Our high-voltage capacitors



are smaller



offer superior electrical characteristics

and have impressed some pretty important people.

Our series of small, high voltage capacitors is designed for installations requiring a high degree of component reliability at operating temperatures as high as 200°C. We're proud of the fact that our capacitors are now being used on Republic's Plasma Space Engine.

The engine is designed for a variety of space applications. As a propulsion device, due to the low thrust-to-weight ratio, this engine can be used to maintain a satellite in a particular orbit, correct interplanetary vehicle course, or provide propulsion for a solar probe.

Bendix capacitors are ideal for applications such as this. They offer excellent qualities of radiation resistance. High temperature capability and mica-like electrical characteristics enable them to withstand extremely high orders of AC in small envelope size at all ambients under 200°C. For full details, write us in Sidney, New York.

Scintilla Division THE Bendix CORPORATION

Circle 97 on Inquiry Card

EDITOR'S MAIL BOX

ROCKET ENGINE'S ABILITY to shatter building materials is being probed at NASA's Langley Research Center. Results should help NASA select spacecraft launch sites that will minimize damage to surrounding communities. Project engineer Henry S. Freynik Jr., reports that space vehicle engines will be many times more powerful and make much more noise than those now being tested. They may develop in excess of 10,000,000 pounds of thrust, generate as much as 145 decibels of noise three miles from the launch.

SOUNDING SENTINEL, developed by Raytheon, makes red lights flash, bells ring, horns blow, or sirens scream when a ship gets too close to shoal water. As accessory for the firm's larger model Fathometer depth sounders, the new DE-734 depth alarm can be set for depths between 10 and 150 feet. When the preset minimum depth is reported by the vessel's depth sounder, the device warns of the approach to dangerous waters.

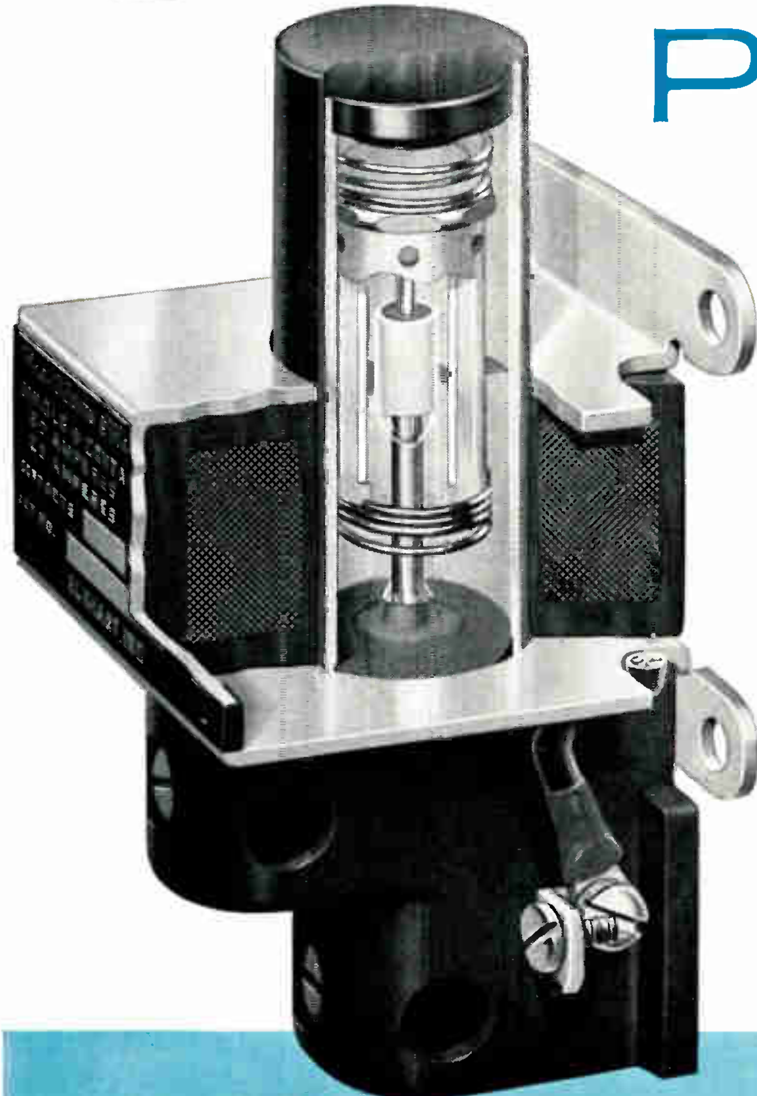
ELECTROSTATIC PRINTING, expected to have a major impact on the printing industry, was patented recently. Also called pressure printing, it permits rapid, inexpensive, and high quality impressions on almost any material from bricks to oranges. Invented by engineers at Stanford Research Institute, the process involves screening dry ink particles onto the material. Ink particles are attracted to the material surface by an electrically charged backing plate. The image to be printed is the other electrode plate. Ink particles are fused permanently on material by heat or chemicals.

EVERYBODY'S USIN' EDP to save time and money, including banks, airlines, hospitals, and even T-men and G-men. Now Northeastern University is going to use EDP to raise money by putting giving on the installment plan with a $40,000,000 Diamond Anniversary Development Fund coming up. A lot of little gifts over a long period entails a big clerical bill. Everybody wants a tax deductible gift acknowledgement, there's bookkeeping on a running gift total, and also universities want their own record of who coughs up what. Reducing human labor will also make the gift dollar go a little further.

MUD, MUD, MUD and how to get rid of it has annoyed military men ever since the first howitzer got stuck in the stuff. Passing DC through mud makes the water go away but past methods have been too slow and too expensive. For the U. S. Corps of Engineers, Cornell U. engineers are considering a grid 15 to 20 feet wide, average road width, and as long as possible. Buried below the grid's center would be a series of pipes, both acting as opposite poles. When activated, the water would surface under the grid and be drawn away in ditches. At the same time, chemicals would be introduced through the pipes to help stabilize the road.

HEART BEATS of an unborn baby have been transmitted from a Milwaukee hospital to a Paris laboratory in Marquette University's first attempt at trans-atlantic transmission of fetal electrocardiograms. Transmission was by telephone cable from Mount Sinai Hospital in Milwaukee. Paris confirmed that the signal was strong, heart beats of both expectant mother and fetus were recorded. Dr. Saul Larks, Marquette professor of electrical engineering, who directed transmission, said the tests open the door for international medical consultation.

IT'S NEW...IT'S SPIN-OUT PROOF



Adlake Type 1155 Mighty Midgets are protected by a patented anti spin-out feature. It doesn't show on the outside. Hardly shows on the inside. Yet, it stops uncontrolled making and breaking of contact circuits. Prevents the self-destruction that would normally result. With this protection, contacts rated 30 amperes at 115 volts have sustained inrush currents of 200 amperes for 10 seconds. Done so without uncontrolled breaking of the circuit load. To find out how this anti spin-out feature works, study the diagrams below. Contact your Adlake representative, or Adlake direct, for additional information.

Spin-out occurs when a mercury plunger relay is subjected to high inrush currents of relatively long duration. This sets up a heavy magnetic field which imparts a rotary motion to the mercury column. Centrifugal force displaces the mercury in the center of the column against the side of the plunger, causing the center of the column to sink. The phenomenon stops when cup and load circuit are exposed. However, it begins again as soon as enough mercury has been restored to the area over the cup and central electrode. Uncontrolled making and breaking of the contact circuit may continue until the relay is destroyed.

In an Adlake 1155 Mighty Midget, ports in plunger and refractory liner let the mercury re-enter the area surrounding the cup and central electrode as illustrated. This completely eliminates the tendency toward self-destruction of the contact mechanism.

ADLAKE MAKES MORE KINDS OF MERCURY RELAYS THAN ANYBODY

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LETTERS

"Improving Semiconductor Reliability"

Editor, ELECTRONIC INDUSTRIES:

I would appreciate it very much if you would publish the list of reference bibliography in connection with my manuscript "Improving Semiconductor Reliability" in order to give credit to other authors in this field.

Bibliography: High Stress Aging to Failure of Semiconductor Devices. G. A. Dodson and B. T. Howard—Bell Telephone Lab.; Statistical Techniques in Life-Testing, Benjamin Epstein—PB 171580, U. S. Department of Commerce; Random Balance, Thomas A. Budne—Industrial Quality Control, Vol. XV 1959; Reliability Training Text, ASQC, IRE, March 1960, Weibull Statistics & Burn-in, J. N. Perry.

Hauw T. Go
Chief Reliability Engineer
Diode Division
Transitron Electronic Corporation
168-182 Albion Street
Wakefield, Massachusetts

Semiconductor Articles—

Editor, ELECTRONIC INDUSTRIES:

In reviewing the June issue of Electronics Industries Magazine, I noticed two fine articles on semiconductors and circuits. Reliability of these devices was discussed. I would like to receive reprints of the following two articles:

1. The Future of Semiconductor Devices by Dr. A. M. Glover
2. The Future of Integrated Circuits by Daniel E. Noble

Thank you very much for copies of these articles.

J. F. Medford
c/o Douglas Aircraft Company, Inc.
Department A2-260
3000 Ocean Park Blvd.,
Santa Monica, California

"Any Back Issues—?"

Editor, ELECTRONIC INDUSTRIES:

If still available, I would like reprints of "Inexpensive Remote Pickup Transmitter" from your September 1961 issue, and "Build a Suitcase Studio" in your March 1960 issue.

Being quite new to the business, I do not have the past issues of Electronic Industries. But judging from the issues I do have, the past issues must have loads of informative articles.

Perhaps some of the readers who want to rid themselves of old issues of E. I. could arrange to send them to me.

W. J. Wolfenbarger,
Chief Engineer,
Willapa Broadcasting Co.
P.O. Box 626,
Raymond, Wash.

"The Search For New Semiconductor Materials"

Editor, ELECTRONIC INDUSTRIES:

I certainly enjoyed reading and would like to compliment you on your fine article entitled "The Search for New Semiconductor Materials" published in the June, 1963 Electronic Industries Magazine. This undoubtedly is the best article I have read in recent months on the "state of the art" on semi-conductor materials.

There is one minor point that I believe may be somewhat misleading and that is your statement on the availability of Gallium. Your first paragraph points out that if any material is to supplant germanium and silicon, it will have to be available in quantities of 50,000 to 100,000 pounds per year. For a compound semi-conductor like Gallium Arsenide, this means that Gallium would have to be available in quantities of 25,000 to 50,000 pounds per year. With present facilities, our calculations indicate that Alcoa alone can supply approximately 37,000 pounds per year of Gallium required. We further believe that with just a minimum of effort extraction rates could be improved with reasonable hope that 50,000 pounds per year could be produced. When you consider the magnitude of the world wide aluminum industry, you can see that Gallium is readily available in the quantities set up as your criterion for adequate supplies.

F. M. Townsend, Manager
Industrial Chemical Sales
Aluminum Co. of America

(*Continued on page* 164)

COULD YOU CONTRIBUTE TO THE DESIGN OF A SYSTEM THAT CAN SURVIVE?

481L. A self-healing system for post-attack recovery and re-establishment of command structure in case of direct nuclear bombardment.

It's MITRE's job to design such a system and make sure it works.

It's just one of MITRE's jobs. Among others are the development of a new aerospace communications system, a nuclear detection and reporting system, a hardened underground command post for NORAD, and a system to help end mid-air collisions.

MITRE needs men for this work. It is probably the most challenging work of its kind in the field of military command technology.

MITRE is located in Bedford, Mass., a country town 25 minutes from Boston, one hour from the White Mountains, a half-hour from the ocean. Advanced degrees in electronics, physics or mathematics are preferred.

If you are interested in working here, write Vice President — Technical Operations, The MITRE Corporation, Box 208 AN, Bedford, Mass. Openings are also available in Washington, D.C. and Colorado Springs, Colorado.

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Pioneer in the design and development of command and control systems, MITRE was chartered in 1958 to serve only the United States Government. The independent nonprofit firm is technical advisor and system engineer for the Air Force Electronic Systems Division and also serves the Federal Aviation Agency and the Department of Defense.

Circle Number 800 Professional Profile, page 178

ELECTRONIC CAPABILITY (Continued)

quality of output and manpower rather than on sales records and size of facilities, will increase.

Q.—What do you suggest we do about this gap in our technological ability?

A.—This is not easy to answer. It's hard to assess the basic competence of the electronics industry, whether it needs to grow, or be stimulated in certain directions. We know that we are not getting what we need, and that our electronics capability must be geared to grow with the space program.

Q.—Are American workers geared to think and work with precise requirements?

A.—This is a real problem. We know there is laxity in precision and perfection in our manufacturing in contrast to the handicraft society as exemplified by the Swiss in their watch movements. The "Let's get the product out on the market" drive has been paramount in our thinking. Success of a space mission may hinge on the absence of any inferior component. Shoddy work and imperfect materials have no place in space equipment.

Q.—Do you consider that we may not have enough highly-trained scientists?

A.—Those who talk about our space program in my opinion usually over-emphasize the importance of highly-trained scientists as opposed to engineers who do most of the work. We need more highly-trained engineers if we are to get the electronics reliability and competence we need to make every space shot successful.

Q.—What can we do about the shortage of trained and experienced electronic engineers?

A.—There is always a shortage of able people in any line. There is not only a shortage of scientists and engineers but also of competent managers to supervise and hold onto the skilled personnel in industry who are more and more in great demand elsewhere. We should offer incentives to engineers, both in education and on the job.

Q.—What remedies do you suggest?

A.—For one thing, our educational system is archaic. It lags behind changes in our society. There is a lack of money for rebuilding facilities and up-dating curricula, and there is a lack of stimulation for change in educational circles. Lack of facilities and insufficient maintenance are also factors. These problems always have beset education, but with the space program, requiring greater emphasis on skills and training, the problem of education is far more severe.

So much is being published today that was not published only a few years ago. This is important, for it helps to motivate young people and to provide instruction and training for those already in the jobs.

Q.—How do we stimulate this lagging educational system?

A.—If you want to lead our society in any particular direction—speed it up, or change its direction—most of this sort of effort, seemingly, must be done in Washington.

Q.—What is the Government's role in this?

A.—Legislation should provide scholarships, funds for new facilities at technical colleges and universities. Actually, NASA is making funds available for new facilities for scientists at the present time, and this program could easily be broadened to include engineering.

Q.—How effective is our total effort to speed up our technological capability through this NASA effort?

A.—NASA's program is just a little wedge toward a solution to the whole problem. However, there is evidence that NASA's current program may be sufficient to replace all the PhDs required by the Government in its space program.

Q.—Do industry leaders support NASA's program and the concept that the Government should place its weight behind stepped-up education and experience programs for scientists and engineers?

A.—I know of no adverse criticism from industry leaders. There may be some support for the program, but such support is not yet particularly noticeable.

Q.—What is the U. S. position on the mobility of scientists and engineers, brought about by the awarding of contracts?

A.—The Government is not sure it wants to get into this problem. In fact, it appears that it is the most highly skilled and valuable person that has opportunities coming his way that causes him to move. There is a question whether the Government should interfere in this phase of our free enterprise society.

Q.—What is your feeling as to the responsibility of Government and industry toward providing training and experience for technical personnel?

A.—Government should support educational opportunities for citizens, and industry should provide training and experience in practical know-how, and in leadership leading to manage-

(Continued on page 165)

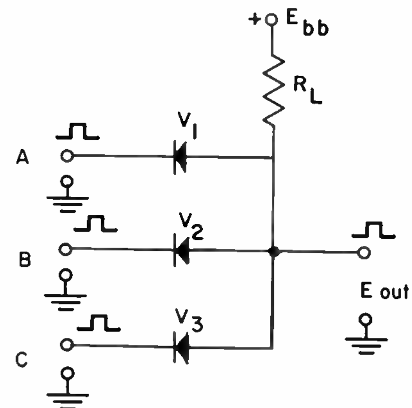
LETTERS

"Diode 'And' Gate"

Editor, ELECTRONIC INDUSTRIES:

The "Diode 'And' Gate" circuit that you have drawn on p. 86 of the July, 1963 issue of Electronic Industries has a mistake in the B diode leg. The circuit as shown will not operate as a coincidence circuit since the B leg is independent of the A and C circuit elements.

The corrected circuit is shown below.



The B leg should be corrected as shown so that the circuit will function as originally intended.

C. A. Kallas,
Electronics Engineer
Missile & Space Systems Div.
Douglas Aircraft Company, Inc.
Santa Monica, Calif.

"Guide To Lamp Selection"

Editor, ELECTRONIC INDUSTRIES:

Congratulations on the very fine and comprehensive article, "Designer's Guide to Lamps, Indicators and Switches," in Jan. 1963 issue. The article reflects your extensive and thorough research of the industry.

One slight misprint occurs in the copy immediately above the cut of the Licon Type 04, Page 166. The second line should read . . . "-crease of switch *operating point,*" instead of "actuating pressure."

Howard J. Roeser
Advertising Manager
Licon
Division Illinois Tool Works Inc.
6615 W. Irving Park Road
Chicago 34, Illinois

(Continued from page 163)
ment positions.

Little known is the fact that the Government sometimes helps in training people for management positions. It often selects talented persons from industry to work for a period in difficult management slots in Government where they get some of the best lessons in management, which can be applied at their companies.

Q.—You implied that our scientists, engineers and production people need to be motivated in order to achieve the excellence and perfection demanded by our space effort. How should this be done?

A.—Motivation is very important. Some feel that motivation is a basic problem with our citizens as compared to grandfather's time; things are not as black as they seem. There is tremendous excitement among our young people over our space program. If we relied on the excitement of our 9-15-year-olds, our space budget would be tripled. Television and reading material on space have aided this and have made our young people much more advanced in knowledge and ability. If we can help them capitalize on that interest through public schools and colleges, we may have solved part of the motivation problem. Public schools have lagged far more than our colleges in training young people for a new and rapidly changing world.

Q.—In your opinion, is it the systems engineer that is in shortest supply?

A.—The man who can plan a complete system is the hardest to find and in greatest demand. This is where we have the greatest shortage. So far, there are few schools, if any, for training in systems technology and planning. Such knowledge comes by experience and not enough people have this experience yet.

Q.—Is the Government doing anything to help encourage—possibly through the Department of Health, Education and Welfare — high school guidance people to steer talented students into science and engineering?

A.—This can be sticky. The Government doesn't want to be a dictator to local schools. I think there is one thing the colleges and universities can do, however, to interest young people in technology. Schooling costs are so high that many talented students are discouraged or drop out before reaching maximum potential and are thus lost to society. I suggest that colleges find a way to reduce tuition fees according to a student's academic record. The better the student's performance the less the fees charged.

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The Systems Engineering Section of ELECTRONIC INDUSTRIES

ELECTRONIC SYSTEMS

"EDGE" ON PRODUCTION

With Navy P-3 Orion patrol plane in BG, production worker at the Lockheed-California Co., Burbank, reports status of job via remote EDGE (Electronic Data Gathering Equipment) unit. Flashed in under a sec. to central RCA computer is production data in 36 subject areas. Lockheed-California now has 127 EDGE units in operation.

New production data reporting and acquisition system conceived by Lockheed, and designed and built by RCA. is being installed in Lockheed plants throughout country. Automatic DPS makes production data from assembly lines available to top management in a few seconds. It will save about $2.8 million next year at Lockheed Missiles & Space Co. alone. Reports are made by production line employees through "nerve ends" called EDGE (Electronic Data Gathering Equipment). Management uses information to locate parts in production, check status of jobs. Days, weeks are cut off normal report times.

WBIR-TV, Knoxville, Tenn., received 297 tons of prefabricated steel for its 1751-ft. TV tower, which will replace an existing 700-ft. support. Tower will extend the WBIR-TV coverage over a 50% greater area. The tower will be equipped with a 2-man elevator for making repairs or changing lights. A man would take an estimated 3 hrs. to climb the one-third mile height. The elevator will ascend it in 15 min. Designed and built by Stainless, Inc., N. Wales, Pa., the guyed, triangular tower will support a high-gain helical antenna. Stainless has already built a 1749-ft. tower in Columbus, Ga., shared by WTVM and WRBL-TV.

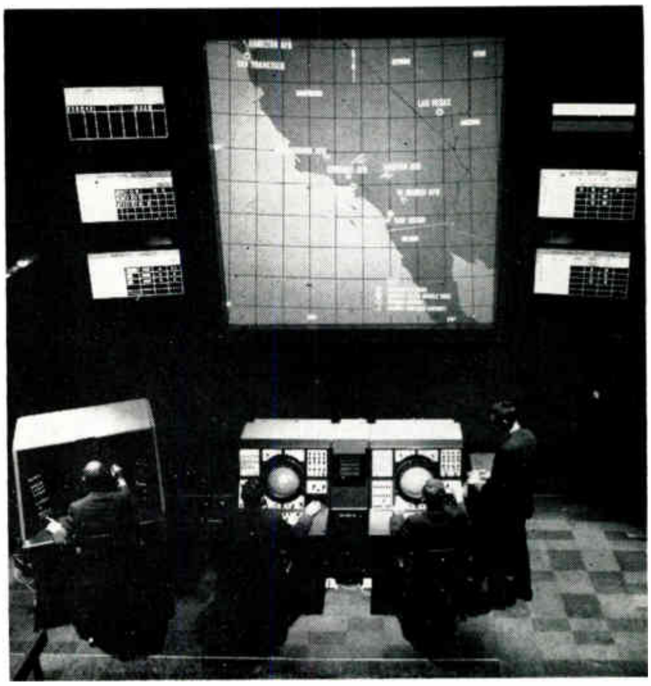
A $36 million contract for the development and manufacturing of an air defense system for Japan was recently awarded to the Hughes Aircraft Co., Fullerton, Calif. The Hughes Tactical Air Weapons Control System was selected over systems proposed by two other American companies. The selection was not made until after 3 years of system development, presentations and demonstrations by the 3 companies, plus exhaustive evaluation by the Japanese Air Self Defense Force.

New equipment FAA has ordered will give air traffic controllers more command over inputs to their radar scopes. Burroughs Corp. is designing the equipment that will be part of FAA's improved national air traffic safety system. Automatic processors will do filtering now performed manually by human operators. Radar and airborne beacon data will be fed automatically into scope unless controller changes type(s) of information desired.

A totally integrated data system designed by G. E. for the Chicago public schools may lead to new methods in educational data processing. Dr. Benjamin C. Willis, General Supt. of Schools, said the DPS will begin operating when school opens this month. It will serve the entire school system within 5 years. "When the system is fully implemented, the Chicago public schools expect to save over $3,500,000 per year," Willis said. The service will reduce the clerical load of teachers, thus making more instruction time available for students.

AIR WEAPONS CONTROL SYSTEM

View of Tactical Air Weapons Control System demonstration facility, at Hughes Aircraft Co., Fullerton, Calif., shows Colordata screen with flanking status boards, Command Console (lower left), and Data Display Consoles with Auxiliary Readout Console (lower center). An H-330 Computer and supporting systems are outside partition at left.



Deep sea vehicles are being used for oceanography and ASW research. In many cases these vehicles are remotely controlled from a surface vessel. A system which provides this remote control via a wire-sea water transmission line, is described here.

For Underwater Vehicles . . .

A DIGITAL WIRE GUIDANCE SYSTEM

A REMOTE CONTROL SYSTEM that handles present underwater needs and can also be expanded for the future has been developed by Westinghouse Ordnance Div. It sends coded information between mother and remote vehicles via a wire and sea water line. A prototype demonstrated the system at distances over 10 miles. It's described here.

* * *

Designers of the communication system had to work for reliability and minimum volume and weight. There were other goals, too:

—The system had to be easily maintained and serviced.

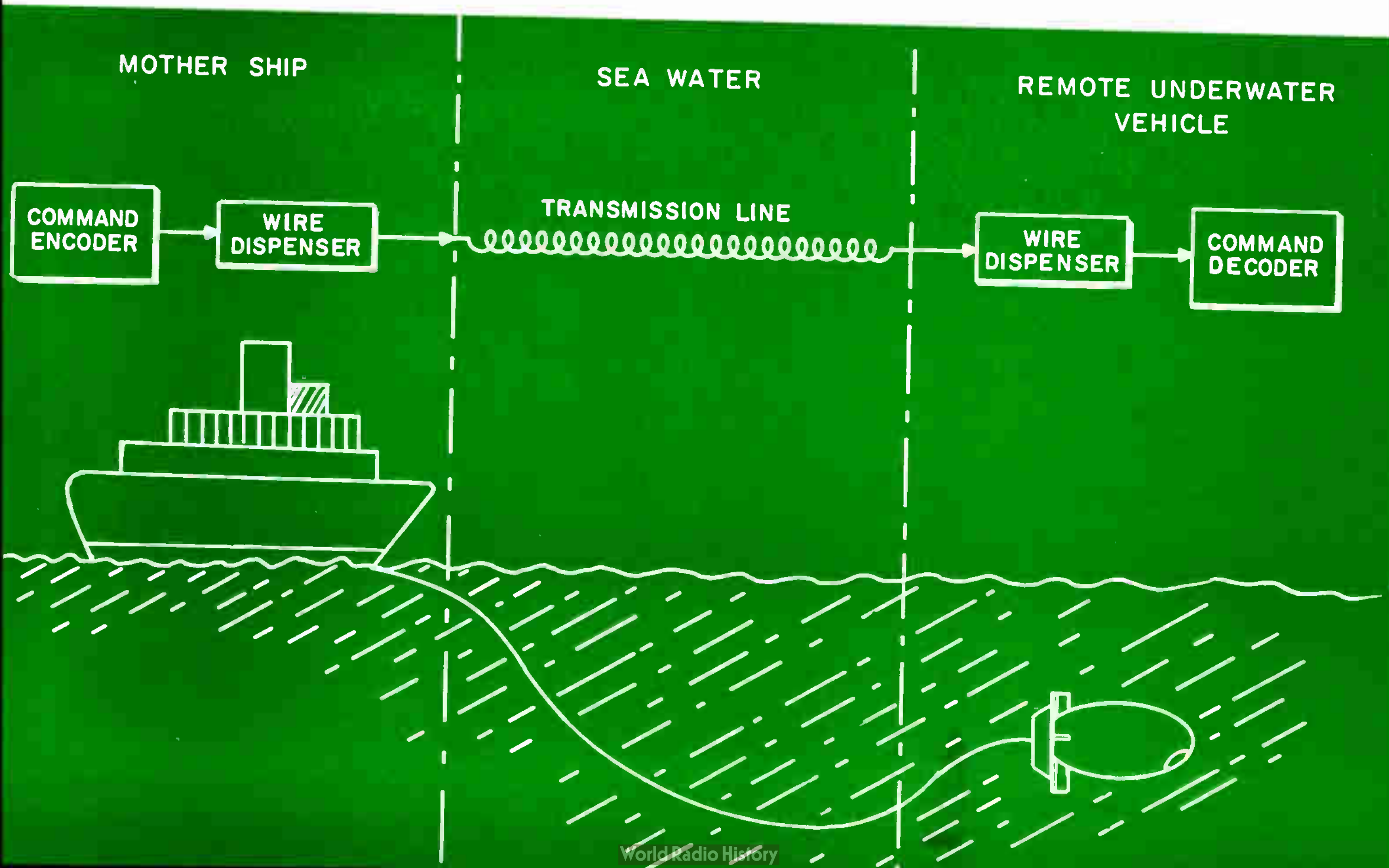
—It had to be compatible with different vessels.

—It needed a range of 10 miles.

Because water won't carry acoustics well over such distances, and because electromagnetic waves are severely attenuated, a direct wire link is the only satisfactory underwater communication channel. And the wire must be small in diameter and expendable, so that compact, lightweight spools can handle it over long distances. A 20-lb. tensile load had to be withstood by the wire, and this determined its minimum diameter. The wire is payed out from spools in both vehicles, so that both can maneuver.

Signal attenuation and distortion must be kept down, and the link's bandwidth kept wide enough to allow adequate transmission rates.

The l-f resistance of the sea is about 2 ohms at these distances. That allows the sea itself to be one



conductor, so that the line is essentially a coaxial cable, with an insulated inner conductor of wire and an outer one consisting of the sea.

More conventional lines using 2 metallic conductors can be used. These will have about twice the series resistance of a wire-sea water combination of the same diameter. However, 2-wire lines have an advantage: their inductance is small and constant. The wire-sea water line has considerable inductance when coiled in a spool. But it decreases as the wire is dispensed from the spool.

Long lines are inefficient at high frequencies. Only the very low end of the frequency spectrum is of value with long, small diameter underwater lines. Electrical characteristics of these lines are due mostly to their distributed series resistance and shunt capacitance, and also to their inductance on the spool if they are the single-wire type (see Table 1 and Fig. 2).

Types of signals that can be used depend on the transmission line characteristics. The signals should have most of their spectrum within the link pass band. The plots in Fig. 2 show that the higher frequencies are greatly attenuated.

Pass bands of the transmission lines can be increased by reducing either their distributed series resistance or their shunt capacitance. Series resistance can be reduced by increasing the wire diameter or, in the case of the copper-clad wire, increasing the amount of copper. Increasing wire diameter increases the volume needed to store a given length. Increasing the percentage of copper in copper-clad wires of equal diameter decreases their breaking strength. This makes necessary an additional increase in diameter to meet the strength requirement. The insulation on the wires contributes little to breaking force resistance.

Shunt capacitance can be decreased by increasing

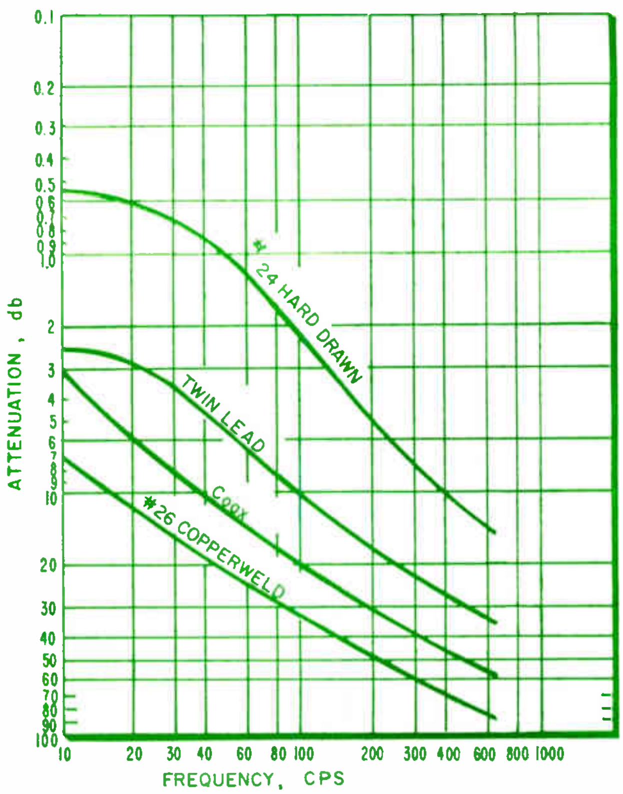


Fig. 2: Attenuation vs frequency characteristics for several lines (when fully dispensed from spools) are plotted here.

the distance between conductors. The insulation for coaxial lines can be thickened, or a two-wire parallel line can be used. Both procedures result in an increase in the cross sectional area of the wire and thus, a decrease in the storage density. Another way of reducing shunt capacity is to use insulation with lower permittivity. However, since Teflon seems to have the lowest permittivity of the practical solid insulation materials now available, no further improvement by this method is possible at present.

If a single wire is used, its inductance can be quite

Fig. 1: (left) System concept is illustrated here. A prototype model was built that successfully demonstrated system's feasibility for use at distances of over ten miles.

By M. F. BORKOWSKI, C. C. CRAVEN

Engineers

and J. B. MYNAUGH

Sr. Engineer
Ordnance Div.
Westinghouse Defense Center
Baltimore, Md.

Table 1

Distributed Parameters of Several Underwater Transmission Lines

	Type 1	Type 2	Type 3	Type 4
Series resistance (ohms/1000 ft)	106	26.17	77	103
Shunt capacitance (farads/1000 ft)	0.069×10^{-6}	0.0444×10^{-6}	0.101×10^{-6}	0.028×10^{-6}

Type 1: No. 26 AWG 30% copper, copper-clad steel wire, 4-mil-thick Teflon insulation. The sea is the second conductor.

Type 2: No. 24 AWG hard drawn copper, 16-mil-thick polyethylene insulation. The sea is the second conductor.

Type 3: A coaxial cable with 20-lb. tensile strength, No. 24 AWG hard drawn copper, 4-mil-thick Teflon insulation.

Type 4: Twisted pair with 20-lb. tensile strength, two No. 27 AWG hard drawn copper wires spaced 4 mils, Teflon insulation.

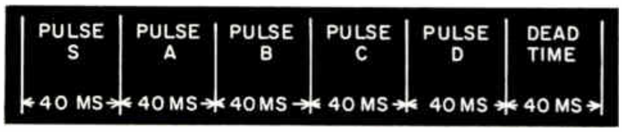
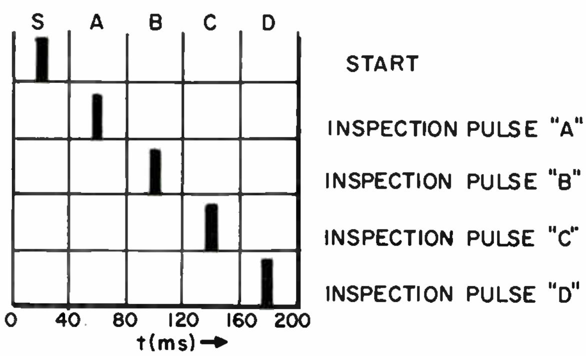


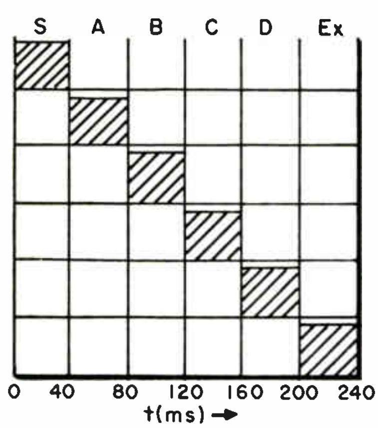
Fig. 3: Command word timing. The time interval for each command is subdivided into intervals of forty milliseconds each.

Table 2

COMMAND	S	A	B	C	D
1	1	0	0	0	0
2	1	0	0	0	1
3	1	0	0	1	0
4	1	0	0	1	1
5	1	0	1	0	0
6	1	0	1	0	1
7	1	0	1	1	0
8	1	0	1	1	1
9	1	1	0	0	0
10	1	1	0	0	1
11	1	1	0	1	0
12	1	1	0	1	1
13	1	1	1	0	0
14	1	1	1	0	1
15	1	1	1	1	0
16	1	1	1	1	1



INSPECTION PULSE GENERATOR OUTPUT (ASSUMING 200ms SIGNAL)



RING COUNTER OUTPUT

Fig. 4: Timing program. Information pulses during the time intervals A, B, C, and D are sensed by AND gates that use counter and inspection pulses generated by the command word.

large when it is coiled in a spool. Effect of the inductance is to modify the transmission line pass band by creating a resonant peak in conjunction with the capacity of wires. Since the inductance decreases as the wire pays out of its container, the frequency of resonance changes. The moving resonance peak places severe dynamic demands on certain types of frequency-sensitive receivers. At times the gain of the receiver would have to be radically adjusted at various frequencies. Two-wire lines do not have this problem.

Selection of the type of line to use is dependent upon relative importance of storage space, band width, and spooled inductance. Amount of wire that can be stored in a cylindrical container is inversely proportional to the square of the diameter of the wire.

The communication system selected uses only the lowest end of the frequency spectrum and thus a wire-sea water line composed of a single No. 26 copper-clad wire was selected. This wire has the highest storage density of those considered, since it has the smallest diameter.

Operation

The selected system uses l-f coded pulses. It has a pulse encoder on the launching vessel which generates a series of pulses coded according to the desired command. The underwater vehicle carries a command decoder which interprets pulses as they arrive and applies them to circuits that execute the command. Although the selected system does not provide for return signals, they could be used by simply reversing the process and using essentially the same equipment on a time-sharing basis.

The system's logic circuitry uses 2 basic circuits: the AND gate and the "set-reset" flip-flop. Each command word is transmitted during a time interval of 200 msec. Separation between commands (dead time) is 40 msec. A total time of 250 msec is thus needed to transmit one command. At this rate, slightly over 4 commands can be transmitted per sec.

Time interval for each command is subdivided into smaller intervals of 40 msec each, Fig. 3, Fundamental operating frequency of this word structure is 12.5 CPS. First pulse is the S or start pulse followed by information pulses. Provision is made to transmit information pulses during time intervals A, B, C, and D. Function of the start pulse is to start action in the decoder and to act as a time reference. Each command word must have a start pulse. Information pulses during the time intervals A, B, C, and D are sensed by AND gates that use counter and inspection pulses generated by the command word, Fig. 4.

(Continued on page 172)

GUIDANCE SYSTEM

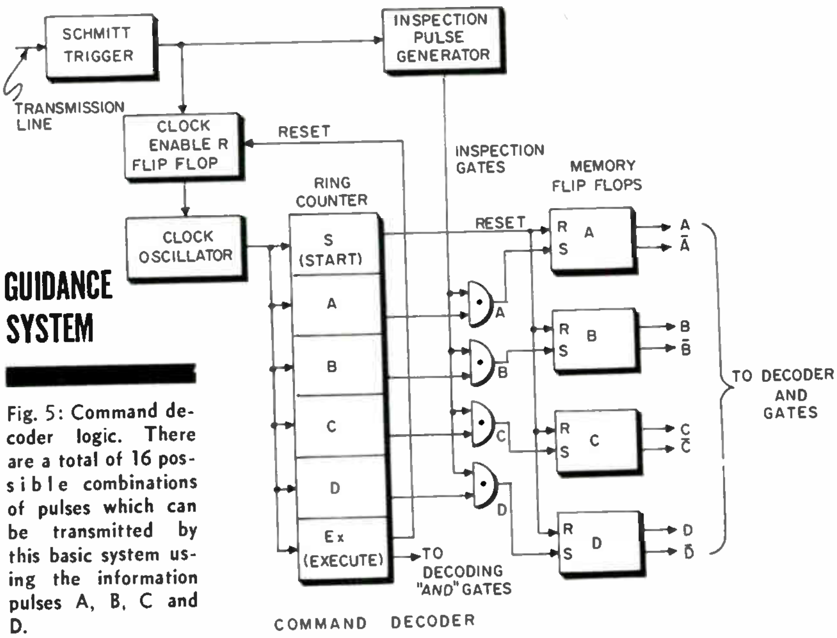
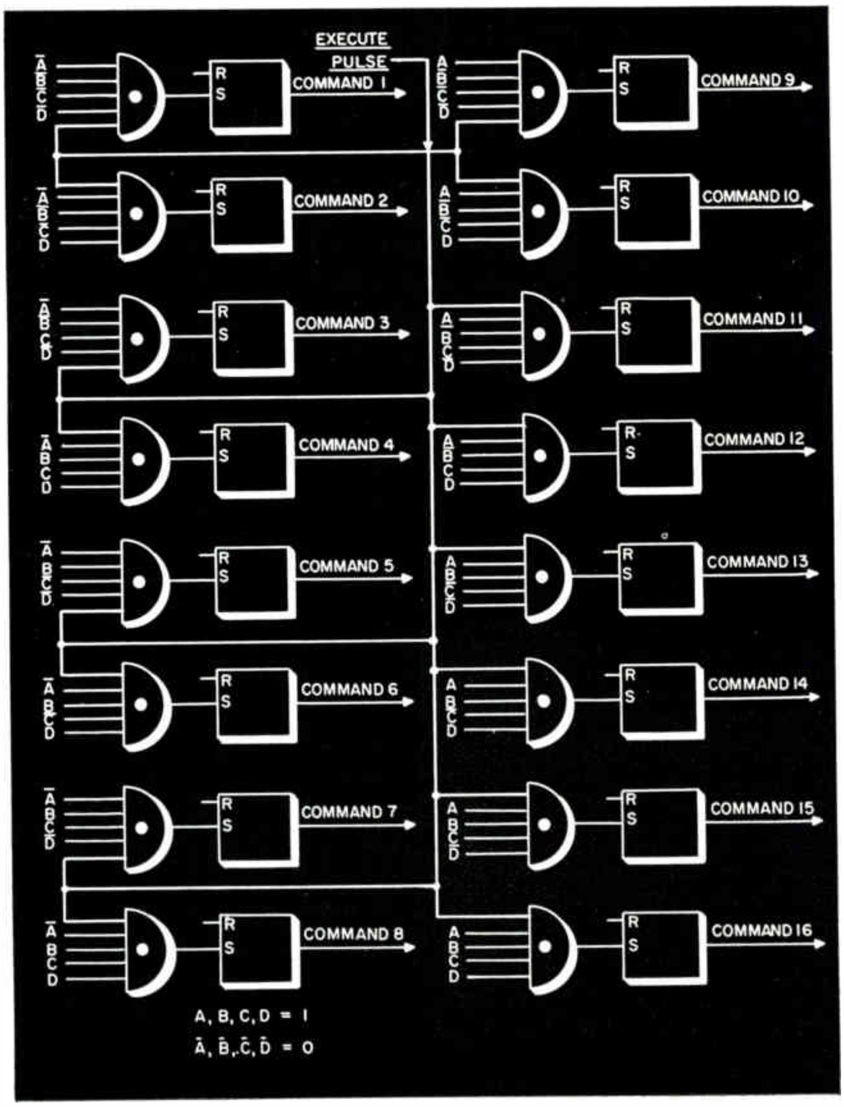


Fig. 5: Command decoder logic. There are a total of 16 possible combinations of pulses which can be transmitted by this basic system using the information pulses A, B, C and D.

Fig. 6: Arrangement of 16 decoding AND gates. These gates are wired to the outputs of the memory flip-flops to decode the command. There is one gate for each command possibility.



Decoding Logic Circuit

The decoding logic circuit is shown in Fig. 5. Transmission line input is fed into a normal Schmitt trigger circuit which reshapes the received command pulses. The first pulse emitted from the Schmitt trigger, which is the start pulse, sets the clock-enabling flip-flop which in turn starts the clock oscillator. The clock starts and regulates the ring counter's progression S-A-B-C-D-EX at 40 msec intervals. When the "S" stage of the ring counter is switched "On," it generates a pulse to "Reset" the memory flip-flops, thus erasing the previous command memory storage and preparing for new storage.

The start pulse also energizes the inspection pulse generator. This unit contains an oscillator that generates pulses 5 msec long and 40 msec apart as long as a signal is being emitted from the Schmitt trigger. This oscillator is delayed to start 20 msec after the start of the clock oscillator regulating the ring counter, Fig. 4.

A, B, C, and D stages of the ring counter individually supply an input to the 2-input inspection gates. The other input is supplied by the inspection pulse generator. If both inputs of an inspection AND gate are energized simultaneously, the gate will conduct and set its corresponding memory flip-flop. The memory flip-flops will remain set until the start pulse of the next command word causes a reset.

With both signals present simultaneously, gate "A" conducts and sets memory flip-flop "A." Thus, the existence of pulse "A" has been established. This same process is repeated as the ring counter progresses, setting to memory the existence of command pulses A, B, C, and D. Nonexistence of a command pulse is also detected because the absence of a command pulse on the line fails to generate an inspection pulse, thus preventing the setting of its particular memory flip-flop. The last stage of the ring counter is the execute command. This stage has a two-fold purpose: it resets the clock-enabling flip-flop, thereby stopping the ring counter, and it supplies one of the inputs to each of the 16 decoding AND gates.

At the end of 200 msec, the pulses of any given command have been accumulated and are stored in the memory flip-flops. There are 16 possible combinations (Table 2) of pulses which can be transmitted by this basic system using the information pulses A, B, C, and D.

To decode the command, 16 AND gates (one for each command possibility) are wired to the outputs of the memory flip-flops per the code given in Table 2. (See Fig. 6.)

After 200 msec, one and only one of the decoding AND gates will be satisfied, except for the existence of the execute pulse. As soon as the execute pulse arrives, the decoding gate transmits a pulse to its output flip-flop which can drive other circuitry to execute the command. Reset inputs of these flip-flops are also controlled by the reset pulse generated by the ring counter start stage at the beginning of the command time. Or, they can be reset by feedback from the device which actually executes the command.

One more bit (F) could be inserted as a parity check. It would be inserted as needed by the encoder to produce an even number of pulses for each command. By doing this we eliminate the possibility that any single noise pulse or the loss of a single pulse could cause a false command.

The Encoder

The encoder or command transmitter for this system is stored aboard the launching vessel. Its circuitry is similar to that of the decoder in a reversed

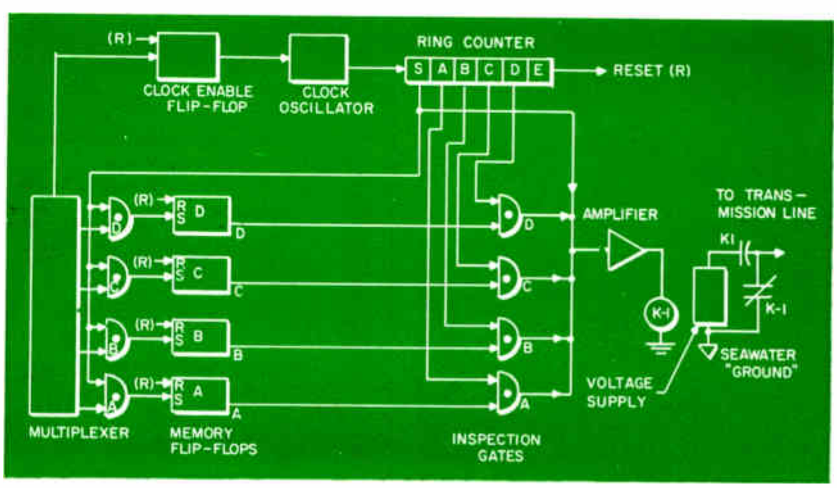


Fig. 7: Command Encoder. A command is generated by manually selecting the desired command on a multiplexer. Approximate volume of the encoder is 25 cubic inches.

fashion, Fig. 7. A command is generated by manually selecting the desired command on a multiplexer (a 16-position, 4-wafer rotary switch can be used). The multiplexer in turn supplies power to energize one input of the 2-input AND gates A, B, C, and D in a combination unique to the command being transmitted.

At the same time that power is supplied to set the memory flip-flops, the clock-enabling flip-flop is energized, thus starting the clock oscillator. The clock starts and regulates the ring counter through its S-A-B-C-D-E progression at 40 msec intervals. When the first stage (S) of the ring counter is switched, it supplies the second input to each of the AND gates, A, B, C, and D. The gates that have both inputs energized will conduct and set their respective memory flip-flops. This procedure prevents changing the memory storage during ring counter progression.

Outputs of the memory flip-flops supply one input to the 2-input inspection AND gates. The other input from the gates is supplied by the ring counter as shown. The outputs of these inspection gates are amplified and operate a relay. The relay in turn connects a voltage source to the transmission line. Thus, as the ring counter progresses, stage "S" switches on the transmitting relay for 40 msec (since all commands must have a start pulse).

Stages A, B, C, and D also switch command power as the ring counter progresses if their inspection gates are satisfied. Stage E in the ring counter provides for 40 msec dead time between commands and supplies the reset pulse to the memory flip-flops and the clock-enabling flip-flop to turn the ring counter "off." Transmitter end of the transmission line is normally shorted out through the contacts of the de-energized transmitting relay so that after every 40 msec transmission, the line is shorted. This is done to prevent the line from charging up during transmission and to create pulses with trailing edge decay times equal to the rise times of their leading edges.

The approximate volumes of the 16-command encoder and decoder are 25 cu. in. and 50 cu. in. respectively. These volumes are based on a 4-command breadboard model of this system that has been built. The size of a spinning reel-type wire dispenser containing 10 miles of No. 26 AWG copper weld wire with a 4-mil Teflon insulation would be about 9.5 in. long and 15.5 in. in diameter.

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AF HITCH-HIKER SATELLITE TO STUDY ATOMIC RADIATION

A 176-lb. hitchhiker satellite, designed to measure angular distributions and energies of charged particles in the earth's magnetic field and upper ionosphere, is now in orbit. It was ejected from another satellite launched by the Air Force from Vandenberg AFB, Calif.

The satellite is part of an Air Force program to gain more data on the rate of decay of radiation caused by recent U. S. and Soviet high-altitude nuclear blasts.

The experimental satellite, which carries six types of instruments, was made by Lockheed Aircraft Corp. Mass. Inst. of Technology and American Science & Engineering, Inc., Cambridge, Mass., built the instrumentation.

Instruments include a proton detector, plasma probe, electron detector, electrostatic analyzers, geiger counter and magnetometers. It also carries a command receiver, tape recorder and telemetry equipment. Power for the equipment will be supplied by solar cells.

The satellite is expected to have a six-month life. Barring damage to the electronic equipment by high-energy bombardment, it could last years.

ASA MEMBERS UNITS URGE GLOBAL VACUUM STANDARDS

The Electronic Industries Association and 5 other member groups of the American Standards Association are urging adoption of global vacuum technology standards.

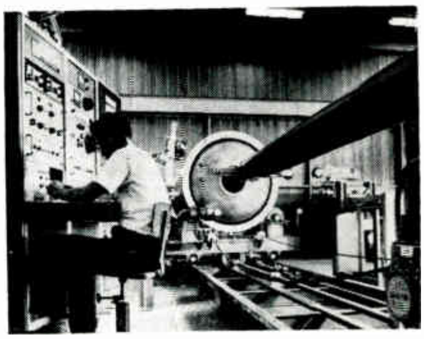
The 6 organizations have backed a British-sponsored move for a study of the problem by the 50-nation International Organization for Standardization. Their action came at a recent ASA general conference in New York.

ASA said the ISO study appears certain, since approval by only 3 other nations will make it official.

The American Vacuum Society was named to organize the U. S. advisory group for the study. Also participating at the New York meeting were the American Petroleum Institute, Manufacturing Chemists Association, National Bureau of Standards, and the Telephone Group of ASA.

Six standards nearing completion by the AVS, along with 2 British standards, may be submitted to the ISO committee for study. One of the AVS standards is a glossary for vacuum technology.

POLARIS A-3 TEST CYCLE



Engineer begins the test cycle of new CEBM (corona, eddy current, beta ray, microwave) Polaris A-3 motor chamber test system. The unit, built by Magnaflux, will test complex glass-epoxy structures. Microwave, beta and corona testing equipment is on end of boom. Eddy current is tested with hand-held probe.

LARGE CENTRAL DPS TO SPEED DOD DATA FLOW

A central computer that allows immediate access to 500 million alphanumeric characters on drums has been selected for the Defense Documentation Center for Scientific and Technical Information.

The contract calls for a Univac 1107 thin-film memory computer and peripheral equipment for the DDC, which in 3 years has outgrown 2 computers.

The storage will contain the information needed to identify and retrieve documents in the Center's master file. More than a million requests are received each year for this data from the Army, Navy, Air Force, other DOD agencies and contractors.

Included in the storage will be identification, security status and release limitations for each document, plus complete information on the amount of service authorized for the more than 4,000 organizations DDC currently serves.

The third-generation 1107 has a 128-word, 330 nano-sec. memory with 32,758 words of core storage. The new DPS will be in operation by early 1964. DDC now is using 2 solid-state Univac 90's.

TAPE RECORDER OPERATES UNDER 100 G ACCELERATION

Magnetic tape recorder that operates successfully under sustained acceleration of 100 g has been developed by Borg-Warner Controls, Santa Ana, Calif.

Designed to obtain accurate data during severe re-entry, launch and other difficult conditions, the new tape recorder, Model R-304, has operated with low wow and flutter under the high-g pull.

Both actual size

PROFESSIONAL GUIDELINES

Reporting late developments affecting the employment picture in the Electronic Industries

Design Engineers
Development Engineers
Administrative Engineers
Engineering Writers
Physicists
Mathematicians
Electronic Instructors
Field Engineers
Production Engineers

HOME-STUDY HELPS COMPANIES TRAIN EDP PROGRAMMERS

Before employers venture to compete for the scarce supply of computer operators and programmers, they should consider training their own personnel, advises John C. Villaume, president of International Correspondence Schools.

ICS currently provides job-related instruction to 100,000 workers and has some 7,000 training agreements with firms, unions and government agencies.

ICS School of Business has expanded its curriculum to include "Programming the IBM 1401 Computer." Comprised of 18 instruction units dealing with economics, accounting, and report writing in addition to programming, the average student can complete it in about 240 hours, or six months of home-study at the normal pace.

The cost to the company sponsoring the training should be under $150 for each worker, says Villaume.

There are nearly 50,000 full-time computer operators in the U. S. today, but the growing use of computers indicates that 200,000 qualified programmers will be needed by 1970.

ENGINEERING SOCIETY URGES AID TO TECHNICAL EDUCATION

The 60,000-member National Society of Professional Engineers is urging Congress to accept the Administration's proposals for expanding and setting up college-level technical institutes.

A spokesman for the Society has pointed out to a Senate education subcommittee that nearly every recent survey on engineering and scientific manpower has confirmed the need for maintaining a ratio of two to five technicians for each graduate engineer. Yet the U. S. is now producing only half as many technicians as engineers.

Paul H. Robbins, executive director of the Society, said that Congress should "adopt a specific, meaningful program to increase the number of college-level engineering and scientific technicians."

He recommended amendments to the Administration's National Defense Education Act proposals which would make students in technical institutes eligible for loans, and which would extend grants to technical institutes for construction from three to five years.

His six-point program recommends:

1. Legislation and action to improve the ability of all educational institutions to attract and hold superior faculty members.

2. Legislation to help stimulate high school students to continue their education beyond high school.

3. Legislation and action to stimulate expansion of technical institute education programs at post high school level.

4. Federal assistance to engineering and science students of proven ability to pursue graduate work.

5. Financial assistance to help qualified students pursue undergraduate engineering education, with selection of students and study program controlled locally.

6. Financial assistance for the study of engineering which insure the full utilization and participation of all engineering schools having ECPD accredited curricula.

PLANNING TUBE PLANT EXPANSION

RCA executives review $11.6 million expansion of Lancaster, Pa., plant to provide 200,000 square feet for making color TV, industrial, military tubes. From left: D. Y. Smith, Electronic Components & Devices; J. B. Farese, Picture Tube Division; C. E. Burnett, Industrial and Semiconductor Division.

ELECTRONIC CAREERS WILL BE OUTLINED TO STUDENTS

Two undergraduates have been assigned to produce Yale University News' annual career supplement, which this year will be devoted to the electronics industry and its career opportunities for college graduates.

"The Electric Future" will include articles by leaders in the industry as well as advertising. The supplement will appear early in October and distribution will cover more than 60 colleges and universities across the nation. At least 100,000 graduates and undergraduates in these institutions will receive the publication free of charge.

Contents will cover vocational opportunities in the manufacture of electronic components, calculators, computers and processing systems.

FOR MORE INFORMATION . . . on opportunities described in this section fill out the convenient resume form, page 178.

ELECTRONIC INDUSTRIES Professional Profile

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 39, Pa.
This resume is confidential. A copy will be sent only to those Companies whose number you circle below.

800 801 802 803 804 805 806 807 808 809 810

DECIDING ABOUT PROGRAMMED INSTRUCTION

An adequate knowledge of programmed instruction is a must for the modern training director. Here are the pertinent facts he must know to make an intelligent programming decision.

TECHNOLOGY'S RAPID GROWTH has spurred a need for efficient in-plant training, and programmed instruction has become more important. Many polemic and prophetic articles have touched on it, without covering the necessary facts.

This article doesn't try to summarize all pertinent facts, but it does provide a good structure for guiding further investigation.

* * *

A program is a training aid, yet it transcends training aids and affects the entire philosophy of training. A program is controlled by an end objective; it is never complete until the student masters this objective. It treats each training task as a specific problem with a specific solution and solves it. Thus, it is similar to mathematics.

The Frame

Heart of the program is the frame. It looks like a short, simple test item, except that it has feedback. The frame presents a problem (stimulus), the student replies (response), and feedback occurs. Some feedback (reinforcement) tells the student if he was right or wrong, and he adapts his behavior. Some feedback goes to the program, sequencing and selecting the stimuli that should next be given to the student. Some feedback goes to the programmer, who revises the text and program logic until it is nearly autonomous—hence, auto instruction. When the program is developed enough to teach by itself, the program is born.

Through use of programmed instruction, the new worker in the remote branch office can become just as efficient as her counterpart in the home office.

By JAMES L. BECKER

Coordinator of Programmed Instruction,
RCA Service Co., Building 204-2
Cherry Hill, Delaware Township
Camden 8, N.J.

The great extent to which it uses feedback establishes programming as an adaptive, thought-provoking process. However, the technology of writing programs can be transferred from one person to another.

Text vs Machine

Programs can be presented in a textbook format or through a teaching machine. The text is generally favored for savings in time and cost, although both methods seem to do an equally good job of teaching. But in certain instances, the machine has a decided advantage.

Teaching machines are either paper-moving, microfilm, or logical. The paper-moving machine is practical when less than 50 copies of a program are needed and these will be used over again many times. When a program needs frequent revision, paper-movers are ideal since only a few copies need be modified and accurate records of the changes can be kept.

(Continued on following page)

PROGRAMMED INSTRUCTION (Continued)

Microfilm machines contain most paper-moving machine advantages plus all storage and postal advantages of microfilm. An 8,000-frame linear program is likely to use more than a ream of paper. The same size intrinsic program will use 16 reams. Hence, microfilming can save money when programs are long.

Some machines use logical circuits to evaluate and utilize feedback. Such equipment may someday be the standard medium for programs, but programming methods cannot now use this refined hardware well enough to justify its expense.

When buying costly hardware, be certain that the features cannot be duplicated satisfactorily on cheaper machines or in programmed texts. Most users of auto-instructional programs prefer the text format. But format is not nearly as important as quality.

Program Limitation

There are limitations; good programs take a long time to prepare, and are apt to lag behind technological advances. Normally, 2 to 6 months should be allowed from the beginning of programming to implementation of the first units. An ambitious project may take years to complete the program.

Although programs as training aids are cheaper than motion picture films, they are still costly. About 2,000 men would have to be trained to justify programming through anticipated reductions in training costs. If they are trained in a 5-year period, will the subject matter still be current? Programs can be updated easier than films, but not without some added costs.

Although teaching can be automated, learning cannot. Mere possession of a good program does not guarantee its use. Programs are best used as tools in the hands of skilled instructors. Thus, the argument that programs will save money on the training payroll is not valid.

Advantages of Programmed Instruction

Still, programmed instruction has many virtues. The first is standardization. Through programming, instruction can be standardized without regard for geographic dispersion and differences among instructors. The new clerk becomes just as efficient in Winabago as her counterpart in the New York home office. Technicians will meet identical, reliable work standards all over the globe. This is especially important where the trainer regards his duty as collateral. Hit-and-miss training practices often inflict tangible harm on a growing industry.

The second basic advantage is reduction in training time. Several experiments have suggested that people generally learn faster and better with programs than under normal instruction, although it's tricky to define "normal." Your learning time may or may not be reduced, but faster ambient training time is common. Programming can be scheduled individually, so that executives need not drop their jobs for long. Matter that used to consume hours of classroom time can often be relegated to homework or self-study. The ease in distributing programs could save the time and cost of travel to and from a training site. This in itself can amortize program cost, even if it takes twice as long as normal training.

Seldom explored but perhaps its most significant attribute, is programmed instruction's ease in hurdling the abilities barrier. Correlations between intelligence and acquirement in classrooms have generally clustered around +0.45, and many think it would be much higher with valid test instruments. But correlations among students using programs have repeatedly approached 0.00. The possibilities in retraining are tremendous.

Programming also offers management a tool to retrain and upgrade the worker, regardless of his limiting endowment.

Sources of Programs

A training director has three sources of programs. He may purchase ready-made stock programs, have consultants write them for him, or try to do them with his own staff. Stock programs come with the lowest price tag. They are generally bought by the copy, but in some cases the purchaser pays a fixed fee for his unlimited use and reproduction. Stock programs can be just as good as customized ones, if the intended audience and teaching objectives are well-matched to the situation. Mere similarity of topic or title won't do; out of 4 or 5 programs on transistors, only one (maybe none) will serve your needs. Computer technicians want the emphasis on switching parameters. A different course is needed for men who repair radios.

There is no standard method, but every program should describe its intended audience and end objectives. Some include formal objectives, or a criterion test, or a diagrammed behavioral matrix. Others merely use a summary paragraph or a table of contents.

Prices for customized consultants' programs run from $4 to $30 per frame. But that doesn't give the purchaser a clear idea of what he gets for his money. The buyer must weigh the program cost against the objectives. If you're thinking mainly of cutting training time, bear in mind that a typical student can work 120 linear frames/hr. Also, many users suggest that not more than four hrs./day be devoted to working programs.

The contract is your best assurance of customized program quality. Make sure it spells out the exact end behavior that you want. Reserve the right to edit the program data, but don't expect to dictate its order of presentation. Require the program to be tested on a sample of the audience on which it will be used. Establish beforehand the standard for acceptance. All this may raise the program cost, but the increased value is generally worth it.

Programmers

The other way to get programs is "do-it-yourself." Any company that wants to use it in much of its curriculum should consider this. In the long run it is the cheapest, yet it takes much time and effort. Programmers must be selected, trained, and given a good working environment.

Prospective programmers must know the subject area. Other desirable traits include success at normal teaching, a high IQ and a flair for written communication. The candidate should enjoy teaching.

Proper training for programmers is not easy to get, although a variety of seminars are scheduled every year. Some are designed for users, others for makers of teaching machines. A few of them deal mainly with program writing. The one, two, or three weeks that they last are not enough to make good programmers out of your candidates, but they are the best start. Attendance at more than one of them may be advisable. Many colleges offer courses, but before enrolling, check to see they are in your area of interest.

Occasionally a firm will retain a consulting company or a psychologist to train candidates. Success depends on who does the job. He must be experienced in writing programs and in training others. But reserve some of your training money to train supervisors. Many pilot projects have been unsuccessful simply because management didn't understand the problems confronting its programmers.

The frames that a programmer writes in one day are best tested that same day, so the programmer shouldn't be too far from his audience. The most frequent mistake is not having test students around to evaluate the work. Another error is expecting too much progress. It takes even a competent programmer 4 or 5 weeks to prepare one hour of instruction. The part-time programmer's efforts are doomed to futility. That shouldn't prevent a person who teaches normal classes during the winter from programming in the summer. Just let him do one thing at a time.

SUCCESSFUL TRANSMISSION

Inspecting 800-line resolution TV picture successfully transmitted by new Lenkurt Electric 76TV microwave eqpt. (in BG) at San Carlos, Calif., facilities are (l to r) M. H. Kebby, Project Mgr.; W. H. Jorgenson, Project Engr., and L. Menta, Tech. Supt. The system will transmit color and B&W. Except for the klystron, it is solid-state.

"PEDIGREED" TRANSFORMER FAILURES 50 TIMES FEWER

Two Sperry Rand Corp. units have devised a "pedigree" system which has bettered reliability of Minuteman missile tranformers by over 50 times.

Wheeler Electronic Corp., Waterbury, Conn., and its subcontractor, Sperry Electro Devices Laboratory, Long Island, devised the program for Autonetics Div., North American Aviation.

The program so far has a laboratory failure rate of .019% per 1,000 hours operation. Normal rate is .1%. A .001% failure rate is the goal.

Complete "pedigree" on every unit enables company to pinpoint each tool, machine and operator and the lot number of material used.

Units are made of carefully selected materials with proven methods in new, air conditioned, dust-free manufacturing space. Workers are pre-screened and specially indoctrinated. (It is found that new people perform better than veterans with set habits.)

Transformers are subject to intensive testing, including vibration, mechanical shock, heat shock, humidity, and high voltage. Failures are analyzed by engineers, physicists and chemists, who then suggest improved specs., controls.

Field results are not yet available, but the failure rate should continue to decline since the same "pedigree concept is being used on equipment coming back from the field.

PHOTO RESIST PROCESS AIDS MICRO-MINIATURE WORK

A "positive working" photo resist process promises to greatly aid micro-miniature work in printed circuits, transistors and precision chemical milling. It was developed by Shipley Co., Inc., Wellesley, Mass.

The new AZ-15 and AZ-17 Photo Resists used can reproduce images smaller than a micron. Line definition is said to be so sharp that lines appear straight even when magnified 250 times.

In this photomechanical process, the unexposed areas remain as the photo resist image for selective etching and electroplating. Thus, multiple-depth etched plates can be made without having to apply a second photo resist coat.

Likewise, etched copper circuits with "plated fingers" can be made from one photo resist coating only. Through-hole plated circuits can be produced with or without dissimilar metal electroplates.

The photo resist films have excellent resistance to most commonly used etching solutions and electroplating baths. The films are very sensitive to ultra-violet light, yet can be exposed to yellow light for days without harm. Conventional photoengraving equipment is used.

FIBER OPTICS CONTROLS HEAT IN HIGH-POWER TUBES

Fiber optics can be used to control the heat in high-power vacuum tubes, according to a patent issued to David M. Goodman, Senior Research Scientist at NYU's Engineering Research Div.

The patent shows a thin glass light pipe placed within the tube to pick up visible radiation from the cathode. Guided by internal reflections in the pipe, the cathode's radiation is transmitted through the tube housing to an electro-optical servo system. The servo automatically controls power supplied to the heater windings. Cathode temp. can be controlled to ±25°C.

ENCAPSULANTS STANDARDIZED

Norms for encapsulants and materials for electronic modules will be developed by the American Society for Testing & Materials. An ASTM task group is writing specifications and nomenclature for this field. Persons wanting to participate should write: Wayne Martin, Industrial Components Div., Raytheon Co., 465 Centre St., Quincy, Mass.

FIRST TYPHON INSTALLATION

Three cranes load the prototype of Typhon Weapons Control System aboard test ship USS Norton Sound. Cloth-covered equipment, built at Westinghouse Baltimore Defense Ctr., is one of largest single pieces of electronic gear ever put on a Navy ship. The system will control anti-air missiles.

ARF CHANGES NAME

The name of the Armour Research Foundation, Chicago, Ill., has been changed to IIT Research Institute. It is located at the Illinois Institute of Technology, thus the new name.

EIA PUBLISHES 5 ENGINEERING STANDARDS

The Electronic Industries Association's Engineering Dept. has published 5 new standards. They are: High Voltage Ceramic Capacitors, Class 2; Signaling Speeds for Data Transmission; Acceptance Testing of Radio Receiver Speakers; EIA Standard for Designation System for Metal Electron Tube Shells; and Mounting Dimensions for Loudspeakers.

The new standards are available from the EIA Engineering Dept., Room 2260, 11 W. 42nd St., New York 36, N. Y. The second and fifth are 50 cents, the others, 25 cents each. Minimum order is $1.

BECKMAN INSTRUMENTS BEGINS DIRECT MARKETING

Scientific and Process Instruments Div., Beckman Instruments, Inc., has begun marketing laboratory instruments through a direct sales and service organization in the U. S. and Canada.

The division, which makes instruments for analysis and control, formerly marketed its laboratory products through 28 franchised dealers.

LOW-POWER LASER CAN OPERATE WITH SOLAR POWER

A 15-w. cw laser developed for the Air Force by RCA has been pumped continuously by the sun. Such a laser could prove valuable for space use, since it would need no other power.

The system, which can also be pumped by a tungsten bulb, was developed for the Air Force Systems Command by RCA Laboratories, Princeton, N. J.

A dysprosium-doped calcium fluoride crystal was selected from 200 types investigated. RCA generated continuous radiation in a longitudinal mode, pumped by a tungsten bulb. Crystal was about 1/16 in. in dia., 1 in. long. It was operated in liquid neon and liquid atmospheres.

A single cuprous-chloride crystal modulates the output beam that handles the dysprosium spectrum. It is capable of 100% modulation of calcium fluoride crystal emission at 2.36 microns. Since available detectors can respond to this wave length, the system of generator, modulator and detector is complete.

Energy levels within the calcium fluoride crystal have also been modulated, using a very small magnetic field.

SNAP VOLTAGE REGULATOR

F. H. Guterman (l), Pres., ITT Industrial Products, and R. Hansen, project engineer, examine package of radiation-resistant voltage regulator. It is for AEC's SNAP program (Systems for Nuclear Auxiliary Power), which is to develop power systems for satellite and interplanetary craft.

THERMIONIC GENERATOR FEATURES 3 DEVELOPMENTS

A hydrocarbon-fueled thermionic generator featuring three developments has been tested successfully by Thermo Electron Engineering Corp., Waltham, Mass.

This generator uses heat from natural gas, propane or leaded gasoline to drive a thermionic converter that produces electricity directly. Thermo built it under contracts with the American Gas Assoc. and the U. S. Army Electronics R & D Laboratories, Ft. Monmouth, N. J.

In the first development, a prototype converter was operated for more than 2,000 hours in a vacuum to show the device's inherent reliability. A total of 14 kw.-hrs. of power were produced in a test during which the converter went through 85 thermal cycles. At test's end, the tube was still producing power and showed no signs of failure.

A burner fueled with natural gas or leaded gas consistently produced temps. over 1500°C. and heat flux densities over 50 w./cm.^{2}. Continuous operation for 300 hrs. was achieved with natural gas.

The third development is a material that protects the converters from oxidation in high-temp. combustion. High Temperature Materials, Inc., supplied protective enclosures made from pyrolytically deposited silicon carbide.

The best sample held vacuum at combustion-produced temps. of 1300° to 1400°C. for almost 900 hrs. Another withstood over 100 thermal cycles from room temp. to 1300°C., and accumulated nearly 525 operation hrs.

ELECTRONIC INDUSTRIES Advertisers—September 1963

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Circle 107 on Inquiry Card

NEW DATA SYSTEM INSTALLED

J. O. Sherrard, General Business Systems Mgr., N. J. Bell Telephone Co., and J. H. Young, GBS Supt., examine first RCA 601 EDPS installed anywhere. Computer processes 35,000 bills/day, correlating such factors as length, time and type of call vs. rate. The 601 and 4 301's process 14 million calls made through 120 exchanges per month.

EIA MANUAL DESCRIBES VALUE ENGINEERING COURSES

The "Value Engineering Education Training Manual," recently published by the EIA, outlines short management training programs on value engineering. It also describes seminars for personnel at all operating levels of industry and the military.

The manual is available from the EIA Engineering Dept., 11 W. 42nd St., New York 36, N. Y., at $2.50

Circle 124 on Inquiry Card

The WELDED MODULE

Shown in the photograph on page 37 was supplied to "Electronic Industries" by ELECTRONIC PRODUCTS CORP., Baltimore, Md.

4 NAVY CONTRACTS TOTAL $7 MILLION

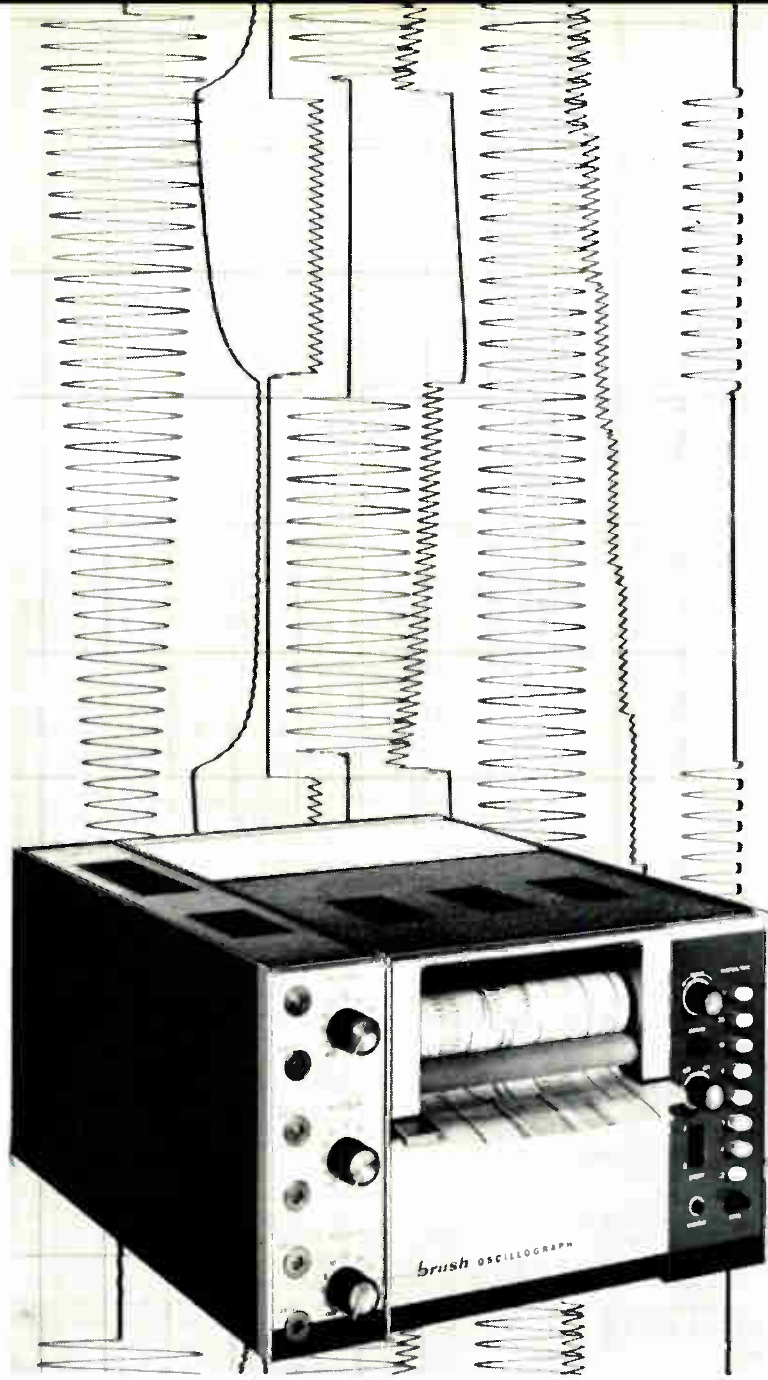
The Navy is awarding four contracts totaling $7,099,942. The Bureau of Ships is awarding two of them. The first is a $1,239,863 fixed-price contract to Sangamo Electric Co., Springfield, Ill., for 15 surface ship sonar transducers and spare parts. The second is a $1,335,079 cost plus contract to Sperry Gyroscope Co., Great Neck, N. Y., for 47 Polaris submarine gyros.

The Bureau of Naval Weapons is issuing two supplements to an existing contract with United Aircraft's Pratt & Whitney Div., E. Hartford, Conn. The first, for $1,725,000, is for continued general development testing of the YTF-30-P-1 aircraft engines. The second, for $2,800,000, is for producing these engines. Previous obligations under this fixed-price contract are $39,417,950.

UMA SPONSORS CONTEST

The Ultrasonic Manufacturers Association is sponsoring a contest for articles dealing with that field. Cash prizes are offered. For more information, write: Ultrasonic Manufacturers Association, Inc., 271 North Ave., New Rochelle, N. Y.

Brush lightbeam recorder eliminates RFI with silent light!



The unique incandescent optical system of this new direct-print oscillograph completely eliminates confused data caused by generation of RF interference into associated equipment. It is the only lightbeam recorder that meets RFI specs . . . MIL-I-26600 and MIL-I-6181D. Whether your application is industrial or aero-space, check out these important facts.

Start and Re-start Recording time . . . 50 milliseconds
Writing Speed . . . Greater than 30,000 in./sec.
Companion Amplifiers . . . Especially Designed
Complete Line of Accessories
8 Pushbutton Record Speeds
Internal Chart Take-up
High Contrast Traces
16 Channels

Now you can record over the whole range of most-used frequencies with Brush systems incorporating all the known refinements in oscillography. Write for full details.

brush INSTRUMENTS

DIVISION OF CLEVITE 37TH AND PERKINS, CLEVELAND 14, OHIO

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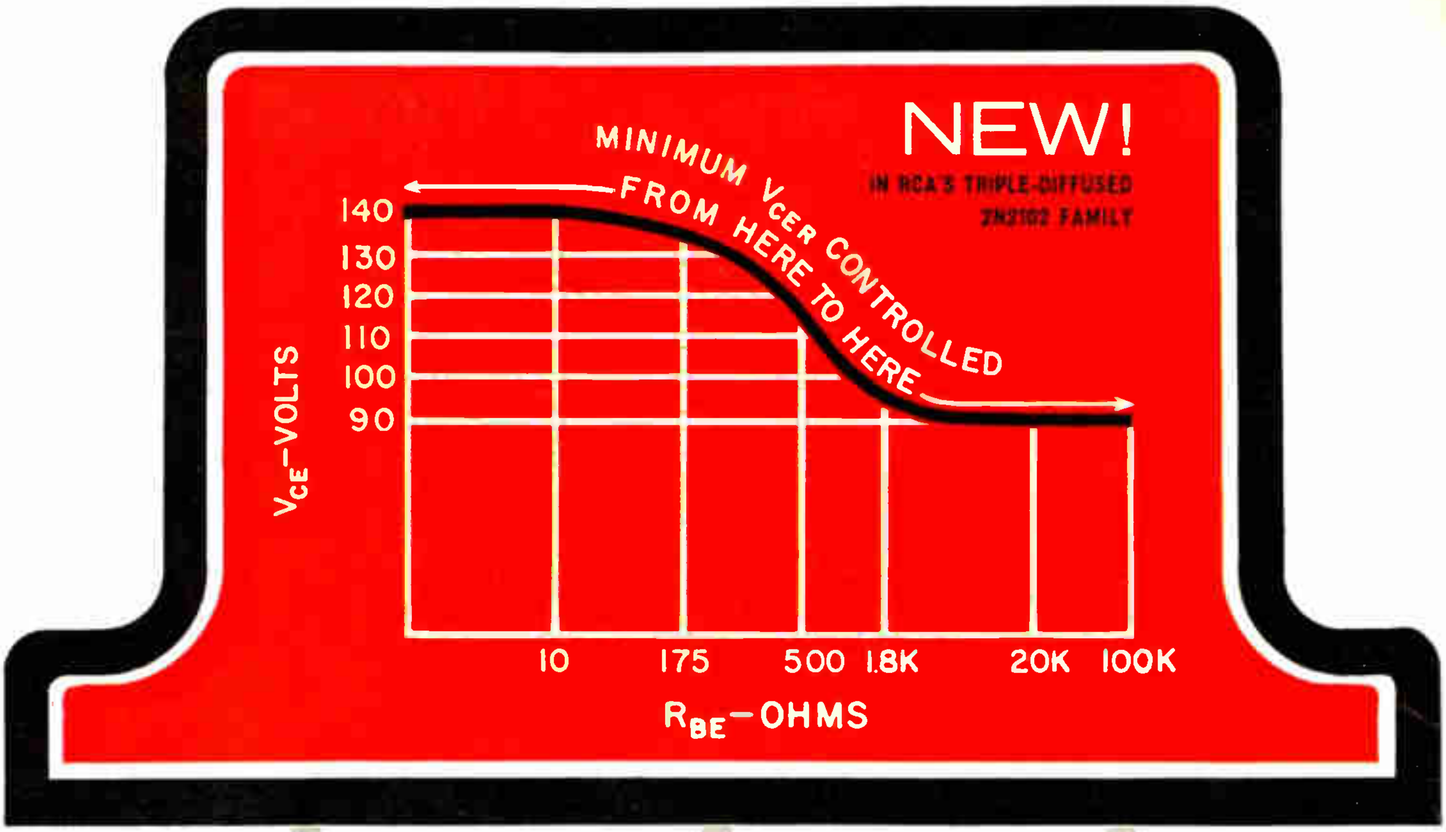
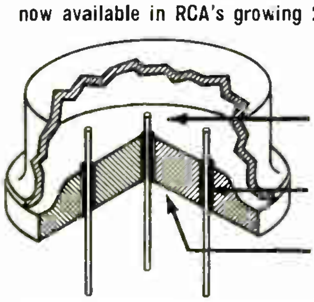


RCA 2N2405 OFFERS 0.5 VOLT MAX. $V_{CE(sat)}$ @150 Ma 90-VOLT MIN. $V_{CEO(SUS)}$; 120 Mc f_T

RCA SOLID-BLOCK METAL HEADER
now available in RCA's growing 2N2102 family



Out of RCA's revolutionary 2N2102, triple-diffused silicon transistor, comes the new high-voltage 2N2405. Using the same technique of multi-point control that defines the 2N2102 at six current levels—RCA CONTROLS MINIMUM V_{CER} OF THE NEW 2N2405 ALONG THE FULL LENGTH OF THE CURVE FROM ZERO OHMS TO 100 KILOHMS.

Through the use of triple-diffused construction—precision manufacturing controls—and RCA solid-block metal header—RCA 2N2405 offers: Min. V_{CEO} (sus) of 90 Volts • Max. V_{CE} (sat) of 0.5V @ $I_C = 150$ ma • f_T of 120 Mc • low leakage, I_{CBO} (max) = 10 nanoamp @ $V_{CB} = 90$V • 5 watts max. dissipation • exceptional mechanical stability.

Check RCA 2N2405 today for your applications where supply-voltage transients are a problem—in video drivers, RF and AF power amplifiers, and high-voltage linear and switching amplifier applications. Ask your RCA Representative about the broad RCA 2N2405—2N2102 family and related types RCA 2N1893, 2N718A, 2N720A. Or write Commercial Engineering, Dept. IJ-8, RCA Electronic Components and Devices, Harrison, N. J.

	TO-5	TO-18	TO-46
HIGH-VOLTAGE TYPES (min. V_{CEO}(sus) = 90 volts)	RCA 2N2405	2N2896	2N2899
UNIVERSAL TYPES (Beta controlled over full current range)	RCA 2N2102	2N2895	2N2898
ECONOMY VERSIONS of RCA 2N2102	RCA 2N2270	2N2897	2N2900

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