ELECTRONIC DESIGN

ALSO IN THIS ISSUE:

COVER: A series of end-fire, dielectric-optical rod antennas has been made possible by combining exotic materials, tight machining, and in-line coaxial feed. Results: reduction in cross section and weight, increase in temperature. In the cover design the artist has broken down the old horn antenna to show replacement by the di-optic antenna. At the same time it shows the size difference between old and new. For the story, see p 76.

Selected Topics In This Issue

Sidelights of the Issue

Technology and Politics

Readers accustomed to circuit drawings and photos of components in our News Department may be a little startled at p 4 of this issue, where the familiar faces of Vice President Nixon and Senator Kennedy are shown.

It is, of course, extremely seldom that *ELECTRONIC DESIGN* finds itself delving into political realms, but in this election year, we felt the role of science and technology to be so important that the candidates' views in this field should be given the widest possible circulation.

Accordingly, Managing Editor James A. Lippke sent telegrams to both men, inviting their answers to several questions which we believed to be highly significant.

Not all the questions were answered directly in the statements supplied to *ED* by the candidates' spokesmen, but both men made their views clear and we feel they are interesting, provocative, and informative.

Report on Maintainability

When ELECTRONIC DESIGN was soliciting information from hundreds of manufacturers for its Staff Reports, "Designing for Maintainability," an all too common reply was, "Of course, our product is maintainable. You never have to repair it."

Our report stems from the realization that nothing lasts forever.

As basic reliability goes up, requirements for maintainability drop, and this report seeks to evaluate and explain just what maintainability is, where it came from, where it is going, and how to design with the concept in mind.

One *ED* editor, incidentally, reported his own experience with maintainability during World War II. In a line shack on a Marine Corps airstrip, he was trying to adjust a radio transmitter with kicks and four-letter words. Suddenly, with the enlisted man's sixth sense of the presence of an officer, he turned around to find a major general glowering at him. The general stared for a minute, then said, "Always like to see young men take an interest in their work. Carry on, son."

Our Staff Report doesn't discuss how to maintain with uninhibited language, but it goes into almost everything else. It starts on p 30.

CIRCLE 2 ON READER-SERVICE CARD ➤

CONTENTS FOR OCTOBER 26, 1960 VOL. 8 NUMBER 22

Coming Next Issue

Like many other aspects of the technology, microminiature electronics was foaled out of Necessity by Economy. With the immense cost of orbiting payloads in space, smaller systems to perform better jobs were required. On the ground, as the jobs that computers were expected to do got bigger, so did the computers. In every field, microminiaturization seemed to be the answer.

But there were many problems, and many of them still remain. In the Nov. 9 issue, *ELECTRONIC DESIGN* will publish a Staff Report delineating the problem areas, the advantages, and the approaches to microminiature design.

ELECTRONIC DESIGN Hayden Publishing Co., Inc., 830 Third Avenue, New York 22, N. Y.

ELECTRONIC DESIGN is published bi-weekly by Hayden Publishing Company, Inc., 830 Third Avenue, New York 22, N. Y., T. ... ord Gascoigne, Chairman of the Board; James S. Mulholland, Jr., President; Robert E. Ahrensdorf, Publisher. Printed at ... reth Press, Bristol, Conn. Accepted as controlled circulation at Bristol, Conn. Additional entry, New York, N. Y.

Candidates' Views on Science and Technology

Nixon Asks Government-Aided Establishment of Basic-Research Centers; Kennedy Calls for a 'National Peace Agency' to Coordinate Efforts

IN THE YEARS since World War II, the U.S. researcher has been thrown into the political arena by the force of great events. But if civilization is to survive and if science and technology is to benefit mankind, he must take an even more active role than he has to date.

These are the general views of both Vice President Richard M. Nixon and Sen. John F. Kennedy as expressed in statements supplied to ELECTRONIC DESIGN by the two candidates' spokesmen.

Mr. Nixon called it "essential that we recognize science as a many-purpose tool, fully as necessary to human progress as it is to the security of free men."

He added that "our nation demands a strong science and a vigorous technology to defend itself, to advance personal liberty, and to raise standards of living."

Mr. Kennedy said: "Today, while automation is displacing human labor, science and technology is lengthening life, curbing disease, ending famine, and producing the luxuries of life in ever-increasing quantity.

"But these technological blessings are creating economic problems which call for political solutions. Today there is no longer any question but that the world of science and that of politics have a strong interaction."

The remarks of the two candidates came as the result of a telegram sent to each by James A. Lippke, Managing Editor of ELECTRONIC DESIGN. In it, he asked the views of both men "concerning the role science and technology should play in the future of the nation." He stated that at the present time "more than 40 independent agencies and administrative departments are engaged in scientific activity, ranging from agronomical research to nuclear detection to Project Mercury." Each candidate was asked if he felt that more centralized responsibility and coordination were necessary, such as the creation of a Cabinet-level Department of Science.

Kennedy Calls For 'Planning'

In response to a question on attacking the problem of disarmament, Senator Kennedy said the immediate necessity was a "national peace agency" for disarmament planning and research to muster the scientific ingenuity, coordination, continuity, and seriousness of purpose which are now lacking in our arms-control effort."

This agency, the Democratic platform plank quoted by the candidate said, "would develop the technical and scientific data necessary for serious disarmament negotiations, would conduct research in cooperation with the Defense Department and Atomic Energy Commission on methods of inspecting and monitoring arms-control agreements, particularly agreements to control nuclear testing, and would provide continuous technical advice to our disarmament negotiators [See "Design for Peace," *ED*, July 20, p 38]."

The Democratic candidate went on to say that "when the hoped-for goal of disarmament is achieved, vast resources will be freed for peaceful use and, through proper planning, these resources will be applied to wipe out our backlog of public needs and provide this nation and other nations with the means for a new international attack on the problem of world poverty."

Nixon Stresses Decentralization In Basic-Research Program

The Vice President called for new aid for research with a decentralized system. "I believe

Vice President Richard M. Nixon

Sen. John F. Kennedy

his statement said, "the next Congress should adopt legislation authorizing the National Science Foundation to take the leadership in sponsoring a major new program for basic research.

"By sponsor, I do not mean control, finance, and operate. The program should be conducted through a number of basic-research institutes located in the principal geographic areas of the country. Financial support of these institutes should be as much as possible on joint public and private enterprise with both federal and state governments participating on one hand, and universities, private industry, and foundations on the other. The federal funds should be made available on a matching basis with the state and private contributions.

"The research institutes should be established cooperatively by our universities which engage in graduate research programs. They should be governed by these universities. A liaison with the National Science Foundation would be desirable but essentially the system of administration would be comparable to that of the Brookhaven National Laboratory on Long Island, an inter-disciplinary facility established to explore the peaceful uses of nuclear energy."

The GOP standard-bearer added that the new institutes would complement in an important way the work of existing government-supported research. He also said the institutes should be small rather than large, since "bigness results in departmentalization and compartmentalization" and tends to preclude cross-fertilization of ideas among investigators.

Candidates Stress Information Exchange

Concerning dissemination of scientific information, which the telegram asked about, Mr. Nixon said this would come under the aegis of the proposed new research centers. "A logical extension of the nascent merging of different sciences in a common cause," he said, "is the mutual use of theory, techniques, and instrumentation which once were the province of a single science. This fusion has created a new dimension in science. Its fulfillment is usually beyond the ability of our conventional research structure."

Answering a question on weather-control, the Vice President said: "In 1958, the U.S. produced only 14 Ph. D.'s in meteorology. The meteorology departments of universities cannot hope to provide essential tools for modern research in weather. These include high-altitude airplanes, upper-atmosphere rockets and the means to launch them, giant wind tunnels, and the like. The most logical facility for the job would be a national meteorological institute. Already such an institute has specifically been recom-

NEWS

mended by representatives of 14 universities who considered the problem, at government request, for many months."

Mr. Kennedy, tracing the history of the Democratic Party's Advisory Committee on Science and Technology, said the committee, if he were elected President, would pursue a program of information dissemination on a national level.

"After the war," Mr. Kennedy's statement said, "scientists entered politics to advocate a civilian agency for the development of atomic energy. In recent years, scientists stimulated public and political discussion of the hazards of radioactive fallout.

"The Democratic Party," he went on to say, "recognized that the citizen-scientist wanted to think about the problems of science and society and to see that his ideas had an effect on national policy. Consequently, the Democratic Party formed its Advisory Committee on Science and Technology.

"This committee recommended, and the Democratic Party accepted, the establishment of an independent government agency for dealing with the technical problems of arms control and with the technology of aiding underdeveloped countries in health and welfare."

The Democratic nominee said these recommendations were incorporated into party policy in the platform adopted at the convention in Los Angeles.

"I know," Mr. Kennedy went on to say, "that the Advisory Committee on Science and Technology will continue to formulate realistic plans for coordination of governmental research, for proper dissemination of scientific information, and for handling the problems which it falls to the government to solve."

'Greater Public Respect and Support'—Nixon

Mr. Nixon said the public should have a new awareness of the researcher, and likened Dr. Jonas Salk's discovery of the polio vaccine to "the capping stone on the pinnacle of a pyramid." He said, "the men who built the rest of the pyramid are the unsung men of science who are known only to their colleagues. They deserve far greater respect and support by the people whom they serve than they now receive."

He added that it was true, if paradoxical, that as technology advances, one thing that can be predicted with certainty is that major breakthroughs will produce the unpredictable. But, he added, "Let us be clear that new and unpredictable discoveries should not disconcert us. We must have leadership which is constantly on the alert for them and their implications. For

new knowledge can readily be phased into, modify or even alter former plans. Imaginative leadership must exist not only in the Executive and Legislative branches of government, but in private industry, agriculture, mining, and all parts of the economy."

Mr. Kennedy stressed the military aspect of technological achievement as a pressing problem, and said that "science and technology have brought us to a New Frontier of history."

He said engineers and scientists have "undertaken political action in the past only when conditions forced them to do so," and he cited as an example the development of the atomic bomb, when "a handful of scientists took the initiative." ■■

Electrical 'Memory' Switch Device Stores Multiple-Digit Numbers

An electrical "memory" switch, capable of storing multiple-digit numbers by using principles of the ordinary combination lock, has been developed by P. D. Shannon of the Massachusetts Institute of Technology Instrumentation Laboratory.

So closely does the switch follow combination-lock principles that Mr. Shannon obtained parts for his first prototype by stripping discarded Laboratory locks. In operation the switch is first "cleared" and then digits are set into it by turning the shaft alternately right and left with one less revolution each time, after the fashion of a combination lock.

Mr. Shannon developed the new device, called the "N-Digit Decade Switch," as a possible method of simplifying automatic control of electrical currents used in testing gyroscopes employed in inertial-guidance systems for missiles and space vehicles.

Accuracy Is Our Policy . . .

Several pieces of erroneous information managed to appear in our Product Feature "Ultra-High Regulation Featured in All-Transistor Supply" (ED, Aug. 3, p 102). The supply manufactured by the Krohn-Hite Corp., Cambridge, Mass., can operate from standard voltage sources of 115 ±10 v and 230 ±20 v. Its temperature coefficient is 0.01 per cent per deg C, or 1 mv (instead of 7 mv) per deg C. The 1-mv change applies up to an output of 10v. Beyond that, the 0.01 per cent applies. Under short circuit or overload conditions, the output current will not exceed the selected limit current by more than 30 per cent, rather than 10 per cent.

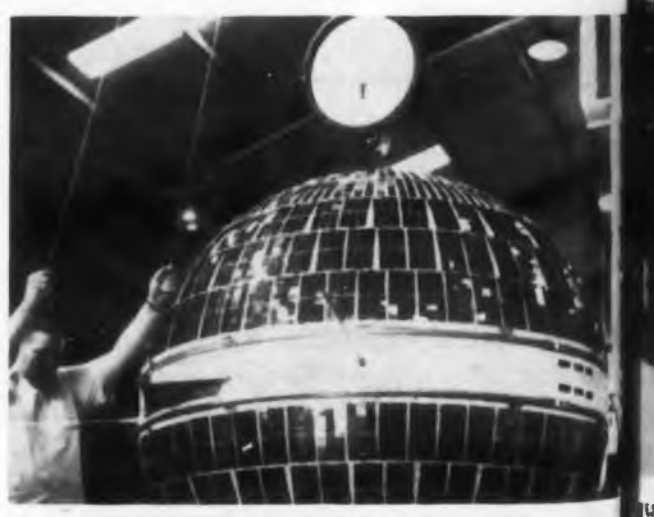
Inside Courier ground station. Operator in foreground controls tracking antenna and operates switching and data-processing equipment as satellite passes overhead. Other equipment includes uhf and vhf transmitters and receivers as well as teletype and recording equipment. Ground-based communications and control equipment was designed by ITT.

Complexity a Feature of Courier Satellite

Tracking antenna for Courier uses unique spinning dielectric lens at focus to provide error signals for automatic tracking. The 28-ft dish simultaneously handles transmission and reception of uhf and vhf signals. Radiation Inc. designed and built the antennas and other tracking equipment at the Ft. Monmouth, N.J. and Ponce, P. R. tracking stations.

WITH the availability of backup vehicles and payloads, Project Courier staged a quick recovery after failure of the initial launch attempt in August. The now successfully orbiting communications satellite marks a new high in complexity of satellite instrumentation.

The more than 300 lb of equipment carried aloft include 38 separate electronic packages. The detailed description of Courier's electronic system presented in the August 31 issue of ELECTRONIC DESIGN is followed here by photographs illustrating design features of the system. ■ ■



Courier weighs in at 500 lb prior to launching. The satellite is almost completely covered by the 19,1[illegible] silicon solar cells needed to power its equipment. Also visible are probe antennas for vhf transmission and one of the notched fin uhf antennas.

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Miniature tape recorder in payload weighs 5 lb and has a capacity of 3 megabits. Five such 30 ips units are included in the payload; four are for digital communications, the fifth records voice and analog signals. Recorders were developed by Datalab Div. of Consolidated Electrodynamics Corp.

UHF telemetry transmitter for Courier handles 30 information channels. The transistorized unit delivers 1.5 w. Philco's Western Development Laboratories is prime contractor for the payload.

Acquisition transmitter is all-transistorized and crystal controlled. Unit consumes 0.25 w for 50 mw power output. Five transmitters are carried aboard courier—another example of reliability through redundancy.

CIRCLE 9 ON READER-SERVICE CARD ➤

NEWS

Balloon-Borne Telescope

56 High-Gain Units Must Be P... In Single Jam-Jar-Sized Cylin...

SUCCESS of recently disclosed plans for a balloon-borne infrared telescope to detect un... announced satellites may well hinge on the abil... ity of Electro Optical Systems, Inc. engineers t... design the ultra-miniature preamplifiers require... in the system. According to Stuart Hauser, proj... ect engineer at the Pasadena, Calif. firm, 56 high... gain units (one for each element in the infrare... detector array) must be packaged in a 3-1/2 in... in diameter cylinder no more than several inche... long.

In order to reduce stray pickup on lead wire... the preamps must be located immediately be... hind the detectors. Since the detectors are them... selves in the optical path of the reflecting-typ... telescope employed in the system, the preamp... are likewise in the path and should be extremel... small so as to minimize light loss.

The following design approaches are current... under study:

- Amplifiers assembled on small, axial... stacked disks, with several stacks arranged... parallel within the cylinder.
- Several amplifiers assembled on full, 3-... in diameter disks again stacked within the cyl... der.
- Thin, tubular amplifiers extending down t... cylinder, with several amplifier bundles stack... in the length of the cylinder.

Molecular-electronic constructions are appa... ently not in the running for this application a... the amplifiers will thus be assembled by hig... density packaging of conventional miniatu... components. Breadboards of each type are be... developed and tested and Electro Optical spok... men appear confident of meeting the Summ...

Miniature infrared detector developed by El... Optical Systems for use in balloon telescope. Unit c... sists of 0.1 mm lead sulfide element behind 2 ... strontium titanite lens.

...eeds Ultramin. Preamps

961 deadline set for testing of the first balloon-borne unit.

The system will include a specially-modified 20-in. focal length Bouwers telescope with optics consisting of a spherical mirror, a concentric corrector plate and an aspheric corrector plate. These elements will be color-corrected for the 0.8- to 2.5-micron spectrum of the detectors. The telescope and electronics package are to be suspended 300 ft beneath the gas bag. In the first unit, no attempt will be made to stabilize the gondola and it has been calculated that natural oscillations of the system may run to 0.5 deg. If it should become necessary, the cab could be stabilized by gas jets or the telescope mounted on a stable platform.

A 0.5-hp electric motor will swing the telescope in azimuth at a rate varying from 0.5 to 2 rotations per second. Initially, the telescope will be aimed about 15 deg above the horizon.

When a satellite is detected, elevation will be increased stepwise after each rotation to a maximum of 75 deg. This will provide a series of intercept signals from which the satellite's orbit can be established.

Each of the 56 detectors consists of a 0.1-mm lead sulfide deposit behind a 2-mm strontium titanite lens. The field of view of each detector is approximately 1 milliradian (mrad) x 50 mrad. However, the detectors are arranged in a linear array giving a 3-deg high vertical field of view. Thus, the satellite image moves along the individual elements of the array at each successive sweep of the telescope.

...mpling Rate of 50,000 Per Sec

The detectors are sampled at a rate of 50,000 per sec by an electronic commutator. In addition, each preamp feeds a discriminator which decides, on the basis of established statistical considerations whether the output is due to noise or due to the infrared energy reflected or generated by the satellite. Signals are then telemetered to a ground station for interpretation and display. Telemetry is to be fm/fm at 10 w.

The telescope will be ground-controlled as to elevation and scan rates. Power supply and winds aloft will permit on-station time of one or two days after which the telescope is returned by parachute. A world-wide surveillance system of this nature would require perhaps 20 telescopes on station at all times. In addition, the infrared detection system could be modified to provide a missile early warning capability, according to Electro Optical Systems scientists. ■ ■

SARUS, Echo Papers Key NEREM Meeting

Navy Will Sponsor Two Classified ASW Sessions; More Than 100 Papers Scheduled for Delivery

THE FIRST technical papers delivered on the SARUS and Echo projects will highlight the 1960 Northeast Electronic and Engineering Meeting. It will be the first time that papers on either project have been delivered.

In addition, the Boston meeting from Nov. 15-17 will feature among its 40 technical sessions two classified sessions on anti-submarine warfare. According to the show's sponsors, this will represent the first time the Navy has sponsored classified sessions as part of a national meeting.

A session on Engineering Manpower Utilization will also be a key feature of the meeting with its discussion of practical ways to eliminate wasteful competitive bidding among military contractors.

SARUS, which stands for Search And Rescue Using Satellites, is a system developed by Space Electronics Corp. It is capable of locating quickly and accurately anything on the earth's surface, using miniature emergency transmitters, artificial earth satellites, and ground interrogation stations. Project Echo involves bouncing signals off satellite balloons. Some of the results of these Echo experiments will be detailed in the paper, which will come from Jet Propulsion Laboratories, the organization responsible for the West Coast transmit-receive station used in Project Echo.

Sub-Detection Methods To Be Discussed

The classified ASW sessions will concern themselves with the various methods which can be employed to detect unfriendly submarines, according to L. Mautner of the Hughes Aircraft Co., who will be chairman of one session.

These methods, he said, will include magnetic anomaly, radar, sonar, and others. In addition, the communications problems connected with carrying efficient airborne searches will come under discussion, he said.

For example, Mr. Mautner said, the Julie airborne detection system will be covered, with communications and data problems between sonobuoys and aircraft and also among the search aircraft themselves presumably coming into the realm of discussion.

Engineering Manpower Loss Is a Matter for Concern

The session on eliminating waste of engineering manpower will concern itself with the money now being spent preparing presentations for bids on specific contracts.

At present, the industry has the spectacle of 10 to 20 large firms each spending as much as $100,000 on proposals during competitions on medium- to large-sized contracts, Mr. Mautner said. Only one of these firms, of course, will be awarded the contract. The waste of engineering talent in the other firms, he said, is a waste of one of this country's most precious resources: engineering manpower.

On an industry-wide basis, the competitive bidding process has made engineers only 50 per cent effective, Mr. Mautner claimed. Two solutions that Mr. Mautner expects will be discussed during the session will be the use of less expensive preliminary competitions and government selection teams. In both

Clearance Needed For ASW Sessions

The two classified sessions on ASW, sponsored by the Navy's Bureau of Weapons, will be open only to those NEREM registrants who have submitted their clearance in advance, certifying their need-to-know. Requests for clearance forms, and non-member requests for these forms, must be on business letterheads and should be addressed to: Mr. Lewis Winner, 152 W. 42nd St., New York 36, N. Y.

ases, the objective will be to narrow the competitions down to a half-dozen firms.

Long-Range Proposals Cited As Partly Responsible

The longer-range, more ambitious proposals that have come about as the result of government plans for space exploration have been partly responsible for the worsening situation on competitive bidding, Mr. Mautner told ELECTRONIC DESIGN.

Problems in command and control systems, raised by the audience, will be discussed by a panel of experts, which will include Maj. Gen. Kenneth P. Bergquist of the Air Research and Development Command and Maj. Gen. Clyde H. Mitchel of the Air Materiel Command.

"And there are many problem areas," said Arthur P. Hill of the Mitre Corp., who will be in the chair for the session. He said a few of them were: standardization, centralization, people vs automatic equipment, and complexity and compatibility of equipment.

U.S., Foreign Experts to Speak At 40 Technical Sessions

The above are only the keynote features of the meeting, whose sponsors claim many firsts. U.S. and foreign experts will deliver more than 100 papers at the 40 technical sessions. "In fact," according to Lewis Winner, one of the NEREM coordinators, "as far as regional IRE meetings go, this one will beat all the others. It will have the largest number of technical papers and exhibits."

Mr. Winner estimated that 95 per cent of the papers have never been given before and that the balance have only been heard by small, select meetings and never gained wide circulation. He added that there would be 350 exhibits.

A relatively new subject, electro-hydraulic and pneumatic controls, will receive considerable attention at the meeting, Mr. Winner said. B. M. Horton of Diamond Ordnance Fuze Laboratories will present a paper of particular interest on the subject—"Amplification by Fluid-Stream Interaction."

All papers delivered at the meeting will be published in the NEREM-60 Record, which will be distributed free to each technical registrant. The NEREM technical registration fee is $2 for IRE members, $4 for non-members. ■ ■

NEWS

Experiments Prove Feasibility Of Ultra-High-Power Microwave Tubes

The new design concepts for ultra-high-power microwave tubes are being developed by General Electric's Power Tube Dept., Schenectady, N. Y., for classified military applications. One of the tubes will be a multiple-beam klystron which is said to employ unique methods for combining a number of beams in one rf structure within a single vacuum chamber. The other tube, to be known as an "Orthotron," is a cross-field, traveling-wave type.

Although actual prototypes of the two tubes have yet to be built, GE spokesmen stated that laboratory experiments have proven the feasibility of the new operating principles. Accordingly, GE has established a Superpower Microwave Tube Laboratory within the Power Tube Dept. to handle advanced development and production design of these tubes. The first production models are not expected to be available until late 1963.

CW and Pulsed Operation Possible

Both tubes will reportedly be capable of CW as well as pulsed operation, in each case at "substantially higher power levels" than conventional units. Size, power, frequency, and other details of the new tubes remain classified. However, the Orthotron's frequency is said to extend into the "micromicrowave" range. Company officials were also vague as to the number beams that could be combined in the multiple-beam klystron. They indicated, however, that more beams could be added to the present design if required. Both tubes can be either air- or liquid-cooled without imposing any design constraints.

Apart from the classified application for which these tubes are earmarked, GE officials also foresaw their eventual use in long-range communications, satellite and space-probe tracking, radar astronomy, and plasma devices (such as sources of high-power, high-frequency magnetic fields for thermonuclear power generators).

The company also hinted at possible uses in wireless, direct-beam power transmission by microwaves, but did not elaborate.

The new superpower laboratory is headed by E. D. McArthur, who developed the planar triode "Lighthouse" radar tube during World War II. Also on the staff is Dr. D. A. Wilbur, a co-developer of the voltage-tunable magnetron principle and an authority on cross-field interactions.

Combat Communications Network Set by AF, Western Union Contract

A contract for the construction and leasing of a high-speed, high-capacity combat logistics communication network has been signed between the Air Force and Western Union. The new system, known as COMLOGNET, will link more than 450 bases, depots, and civilian suppliers in the continental U.S. and will include entry points for overseas communications.

Initial capacity of the system, to be activated early in 1962 will be 7 million punched cards or an equivalent 100 million words daily. The yearly rental for COMLOGNET will be $22 million. According to Western Union officials, the $50 million development costs for the system were not government funded. COMLOGNET will eventually include ten high-speed switching centers using advanced data processing and handling equipment developed by RCA. Computers will be similar to the company's commercial 601 units. Initially, the system will include only five switching centers linking some 240 terminals, but will be gradually expanded to its designed capacity.

Since COMLOGNET will be an integral part of the Air Force's global communications complex, it will be capable of interchanging traffic with other Defense networks on an automatic, compatible basis.

Four of the five centers will have a capacity of 50 message-switching channels and 50 circuit-switching channels. The fifth center provides an additional 50 message channels. Provision is made for modular expansion to 100 message and 200 circuit channels. The channels will have an initial capacity of up to 4,800 bauds, but can be increased to 50,000 bauds by future expansion.

The system emphasizes digital transmission, but includes facilities for analog signals such as voice and facsimile. Bandpass of the analog switching circuits is at least 50 kc. Since all data trunks are link-encrypted, separate analog trunks are provided.

All digital channels will be operated in full duplex to provide simultaneous two-way operation. Switching centers can operate with half-duplex channels for alternate two-way transmission or with open-loop, one-way channels where necessary.

The common language chosen for COMLOGNET is an eight-element code that includes one bit for parity check. Alphanumeric characters are transmitted in accordance with the Air Force's recently adopted Fieldata code. Transmission will be at 150 bauds in the eight-level code. Automatic error detection will limit undetected errors to one in 10 million characters.

NEWS

New TH Microwave Relay

Large-Scale TWT Application Is Said to Be First in Country

A NEW 6,000-mc high-capacity microwave relay system between Denver and Salt Lake City scheduled to enter service early next year is now undergoing final tests by the Long Lines Div. of the American Telephone and Telegraph Co.

The new link, designated TH, affords eight 10-mc transmitting channels in each direction, with each channel having a capacity of 1,860 telephone conversations. Each of the 16 stations in the system will employ a total of 36-444A traveling-wave tubes as oscillators and final amplifiers. According to a Bell Telephone Laboratories spokesman, this marks the first large-scale commercial application of TWTs in this country.

A peak frequency deviation of ± 4 mc is permitted for each of the 16-transmitting channels. In addition, there are four narrow-band auxiliary channels for inter-system communication. Total utilization of space within the 5,925 to 6,425-mc common-carrier band is 90 per cent; only 10 per cent is reserved for group separation and guard bands.

This high percentage of band utilization is primarily due to frequency and polarization interleaving among channels. Adjacent channels are alternately polarized horizontally and vertically. Parabolic horn reflectors and circular waveguides capable of handling both polarizations are therefore used in the antenna and feed system. Polarity-sensitive elements achieve a 20 db discrimination between the two polarizations.

In addition, retransmission of signals repeater station is at a frequency different than that of the incoming signal. Messages received on a low-frequency channel are retransmitted over a high-frequency channel and vice-versa. The typical frequency shift is about 250 mc.

Diodes Permit High-Speed Switching

Four of the 16 transmission channels are held in reserve as protection against equipment failure, propagation difficulties over a particular channel, and for use during routine maintenance. Automatic switching between channels is performed by high-speed diode circuits. Switching time is on the order of 35 msec, of which all but a few microseconds is consumed in set-up time for the switchover. In the event of fading, however, the need for switchover is automatically anticipated and set-up is performed before

Being Tested in Rockies

the signal deteriorates to the point where switching is required. Actual switching thus occurs in only a few microseconds. Similarly, the switchovers required during normal maintenance are also set up in advance to minimize switching time. Only in the relatively infrequent case of equipment failure are the full 35 msec required. This rapid switching capability was built into the system in anticipation of future digital data transmission traffic.

Common Microwave Supply Drives 20 Carrier Frequencies

The 20 carrier frequencies are driven from a single 14.826 mc crystal oscillator. The 17th, 24th, 408th, and 425th harmonics are then generated and are appropriately combined by gold-bonded germanium-diode modulators in each transmitter. The two higher-order harmonics are amplified by TWT's before mixing

This common frequency supply permits a sharp reduction in the number of vacuum tubes needed as compared with a system using individual-frequency generators for each transmitter. Elements of the common system are of course provided in duplicate against failure.

The carrier frequency is amplified in the transmitter by a TWT and modulated by an information carrying intermediate frequency in a second gold-bonded germanium diode. The modulated signal is amplified by a second TWT and impressed upon the feed line through an isolator and combining filter.

Receivers employ silicon-diode modulators rather than TWT's to generate the intermediate frequency. While system noise is somewhat increased, this arrangement permits operation of the modulator at the lowest possible level to minimize interference due to cross modulation with adjacent channels. The beat-frequency signals are derived from the common microwave carrier supply in the same manner as for the transmitter.

Broad-Band Traveling-Wave Tube Requires Few Adjustments

The 444A TWT as used in the transmitter output stage develops 5 w. Its broadband performance in the 6 kmc range permits it to be used interchangeably among transmitters with only minor adjustment. One TWT could conceivably serve as the final oscillator for all channels.

TWT gain at 5 w is a minimum of 30 db. The tube's noise figure is 28.5 db. ■■

NEWS

Electronic Watch

Transistorized Timepiece Employs Tuning Fork

A TRANSISTORIZED wrist watch, called Accutron, has been designed by the Bulova Watch Co., Inc. of Woodside, N.Y. The timepiece is approximately 10 times as accurate as a conventional wrist watch, according to the company. It is guaranteed not to gain or lose more than a minute a month. Accutron has 12 moving parts, compared to 19 in manually-wound watches and 26 in self-winding watches.

All conventional watches "tick," signifying the periodic release of energy through interaction of the escapement and the balance wheel and hairspring mechanisms, causing the gear train to move the hands.

No Tick, but a Hum

The Accutron does not tick; it hums. The humming sound in electric timepieces is caused by the vibrations of a tiny electromagnetically driven tuning fork and its associated index mechanism.

Another external difference is the absence of a winding and setting stem. Accutron's power source is a 1.3-v mercury cell. The setting mechanism is engaged by a small recessed handle on the back of the case adjacent to the screw cap that hermetically seals the opening in the case for the power cell.

The things that make the new Bulova watch unique are:

- The use of a precision tuning fork as the time standard.
- The successful miniaturization of the entire circuit and the mechanical assembly to its 0.5 cu-in. size.
- The development of a highly efficient mechanism and circuit which require such a small amount of power that the self-contained power cell has a life of at least 12 months.

Briefly described, the Accutron is

Has More Accuracy

a wrist watch controlled by a tuning fork. Energy from the power cell, controlled by a transistorized pulser, causes the tuning fork to vibrate continuously at 360 cps. Vibrations are converted mechanically to rotary motions that are transmitted through a gear train to the hands.

Balance Wheel Eliminated

The most recent development in watch design was the electric watch, in which the mainspring was replaced with a battery as the source of power. Use of the battery eliminated the need for winding, but the design retained the balance wheel, which tends to be the weakest part and the greatest source of trouble in a watch. Make-and-break electrical contacts in electric watches are another source of trouble. In the Accutron design, the balance wheel and escapement mechanisms are eliminated, and there are no complicated elements or make-and-break contacts. The Accutron was designed to be serviced by watchmakers.

The greatest difference between Accutron and conventional watches is the use of the tuning fork as the time standard instead of the traditional balance wheel and hairspring. Attached to one tine of the fork is a tiny finger-like index spring. On the top of the index spring is a jewel that engages ratchet teeth on an index wheel. As the fork vibrates, the jewel-tipped spring moves back and forth with it, advancing the index wheel one tooth for each cycle of the tuning fork.

Micro-miniaturization in the device is perhaps best represented by the index wheel. The index wheel is 0.095-in. in diameter and 0.0015-in. thick; yet, it has 300 precisely machined ratchet teeth. Teeth are separated by a 0.001 in. space. ■ ■

CIRCLE 18 ON READER-SERVICE CARD ➤

NEWS

Midwest Is "Stagnancy" Center, Stanford Provost Says at NEC

The Midwest, dulled by insufficient research funds and by unimaginative challenge to graduate students, has been cited as the center of "electronic stagnancy" by a leading educator.

Largely responsible, according to Dr. Frederick E. Terman, Provost of Stanford University, are a lack of new-product development and waste of intellectual resources at local universities. He made his remarks at the National Electronics Conference, held in Chicago Oct. 12-15.

Although present industry in the Midwest is not in dire straits, Dr. Terman said, both East and West Coast companies will enjoy progress at the Midwest's expense, unless a drastic change in policy goes into effect. The key to progress, he pointed out, is the stimulation of advanced graduate training for local students who will have the incentive to remain and contribute to the Midwest's development. Present students at Midwestern institutions, he said, tend to switch to schools in other areas for advanced training and then to remain in those areas for employment.

Midwesterners Blame Geography, But Critics Dispute Contention

Midwestern representatives at the conference said geographic climate was a key excuse, but critics suggested lack of aggressive leadership and failure of local industry and educational groups were primarily to blame for the situation.

Conference sessions on microminiaturization drew large crowds eager to glean the latest development trends, which were outlined in 12 papers. Representatives from Bell Telephone Laboratories, Motorola, General Electric, Lockheed, and Wright Air Development Center discussed progress in thin-film efforts in the micromin field. Although deposition techniques are capable of supplying high-density assemblies, additional time and study are needed to achieve high yield and reliability.

In addition, they said, the approach must be equipped with some reasonable degree of mechanization to lure customers other than space-program contractors.

Highlighting the new-product announcements from NEC were epitaxial transistors by Rheem Semiconductors Corp., Mountain View, Calif., Motorola, Inc., Phoenix, and Sylvania Electric Products. The new devices, with their lower collector resistance and highly improved switching times, are expected to find rapid use in high-speed computer applications.

Better Instrumentation Is Required To Show Astronauts' Stress, Strain

Designers of instrumentation for measuring physiological parameters have not kept pace with those producing devices for instrumenting machine systems. Needed, in the space effort especially, are a battery of instruments for monitoring stress and strain patterns of space travelers.

This theme ran through the American Rocket Society's Conference on Anatomy of Manned-Space Operations, Oct. 10-12 in Dayton, Ohio.

Dr. S. A. Talbot, Johns Hopkins Medical School, Baltimore, told participants in the conference that not only should such parameters of physiological environment as departures from normal air pressures, oxygen, carbon dioxide, temperature, humidity, and ventilation be measured and monitored, but the more difficult psychological and physiological parameters constituting the "strain pattern" must also be monitored. Included in these measurements would be data on normal and abnormal systolic pressure, respiration, hearts rates, brain activity as indicated by electroencephalograph (EEG) measurements, changes in bodyweight (despite conditions of weightlessness), and waste elimination.

Greater Challange for Designers Seen in Different Situations

Dr. Talbot said that many other physiological measures might be required, depending on specific situations. Some of these greater challenges would be measures of electrocardiogram pattern, perspiration, galvanic and other reflexes, and sensory activity.

He added that in addition to devices for measuring and monitoring actual patterns of stress and strain, equipment has to be developed for analyzing and remedying the causes of strains and impaired performance.

Designers are attacking the problem areas described by Dr. Talbot. At the conference, Capt. George Potor Jr., Wright-Patterson Air Force Base, Dayton, Ohio, reported on designs that solve or approach solving some of the problems.

These include an amplifier with a stable common-mode rejection reportedly well over 100,000 to 1. Input impedence is 500 K, output impedance, 20 K, and amplification is 2,000. Another amplifier, designed in Europe for EEG equipment fits eight channels and a battery power supply into a 1.5-x-5-x-7-in. volume. A versatile electrode of new design has also been developed at Wright Air Development Div. It consists of a conductive cloth, silver deposited on nylon, stretched on a flat sponge-rubber pad. Although its resistance is about 50 K, it is said to be an important improvement over existing electrodes because it operates dry.

WASHINGTON REPORT

Ephraim Kahn

PRIVATE USE OF SPACE SATELLITES is an almost distant prospect, though experiments will start in a matter of months. Statements by T. Keith Glennan of NASA that the "nation's great communications organizations" are seriously considering "the undertaking of substantial expenditure from their own corporate fund for the development of such systems" raises far more basic questions than have been answered. There is general agreement, to be sure, that private enterprise should participate to the maximum possible extent in development of space communications. There are major differences, however, when it comes to deciding what is appropriate for private enterprise and the reward that private enterprise should reap for its participation. The new Administration's attitude will be controlling; present policy (to the extent it has been formulated) is at best firm only through Jan. 20, 1961.

CONGRESS WILL UNDOUBTEDLY take this up next year. In fact, both Senate and House space committee staffs are looking into it now. The Commerce Committees too, may interest themselves from the standpoint of communications. So will executive agencies FCC, NASA, and the DOD. But before any problems can be solved to the mutual satisfaction of both government and industry, some fundamental decisions have to be made.

THE BASIC QUESTIONS are raised quite starkly by Glennan's statement. One is that of patent policy. The appropriateness of turning over to industry for use as a profit a huge amount of government-paid R&D is certain to be raised. The question whether there should be government regulation—and how much—is another. If there is to be control, who will exercise it? Can private industry handle the international problems involved? Would it be proper to grant a state communications monopoly to any firm? If so should it be one of the existing companies? Or should provision be made for entry of new comers into the area on equal terms?

YET TO BE DECIDED, too, is the almost philosophic question of the motivations of the firms which seek to get into the field. It is known that NASA has already had conferences with five or six companies. The feeling in some government circles is that no solution will be reached without a good deal of statesmanship on all sides, and that it will take a lot of soul-searching to come up with the decision which will do the least harm and the most good.

GOVERNMENT OFFICIALS are certain to be wary of any industry approach that plays a mini-max game—which tries to treat obtaining a favorable position in space communications as a purely economic problem in which the objective is to put in as little money as possible consistent with obtaining a pre-eminent position.

VALUE-ENGINEERING PROVISIONS will be written into Air Force contracts soon. Hitherto, the Air Force has tried to push contractors to make components cheaper—without adversely affecting reliability—but it has not incorporated this concept in its contracts. Now proposed legal language is being studied. The formal value-engineering program will be applied both to prime and subcontractors. It will, for all practical purposes, be inseparable from contract management. Technically speaking, the objective is to save money by re-engineering and by modifying specifications. In effect, this could boil down to a change of suppliers, elimination of needlessly elaborate devices, and keeping a sharper eye on overhead costs.

CHARGES OF OVERCOMPLEXITY in the Minuteman and other missile programs have been dismissed by Air Force experts as exaggerations based on insufficient knowledge. Minuteman has been pushed forward to 1962, they acknowledge, even though this means that reliability will fall short of perfection during the first year or so. They insist, however, that even so it will be cheaper than either Atlas or Polaris in terms of cost-effectiveness. Minuteman costs will run, a recent study shows, about 45 per cent for hardware and 55 per cent for on-the-ground costs, including construction. Increasing complexity, though not to be sought for its own sake, is a fact of life. "We simply couldn't do the things we're doing if we didn't have such complex equipment," is the general tenor of comment.

OFFSHORE-BUYING POLICY REVERSAL will have limited impact on electronics. Largely because of Treasury pressure, the military abruptly switched from granting preferential status to foreign purchasing of goods meant for allies of the U.S. to favoring American sources of supply unless it "is essential to support overriding U.S. foreign policy and Military Assistance Program objectives." Foreign purchases will be paid for "to the maximum extent" with foreign currencies held by this country. In any case, contracts for foreign goods will be let "only if they conform to sound military procurement practices."

COURIER SATELLITE IS PRACTICAL for low-priority military communications, according to Army officials (see p 8). Though usually considered a first step toward far more complicated devices, its early performance has indicated that it could be used operationally right now. Long-term reliability—and budget considerations—would be major factors if a decision to set up a Courier satellite system ever has to be made. As things stand, a single satellite of this type probably could handle all the Army's bulk, low-priority, "store-and-forward" messages for the next three years or so.

SLAP ON THE WRIST to small business—an unusual occurrence—has been administered by the Air Force Deputy Chief of Staff for Materiel, General Bradley. Aware of Congress' tender feelings for little firms, the military rarely criticizes them. But Bradley has noted that they are sometimes guilty of "overreaching" in their search for government contracts—that is, they try to get contracts which they are incapable of performing satisfactorily. At the same time, Bradley notes, they sometimes fail to bid on purchases that they could handle very well.

NEWS

Broad Use of Optical Masers Seen by Experts at BTL Meeting

Leading scientists predicted wide use of optical masers in scientific, industrial, and military systems at a recent demonstration of such a device by the Bell Telephone Laboratories. New applications transcending the already proposed communications, radar, and death-ray systems were foreseen by Drs. Arthur L. Schawlow and Charles H. Townes, who in 1958 first suggested the development of optical masers.

The control of chemical processes by optical-maser beams was considered a likely possibility by Dr. Schawlow. "We know that many chemical and physical reactions are affected by light and we now can look forward to a source of intense, highly controllable light for this purpose," Dr. Schawlow said. The optical maser was also seen as a tool for studying the interactions between light and matter so as to discover new effects of light upon physical and chemical processes.

Dr. Schawlow also suggested the possibility of shifting the orbit of a satellite by the light pressure of continuously applied optical maser beams. This could prove feasible for the remote control of lightweight bodies. One can envision maser "duels" in which an enemy observation satellite is shifted with maser beams while the enemy uses the same technique to keep the vehicle in its assigned orbit.

Dr. Townes predicted significant increases in measuring accuracies through use of optical masers. Velocity measurements by optical doppler methods and distance measurement at ranges of many miles by interference patterns could give accuracies several orders of magnitude higher than present methods, Dr. Townes said.

Both scientists agreed that currently available materials limited masers to optical frequencies, but that ultraviolet and X-ray masers might eventually be developed.

CHANGES IN PRICE AND AVAILABILITY

GALLIUM ARSENIDE TUNNEL DIODES have been reduced 93 per cent in price by Canadian General Electric Co., Ltd. The new prices are now $5.17 each and $6.90 each in large quantities to original equipment manufacturers. They previously sold for $63.25 each and $97.75 each.

Broad-Band Communications System Sends, Receives, 'Intelligent Noise'

A new broad-band military-communications system, known as "Phantom" system, will receive and transmit "intelligent noise or static" without interrupting or causing static on local radios.

It represents a different approach from the conventional narrow-band military communications technique in which each transmitter and receiver is allocated a specific narrow bandwidth to avoid interference and to crowd as many channels as possible into the electro-magnetic spectrum.

In broad-band communications the transmission bandwidth is many times larger than the intelligence bandwidth, or signal being relayed. For military communications broad-band techniques provide three types of security: security against jamming because of the tremendous amounts of power required to interfere with the transmitted signal; transmission security since the average power is spread over a wide bandwidth making the signal extremely difficult to detect; and message security in that even if the signal is detected, it can be made very difficult for an unauthorized listener to understand what is being transmitted.

The system is under development at General Electric's Military Electronic Dept. of Syracuse, N.Y.

Raytheon Hot-Spot Detector

A lipstick-size electronic device developed by Raytheon Co. of Waltham, Mass., is reported the smallest-known infrared detector and is capable of spotting objects warmer than the human body from miles away. Used in detection units, it peers through the night to pick out heat emitted by aircraft, missiles, launching pads, and rocket-test areas. The detector generates no telltale beam from which the enemy might trace its location. Its long-range operation, small size, and metal casing make it particularly applicable for aircraft and missiles.

◄ CIRCLE 24 ON READER-SERVICE CARD

Boiling Liquid Cools Radar Power Supplies

Corona Prevention Is Provided; Development Allows Size Reduction

HIGHER and higher power levels for microwave-radar transmitting tubes have led to the use of liquid ebullient cooling in high-voltage power supplies for these systems.

The ebullient cooling process makes use of a fluid with a high heat of vaporization to remove heat from components through boiling. Corona prevention is also provided.

A packaging technique to take advantage of this process has been developed by Raytheon Co.'s Missile Systems Div. under a program in progress since 1954. A high-voltage power supply, and also the klystron it is feeding, is contained in a flexible Teflon liner which is first evacuated and then filled with an insert fluorocarbon fluid. As the unit operates, heat is first removed by convection currents, but as the boiling point of the fluid is reached, ebullient cooling begins —transferring large amounts of heat from high dissipation elements.

A Number of Liquids Tried

Extensive tests of many possible coolants for the ebullient process by Raytheon indicated that no one fluid was suitable for all applications. For the initial applications of the technique Freon F-114, which boils at about 36 C and remains liquid to −94 C—meeting the military requirements for operation down to −65 C. This fluid has the advantage of low cost but causes decomposition of silicone rubbers, requiring careful materials selection for power supplies, according to Lee Renaud, Raytheon's Missile Systems Div., at the recent Electronics Packaging Conference at Boulder, Colo.

Currently Raytheon is using FC-75, produced by Minnesota Mining & Manufacturing Co., for ebullient cooling. This fluid was found to be essentially inert except for minor reactions with most silicones—allowing use of most high-voltage cables. Boiling temperature is about 100 C, so that operation at 15 psia internal pressure is possible with component temperatures remaining below 110 C, according to Mr. Renaud.

Silicone Pads Protect Liner

The flexible liner covering the power supply expands or contracts to compensate for effects of volumetric changes in the fluid with temperature variations. Sharp corners on components in the supply are covered with a thin silicone rubber pad to prevent puncture of the liner.

Size Reductions Are Significant

Designing for ebulliently cooled equipment allows significant size reductions for many supplies, such as magnetic cores, high voltage rectifiers, and resistors. Power resistors, for example, can be uprated to dissipate five times the normal power, Mr. Renaud said.

An airborne power supply built by Raytheon using FC-75 for ebullient cooling occupies 0.6 cu ft. Electronic circuits dissipate some 700 w and klystron dissipation is about 1,500 w. This power is absorbed by an external coolant flowing

Breadboard layout of 15-kv dc, 125-ma power supply designed by Raytheon for ebullient cooling using Minnesota Mining's FC-75. Miniaturization of many high heat dissipation components is possible using the ebullient cooling approach.

Hot klystron boils fluorochemical fluid with high heat of vaporization. Klystron is packed inside its power supply in the new flexible liner packaging approach.

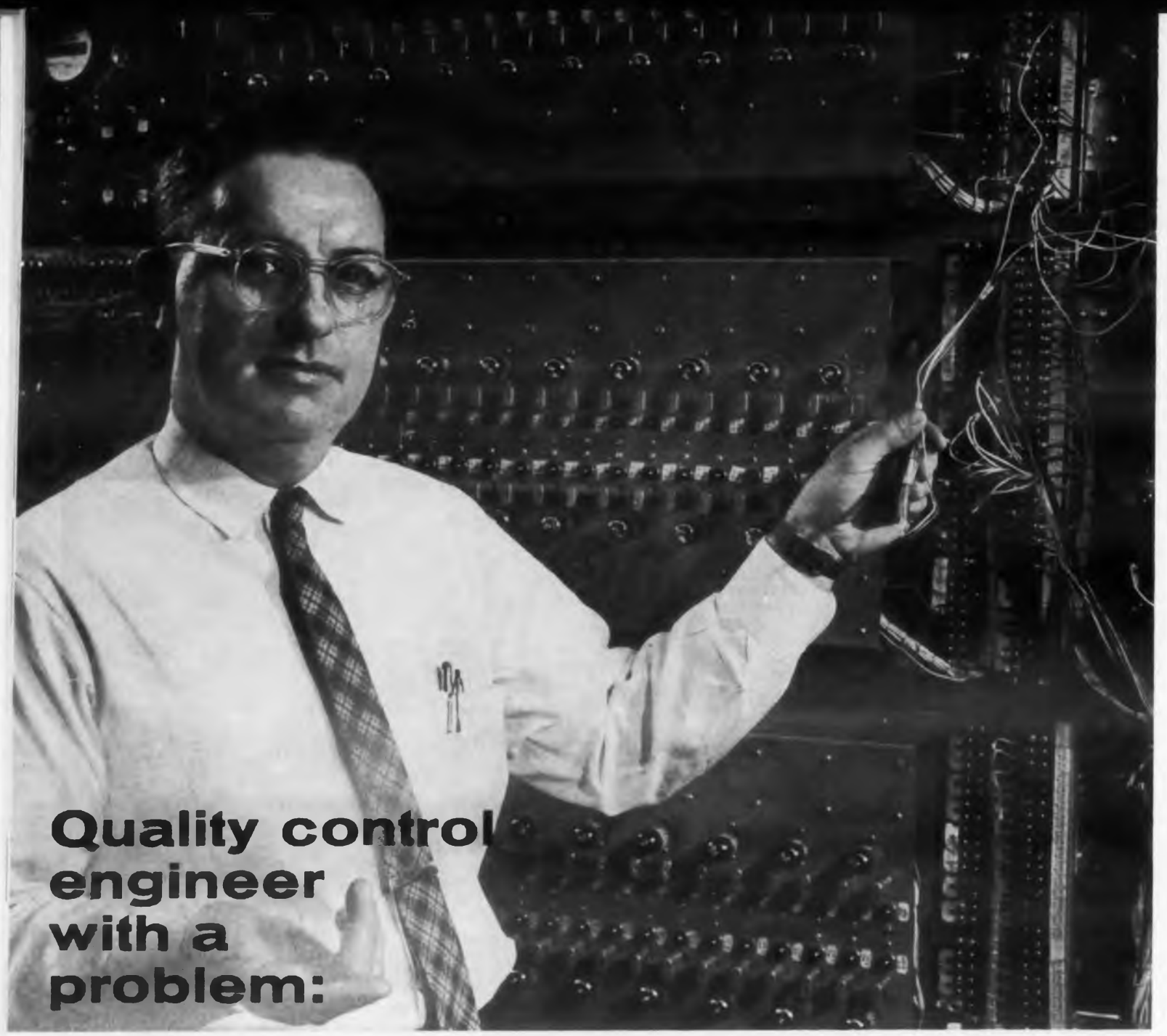
through an FC-75 vapor condenser. Maximum output of this supply is 15 kv dc at 125 ma, regulated for line voltage and load changes.

Placing the klystron inside the power-supply package eliminates the need for a multi-pin, high-voltage connector designed for corona-less operation at high altitudes, which offers a difficult mating problem. Careful shielding to protect stray pickup and testing of the high voltage cable between the supply and the exterior klystron is also eliminated.

Plastic Foam Lowers Fluid Required

Since FC-75 is expensive, low thermal dissipation areas within the supply are filled with lightweight plastic foam to reduce the amount of fluid required.

In response to questions at the Packaging Conference Mr. Renaud indicated that the properties of FC-75 were not affected by long periods of boiling under Raytheon tests. It is necessary to maintain an adequate supply of fluid to handle heat transfer requirements, he commented, or there is danger of burning out the klystron. Even with advanced sealing techniques there still will be some leakage of fluid over long operating periods, he commented. ■ ■



"I can't test every relay!"

You shouldn't have to! Besides, quality can't be "tested into" relays—it has to be built in at every step of the production cycle. At General Electric it is.

Not simply individual tests for shock, vibration, etc., but *complete* quality control is what gives General Electric relays exceptional reliability.

Quality control begins with stringent material tolerances General Electric demands of its vendors, monitored by frequent appraisals on everything from tool calibration to their reporting procedures, and checked by G.E.'s careful processing of incoming materials. Result: less than 1% of incoming material must be rejected.

Quality control continues with equally exacting measures in our own plant:

- Of average relay manufacturing time, General Electric spends 30% in planned quality checks—much more for specials.
- More than 25% of total factory floor space is used to test relays.
- Advanced equipment and techniques are used, including the unitized testing console. This automatic, on-line testing center eliminates human error from production acceptance tests, eliminating another variable of relay reliability.

But, quality control doesn't end here. General Electric quality control even follows relays into the field to analyze malfunctions and, if necessary, re-assess testing procedures, or design.

It all adds up to complete quality control—a highly developed monitor and feedback network that guides General Electric's manufacturing process through the consistent production of industry's most reliable sealed relays.

For information on our special customer-requested testing program, or more on quality control, see your G-E Sales Engineer. General Electric Co., Specialty Control Dept., Waynesboro, Va.

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CIRCLE 28 ON READER-SERVICE CARD

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MICRO-MINIATURE

Small and light for military use, the General Electric Micro-miniature's dual-coil construction provides a highly efficient magnetic circuit, requiring minimum operating power. A balanced armature combined with extremely high tip forces gives the relay exceptional resistance to shock and vibration. It is available in current-calibrated and voltage-calibrated forms, SPDT or DPDT. Other specifications:

Operating Sensitivity: 200 milliwatts; 300 milliwatts.

Vibration: 20 G's, 55-2000 cps (except for certain mounting forms).

Shock: 50 G's per MIL-R-5757C.

Ambient Temperature: −65C to +125C.

Operating Time: (25C) 6 milliseconds maximum.

Release Time: 5 milliseconds maximum.

Contact Rating: 2 amps resistive at 28 VDC or 115 VAC.

Life: 100,000 operations minimum at rated load.

Dielectric Strength: 1000 V rms except 700 V across terminals.

Insulation Resistance: 1000 megohms minimum.

Contact Resistance: .05 ohms maximum at rated load.

MINIATURE: Long-life type: rated 5 amps at 28 VDC; in 2- or 4-pole double-throw and 6PNO forms. Ideal for ground applications.

4-POLE MICRO-MINIATURE: Welded construction, exceptionally long life. Rated 2 amps at 28 VDC, or 115 VAC resistive; requires only 10 milliwatts per pole.

GRID-SPACED MICRO-MINIATURE: Long-life crystal-can type, rated 3 amps at 28 VDC, operating sensitivity 300 mw; 16 mounting for ms; 30 G's vibration to 2000 cps.

General Electric Company
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GENERAL ELECTRIC

CIRCLE 29 ON READER-SERVICE CARD

EDITORIAL

Science, Electronics, and Elections

That science and technology has not become an election issue in 1960 comes as no great surprise. Few, if any, can see any issue at stake. But is there really no national policy involved?

Will the benefits of science and technology—new materials, new control over our environment—automatically benefit mankind? Bertrand Russell has said science can enhance among men two great evils, tyranny and war. Are we fully aware of what is at stake?

More scientific and technical information is necessary if we are to make policy decisions on the control of nuclear testing and disarmament. The nation's emphasis on basic research is important; governmental policy must be conducive to free inquiry into all of nature. The Presidential candidates' views on these matters are important. How the candidates view the dissemination of scientific information, both to researchers and the public at large, is vitally important. Secrecy defeats scientific inquiry. If the voters do not understand the issues involved, they cannot make informed decisions at the polls.

Scientific objectivity must be separated from political opinion. This has hardly been achieved so far in the U.S., as is indicated by the official reports on the danger of nuclear radiation. If scientists and engineers are to perform the role proposed for them by Prime Minister Macmillan as the first step towards disarmament, they must be able to shun political pressures.

In the past, we have had little way of knowing if our actions have been consistent with our national objectives. We have not yet taken advantage of operations research, or systems research, to determine if the many variables at stake are being properly interrelated. We need such research if we are to achieve any success in, for example, disarmament and weather control.

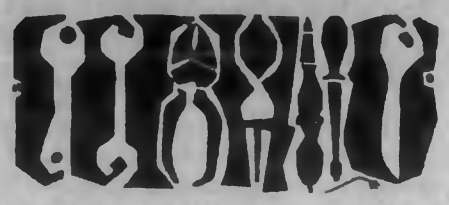
Britain's new Minister of Science has said, "My purpose is to make the voice of science coherent and articulate under government encouragement and in one sense to make science self-governing under governmental inspiration."

Is not this the challenge before us now? The President has a responsibility in these areas and if he does not lead, it is up to those in the technical professions to see that the issues are clear.

(For the views of the two candidates on scientific subjects, see p. 4.)

James G. Kippton

Designing for Maintainability



An *ELECTRONIC DESIGN* Staff Report

George Rostky
Associate Editor

Only recently an infant stepchild of reliability, [illegible] maintainability philosophy has emerged as an important new discipline. Often in conflict with the demands of its elder, reliability, it has aroused the increasing interest of both industry and the military.

All three military services have spent large sums of money for maintainability studies, but by their very

Contents

Maintainability—Where It

GONE are the halcyon days when the electronics engineer had merely to design equipment to work. They have been replaced by an era wherein, seemingly, each day brings new disciplines, new requirements and new challenges.

With a touch of bitterness, some engineers have dubbed these days "the age of over-the-shoulder men." But they have learned to live with the needs of the age. Overcoming a psychological hurt, they have come to expect and, at times, to respect the words of thermal-design engineers, packaging engineers, human-factors engineers, quality-control specialists, production men, and, of late, reliability engineers.

Had the quest for reliability been more successful, it is likely that the parade of new disciplines might have halted. Alas, though equipment reliability increased, it was no match for the soaring needs of the times. Realists appraised the situation coldly and concluded that: If an equipment *can* fail, it *will.*

And maintainability was born.

Almost everybody seemed to agree, "If we can't make an equipment last forever, let us at least design it so we can keep it going as long as possible, so we can fix it in a hurry when we need to—with the men available and with the tools available."

Engineers Must See Designs As Technicians See Them

As with so many fine ideas, this was more easily said than done. Some electronic design engineers, trained to design "the best," or worse, "the most sophisticated" equipment, found it hard to design *simple* equipment to perform complex tasks. These highly trained men found

...ture, many maintainability techniques will continue to clash with some requirements of other disciplines.

How to evaluate these conflicts, how to decide on optimum trade-offs, and how best to measure maintainability itself continue to be areas of much-needed additional research. Estimates of the annual cost of maintenance range from a low of 0.6 up to a high of 12 times the initial equipment costs, and it is essential that more electronic design engineers become proficient in the art of designing for maintainability.

It is with this objective that ELECTRONIC DESIGN*'s editors have prepared this Staff report and have invited guest contributors to participate in this presentation of maintainability's past, present, and future.*

e Itomes From; Where It's Going

it hard to believe that their beautiful designs could fail in the field. But somehow, fail they did.

They simply didn't stop to think that the man who had to repair the equipment, a man with no engineering degree, might have to work in bitter cold (with gloves), in sweltering heat (with sweat), or in storm-drenched mud.

Even with the full understanding of the electronics designer, the road to maintainable equipment is not a smooth one. There are many obstacles, many roadblocks, and many conflicting requirements. There are times when maintainability features must be traded off for greater reliability. And there are many features which may enhance maintainability but degrade reliability.

Plug-in modules, for example, cornerstones of maintainable equipments, may be anathema from the viewpoint of reliability. Plug and connectors are weak links in reliable equipment.

Interdisciplinary Conflicts Breeding New Disciplines

Conflicts like this one, between maintainability and other disciplines, are beginning to breed a new discipline—availability. This new discipline (also called readiness, or operational availability), is supposed to lead to a harmonious unification of maintainability, reliability, and still another discipline—supportability. This last is largely a recognition of the logistics involved in keeping equipment working in the field.

In essence, availability is a philosophical concession to the approach of the line officer: "I don't care how much reliability it has, nor how much maintainability it has. What I want to know is—when I need it, is it ready?"

Availability embodies the quest for the best compromise between the various disciplines for a given system. The need for maintainability itself varies very widely, depending on many factors. As such, maintainability has enthusiastic supporters and equally enthusiastic antagonists.

Military Sees Maintainability In Widely Different Lights

The Air Force, the Army Signal Corps, and the Navy's Bureau of Ships are strong supporters of maintainability efforts. Naval Ordnance, on the other hand, is quite unfriendly to the concept, and insists on greater efforts to improve equipment reliability.

In a talk before the First EIA Conference on Maintainability of Electronic Equipment, H. A. Wilcox, head of the Weapons Development Dept. of the U. S. Naval Ordnance Test station in China Lake, Calif., presented his position this way:

"Your design for easy maintenance has to take into account dirt, rain, ice, heat, cold, vibration, and tooth-tingling shocks in handling. And it has to cope with the bored, curious, intelligent man who wants to take it apart to see how it works—confident that the 'tuning up' he gives it will improve its operation and relieve a dull afternoon.

'If Repair Is Allowed, Repair Becomes Necessity'

"It is my conviction," Mr. Wilcox elaborated, that most field repairs reduce instead of enhance the reliability of the item 'fixed.' "Repair is a self-justifying operation. If repair is allowed, the reliability drops so low that repair automatically becomes a necessity."

He emphasized the fact that an ordnance item, whose sole use is in wartime, should be designed for long shelf life, almost no maintenance, and absolutely no field repair. Insisting that reliability should be uppermost and that equipment must be maintenance-free, Mr. Wilcox summarized his attitude by saying that "test equipment should in fact be eliminated altogether."

BuShips Awards Contract To Find Practical Yardstick

Holding the opposite position, the Navy's Bureau of Ships awarded a contract to Federal Electric Corp. of Paramus, N.J., to establish a practical procedure for measuring and predicting the maintainability of fleet electronic equipment during the design stage. This recently completed two-year study is the first step in a long range BuShips program to develop a practical method of numerically specifying maintainability in procurement contracts.

BuShips' Capt. William I. Bull points to special Navy problems which emphasize the need for better maintainability. In common with the other services, the Navy has the problem of a low reenlistment rate (12 to 14 per cent) for first-cruise electronics technicians. But the Navy has mission times which average up to 90 days—far more than the other services.

And where the Army and Air Force can use experienced contract technicians, the Navy normally can not. Captain Bull emphasizes the point that shipboard equipment can rarely go back to the factory during a mission. Naval equipment must have as much self-sufficiency as possible.

Mr. F. N. Stehle, head of the BuShips Reliability and Maintenance Unit, goes a step further in describing the special position of the Navy. The

size of a ship, he points out, can have a profound effect on the type of maintenance it can support. A destroyer, with relatively few instruments of a given type, and with a relatively small crew, has requirements which differ vastly from those of a carrier.

Air Force Publishes First Maintainability Specifications

The Air Force, another enthusiastic backer of maintainability, holds the distinction of being the first to publish a maintainability specification, Mil-M-26512. Published in June, 1959, it is still the only military specification on maintainability. (The Signal Corps expects to publish one early next year and the Navy hopes to have one by the end of the year.)

Mil-M-26512 defines maintainability in terms of repairability and serviceability. It then defines repairability as a product of two probabilities—the probability of correcting a failure in a given time with a given expenditure of manpower, and the probability of the system then operating satisfactorily for a given time.

The parameters given to determine repairability include the time to diagnose and isolate malfunctions, the time to repair malfunctions, the manpower and skill levels required for repair, and the time the equipment operates satisfactorily without corrective maintenance.

Sidney Hirshon, who deserves most of the credit for developing the specification, recognizes that it has generated differences of opinion—some of them rather sharp. He points out that the Air Force will continue to improve the specification of maintainability and that Mil-M-26512 is now undergoing revision. Bulletins are being published which will amplify and clarify some of the less clear aspects of the spec.

The Air Force's Col. George Getz, attempting to get to the root of the maintainability problem, suggests that the situation would be much improved if manufacturers (and electronic designers) knew who their customer was. A very important part of the composite customer, says Col. Getz, is G. I. Joe.

Knowing Customer Through Market Research Can Help

He suggests that companies producing equipment for the military services should conduct some kind of market research so they could better understand their customer and his needs. They should know the proposed environment for equipment they design in terms of the skill, tools, and test equipment available as well as the physical environment.

To help manufacturers know their customer better, the Air Force has conducted several tours of AF maintenance technicians through contractors' factories. Results of these tours, which the Air Force hopes to continue, were highly satisfactory to the Air Force and the contractors, though not always too flattering to the design engineers.

In one case, a corporal, a maintenance technician, educated (and embarrassed) a rather tall design engineer who had mounted a display high on an equipment console. The 5-ft, 3-in. corporal couldn't read the display. In this case, the designer solved the problem quickly. He tilted the display down so it could be read by a short or a tall man.

The Air Force, the Navy's Bureau of Ships, and the Army Signal Corps can all be counted as strong supporters of maintainability.* Naval Ordnance holds an opposite position. The "halfway" position can be found at the Bureau of Naval Weapons.

Mr. Henry Thoman, head of the Material Coordination Unit of the Avionics Div. of BuWeap, favors maintainability and is very much impressed with the advantages possible from the use of expendable modules but he leans most heavily toward reliability.† In most cases where a trade-off is necessary between a maintainability feature and a reliability feature, Mr. Thoman says, he would have a tendency to favor the reliability feature.

The different military attitudes toward maintainability find their counterparts in attitudes in industry. It would be hard to find an authoritative executive in industry who would be outspoken in his opposition to maintainability. Instead one finds people who are lukewarm in their support or who offer conditional support. These men are primarily concerned with the harmful effect which too much emphasis on maintainability may possibly have on reliability efforts.

As typical of this concern, one can take the comments of W. Van Alan Clark, Jr., president of The Sippican Corp. of Marion, Mass.

"First," he says, "we feel very strongly that undue concern with maintainability has tended to cause designs which require maintenance. In general, complex electronic systems come apart too easily, which means that they do come apart. We feel that the emphasis we find on easy field maintenance has not only made equipment less reliable than it should be, but has had a highly undesirable effect upon the skill and training of the field-maintenance personnel. The military, in particular, are finding the cost of training field-maintenance personnel to be astronomical. Were the equipment to be designed with larger, swappable or chuck-away units, field personnel could concentrate on how the system works, and not worry about individual component or circuit behavior."

Call for Equipment Design For Different Modes of Maintenance

Mr. Clark goes on to recommend that equipment be designed for different modes of maintenance at different positions in the logistic train. As an example, he cites a computer, designed to be disassembled a large number of times in its "shop" mode, which could be put in a "ready" mode by welding every connection and having no mechanical joints of any kind.

This computer could make about four round trips from "shop" to "ready." But this limitation on round trips from service to repair was well compensated by a very high basic reliability and compactness.

Some Observers See Trend To Factory Repair of Equipment

Unlike most observers, Mr. Clark sees trends to performing almost all electrical maintenance at the source. "Maintenance activities," he comments, "can damage equipment terribly. Diagnosis of what is wrong in most equipment is best carried out by specialists who have known the equipment during its design and development stages.

"Equipment is becoming much more compact, which means that it is easier to transport to rear areas or to factories for maintenance. Finally, transportation to any point of the globe is now really rapid, and the money which may be spent maintaining a complex electronic device dwarfs the cost of flying out a sub-system and flying back the other section for factory overhaul."

In supporting these views, Mr. Clark gives an example in which ". . . one fourth the volume of a modular design we are now building is taken

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* The Signal Corps approach to measuring and specifying maintainability differs substantially from other approaches which depend heavily on measuring time. It is therefore presented separately in this report as an article entitled "No Time-Base Needed in Signal Corps Maintainability Specifications, p 58."

† The Bureau of Aeronautics, now integrated in the Bureau of Naval Weapons, sponsored the National Bureau of Standards research which resulted in the report "Expendable Modules as Bases for Disposal-at-Failure Maintenance." This report is available at $2.25, from the Office of Technical Services, Washington 25, D. C.

up by an idiot-proofed test connector; we pay this price to make sure that field experts don't wreck the machine."

Speaking in a similar vein, Mr. W. L. Kirchoff of the Walkirt Co. at Inglewood, Calif., says: "Some of the novices in the industry tend to overemphasize maintainability to the detriment of economy, and even to the detriment of maintainability itself."

"This sounds conflicting," Mr. Kirchoff admits, "but it really isn't." Take the case of the trend toward modular circuitry, where, a circuit comprised of perhaps 20 components is unitized as a plug-in device. Modular circuitry certainly enhances maintainability.

"Yet, we still encounter people in the field (although their ranks are thinning) who insist that each component in this modular circuit shall be replaceable. They theorize that it is uneconomical to discard a $20 package for the sake of a burned-out 10-cent resistor. They then have created 'maintainability' to the degree that each component may be replaced."

Though Mr. Kirchoff and Mr. Clark may be lonely in their over-all views on maintainability, they are by no means alone in their attitudes on module size.

Controversy Continues On Module Size and Throw-away

Many of the strong supporters of maintainability are strongly opposed to replacing individual components in the field. There is still a lot of discussion on just how large a module should be and the question of throw-away modules is still a matter of controversy. But there are very few who would advocate making low-cost components (like resistors) accessible in the field except in situations where the equipment design is such that the maintenance technician can find a faulty resistor very quickly.

The whole problem of module size is a very touchy one, interrelated as it is with problems of module cost, time required to locate a fault, component density, spare-parts inventory, skill-level of personnel required, length of mission, and others.

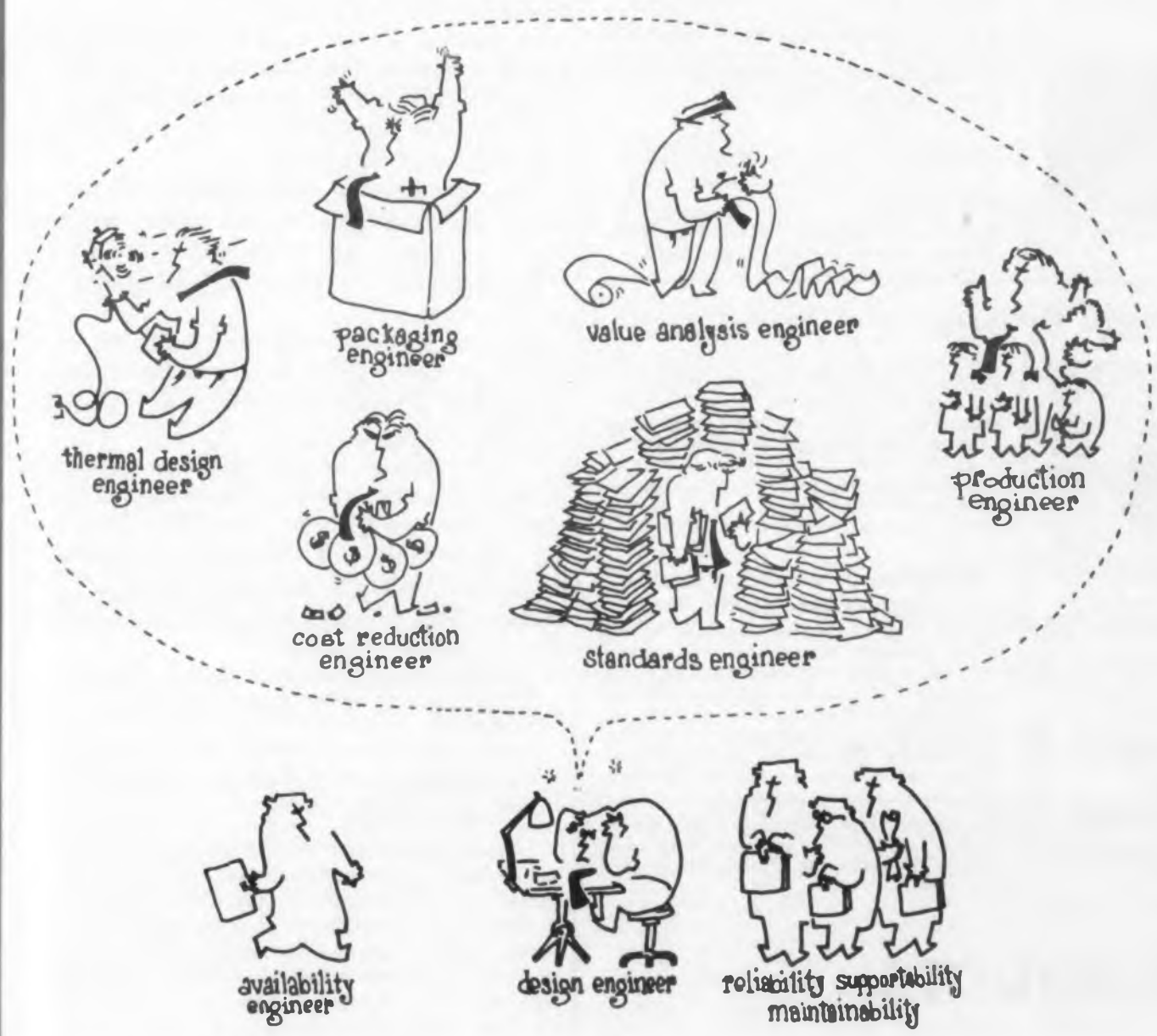
In general, it is easier and faster to track a malfunction down to a faulty module and to replace that module with a good one than it is to locate and replace a faulty component. No one denies this.

But it is easier, in general, to provide logistic support in the form of individual components which can serve an entire system than it is to store spare modules for the many equipments which make up a system.

Even where the module-replacement formula is adopted, this still leaves open the question of whether to repair faulty modules in the field (at leisure), whether to return them for factory repair, or whether to throw them away.

The last choice, of course, affords an advantage in that throw-away modules lend themselves most readily to encapsulation and to the improved reliability which encapsulation may impart.

But, to throw away or not to throw away, that is the question. It has by no means been resolved, although there is growing support for the throw-away concept. A recent National Bureau of Standards study, based on analyzing tube modules only, concluded that, for airborne equipment, an optimum module would include four to eight tubes. Thus study found that the cost of procuring, maintaining, and supporting expendable modules was practically the same as the cost with repairable modules.



Study of Fire-Control System Compares Four Philosophies

On the other hand, a study of expected costs of different maintenance philosophies for the Polaris submarine fire-control system gave opposite conclusions. In this study, total cost using the throw-away philosophy is greatest.

Describing this economic analysis by the General Electric Co. in Santa Barbara, Calif., Ernest J. Mosbaek gives results for four maintenance philosophies—use of throw-away modules, repair on the submarine, repair on a tender, and repair at the factory.

In this study, using throw-away modules proved most expensive; repair at the factory was next; repair on a tender followed, and repair on the submarine proved least costly. Using throw-away modules, the study found, would be two and one-half times as costly as the system requiring repair aboard the sub.

Conflicting Results Show Need For Separate Systems Studies

The apparent conflict between the findings for a submarine system and those for airborne equipments leads to an important conclusion: One cannot design for maintainability in general.

One can only design maintainability into a specific system. One must know its specific en-

Nickelonic News

VOL. 1 — DEVELOPMENTS IN NICKEL AND NICKEL ALLOYS AND THEIR APPLICATIONS — NO. 8

Designers insure magnetron reliability with 4 nickel alloys

WALTHAM, MASS: Recently announced by Raytheon Company, the #6177 Magnetron is compactly designed for height finding, other airborne radar uses. Size is small, weight only 1 lb, range is 4261-4300 megacycles at 1 watt.

To insure the magnetron's operating reliability, Raytheon designers use 4 nickel alloys in 13 critical parts. (8 parts are numbered in above photo.) Designers report why:

Electronic Grade "A" Nickel offers outstanding purity in ribbon (1).

Inco "220"* Nickel assures proper outgassing in washer ring (2), tube (3), tube shield (4).

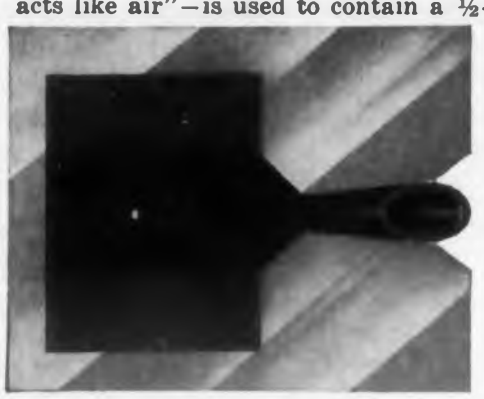
Another nickel-chromium alloy retains non-magnetic characteristics in reed (5), and reed coil support (6).

Alnico (nickel-iron alloy) magnets provide stability (7); cupro-nickel pole support provides strength, non-magnetic characteristics (8).

Pertinent Literature: **Send for 51-B; "Nickel Alloys for Electronic Uses" (see box, below) and T-15; "Engineering Properties of Nickel."**

Metal that acts like air wraps half-mile vacuum

UPTON, N. Y. In the huge new 25-Bev Synchrotron at Brookhaven National Laboratory, Inconel "X"* age-hardenable nickel-chromium alloy—"a metal that acts like air"—is used to contain a ½-mile-long proton beam vacuum cavity.



Tube of low-magnetic Inconel "X" alloy carries Synchrotron's 25-Bev proton beam between magnet jaws. Tube's assembled, in sections, into a circle ½ mile around.

Inspecting one of Synchrotron's 240 magnets. This one weighs about 17 tons. Inconel "X" tube fits into narrowest gap between jaws.

Principal reason for the selection of Inconel "X" alloy, reports Brookhaven, was its high electrical resistivity. This resistivity, about 740 ohms per circular mil-foot, results in the avoidance of high eddy currents. In addition, the low magnetic permeability of Inconel "X" alloy, approximately the same as air, has virtually no effect on the strong magnetic field passing through the tube walls to guide the proton beam.

Inconel "X" also benefits vacuum cavity tube in other ways

Its high structural strength permits thin-wall construction—tensile strength after heat treatment, above 130,000 psi. Other physical properties important to this application—the alloy's low vapor pressure, good degassing, freedom from porosity.

Inconel "X" alloy provides good fabricability, too—tube is formed in sections from 0.078-inch sheet, welded and flanged.

Pertinent Literature: **Send for 51-B; "Nickel Alloys for Electronic Uses."**

Monel speeds sound brazing of resistor caps

Close-up of Monel caps soundly brazed to wire winding and leads of semi-finished resistor. Made by Sage Electronics Corporation, 302 N. Goodman St., Rochester 7, N. Y.

ROCHESTER, N. Y.: Monel* nickel-copper alloy now makes possible, fast, sure brazing of connections in resistors designed for severe service by Sage Electronics Corporation (see photo, left).

In the caps, Monel alloy also gives excellent resistance to corrosion in murderous environments... and provides essential strength for anchoring leads.

Monel boosts durability in other electronic components, too

In one magnetron, for example, Monel alloy provides an output flange and mounting plate with the toughness and strength needed for 6000-hr life. In fastenings, Monel alloy stands up against both corrosion and hard knocks. In backing for contact points, Monel alloy contributes important strength and brazing properties.

Pertinent Literature: **Send for 51-B; "Nickel Alloys for Electronic Uses" and T-5—"Engineering Properties of Monel and 'R' Monel."**

*Inco trademark

Designing for Maintainability

vironment, the specific costs of supporting the system (with supplies, test equipment, and maintenance men), and costs of down-time or failure.

There are no absolute rules though there are useful guides. One approach is provided by R. E. Kuehn, manager of reliability engineering at IBM Corp. In a paper presented before the Second EIA Conference on Maintainability of Electronic Equipment, Mr. Kuehn recommended that throw-away modules be designed to have a mean-time-to-failure of 2.5 times the design operating life.

Mr. Kuehn provided economic justification for the throw-away module (in aircraft equipment) on the basis of the costs of unreliability and on the higher reliability and volumetric efficiency of the non-repairable module.

In addition to lower cost, he cited supplementary, hard-to-measure advantages of the throw-away module. Using non-repairable units, he said, gives 50 per cent more volume and a 40-per cent lower failure rate.

The contradictory evidence provided by different maintainability studies shows, not only that each system must be studied separately, but it highlights another fact as well: Maintainability is still young.

Some of the pioneering works in this field are only four years old.* At that time, maintainability was a rather unnoticed stepchild of the discipline of reliability.

Its recognition as an important discipline, when it began to stand on its own feet, began three years ago with the First EIA Conference on Maintainability of Electronic Equipment in December 1957. The second conference,†† held in May 1958, solidified maintainability's position as a recognized discipline.

The third such conference will be held in San Antonio on Dec. 5, 6, and 7.† This conference

* See bibliography for a brief list of some of the important maintainability studies.

† Papers presented at the first and second conferences are included in "Maintainability of Electronic Equipment," available from Engineering Publishers, P. O. Box 2, Elizabeth, N. J. at $6.00 for both. Papers to be presented at the Third EIA Conference on Maintainability of Electronic Equipment, are included in "Maintainability of Electronic Equipment—Vol. 3," now available from the same publisher at $10.00.

should resolve or at least shed more light on many of the problems that confront design engineers. For example, Dr. M. J. Marcus of IBM's Military Products Div. will identify those factors which remain invariant from one hardware system to the next.

Other speakers will nail down other elusive aspects of designing for maintainability, such as how to determine the operational availability of complex systems, how to evaluate automatic test equipment, and how to forecast the requirements for spare parts.

The Third EIA Conference on Maintainability of Electronic Equipment will surely add maturity to a young field which is growing, and indeed, must grow, very, very rapidly. ■ ■

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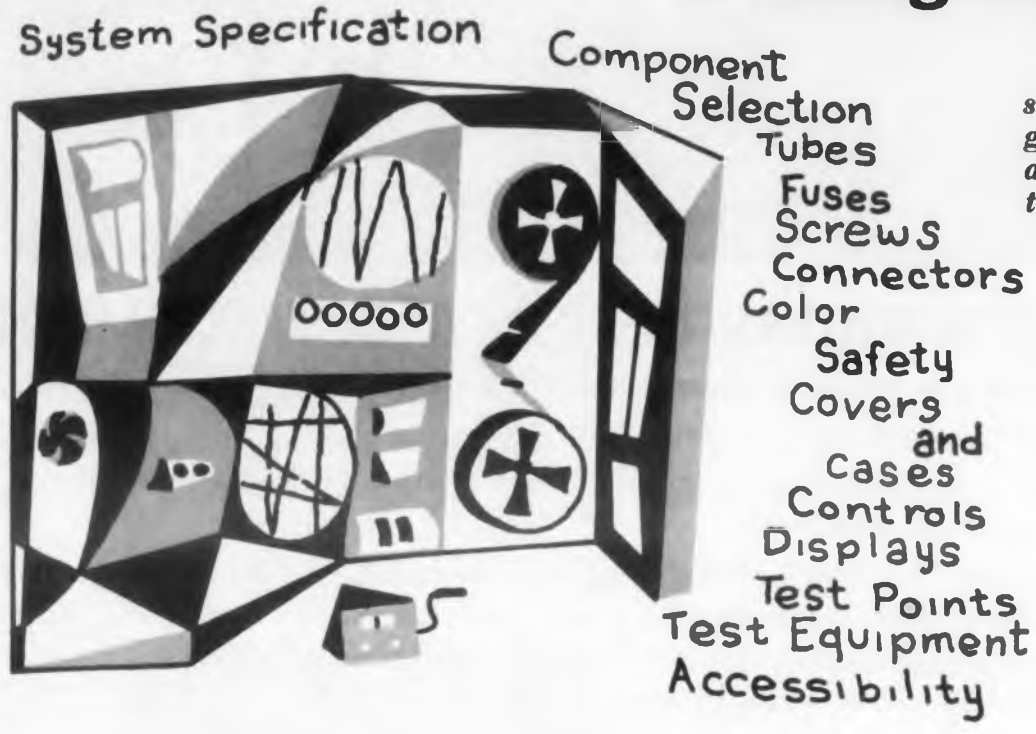
TECHNIQUES

Techniques in Designing for Maintainability



Though no single maintainability technique can serve all systems with equal value, the guidelines, the general approach, and the specific suggestions in this article should prove invaluable to all designers of maintainable equipment.

J. F. Corso, J. M. McKendry, G. Grant
HRB-Singer, Inc.
A unit of the Singer Military Products Div.
Singer Manufacturing Co.
State College, Pa.*

SOLUTION of the maintainability problem lies mainly in the designer's hands. The designer must realize that each of the three phases in the maintenance process brings about unique problems.

In fault detection, a technician must sense a change which has some visual, auditory, or tactual consequence. The best way to solve this problem is to display indicators of degraded performance in such a way that the probability of detection is maximized.

The second phase, fault localization, involves a complex problem which mixes elements of problem solving with those of information display. This problem is best solved by decreasing complexity and increasing the probability of information transfer.

Finally, the third phase, fault correction, is primarily a problem of accessibility and skill.

These problems in the maintenance process have stimulated several approaches to their solution. Each approach has brought with it further problems of its own. One approach attempts to improve the proficiency of the technician by training. But the turnover of military maintenance personnel is so great that there is not sufficient time to train these people.

Another approach tries to provide equipment with maximally effective maintenance manuals. Benefits here are limited by the design techniques which may be available.

A third approach tries to head off troubles before they occur by periodic replacement of parts. But this technique assumes that electronic components gradually wear out in some predictable fashion—a belief which, for the most part, has been contradicted by a large body of research.[1,2]

Offering most promise is the approach of designing for maintainability. But here it is essential that positive steps be taken as early as possible to avoid costly equipment redesign.

Specific suggestions to help the designer through various decisions he must make are presented here.

Maintainability Starts With System Specification

Preliminary engineering work traditionally begins with a careful study of customer demands and ends with the production of a preliminary system description of the proposed equipment in block-diagram form.

The first important step during this phase is to fix responsibility for maintainability. This is best done by assigning one person to the job of insuring that suggestions provided in available guidebooks[1] are followed. The second step is to study the maintenance structure of the potential user. This should reveal the levels of maintenance support which are available, the skill level of the servicing technicians working at each level, and the peculiarities associated with each work environment.

As the equipment begins to take shape in the form of a rough block diagram, the designer should remember two more points. At this point in the operation he should:

- Try to choose elements or stages with clearly defined output characteristics. The best choice from the technician's viewpoint is something which works in an "all-or-none" fashion.

- Try to eliminate complex feedback loops which confuse the troubleshooter. If the designer cannot eliminate complex feedback, he should provide additional checks on interacting stages. One way is to provide a switch to decouple the feedback.

When a tentative block diagram is available,

* Mr. Corso is also Professor of Psychology at The Pennsylvania State University, University Park, Pa.

the designer can make two more decisions—one on packaging, one on checkout facilities. Recent research[3] has shown that some packaging techniques are more effective than others.

Four Packaging Techniques Serve Different Needs

Four of the important packaging techniques are:

1. The Standard Method. This technique has no clearly defined rationale other than a compromise between conflcting demands such as heat dissipation, weight and size limitations, impedance difficulties, etc. The technique prevails in radios and TV sets. It provides little uniformity from one equipment to the next so the technician must learn each new layout. He may have to study complex schematics to understand how different elements work together.

2. The Circuit-Grouping Method. With this technique, each individual circuit is in a plug-in module, and similar circuits are grouped in one location. This method is particularly conducive to the use of automatic test equipment.

3. Component-Grouping Method. Here, all similar components are grouped in one place on the equipment. For example, all tubes are together, all transistors are together, and cheap components like resistors and capacitors are on separate plug-in boards which are mounted under the chassis. Justification for this method is that components which require much time to replace can be checked by a mass-replacement technique that still keeps costs low. There is also great potential for a simplified checkout procedure when all the elements in one place are similar.

4. Logical-Flow Packaging. Here, modules and sub-assemblies parallel stages on a block diagram so their layout makes sense to the technician. Simple input and output checks can be provided for each unit and interaction effects can be handled by separating feedback loops from the main line so the loops appear to have a unidirectional signal flow.

Logical Flow Method Best, Standard Method Worst

Investigations have shown[3] that the circuit grouping, component grouping, and logical flow

methods are all superior to the standard method in reducing fault localization time. The logical-flow method is best.

Clearly Identified Test Points Simplify Checkout Procedures

Clearly identified test points can simplify system checkout procedures. These points should be visible from the top of the equipment and should have jacks so test equipment can be attached easily. Two levels of test points should be used and they should be differentiated by color coding if possible.

The first set should help isolate a fault to a particular equipment in a complex system. The second set should help localize a trouble to a specific subassembly within a unit. The same process can be applied again, at a later stage in design, to provide test points to pinpoint a trouble to a specific module. The test-point system is much easier to achieve with the logical-flow method of packaging.

Intermediate Design Phases Become More Specific

In the intermediate phases of design, the work usually starts with specification of circuits and ends with specification of components. Hence, the work becomes progressively more concrete and the maintainability suggestion becomes more specific.

Standardized Circuits can provide three substantial advantages: a saving in design time, a saving in manufacturing cost, and a saving in maintenance time employed for increased reliability and increased familiarity on the part of technicians.

Circuit Simplification, an important maintainability consideration, can best be achieved using these procedures:

1. Use standardized circuits where appropriate.
2. Design and package similar circuits in the same manner for interchangeability and quick substitution checks.
3. Avoid circuits with critical characteristics and close-tolerance parts.
4. Standardize component layout.
5. Package each functional change separately.
6. Avoid criss-crossing of signals between circuits.

Test Points should be provided to monitor important circuit parameters. Highest priority should be given to those parameters which yield most information[4] in troubleshooting. Most important tube-circuit parameters are:

> Pin voltages, Output waveform, Input-signal voltage, Output-signal voltage, Input waveform.

Less important tube-circuit parameters are:

> Grid-signal voltage, Plate-signal voltage, Grid waveform, Pine resistance, Plate waveform, Cathode-signal voltage, Cathode waveform.

Most important transistor-circuit parameters:

> Output-signal voltage, Output waveform, Pin voltages.

Important transistor-circuit parameters are:

> Input-signal voltage, Collector-signal voltage, Base-signal voltage, Emitter-signal voltage.

Less important transistor-circuit parameters:

> Pin resistances, Input waveform, Emitter waveform, Base waveform.

The data for transistor circuits are not as well substantiated as those for tube circuits.

Prototype Layout should lead to rapid location, rapid removal, and rapid replacement of faulty components.

Component Selection Has Two Prime Guideposts

Component selection should be guided by two dictates: (1) Choose reliable components. (2) Choose components which can be removed and replaced easily.

Beyond these principal considerations, special attention can be given to different component types.

With Tubes—

1. Avoid selected tubes.
2. Don't use tubes in applications which require the use of parameters not controlled by procurement specifications. For example, don't use a thyratron as a noise source.
3. Orient miniature tube sockets with their gaps facing one direction to expedite tube replacement.
4. Make tubes accessible so replacing them does not require unit disassembly.
5. Secure tubes and other plug-in items with positive-holding clamps which are easily released.
6. Space unshielded tubes at least 1-1/2 tube diameters apart.

With Fuses—

1. Fuse each unit of a system separately.
2. Put fuses on front panels where they can be seen and replaced without removing other parts.
3. Provide spare fuses in a convenient location.
4. Have fuses replaceable without tools.
5. Remember that fuses in unpressurized areas of aircraft cannot be replaced in flight.
6. Use indicator-type fuse holders.

With Screws—

1. Use screws with enough tensile strength to take normal wear.
2. Don't use too many screws. If four screws will hold a plate, do not use 16.
3. Use as few types as possible. Alternation between slotted-head and Phillips-head screws forces the repairman to dig through his tool box.
4. Where different type screws are needed, be sure they can be identified readily.
5. Use different sizes for screws with different threads to avoid screws being forced into wrong holes and stripped.
6. Use bolts which require only a few turns to be secured or loosened.
7. Use rack-mounting bolts or nuts which are semi-permanently attached to rack members to avoid the need for holding both nut and bolt.

With Mechanical Fasteners—

1. Avoid hardware requiring non-standard tools.
2. Use captive fasteners.
3. Favor hand-operated fasteners which require no tools.

With Connectors—

1. Make cables accessible.
2. Fan them out in junction boxes if other test points with the same information are not provided.

Other Considerations Follow Component Selection

After choosing and using components optimally from the maintenance viewpoint, the designer must consider other factors which play an important role.

With Color-Coding—

1. Use vivid, attention-getting, permanent colors.
2. Use no more than 10 colors with one equipment.

3. Keep the meaning of a particular color consistent throughout a prime equipment and its maintenance support.

For Safety—

1. Provide means to disable each interlock temporarily, so equipment can be serviced with power on.
2. Use an indicator to show when power is on.
3. Place checkpoints away from dangerous components or potentials.
4. Leave extra space around high-voltage parts.
5. Don't expose hot leads on disconnected plugs and connectors.

With Covers and Cases—

1. Mount chassis requiring frequent removal on roll-out racks or slides.
2. Have roll-out chassis lock automatically in a servicing position.
3. Provide limit stops to prevent pulling a chassis out too far. But have units free to open their full distance and remain open without being held.
4. Design cases to be lifted from units rather than the reverse. Cases are lighter.
5. Design cases to slide easily without interfering with wiring.
6. Make the method of opening covers obvious or attach a permanent instruction plate to the outside of the cover.
7. Make it obvious when a cover is in place but not secure.
8. Make ventilation holes small enough so test probes or other conductors cannot be inserted inadvertently.
9. Provide extra-large holes to pass mounting screws through covers or shields.
10. Make cases and covers larger than their units so wires and other components aren't damaged when cases are put on or taken off.
11. Use guides, guide pins, or tracks to prevent cases from cocking to one side.
12. Fasten panels, covers, and access doors with captive springbolts or screws, drawer bolts, trunk fasteners, dogs, levers, and latches to provide quick and easy access to interiors.
13. Design and space fasteners to be consistent with the required degree of enclosure and frequency of required access.
14. Use the same type fastener for covers and cases on a given equipment.
15. Use quick-acting fasteners for dust covers.
16. Use fine-threaded screws for pressurized units.
17. Design for only one access panel to be opened for removing and replacing a unit.
18. If opening space is a problem, use double-hinged doors.

(continued on p 40)

With Controls—

1. Minimize the number of controls and indicators.
2. Make all controls, knobs, switches, and dials uniform when they are used for a similar purpose.
3. Use selector switches for scales and functions rather than multiple jacks.
4. Arrange controls by order of operation.
5. Distribute tasks for both hands equally.
6. Indentify control positions unambiguously.
7. Design controls to turn in a way compatible with the usual human tendencies—clockwise for increase, counterclockwise for decrease.
8. Mount often-used controls at elbow height but have them near displays they affect, if possible.
9. When order is important, design equipment so controls will not operate unless proper sequence is followed.
10. Position knobs and settings for a particular instrument in the same place on new models.
11. Prefer less complex controls such as toggle switches, jacks and plugs, pushbuttons, and selector switches.
12. Wire toggle switches so "on" is in the upper or right-hand position, and "off" is in the lower or [illegible] position.
13. Don't require too much finger pressure on push buttons.
14. Provide enough spring loading so selector switches are not left between detents.
15. Design linear-control knobs, so a slight movement of the knob does not result in a disproportionately large display change and large movement of the knob does not produce a disproportionately small display change.
16. Use hand-operated knobs for frequently used controls rather than tool-operated knobs.
17. Increase the size of knobs as the force required to operate a control increases.
18. Locate maintenance controls where they can be seen and operated without disassembly or removal of any part of the installation.
19. Have maintenance controls screwdriver-adjustable, and those which are used also as operating controls knob-adjustable.
20. Keep controls away from high voltages and hot tubes.
21. Keep adjustments in a single area.
22. Use round knobs for smooth, continuous movements in operation.
23. Use bar or pointer-type knobs for detent-type switching.

With Displays—

1. Locate displays used in system checkout so they can be observed from one position.
2. Mount checkout displays at proper eye height.
3. Arrange displays so an operator can't cover a display while manipulating a control.
4. If a display must be located in a difficult viewing position, provide a mirror.
5. Arrange dial elements to be coplanar to avoid parallax.
6. Have display devices providing special warnings and cautions as near as possible to parts of the equipment to which they apply, and have them indicate that they are directly usable without further corrections or interpretations.
7. Have display scales provide only the information actually needed.
8. Make the indicators on center-null displays fall out of the in-tolerance position if power fails.
9. For increasing functions, have a pointer move clockwise past a fixed scale or have a moving scale move counterclockwise past a fixed pointer.
10. Provide for pilot-lamp replacement from the front.
11. Distinguish between different scales in the same instrument.
12. Make apertures in open-window dials wide enough to show at least two numbers.
13. Use similar scale progressions on dials on the same panel.
14. Provide displays which show when an instrument is not operating properly.
15. Use numerical scales only when a technician must have quantitative information.
16. Avoid irregular scale breakdowns.
17. Differentiate scales by color coding.
18. Label displays with the functions indicated.
19. Avoid the need for scale conversion. If arbitrary scales are essential, list necessary conversions in a table attached to the instrument.

With Test Points—

1. Label test points clearly.
2. Indicate standards and tolerances at each test point.
3. Show location of all test points on a plate on the outside of the equipment.
4. Label test points to correspond with similar designation on schematics.
5. Label test points with the designation of the unit being tested.

Test Equipment Planning Must Take Place Early

Early in the planning stages, the prime-equipment designer must consider the types of tests and test equipment which will be required, the maintenance procedures and materials, and the logistics support. He will have to decide whether tests should be made by general-purpose test equipment, built-in monitoring equipment, or automatic or semiautomatic-checkout equipment.

In specifying test equipment, the designer must remember that technicians often do not use certain test equipments because they believe they are inaccurate, inoperative, or difficult to operate. It is therefore essential that test-equipment design be simplified. The following measures can help.

With Test Equipment—

1. Provide a simple method for checking the accuracy of test equipment with an auxiliary calibration instrument.
2. Build in some signal which will indicate when the equipment is functioning and when it is not.
3. Provide devices to show that a correct manipulation has been performed before actual testing is done.
4. Minimize the amount and variety of test equipment required by a procedure.
5. Obviate conversion of one type of reading to another, such as milliwatts to dbm.
6. Use standard test equipment at all echelons of repair.
7. Provide sturdy test equipment in square or rectangular form, with recessed or hinged handles.
8. Provide adequate storage space for leads, adapters, and other removable items in the lid or cover.
9. Have closing of the lid shut off power.
10. Provide break- and scratch-resistant windows for dials.
11. Keep dial pointers stationary while equipment is being transported.
12. Prefer selector switches to plug-in connections.
13. Where plugs are necessary in test equipment, use plugs with pins that are stronger than those which would be used for regular equipment.
14. Attach test leads to test equipment permanently.
15. Use shock mounts on fragile test equipment.
16. Design for eye appeal. Drab and unattractive equipments invite rougher treatment.

Write Maintenance Manual For User—Not Designer

To help the maintenance technician, each equipment should have a good maintenance manual. It should be scaled to his exact needs at each logistic level.

In general, the manual should be kept as simple as possible. Its preparation should begin in the early design stages and its development should parallel design progress. In its final form, it should be written by a communications specialist in the language of the maintenance man—not the designer.

Manual Should Include—

1. Essential test voltages and waveforms.
2. Typical performance limits.
3. Typical maintenance routines.
4. Symptoms of malfunctioning equipment related to probable causes.

Whole Must Be Accessible As Well As Parts

So much of designing for maintainability entails accessibility to parts of equipment that some designers, in concentrating on parts accessibility, forget over-all accessibility. Designers, in all cases, must consider the environment in which equipment must operate.

It is of little use to provide rear-access doors on an equipment which must be mounted rigidly against a wall. It is just as bad to provide access to the top of an equipment which will stand just a few inches from the roof of a van.

It may be a fine practice to mount seldom-used controls behind an access port, but the advantage is negated if the access port is too small for a hand or a tool to get into and move. ■ ■

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Acknowledgment

This article is based on work supported by the U. S. Navy under Contract N61-339-330, monitored by the Flight Trainers Div., Human Engineering Dept., of the U. S. Naval Training Device Center, Port Washington, N. Y. The opinions and conclusions in this paper are those of the authors. They are not to be construed as reflecting the views or endorsement of the Department of the Navy. Acknowledgment is made to The Singer Military Products Division and to members of the technical staff at HRB-Singer: George Herlt, Frank Baxler, Fred Scheihing, Robert Brubaker, Paul Baker, and Charles Smith. In addition, assistance and enthusiastic support were contributed at the Naval Training Devices Center by: Halim Ozkaptain, Martha Guestella, and Harold Voss.

Designing for Maintainability

ACTION

Maintainability in Action

HUNDREDS of features can contribute to equipment maintainability. Though almost all these features seem obvious, and though it would seem that even a modicum of "common sense" would dictate their use, truly maintainable designs stand out as exceptions rather than the rule.

Many of these design features are small points, mere details, easily overlooked in the scramble to rush an equipment into production. Presence of these details is rarely noticed. Their absence is recognized immediately by the maintenance technician whose colorful comments it might be good for the designer to hear.

Recent military emphasis on maintainability has prompted many manufacturers to become conscious of this discipline. Other manufacturers have been designing for maintainability for years. Results of some efforts are shown here.

Key Feature, Accessibility, Embodies Other Features

Accessibility is probably the most important single feature in maintainable equipment. A very broad quality, it encompasses many other features. It is served by roll-out and swing-out cabinets, conveniently placed test points, open construction, quick-acting fasteners and couplings, properly grouped controls, well designed layouts, modular construction, and a host of other design features. Examples of accessibility can be seen in virtually all maintainable equipments.

Accessibility at many levels is incorporated in a complex system designed by Lockheed Electronics Co. of Plainfield, N. J. The photographs in Figs. 1 to 3 show several levels of access.

Fig. 1. Swing-out door provides rf shielding and drip-proofing for drawer-mounted chassis in this piece of Lockheed equipment.

Fig. 2. Push-to-unlatch catches give quick access to drawer-mounted chassis.

Fig. 3. Chassis slides out to give top access, then tilt up for bottom access.

Output Monitors Give Front-Panel Fault Warning

Richard Holmberg, manager of LEC's Shipboard Electronics Dept., cites other aspects of the equipment which further improve its maintainability. Monitors, attached to the output of each pulse-circuit board, energize front-panel lights, whenever there's a malfunction. The equipment thus localizes a trouble to an individual plug-in circuit board which can quickly be replaced.

On analog circuits, pulse monitors are not effective, so another approach is used. Meters are provided to monitor signals between individual modules, and test signals are provided to further isolate a fault to a module. A separate module tester can check every module in the system.

Computer Like an Open Book, Gives Rapid, Easy Access

An unusual approach to accessibility is apparent in the PB-250 general purpose computer manufactured by Packard Bell Electronics Corp. in Los Angeles. The computer (Figs. 4 to 6) is book-shaped.

Industrial designer Bernard Caminker and mechanical designer Jack Peterson are responsible for the unusual mechanical features of this computer. In addition to these maintainability features, the machine also includes a diagnostic test routine.

For error diagnoses, a special tape is run

Fig. 4. Book-shaped Packard Bell computer slides out of "book-case" in rack version; sits on cast base in desk-top model.

Fig. 5. Computer opens to expose pages of wiring and input cables which travel up spine and branch out to logic modules.

Fig. 6. Back of book exposes connections and plug-in modules of which there are only 13 types.

through the machine and pushbuttons can select any of 13 levels of test. The machine will print out any failures and identify a specific function group responsible.

If a technician finds, for example, that an adder group is at fault, he can remove an entire group of perhaps four or more cards, replace them with spares, and test the other cards separately. To simplify this maintenance job, Packard Bell hopes to have a special card tester available in a few months.

Book-Type Package Serves Large Computers, Too

The book-type package can be used in large computers as well as in small ones. It is used, in fact, in one of the largest-scale, general-purpose computers available, the 1604, manufactured by Control Data Corp. of Minneapolis.

In the 1604 (Figs. 7 and 8), pages of the book are substantially larger than they would be in a small computer, and there are eight of them, each with room for 1,000 PC cards.

Fig. 7. Pages in the book-shaped layout of large-scale, Control Data Corp. computer can hold 1,000 PC-card modules as well as core arrays.

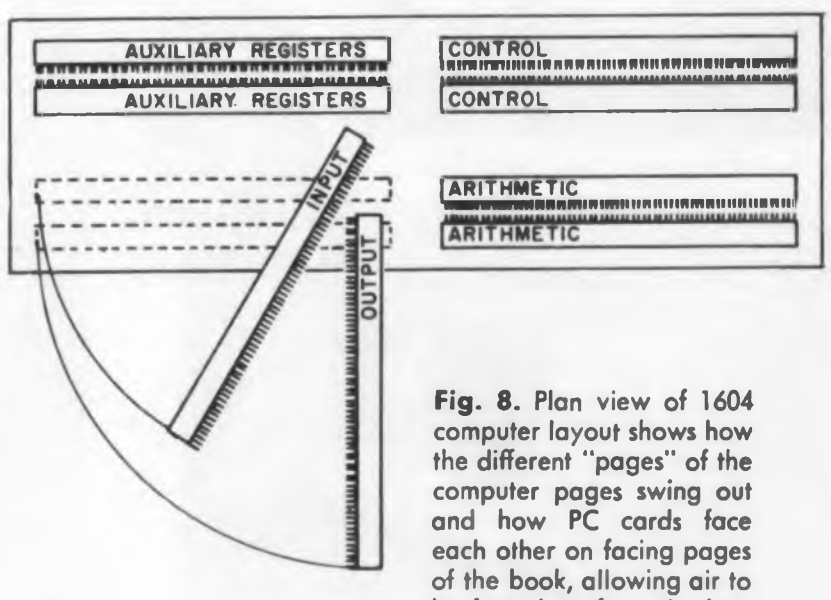

Fig. 8. Plan view of 1604 computer layout shows how the different "pages" of the computer pages swing out and how PC cards face each other on facing pages of the book, allowing air to be forced up from the bottom of the cabinet between the cards.

Mr. C. T. Casale, senior engineer responsible for the layout of the 1604, cites additional maintainability features. Scope access to every single card in the machine is provided, even with the computer operating. In the storage sections of the machine, replaceable magnetic-core arrays are located near their associated PC cards.

The storage section on each of the eight chassis is identical so maintenance personnel need learn the locations of only a small number of cards. Within each storage section, cards are grouped along the same functional lines.

Functional grouping is used throughout the computer so maintenance men rarely have to refer to diagrams. The computer console can reveal any failure in any chassis, then a built-in algorithm, the Storage Sweep mode, can be cycled through the core storage to pinpoint an ailing PC card.

Sit or Stand to Reach Maintenance Controls

To further enhance accessibility and ease in fault location, the 1604 has a combined maintenance and operator's console with all necessary controls. Maintenance and operator switches, though they are separate, are positioned so they can be used from either a sitting or standing position.

Diagnostic routines and a high order of accessibility are by no means unusual in computers.

Virtually every computer manufactured in the

Fig. 9. Only 11 basic modules serve entire numerical control system designed by Hughes Aircraft Co. Unusual modules have components neatly stacked in cordwood fashion and soldered in slots in plastic spacers.

past few years shows a great deal of attention to improved maintainability and reduced downtime.

Sophisticated Routines Can Pinpoint Troubles

Several sophisticated routines appear in the Mobidic computer, developed at Needham, Mass., by Sylvania's Data Systems Operations. These routines differ from most others in that, with the aid of a special manual, they can localize a fault to a small group of transistors, or even to a single transistor. A preventive maintenance system in Mobidic can be used to force all marginally operating transistors to fail during a scheduled maintenance period.

Describing some of Mobidic's maintainability features, Joel Cohen and Lewis Whitaker point to the console. It has built-in alarm indicators that quickly indicate certain types of machine malfunctions or program errors.

Cordwood-Stacked Modules Instead of Printed Circuits

A departure from the conventional, PC-card modules appears in Hughes Aircraft Co.'s NC-200 numerical control system for machine tools. In this system, according to Don Davern who heads the machine-tool controls group, most components that can fail are in the logic circuits. These are packaged in modules of which there are only 11 basic types (Fig. 9), and these can be stored in a spare-parts kit.

If the machine-tool control system should stop working, even an unskilled workman can simply pull out and replace one module after another until the machine starts again. All modules are clearly labeled and keyed to the chassis.

Accessibility Features Take Many Forms

A variety of accessibility features can be seen in some of the equipment manufactured by Radio Engineering Laboratories, Inc. of Long Island City, N. Y. Figs. 10 to 14 show a number of these features, including wheel-out carriages for klystron assemblies, swing-out and lift-out doors, and some unusually simple coil supports.

Fig. 10. Receivers (above), for the Atlantic Pact, manufactured by Radio Engineering Laboratories, provide front- and rear-door access.

Fig. 11. Convenience outlets (left) on NATO communications receiver allow test equipment and tools to be plugged in right at working area.

Fig. 12. Stepped coil supports (right), easily turned aside with a few turns of a screwdriver, allow large coils on klystron carriage to be lowered easily, then returned to their exact original position.

Fig. 13. Entire klystron carriage (left) rides on wheels on NATO "Ace High" 10-kw power amplifiers. Tracks guide entire assembly which can be rolled in or out for maintenance.

Plug-in modules can be used to house not only conventional electronic components, but electromechanical components as well. The amplifier of Fig. 15 includes a number of such plug-in modules (Fig. 16). Each is secured to the chassis by two screws. The front panel has connectors for making all system interconnections as well as a convenient test-point area.

A key part of the HU2K-1 helicopter automatic stabilization system, this particular module concept was evolved in broad terms by the Kaman Aircraft Corp. of Bloomfield, Conn., with the final design detail and manufacturing accomplished by John Oster Manufacturing Co. in Racine, Wis.

99 Per Cent Plug-In in Digital Voltmeter Series

Some rather new devices showing very close attention to maintainability factors are the digital voltmeters manufactured by Non-Linear Systems, Inc. of Del Mar, Calif. In these meters, plug-in stepping switches can be changed in three minutes rather than the two to twelve hours normally required. Voltage-divider decade resistors are also packaged in plug-in containers so they, too, are completely interchangeable.

In the Series 20 instruments (Fig. 17), four of the circuit boards are completely interchange-

Fig. 14. Performance-monitor panels on BMEWS communications equipment, designed by REL, are mounted on hinges which are secured through special slottings. Panel can be swung out or removed entirely.

Designing for Maintainability

ACTION

Fig. 15. Some of the plug-in modules in this amplifier (left) contain conventional electronic circuits. Others house mechanical assemblies. Module design is joint effort of Kaman Aircraft Corp. and John Oster Manufacturing Co.

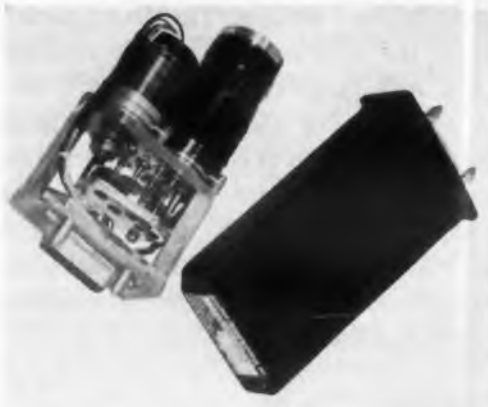

Fig. 16. A typical electromechanical module (right) before and after being hermetically sealed.

able. A failure of any one of them does not cause the instrument to fail completely. Instead, the malfunctioning circuit board can be inserted in the least significant decade and the voltmeter can be used as a three-digit instrument rather than a four-digit instrument.

Test-equipment manufacturer Hewlett-Packard of Palo Alto, Calif., has several approaches to improving maintainability. In each equipment, H-P lays out components to assure accessibility. Internal controls required for periodic maintenance and/or recalibration are grouped and clearly identified.

Infrequently used controls are normally not accessible to the operator. This reduces the possibility of accidental or unintentional adjustment. Frequently used calibration controls are often grouped behind access doors so the instrument can be calibrated without being removed from its cabinet.

Fig. 17. More than 99 per cent of the components on this Non-Linear Systems digital voltmeter are on plug-in modules. Even the digital readout snaps out for easy lamp replacement.

H-P also provides manuals with very thorough maintenance information and troubleshooting procedures.

Different Techniques Needed For Different Requirements

Mr. R. E. Young, electronics manager at Sir W. G. Armstrong Whitworth Aircraft Ltd. of Coventry, England, reports on a number of techniques used to improve equipment maintainability. The "open" construction illustrated in Fig. 18 maximizes access to components. The standard base on which the components are mounted also serves as an excellent heat sink.

Of course, where high component density is a paramount consideration, this approach is not satisfactory; the one shown in Fig. 19 is better. Here, specific functions are isolated within appropriate equipment blocks which are easily withdrawn from a larger assembly. The isolation helps eliminate undesirable interaction between circuits during tuning and adjustment.

In this Armstrong Whitworth Aircraft equipment, each module is laid out to protect vulnerable parts from damage during service. Thus, when a module is placed on its side for service, it will rest on a pair of pillars or on a sturdy, metal-cased capacitor.

Patchboard Test-Point Area Provides Circuit Nerve Center

Engineers at Hagan Chemicals & Controls, Inc. in Pittsburgh rely heavily on the use of modular construction to improve maintainability. Each module has a patchboard (Fig. 20), with test points wired to important circuit junctions.

Product-engineering manager, Robert Nelson, points to an additional advantage of these access points in an analog control system. For special system requirements, they can be wired to external relays or switches to provide additional circuit flexibility.

In the Hagan equipment, the use of access points is carried over to a system nerve center (Fig. 21), where interconnections between operational-amplifier modules, panel-control stations, transducers, and final control elements are

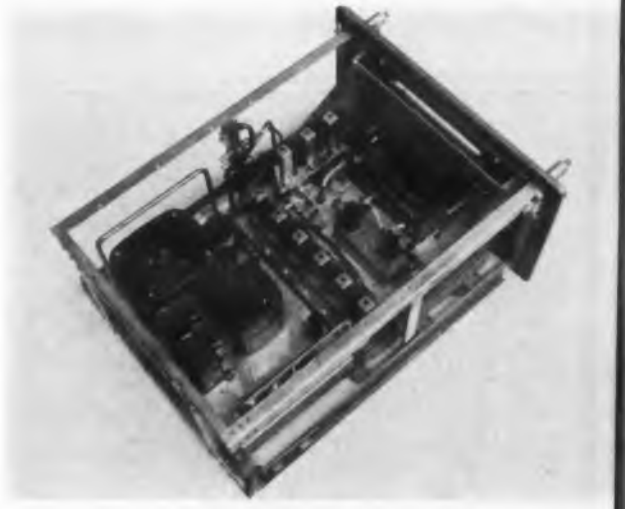

Fig. 18. Airy, open construction in this Armstrong Whitworth Aircraft Ltd. uhf receiver makes everything easy to get at. But component density is low.

Fig. 19. For higher component densities, AWA isolates functions to specific plug-in blocks.

brought to another patchboard. There, each module is identified by a number and each wire by a letter.

Centralized Nerve Center In Pull-Out Drawer

A particularly convenient application of the "nerve-center" approach appears in Minneapolis-Honeywell's load and frequency-control system. All critical test and calibration points in this system are brought out to a single, pull-out drawer (Fig. 22), providing a centralized, accessible, test area. The Honeywell system also uses plug-in modules for all major components of the system.

Expendable Module Concept To Lower Operation Cost

The plug-in module has become an accepted feature in a vast array of equipments in the past few years. It was popular even before great emphasis centered on maintainability. But with the growing emphasis on maintainability, a new type module has come to be recognized, and with it, a new philosophy has come to receive more and more serious attention.

In about 1 cu-in., the new type module is, of course, the expendable one—designed to be thrown away if it should fail. Lear, Inc. of Grand Rapids, Mich., has designed such a module—a hermetically sealed, oil-filled, throw-away module with components mounted on a flexible pc board (Fig. 23).

Roy Malarik, responsible for the design of the Lear module, points out that the most complex of these standard modules, a seven-transistor amplifier, has a predicted mean time to failure of 1,200 hr and a price of about $180. These characteristics compare very favorably with the optimum module size proposed by the National Bureau of Standards.*

The NBS study, considering only vacuum-tube modules, concluded that an optimum expendable module should have from four to eight tubes; it should have an average mean time between failures of 1,000 to 2,000 hr; and it should cost between $95 and $185.

Varied Approaches To Power-Supply Design

That there are different approaches to maintainability is apparent in the power supplies

* The NBS report, "Expendable Modules as Bases for Disposal-at-Failure Maintenance," is available at $2.25 from the Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. A digest of this report appears in ELECTRONIC DESIGN, Aug. 17, 1960, pp 156-159

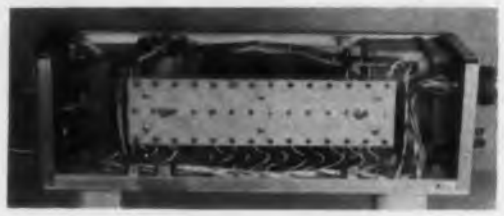

Fig. 20. Chassis patchboard gives access to important circuit junctions in this piece of equipment designed by Hagan Chemicals & Controls.

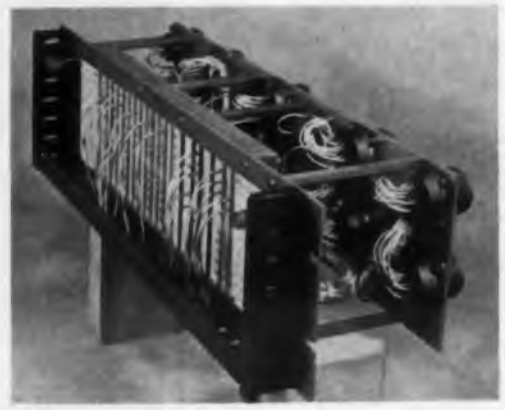

Fig. 21. System patchboard serves as nerve center for entire equipment.

designed by two manufacturers—Mid-Eastern Electronics, Inc. of Springfield, N. J., and Victory Electronics, Inc. of Westbury, N. Y.

Mid-Eastern, a test-equipment manufacturer who made no power supplies, conducted a survey and learned that power-supply users were complaining. They objected to the fact that if something went wrong in a power supply, it was extremely difficult to troubleshoot the unit since parts layout was awkward and parts were inaccessible. The power-supply users also complained about the use of balanced amplifiers with selected transistors.

In response, Mid-Eastern provided a line of 19 power supplies using pre-assembled, standard, plug-in modules (Fig. 24). Three of the modules are interchangeable for all models in the series. Five other modules can be used for a variety of different voltage-current combinations. The entire series uses identical color coding.

Since there are no selected parts in the units, and since they all are designed along identical lines, a technician who learned to repair any model could easily repair all 19.

Power Supply in Two Parts To Reduce Down Time

A somewhat simpler approach to power-supply design appears in the supplies manufactured by Victory Electronics. Reasoning that the basic power supply, with a transformer, choke, and silicon diodes is quite reliable, and that elements for close regulation—transistors and feedback circuitry—are less reliable, Victory designed two separate units.

A basic supply provides 1 per cent regulation. A separate regulator, for 0.25 per cent regulation or one for 0.05 per cent regulation, can be mounted on the basic supply without any change of wiring. Both basic supply and external regulator can be operated independently.

By separating the more complex regulator from the basic supply, Victory feels that maintainability is enhanced.

Flat-Tray Chassis Simplify Component Testing

Another approach to accessibility appears i the marine radio-telephone equipment manu factured by Pearce-Simpson, Inc. of Miami. E gineers at Pearce-Simpson design all chassis a basically flat trays. They never use deep chass as designers at the company feel that deep cha sis invariably cover up many components an make testing and replacement difficult if n well-nigh impossible.

In component placement, they try to avoi layer construction. But where they must cov one component with another, they make th more reliable component the one which is t more inaccessible.

Integral Units Needed In Individual Subassemblies

At Shepherd Industries, Inc. in Nutley, N. the concept of individual subassemblies is us

Fig. 22. Centralized test and calibration area, mounted on a pull-out drawer, serves as nerve center in Minneapolis-Honeywell control system.

Fig. 23. Lear's expendable module, with flexible PC board, has all input, output, and reference signals conveniently available for maintenance at the header. The 1 cu-in. module is available with several basic configurations.

Fig. 24. Basic modules can be used in 19 different power supplies designed by Mid-Eastern Electronics.

Fig. 25. Integrated, individual sub-ass blies fit together easily in Shepherd dustries' tape transports.

in the design of tape transports. But in the Shepherd equipment, each subassembly must constitute an integral unit as shown in Fig. 25. Most subassemblies in the tape transport are easily removed by releasing a connector and unscrewing four bolts. Test points are located on PC boards with their associated circuitry.

An important feature cited by William Murphy, manager of electronic circuit development, is the close-tolerance spacing from the mounting surface of magnetic heads to the first track. If it ever becomes necessary to replace a head, it is necessary only to unplug and unscrew the old head and replace it with a new one. In most cases, no adjustment is necessary to align the head on the transport.

Large, Round-the-Clock Systems Need Special Features

Large systems, especially those which must operate on a round-the-clock basis, often require special maintenance features not necessary with systems designed for intermittent operation. One example is the Air Traffic Control Beacon Ground Station designed by Telecomputing Corp. in Hollywood.

This system features a standby channel which can be switched into operation at any time. It can be operated, tested, or serviced without affecting the operating channel. For those portions of the circuit that cannot be channelized, spare units are installed next to operating units so connections can be switched rapidly. All units in the system are designed for servicing from the front of the system.

In addition, small components, terminals of large components, test points, and adjustments are accessible when the front door of the unit is opened. Small components are mounted on vertical terminal boards that swing 45 deg to the right or left to improve access in the equipment. All wiring is color-coded and symbol designations of all components are marked adjacent to the components.

Common Features Mark All Maintenance Units

To the extent that any equipment is designed for maintainability, it will share certain features with all other such equipments. If not in the details, then certainly in the broad concept, each will show attention to the needs of the maintenance man.

From the broadest viewpoint, these needs reduce to two—the need to localize faults quickly and the need to put a system back in operation quickly. The success of any maintainability effort can be measured by these two yardsticks. ■ ■

Designing for Maintainability

CHECK LIST

Check List of 241 Design Features For Maintainable Equipment

IN "NO TIME-BASE Needed in Signal Corps Maintainability Specifications," (p 58), author Robert Redfern cites the key role played by a check list of design features for maintainable electronic equipment.

Implicit in Mr. Redfern's approach is the concept that it is a lot easier to determine, for example, if all displays can be observed from one position, than it is to measure the average time required by a technician with average skills to localize an average fault and to effect an average repair under average environmental conditions. And the more easily obtained results are more meaningful and more useful in arriving at an evaluation of the maintainability of a given equipment.

With the kind permission of the copyright holders, American Institute for Research, of Pittsburgh, Pa., ELECTRONIC DESIGN is pleased to present this checklist. It is taken from a research report, "Development of an Index of Electronic Maintainability," authored by M. R. Munger and M. P. Willis, and prepared by AIR for the U. S. Army Signal Material Support Agency.

The editors of ELECTRONIC DESIGN feel that this check list should prove of great value to all electronics engineers who must design equipment for maintainability.

Displays and Controls

1. Are all displays in equipment checkout located so they can be observed from one position?
2. On units with operator's display, are maintenance displays behind an access door on the operator's panel?
3. On units without an operator's panel, are maintenance displays on an accessible face of the equipment?
4. Are all displays located so they can be observed without disassembling or removing any portion of the installation?
5. Do labels tell which block in the block diagram of the equipment is being monitored?
6. Do labels tell what function is displayed rather than just what electrical characteristic is indicated?
7. Do display scales give only information needed by the maintenance technician?
8. Where center-null displays are used, is the circuit designed so the indicator will not rest in the in-tolerance position if power fails?
9. Are moving-pointer, fixed-scale indicators used for displays for adjustment procedures?
10. Are all-or-none type displays used when they will convey sufficient information?
11. Are numerical scales used only when the maintenance technician needs quantitative information?
12. Do display scales show the tolerance band as well as correct reading? Tolerance band should be shown as a single, center-scale colored area.
13. If arithmetic must be applied to measured data, are decimal transformation factors provided (in the manual or on the equipment) to simplify the calculations?
14. Do display scales have only enough graduations to give the required accuracy without interpolation becoming necessary?
15. Are special calibration points provided either on the dial face or on a separate overlay if the edges and midpoint of the tolerance range are not sufficient for accurate calibration?
16. Do loud auditory signals supplement telelights for displays that are not constantly monitored when it is important to note changes in their indications immediately?
17. Do indicators provide immediate adjustment information during the adjustment procedure?
18. Are all adjustment controls located on a single panel?
19. Are all controls located where they can be seen and operated without disassembling or removing any part of the installation?
20. Are front-panel maintenance controls covered by an access door?
21. Are controls placed on the panel in the order in which they normally are used?
22. Are controls numbered in the sequence of their operation when they are used in a fixed procedure?
23. Do knobs for precision settings have about 2-in. in diameter?
24. Do labels state the function of the controls?
25. Are control-position markings descriptive rather than coded?
26. Are scales on controls fine enough to give only required accuracy?
27. Do controls move smoothly except at detents?
28. Do multiposition selector switches have sufficient spring loading so a switch cannot be left between detents inadvertently?
29. Are push-buttons spring-loaded so they do not produce inconvenient pressure against the finger?
30. Do tool-operated controls take a screwdriver or other medium-size tool?
31. Does each step in adjustment procedure require only one control to obtain an in-tolerance indication?
32. Are all related displays and controls put on the same panel?
33. Is each display placed so it can be read accurately and conveniently while the control is operated?
34. Are display labels and control labels correlated so the display label suggests which controls affect the reading?
35. When large display movements are required, are they obtained through small control movements?
36. When fine adjustments are required, are they obtained through large control movements?
37. Where a precise setting in a wide range of display movement is required, is a coarse-fine control provided?

External Accessibility

1. Are maintenance accesses installed on equipment faces that will be accessible when the equipment is installed?
2. Is each access labeled uniquely so each one can be clearly named in job instructions?
3. Does each access label indicate the items which are accessible?
4. Does each access label indicate what auxiliary equipment is to be used at the access?
5. Does each access label indicate the recommended time period for performing maintenance operations?
6. Is a transparent cover or a quick-opening metal cover used for visual-inspection?
7. Are access openings without covers used where they are not likely to impair performance?
8. Are hinged doors used instead of cover plates held by screws?
9. If there is insufficient space for opening hinged doors, are cover plates with captive quick-opening fasteners used?
10. Are no more than four screws used in screw-fastened access plates?
11. On hinged access doors, is there some means to hold the door open?
12. Are all units and parts labeled fully?
13. Are parts, such as resistors, capacitors and tubes, marked with relevant information about their electrical characteristics?
14. Is each terminal labeled with the same code symbol as the wire attached to it?
15. Are labels etched or embossed into the components or chassis rather than painted or stamped on the surface?
16. Are labels visible?
17. Is the color code explicit in job instructions and/or on a panel of the color-coded equipment?
18. Is the meaning of a particular color consistent for a given application (resistor, capacitor, wiring)?
19. Do color-coded markings resist chipping, and are they located away from points of physical wear?
20. Is each wire labeled uniquely to facilitate tracing?
21. Is there an overload indicator for each major component even if it may be desirable to keep overloaded circuits operating?

22. Are capacitors and other parts that retain heat or voltage after the equipment is turned off located where technicians are not likely to touch them while changing parts such as tubes?
23. Are internal controls such as switches and adjustment screws located away from high voltages?
24. If screwdriver adjustments must be made blind, are the screw shafts vertical so the screwdriver will not fall out of the slot?
25. Are screwdriver guides provided on adjustment points near high voltages?
26. Are controls located away from high-voltage points and hot tubes?
27. Are internal displays lighted when necessary?
28. Are units that frequently must be pulled out for checking mounted on roll-out racks, slides, or hinges?
29. Are stops always provided on roll-out racks and drawers to prevent their being dropped?
30. Is it easy to override stops for replacement of racks and drawers?
31. Can units in drawers and slide-out racks be pulled out without breaking electrical connections?
32. Are units and assemblies positioned so replacing one unit does not require removing other units for access?
33. Are parts mounted in an orderly array on a two-dimensional surface and not stacked on one another?
34. Are parts mounted on one side of a surface and associated wiring (including printed or soldered circuits) on the other side?
35. Are easily damaged components (such as miniature tubes) mounted so they are protected from damage?
36. Are parts such as resistors, capacitors, tube sockets, etc., mounted on subassemblies rather than on the unit's chassis?
37. Are all replaceable parts made accessible by fold-out construction or other special construction techniques when necessary?
38. When fold-out construction is used, are parts and wiring positioned to prevent damage when the assembly is opened or closed?
39. Are hinged assemblies braced or otherwise held in the "out" position while they are being repaired?
40. Are easily damaged conductors such as waveguides, high-frequency cables, or insulated high-voltage cables protected?
41. Are field-replaceable units independently mounted to the housing and not to each other so only the unit to be replaced need be moved?

Test Points

1. Are test points accessible?
2. Are internal test points clustered where they will be most accessible when installed?
3. Are test points located so parts of equipment do not impede access to them?
4. Are test points grouped conveniently for sequential checking?
5. Is each test point labeled uniquely?
6. Is each test point labeled with the proper signal (with tolerance limits) that should be measured there?
7. Does each test-point label indicate the unit whose output is available at the test point?
8. Are test points color-coded so they can be easily located?
9. Are luminescent markings used so test points

Designing for Maintainability

CHECK LIST

can be read in very low illumination?

10. If maintenance procedures require a test probe to remain connected to a test point without being held by the technician, does the test point have a quick-disconnect fastener?

11. Is there an exposed test point at the input and output of each group of major units?

12. Is there an accessible test point at the input and output for each major unit or assembly?

13. Are there test points for the direct check of all replaceable parts?

14. Is there an accessible test point at the input and output of each circuit or stage?

15. Are cables "fanned out" in junction boxes for checking if standard test points are not provided?

16. For non-permanent connections, do test leads require only a fraction of a turn for attachment to prime equipment receptacles?

17. Are test points located close to the controls and displays used with these test points?

18. Is each test point used in an adjustment procedure associated with only one adjustment control?

19. Does the signal available at each test point indicate clearly when the associated control is in the required position?

20. Is the test point located so the technician at the control can read the signal available at the test point?

21. Are all signal inputs for alignment procedures available in one standard signal generator?

22. Are units activated by a triggering pulse that has a self-triggering capability?

Cables and Connectors

1. Can units that are difficult to connect when mounted be moved to a more convenient position for connecting and disconnecting their cables?

2. Are cables long enough so each functioning unit can be checked in a convenient place?

3. Are cable harnesses designed so they can be fabricated in a shop or factory and installed as a unit?

4. Are cables routed so they cannot be pinched by doors, lids, etc.?

5. Are cables routed so they will not be walked on or used for hand holds?

6. Are cables routed so they are accessible to the technician and are not under floor boards or behind panels that are difficult to remove?

7. Are cables routed so they need not be bent sharply when connected or disconnected?

8. Can cables with attached connectors pass easily through walls, bulkheads, etc.?

9. Do plugs and receptacles have painted arrows or other indications to show proper position of keys for aligning pins?

10. Are plugs and their corresponding receptacles coded alike?

11. Can plugs be quickly disconnected?

12. Are the pins in each plug clearly identified?

13. Are plugs designed so it is impossible to insert any plug in the wrong receptacle?
14. Do aligning pins or keys extend beyond electrical pins?
15. Are unkeyed, symmetrical arrangements of aligning pins avoided?
16. Are plugs having a self-locking safety catch used instead of plugs that must be safety-wired?
17. When a portion of the equipment is removable, does the cable connecting the removable portion to the rest of the equipment have a plug and receptacle that will disconnect before the cable breaks?
18. Is the equipment designed so receptacles are "hot" and the plugs are "cold" when disconnected?
19. Are cables connected to equipment by plugs and receptacles rather than by pigtailing?
20. Are field-replaceable assemblies and subassemblies plug-in rather than solder connected?
21. Can connectors be reached easily for replacement or repair?
22. Does the design of connectors prevent electrical contacts from being short-circuited by external objects?
23. Are connectors located far enough apart so they can be grasped firmly?
24. Are terminals for soldering far enough apart so work on one terminal does not damage neighboring terminals or other parts?
25. Are terminals and other connections for soldering long enough so insulation and other surrounding materials are not burned by the soldering iron?
26. Are U-lugs used rather than O-lugs?
27. Are connectors designed to prevent excessive tightening?
28. Are connectors for auxiliary equipment designed so no tools are required for their operation?
29. If tools must be used to operate connectors, are standard hand tools sufficient?
30. Do connectors for auxiliary equipment operate in a fraction of a turn or with quick snap action?
31. Is no more than one full turn of a connector required to connect test equipment to a test point?
32. Can wires be unsoldered and removed from lugs without damaging the lugs?

Internal Accessibility

1. Is accessibility to parts impeded by large parts that are difficult to remove?
2. Are components placed so there is sufficient space to use a test probe, soldering iron, and other tools without difficulty?
3. Are units placed so structural members do not prevent access to them?
4. Are components placed so all throw-away assemblies or parts are accessible without removing other components?
5. Is equipment designed so it is not necessary to remove any assembly from a major unit for troubleshooting?
6. Can screwdriver-operated controls be adjusted with the handle clear of obstructions?
7. Are units laid out so maintenance technicians need not retrace their movements during checking?
8. If field-maintenance procedures require tube replacement, is it possible to do this without removing units?
9. Are units placed so tubes can be replaced without removing assemblies and subassemblies?
10. Are units placed so resistors, capacitors, wiring,

CHECK LIST

etc., do not interfere with tube replacement?

11. Are all miniature tube sockets oriented with the gap facing one way?

12. Where tubes must be inserted through small accesses, is there an external indication of the proper position insertion (such as, matching stripes or dots on the tube or plug top and on the cabinet)?

13. Are all fuses located so they can be seen and replaced without the necessity of removing other parts or subassemblies?

14. Are fuse assemblies designed and placed so no tools are required for replacing a fuse?

15. Do edges of accesses have internal fillets of rubber, fiber, or plastic to protect the technician's hands or arms?

16. Are there safety interlocks on accesses that lead to high-voltage equipment?

17. Do access openings permit the most direct possible access?

18. Is sufficient room provided for the various tasks performed on the equipment with one hand?

19. Is enough room provided for tasks requiring insertion of two hands and two arms through the access?

20. If the technician must see what he is doing inside the equipment, does the access provide enough room for hands or arms and for an adequate view?

21. Are irregular extensions such as bolts, tables, waveguides, and hoses easily removed before the unit is handled?

22. Do access doors have whatever shape is necessary to permit passage of necessary components and implements?

23. Are units removable from the installation along a straight or moderately curved line?

24. Are heavy units (more than 25 lb) within normal reach of a technician?

25. Are provisions made for supporting units while they are being removed or installed?

26. Are there rests or stands on which units can be set to prevent damage to delicate parts?

27. Is a special guide tool attached to the access when an adjustment control under the access would otherwise be difficult or dangerous to locate?

28. If the technician must work on the equipment with the power on, is a cheater switch provided that automatically resets when the access is closed?

Cases

1. Do fasteners for assemblies and subassemblies fasten or unfasten in a maximum of one complete turn?

2. If bolts are used, is the number of turns required to tighten or loosen them minimized (less than about 10 turns)?

3. When tool-operated fasteners are necessary, do these fasteners require only standard hand tools?

4. Are combination head mounting bolts that have a deep internal slot and hexagonal head used?

5. Do all bolts requiring high torques have an external hexagonal head?

6. Are mounting bolts made semi-permanently captive (for example by providing snap-on collars)?

7. Are mounting bolts and fasteners clearly labeled as such?

8. Are screws with different threads made in different sizes to prevent their being forced into the wrong holes and consequently stripped?

9. Are the heads of mounting bolts and fasteners unobstructed by nearby components or structural members?

10. Are only standard hand tools used in replacing assemblies and units?

11. Are guide pins always provided on units and assemblies for alignment during mounting?

12. Are the holes in covers and shields through which mounting screws must pass to the basic chassis large enough so a screw can pass even without perfect alignment?

13. Are cases designed so they can be lifted off units rather than units lifted out of cases?

14. Are cases made enough larger than the units they cover so that wires and other components will not be damaged when the cases are put on and removed?

15. Are guides and tracks provided to help prevent cases from tilting?

16. When the edge of a case must be slid over rubber stripping or other sealing material, does the sealing material adhere tightly enough so it does not buckle or tear, damaging the seal or jamming the case?

17. Is the method of opening a cover obvious? If not, is an instruction plate attached to the outside of the cover?

18. Do covers and cases have rounded corners and edges for safety?

19. Is it obvious when a cover is not in place and not secure?

20. Are no more than six fasteners used to secure a case?

21. Are the same size fasteners used for all covers and cases on a given piece of equipment?

22. Do covers and cases have their own stock reference in the event they must be replaced?

23. Are ventilation holes in covers made small enough so test probes or other conductors cannot be inserted inadvertently and touch high-voltage sources?

24. Do units weighing more than 10 lb have convenient handles to facilitate removing, replacing, or carrying?

25. Are handles provided on small, light units that otherwise would be difficult to grasp, remove, or hold without gripping delicate components?

26. Are handles provided on covers to facilitate holding the cover and carrying the unit?

27. Are handles placed over the center of gravity of units so they do not tip when being lifted or carried?

28. Are handles the technician must grip firmly at least 4-1/2 in. high and 2 in. deep?

29. Are handles and grips comfortable?

30. Are handles and grips placed where they are not likely to catch on other units, wiring or structural members?

31. Do heavy units have recessed grips near the back to facilitate handling? *(continued on p 56)*

Designing for Maintainability

CHECK LIST

Lubricants and Tools

1. Has a lubrication schedule been made for all lubrication requirements?
2. Can lubrication requirements be satisfied by standard lubricants listed in SB-38-5-3?
3. Are lubrication points provided if lubrication is required?
4. Are lubrication points plainly identified?
5. Are lubrication points accessible?
6. Can lubrication be applied with standard tools and devices?
7. Can mechanical components such as gear trains be lubricated without disassembly, or are they designed so that they do not require lubrications?
8. Is the equipment accompanied by a comprehensive list of tools needed for all maintenance tasks?
9. Have tools been specified to cover all maintenance procedures?
10. If special tools are required have they been provided with the equipment?
11. Is each of the tools provided adequate?
12. Are tools that must be used near high voltages adequately insulated where the technician is likely to touch them?
13. When screws must be rotated through many revolutions are speed tools provided if downward force on the equipment will not be harmful?
14. Do screwdrivers have clips to hold free screws that cannot be held easily with the fingers?
15. Do screwdrivers for small-sized adjustment screws have funnel-like shields that aid placement on the adjustment point and prevent slipping off?

Manuals

1. Are check lists provided for routine procedures?
2. If it is necessary to adjust controls with interacting effects, is a step-by-step procedure provided for alternate adjustments?
3. Is step-by-step instruction rather than a narrative paragraph format used to detail maintenance procedures?
4. Are tables and charts used whenever data can be organized in tabular form?
5. Are measurement data referenced to the measurement procedures to be used?
6. Can relationships and interconnections between circuits and between units be determined easily on the schematic diagram?
7. Are waveforms and voltages indicated on the diagram?
8. Do drawings and photographs in the manuals adequately identify the physical features of the equipment to facilitate location?
9. Is nomenclature used consistently in the manuals and does it correspond with markings on the equipment?
10. Is information provided in the manual about the required signal characteristics and tolerances at each test point?

Test Equipment

1. Are instructions for using test equipment written in step-by-step format?
2. Is a signal provided that shows when test equipment is warmed up?
3. If it is not feasible to use such a signal, is the warm-up time required clearly indicated near the warm-up switch?
4. Is there a simple check to indicate when test equipment is out of calibration or is otherwise malfunctioning?
5. Are useful data presented directly on test equipment displays, rather than data which require multiplication or other manipulation?
6. If manipulation of display values is required, are conversion tables provided for the user on the test equipment?
7. If it is not feasible to provide a conversion table, is the transformation factor indicated beside each switch position or display scale that uses the factor?
8. When more than one scale must be viewed, are they and their associated control knobs clearly differentiated by labeling and color coding?
9. Are selector switches provided on test equipment instead of plug-in connections?
10. Are there devices such as circuit breakers and fuses that will prevent damage if the wrong switch or jack position is used?
11. Are there devices such as warning lights, power switches that open automatically when the test-equipment lid is closed, and written warnings that insure the test equipment's being turned off after use?
12. Are the purposes of the tester and cautions in its use indicated on its outer surface?
13. Is there a label on every item the technician must recognize, read or manipulate?
14. Are the outer case and removable parts of items of test equipment clearly labeled using official nomenclature?
15. When adaptors must be used, are they a part of the test-equipment removable items?
16. Are storage compartments for accessories fastened?
17. Is portable test equipment rectangular for convenient storage?
18. Are handles on the outside case of portable test equipment recessed or hinged so they do not take up excessive storage space?
19. Is adequate storage space provided in the lid or cover of test equipment for storing removable items such as leads and adaptors?
20. Are proper locations for the items that go into the storage space indicated?
21. Is there provision in the lid or a special compartment for storing instructions for using the test equipment?
22. Are normal plugs used to connect test equipment and/or bench mock-ups to the outputs and inputs of field replaceable units?
23. Have intercomponent cables been provided to eliminate a mock-up?
24. Is a newly designed mock-up specified only when there is no currently produced mock-up that can be adapted for use?
25. Can test equipment be connected to the prime equipment within about 2 min? ■ ■

No Time-Base Needed In Signal Corps Maintainability Specifications

Robert Redfern, who was an engineer with the Signal Corps for 16 years, has spent most of the past three years developing maintainability criteria for Signal Corps communications-electronic equipment.

An associate member of the EIA Sub-Committee on Maintainability and of the Task Group on Measurement, Reporting, and Evaluation Techniques, he has played a very important role in developing a detailed, objective procedure for evaluating equipment maintainability during the development cycle. He gives credit for this procedure to American Institute for Research, which developed it under a Signal Corps study contract and which holds a copyright on other than U.S. Government use.

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THE SIGNAL CORPS has an answer to the challenge of specifying and measuring maintainability. A three-fold approach, it establishes a quantitative maintainability requirement for equipment types, specifies the quantitative value of design features, and provides the method for measuring degree of attainment.

Without relying on hard-to-measure *time*, the approach deals exclusively with the equipment design or configuration on the premise that, in terms of a development program or contract, hardware is the only facet the designer can control. A corollary Signal Corps program is aimed at improving the military maintenance system to support the maintainable equipment.

Any quantitative measure of maintainability should consider all facets affecting equipment maintenance; it should be readily understood by all levels of technical and semi-technical personnel; and it should be quickly computable without recourse to lengthy computation.

A measure should provide a clear-cut yardstick by which the worth of an item of equipment, from the standpoint of maintainability, can be evaluated objectively.

Such a measure should provide the basis for maintainability specifications of a precise, definitive nature which permits a more exacting control over the kind of equipment procured for military use. In addition, a maintainability index should provide equipment designers and developers with a means of checking on the quality, as far as maintenance goes, of their design plans. For these measures or scores to be meaningful, it is necessary to establish minimum acceptable scores for each factor.

Bibliography Shows Wide, Confusing Variety of Definition

A survey of existing maintainability bibliography reveals a confusing variety of definitions of maintainability indicative of the variety of concepts engendered by the peculiarities of the missions of each sponsoring service or agency. Indicative of the variety are the following:

1. Department of Defense defined maintainability as "a quality of the combined features and characteristics of equipment design which permits or enhances the accomplishment of maintenance by personnel of average skills, under natural and environmental conditions in which it will operate."

2. AGREE (Advisory Group on Reliability of Electronic Equipment) coined the following: "Maintainability is defined as the reciprocal of mean net time to repair failures, where both failures and repairs take place under specified simulated field conditions."

3. RCA, under contract AF 30(602)1623, sponsored by Rome Air Development Center (RADC) said: "Maintainability is the average man-hour requirement rate for all maintenance performed per unit of equipment complexity, with existing personnel under the specified environmental and usage conditions."

4. American Institute for Research, under RADC Project No. 7502, Wright Air Development Center (WADC) Task No. 71502 stated: "Maintainability is a function of the rapidity and ease with which maintenance operations can be performed to help prevent malfunctions or correct them if they occur."

5. The Navy developed a maintainability formula based on down-time for corrective and preventive maintenance related to an average at-sea period.

6. Enticingly concise is the definition proposed by Capt. J. L. P. McCallum of the Navy's Bureau of Weapons: "Maintainability is the ease with which the device can be kept operating."

Each of these definitions provides a concept of maintainability directly related to the approach or field of interest of the sponsoring organization. None, however, provides the basis for evolving a quantitative measure of the maintainability of the hardware product at the point

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of emergence from development. Indeed, some even contain terms which, in themselves, raise problems of definition.

To establish a basis for expressing the Signal Corps concept of maintainability a new definition was evolved, expressed as "the degree of facility with which an equipment can be retained in, or restored to, serviceable operation. It is a function of parts accessibility, internal configuration, use and repair environment, and the resultant time, tools, and training required to effect maintenance."

Maintenance Tasks Broken Down to Job Segments

The basic step in developing an index is to identify the elements of the general term "maintenance." The job segments, or elements, are broken down as follows:

*1. **Checking*** (preventive and corrective). (a) Inspections, (b) Control checks, (c) Test equipment checks.

*2. **Adjusting*** (preventive and corrective). (a) Mechanical adjustments, (b) Electrical adjustments.

*3. **Servicing.*** (a) Lubricating, (b) Replenishing, (c) Changing.

*4. **Troubleshooting.*** (a) To major unit, (b) To sub-unit, (c) To part.

*5. **Replacing*** (preventive and corrective). (a) Major units, (b) Sub-units, (c) Parts.

*6. **Repairing.***

Each of these maintenance elements is affected, to varying degrees, by the factors of equipment design and the conditions of use. The illustration portrays the interaction of the factors of design and conditions of use upon the elements of maintenance.

'Maintenance Consequence Areas' Reveal Poor Maintainability

To establish the relationship between design features and conditions of use, the concept of "maintenance consequence areas" was developed. A maintenance consequence is defined as the way in which inadequate design for maintainability affects maintenance load and operations, or mission accomplishment. Analysis of all identified consequences results in consolidation into five primary consequence areas, namely:

*1. **Equipment down-time*** —the time required to perform preventive and corrective maintenance which prevents operation of the equipment during a period of scheduled operation. This total time does not include maintenance lag time, which is the time lost due to unavailability of parts, personnel, etc. Down-time is generally expressed in terms of equipment hours.

2. *Maintenance time*—the total time required to carry out all preventive and corrective main-

TIME-BASE

tenance actions. This total time is expressed in terms of man-hours.

3. Logistics requirements—the demands made on the logistics system in terms of tools, parts, personnel, facilities, etc., to support maintenance.

4. Equipment damage—the probability that damage to the equipment will result during the act of performing normal maintenance actions.

5. Personnel injury—the probability of injury to maintenance personnel during performance of normal maintenance actions.

These maintenance consequence areas are not completely independent variables. There is considerable interaction among the five areas. The exact nature of this interaction, however, depends on the specific equipment and its maintenance support.

Five Consequence Areas Show Equipment Maintainability

It is necessary to use all five consequence areas adequately to describe the effects of designed maintainability on a particular maintenance situation. The five consequence areas provide, in effect, a profile of maintainability.

By using this consequence-area approach, the relationship of design features to the field requirement for maintainability can be developed. This is done by comparing the degree of consequence, or score, resulting from the absence of specific design features, with the tolerance the field has for meeting the resultant consequences, expressed as a design standard.

Time-Based Index Has Many Drawbacks

At this point we note the significant departure in the Signal Corps method of measuring maintainability from other proposed methods, and from the reliability approach.

Time is the prime element in determining reliability and this same element is the basic factor in practically all other approaches to the measurement of maintainability. The measurement of time in relation to maintenance, however, has many limitations or drawbacks, namely:

1. Time to effect a sample repair in the laboratory environment cannot reflect the multiplicity of field conditions that combine to degrade that measurement.

2. There is no determinable "average" condition or environment under which one can time maintenance actions.

3. There is no "average skilled" personnel representative of the wide range of "butchers and bakers turned technicians" who must perform field maintenance under a wide variety of constraints.

4. There is no known "average" time for simulating time required to assemble the tools, test equipment, parts, etc., required to effect any sample failure repair under the wide variety of field maintenance and logistics conditions.

5. The sample of repairs used to demonstrate the time element is normally based on the most common and repetitive types of failures revealed by experience. A determination of high maintainability based on this sample does not reveal the possibility of very low grade maintainability resulting from random failures of unsampled items which may be induced by new design concepts, new circuit applications, unfamiliar skill requirements, side effects of other repairs, and other stresses too numerous to mention.

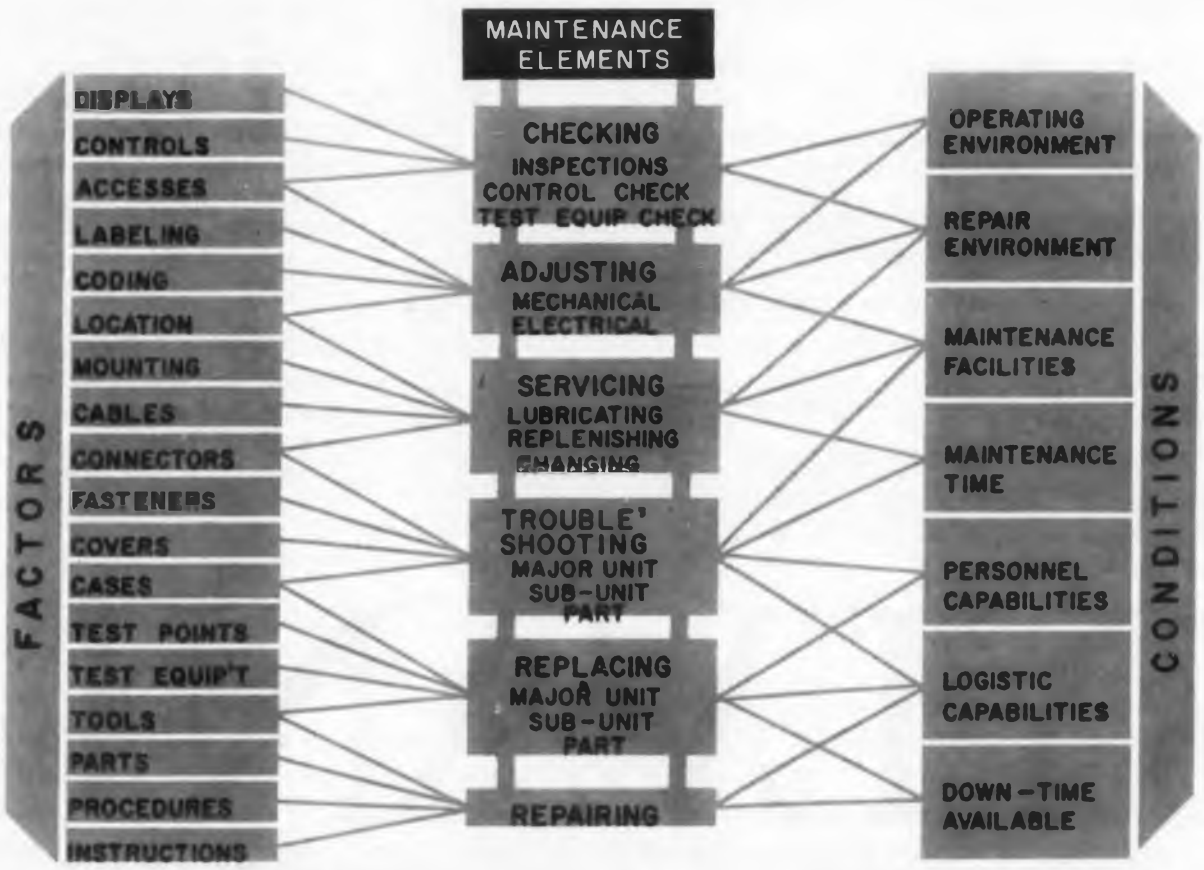
6. Time, as an element to be measured, requires the expenditure of time in effecting the trial or test, thus contributing considerable delay time at the end of the development cycle if maintainability acceptance is to be determined before going into production. The alternative is to barge into production and make an after-the-fact determination of maintainability by the compilation of data logs. This is obviously unacceptable since it does not preclude introducing a maintenance problem in the field.

241 Design Features Affect Equipment Maintainability

The first task is to identify those design features which affect or influence the maintainability of equipment. This resulted in a listing of 241 features, applicable to communications-electronic equipment, which were general enough to be pertinent to the variety of equipment types involved and yet specific enough to allow positive determination as to whether the feature had been incorporated in a specific equipment.*

These design features were submitted to many experienced field-maintenance personnel who rated each feature on a five point scale indicating its relative importance in each of the consequence areas. These relative values, from 0 to 5, provide the "weighting factor" for each design feature by which the equipment can be rated or scored. Estimates of reliability of the relative importance of the different features were computed and results showed a high degree of confidence in the reliability of the assigned weights.

The design features were arranged in nine design-factor groupings for sequencing equip-



Strong interrelationship exists between design factors, maintenance job elements, and maintenance conditions for any equipment.

*These features are included in this issue as "Check List of 241 Design Features for Maintainable Equipment."

ment evaluation and providing rapid readout of the areas in which an equipment was weak or strong from a maintainability viewpoint.

The nine design-factor areas are (1) displays and controls, (2) external accessibility, (3) test points, (4) cables and connectors, (5) internal accessibility, (6) cases, (7) lubricants and tools, (8) manuals, and (9) test equipment.

Design feature scores are computed for each design-factor area as well as for each of the five consequence areas. To standardize the scoring in each of these areas the scores are converted to a base of 100. To convert the total raw scores, the total "yes" (indicating presence of the design feature in the equipment) scores are divided by the total "yes" scores plus the total "no" scores. The result is multiplied by 100 to eliminate the decimal. All design features not applicable to the specific equipment being evaluated are eliminated from consideration in the scoring.

Maintainability Scores Can Relate to User's Requirements

For the scores obtained under this or any other procedure to be significant, they must relate to a requirement, or standard, representing the user's minimum acceptable maintainability requirements.

To obtain these standards a questionnaire was administered to a comprehensive cross-section of command personnel who expressed their requirements on a hundred-point scale for each consequence area under six different equipment family-type groupings.

Weighting Factors Help Engineer Evaluate Trade-Off

Having acquired a means for measuring maintainability, it became possible to establish a technical requirement, or specification, of maintainability in precise, definitive, and quantitative terms. Even more important it became possible to delineate specific design features which would enhance the maintainability of the product.

The weighting factors for each feature give the design engineer valuable guidance when it becomes necessary to trade-off between maintainability features or between a maintainability feature and another feature, such as packaging, form factor, producibility, and reliability.

The Signal Corps approach to the specification of maintainability requirements is contained in a correlated set of documents which are designed to eliminate duplication, repetition, and reiteration of philosophy, policy, guidelines, and criteria.

The first in the series, "Maintenance Engineering for Signal Corps Equipment," is a general specification of maintenance-engineering requirements which will be incorporated in the design

and development of all Signal Corps systems and equipment.

It includes an explanation of the maintainability concept and approach, definitions of terms, an outline of the guidance factors to be found in associated specifications, and the program for coordination and guidance between the design engineer and the maintenance engineer during each phase of the development. Also included are general design requirements applicable to the whole field of Signal Corps equipment.

Next is a set of documents covering a category or family of equipments. Titled "Maintainability Design Requirements for Signal Corps Equipment," the set currently includes the following category types: permanent installation, fixed field installation, mobile and/or operator carried, airborne, test equipment, and electromechanical.

Specification Gives Scores For Five Consequence Areas

Only the appropriate category specification is included in the documentation on any specific contract. This specification gives the first quantitative maintainability requirement in terms of the minimum acceptable score to be achieved in each of the five consequence areas. It also includes a delineation of the maintenance concept for the specific type of equipment and the support facilities, personnel, and skills available.

The third in the series is a check list format under the title "Maintainability Design Factors for ....." The blank is filled in with the specific nomenclature of the particular equipment under development and the check list is marked to provide specific details such as: design for throw-away, modular design requirement, number of modules recommended, cost limit for encapsulated throw-away modules, permissible down-time out of each operating period.

This three-part break-down of the documentation has one major important feature. Designers frequently employed on Signal Corps projects quickly become familiar with the general requirements and program in "Maintenance Engineering For Signal Corps Equipment." Detailed study is not required for each and every project. By the same token, if his field of activity is limited or generally associated with one of the cate-

gory types he is soon familiar with the guidance and requirements found in the Maintainability Requirements for that category type. This means that to get quickly to the core of the specific maintainability factors applicable to a specific project he has only to refer to the specified equipment requirements detailed in the third document, the check list.

The fourth and final document is a "Handbook of Maintainability Design Features for Signal Corps Electronic Equipment." This has five tables of design features covering the five consequence areas. Each design feature related to a consequence area is listed with its associated weighting factor for that consequence area. By setting the 241 design features in a handbook the designer is provided with a handy reference work.

Pass-Fail Evaluation Depends on Weighing Scores

Evaluation of an equipment becomes a process of weighing the variations of the obtained scores over and under the specified minimum acceptable score. The weighing must take into account the relative importance of the consequence area in relation to the maintenance plan for the equipment, the magnitude of the variation from the standard, and the effect on the accomplishment of the specific mission of the equipment and its using organization.

In some cases it may be possible to accept a low score in one area because it is more than compensated by a predominance of high scores in other areas. Changes to maintenance-support planning may be possible to reduce the effect of low scores in the logistic support area. On the other hand a low score in the down-time area for an equipment having high operating time requirements signals an imperative need for improvement in this area regardless of how well it might score in other areas.

The capability of identifying problem areas, or maintenance "soft-spots," by studying low-scoring design-factor areas, will permit adjustment of maintenance planning to provide increased maintenance support capability to compensate for low-maintainability design. Equally important will be the identification of specific areas to receive increased attention in future redesign or development of similar equipment.

References

1. DOD Directive No. 3232.1, 3 Nov. 1955, "Department of Defense Maintenance Engineering Directive."
2. DOD Directive No. 3222.1, 5 July 1956, "Approval of New Electronic Equipment and Systems for Service Use."
3. American Institute for Research—Signal Corps Contract DA 039 SC-66488, "Development of an Index of Electronic Maintainability." Research Report ASTIA No. AD 219 988.

Designing for Maintainability

PRODUCTS

Products for Maintainable Designs

Fig. 1. Grant slides provide access to equipment which must be mounted in "impossible to reach" places on Douglas Interceptor.

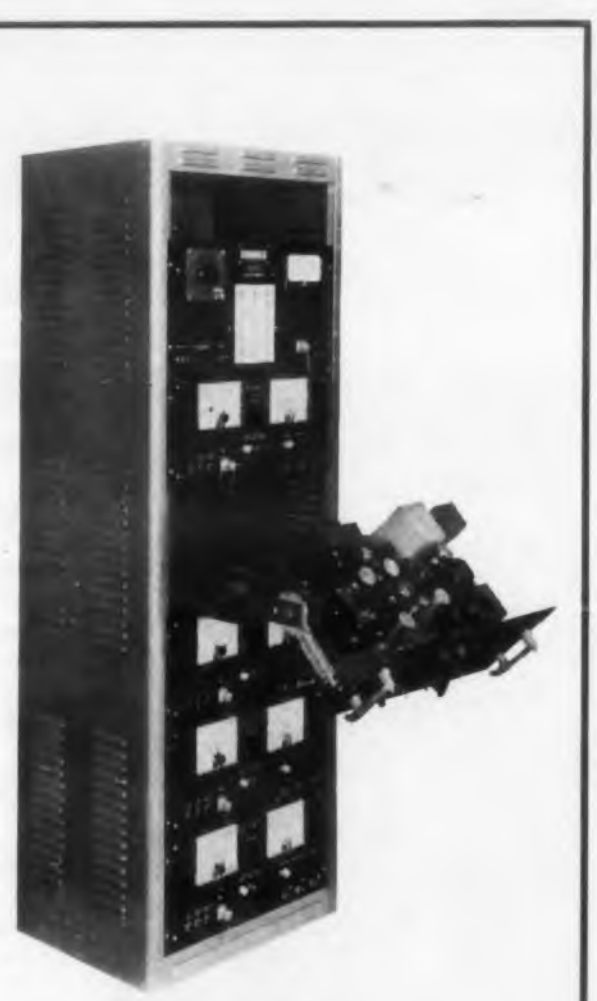


Fig. 2. Chassis-Trak slides give access to the electronic equipment from virtually any angle.

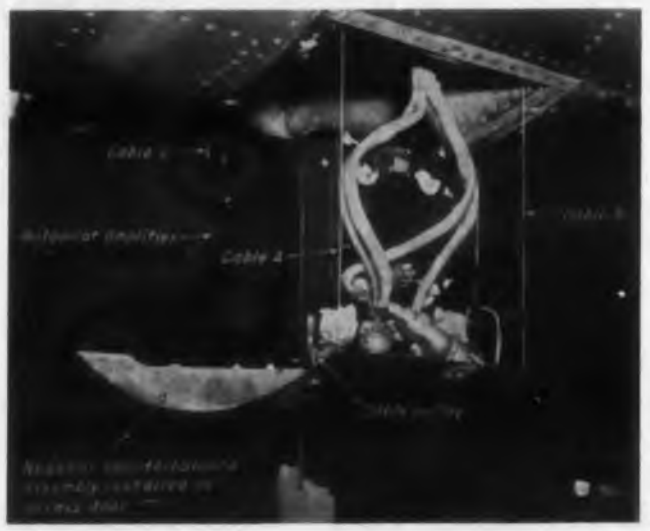


Fig. 3. Neg'ator assembly counterbalances 36-lb assembly in Republic's F-84G Thunderjet.

HOW COMFORTING it would be if a manufacturer would offer a product to solve all maintainability problems. A vast array of problems could be wiped out in one fell swoop.

Unfortunately, just as there is no single concept to lick the maintainability problem, there is no one product that will by itself make an equipment maintainable.

But there are many products and product types that can enhance the maintainability of a given equipment and, in some cases, can make the big difference between a product that's easy to maintain and one that's not.

Two paramount features of maintainable equipment are ease in fault location and accessibility. Of these two, the latter might well be voted more important, since accessibility so often serves to simplify fault location as well as to facilitate testing and servicing parts.

Prime Need, Accessibility, Served at Many Levels

Accessibility, in its turn, is served by many products, at many levels. At the broadest level it is served by doors which swing out of the way to expose entire racks of equipment. At a lower level it is served by slides which allow chassis to be withdrawn from cabinets to any extent and allow them to be tilted through a wide arc for easy inspection and servicing. Slides such as those manufactured by Grant Pulley & Hardware Corp. of West Nyack, N.Y. (Fig. 1), and by Chassis-Trak, Inc. of Indianapolis (Fig. 2), are available for a wide range of loads and a wide range of environmental conditions.

Another approach, shown in Fig. 3, improves equipment accessibility by allowing even heavy equipment to be suspended by cables. Weight of the equipment is counterbalanced by a Neg'ator

Fig. 4. Taylor Wiring duct allows for neat, easy-to-get-at inter-chassis cabling. Here the duct is used in a large bank of relays.

assembly, manufactured by Hunter Spring Co. of Lansdale, Pa.

At another level, wiring ducts, such as those made by Taylor Electric, Inc. of Detroit (Fig. 4), simplify tracing faults related to inter-chassis cabling.

For use between modules or other types of packages, there is an array of quick-disconnect connectors to speed access. An unusual product in this array is the recently announced, quick-disconnect terminal strip (Fig. 5), manufactured by Infrared Industries, Inc. of Waltham, Mass. This device combines the accessibility of the conventional barrier strip with the fast-replacement feature of the quick-disconnect connector.

On the module level, there is now available a very wide variety of plug-in circuits and components. Particularly for computer, industrial control, and military applications where down-time must be minimized, the increasing cost and complexity of plug-in devices can be seen. One such

Fig. 5. Infrared Industries' quick-disconnect terminal strip combines barrier-strip test points with quick-disconnect connector.

device is a plug-in dial timer (Fig. 6), manufactured by Automatic Timing and Controls, Inc. of King of Prussia, Pa.

The plug-in concept has been applied on the component level as well as on the level of complex units and subassemblies. Even at this level, ease of replacement can often justify the added cost of the plug-in feature. A wide variety of components—resistors, capacitors, rectifiers—has been made available in plug-in form. One of these is a plug-in silicon rectifier (Fig. 7), which is manufactured by International Rectifier Corp. of El Segundo, Calif.

New Encapsulents and Strippers Yield Access to Potted Parts

One of the greatest objections to encapsulation, the problem of testing and replacing small parts,

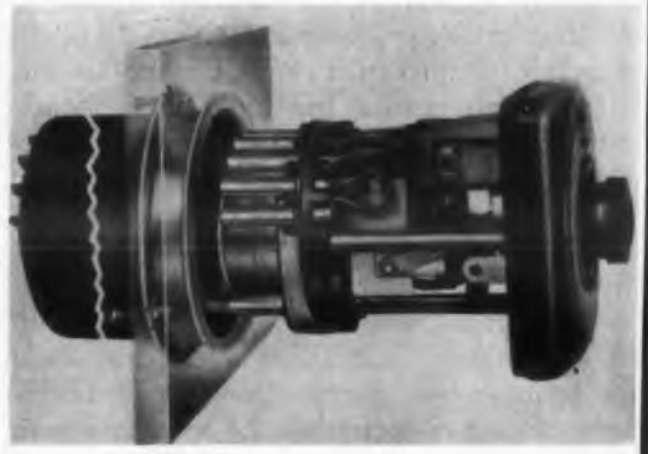


Fig. 6. Plug-in timer, by Automatic Timing and Controls, provides long, keyed, guide pin to insure accurate alignment and to protect electrical contacts.

Fig. 7. International Rectifier Corp.'s plug-in rectifiers extend plug-in concept to component level.

Fig. 8. Dow Corning Corp.'s transparent Dielectric Gel heals itself after being pierced by test probes.

has been largely overcome by some new products. These include strippers that flake away epoxy and polyester encapsulents without harming most circuit components, transparent potting compounds which heal themselves after being pierced by test probes, and encapsulents which can easily be cut or torn away from faulty components and can just as easily be mended.

Two types of strippers are available from the Electronic Components Div. of Telecomputing Corp. in Van Nuys, Calif.—a liquid type, Tele-Solv, and a gelatinous Tele-Solv G that can be applied to surfaces which can't be immersed in a liquid.

A transparent, pierceable encapsulent, Di-electric Gel, (Fig. 8), is offered by Dow Corning Corp. of Midland, Mich.

Expendable Modules Simplify Fault Location

The concept of designing modules for throw-away, which has received so much attention re-

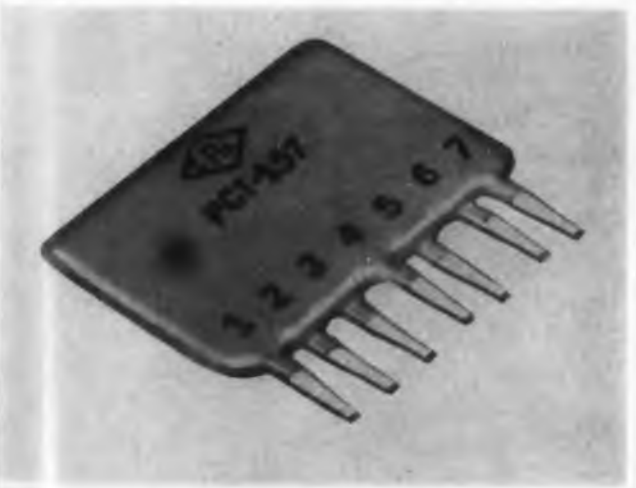


Fig. 9. Centralab's packaged electronic circuits provide built-in failure indication. If a resistor or capacitor should short, the heat generated will discolor the PEC and a dark brown spot on the coating will show the location of the burned out component.

PRODUCTS

cently, is by no means a new one. Examples of throw-away circuits which have been available for years are the packaged electronic circuits (Fig. 9), sold by the Centralab Div. of Globe-Union, Inc. in Milwaukee. These PEC's can house as many as 20 resistors, capacitors, transistors, and other small components. Cost of one of these packaged circuits can be significantly lower than the cost of tracing a fault to an individual component, and the time saved can be substantial.

Fasteners, Clamps, and Seals, Can Speed Access

One of the more troublesome but less recognized areas of designing for maintainability lies in the means of fastening and sealing. An inordinate amount of time can be wasted in searching for lost nuts or in testing *around* a sealed enclosure with the hope that the trouble isn't really in the enclosure.

Fortunately, many recent developments in both fasteners and seals have minimized these problems. Captive fasteners have been one approach to avoiding lost nuts and bolts. Another approach has been the use of inserts like the Banc-Lok insert manufactured by the Boots Corp. of Norwalk, Conn. (Fig. 10). This one-piece fastener is pressed into a prepared hole where it provides

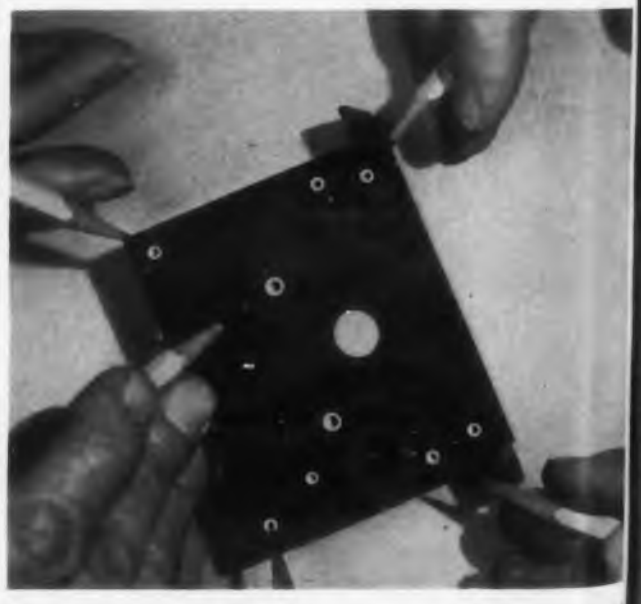


Fig. 10. Boots Corp.'s Banc-Lok inserts eliminate need for tapping and eliminate problems of lost nuts.

Fig. 11. Timber-Top's Synclamps require only screwdriver space between components being mounted.

Fig. 12. Parker seals are removable, re-usable.

vibrationproof screw threads with self-locking action in sheet metal, plastic, metal castings, wood, and composition materials.

From a maintainability viewpoint, any fastener should hold something securely; it should allow the component to be removed easily and quickly; and it shouldn't have loose parts which may get lost. One particularly simple device that satisfies these requirements is the Synclamp (Fig. 11), made by Timber-Top, Inc. of Freeport, Long Island, N.Y. A quick-release synchro clamp, it locks and unlocks simply with the turn of a screw.

Many of the problems usually posed by seals are averted with one-piece, molded-in-place seals. One such product, the Gask-O-Seal, manufactured by Parke Seal Co. of Culver City, Calif. can provide hermetic sealing with an easily removable and even re-usable seal. It can be used for waveguide seals (Fig. 12), and for sealing vacuum or pressurized enclosures.

Of course, there are hundreds of products which, used properly, can enhance the maintainability of an equipment. Used improperly, even the best of them will not improve a basically bad design. ■ ■

All-Pass Networks

Part 2

Using Networks to Shape Transient Response

An all-pass network, which shifts phase but does not introduce attenuation, is readily applicable to improving another network's transient response. In this second of a series of articles on all-pass networks, Yale Jay Lubkin illustrates this application with a detailed example. A pulse transformer is chosen as the network whose transient response is to be improved. The succeeding article will describe how all-pass networks can vastly improve delay lines.

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THE PHASE-SHIFT, or all-pass, network is an excellent tool for shaping another network's transient response. By minimizing phase distortion, for example, it improves rise time.

This method of improving rise time will be used to demonstrate the application of phase-shift networks to transient response. A phase correction network for a pulse transformer will be designed using results obtained in Part 1 of this series (See *ED*, Oct. 12, 1960, p 36).

After choosing the all-pass network, the transformer's transient response will be computed to demonstrate that minimizing phase distortion improves rise time. This will be done with the differential equations of the phase shift network.

Finally, the network will be designed again, this time using only the transient response; no frequency calculations will be required.

The significant parameters of a pulse transformer are primary inductance, turns ratio, leakage inductance, and distributed capacitance. The significant parameters of the associated circuitry are source and load impedance.

In most transformers, the primary inductance has little effect on the rise time and the other transformer parameters have little effect on the

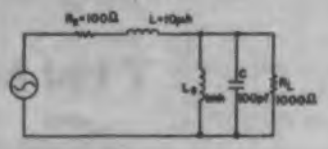


Fig. 1. Equivalent circuit for the leading-edge response of a pulse transformer.

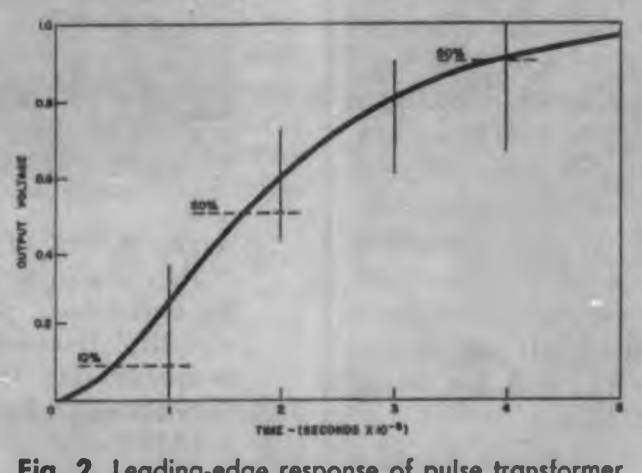


Fig. 2. Leading-edge response of pulse transformer to unit step.

Table I: Model Computations for Solving Difference Equation

t	e^{-t}	g	g'	x''	x'	x	$g-h$	h
0.0	1	0	0	0	0	0	0	0
0.1	0.905	0.0045	0.0905	0.362	0	0	0	0.0045
0.2	0.809	0.027	0.164	0.583	0.0362	0	0	0.027
0.3	0.741	0.037	0.222	0.728	0.0945	0.0036	0.0018	0.035
0.4	0.670	0.062	0.268	0.707	0.1673	0.0101	0.0068	0.055
0.5	0.606	0.091	0.303	0.656	0.2380	0.0268	0.0185	0.072
0.6	0.548	0.123	0.329	0.556	0.3036	0.0506	0.0386	0.084
0.7	0.496	0.157	0.347	0.417	0.3593	0.0810	0.0658	0.091
0.8	0.449	0.192	0.359	0.284	0.4010	0.1169	0.0990	0.093
0.9	0.406	0.239	0.365	0.112	0.4294	0.1570	0.1370	0.102
1.0	0.368	0.264	0.368	—0.009	0.4406	0.1999	0.1785	0.088
1.1	0.333	0.301	0.366	—0.146	0.4397	0.2440	0.2220	0.079
1.2	0.301	0.338	0.361	—0.249	0.4251	0.2880	0.2660	0.072
1.3	0.273	0.372	0.355	—0.372	0.4002	0.3305	0.3093	0.063
1.4	0.247	0.407	0.346	—0.455	0.3631	0.3705	0.3505	0.056
1.5	0.223	0.443	0.335	—0.518	0.3176	0.4068	0.3887	0.054

Input: $g=1-(1+t)e^{-t}$
$g'=te^{-t}$

Equations for Generating Difference Solution:

$$x''=4ag'-2ax'-r^2x$$
$$x'(t+\triangle t)=x'(t)+x''(t)\triangle t$$
$$x(t+\triangle t)=x(t)+x'(t)\triangle t$$
$$(g-h)\ (t)=1/2x(t)+1/2x(t-\triangle t)$$

Initial Conditions: $x(0)=0 \quad x'(0)=4ag(0)=0 \quad x''(0)=4a[g'(0)-2ag(0)]=0$

pulse fall. Hence it is customary to consider three different equivalent circuits for the transformer: one for the pulse rise, one for the body of the pulse, and one for the pulse fall.

It also is customary to refer all parameters to the primary so calculations can be made without considering turns ratio.

The analysis to follow is based on a pulse transformer with the following characteristics: primary inductance, $L_p = 1$ mh; Leakage inductance, $L = 10$ μh; distributed capacitance, $C =$ 100 pf; turns ratio, 1:1; source impedance, $R_s =$ 100 ohms; load impedance, $R_l = 1{,}000$ ohms. Such a transformer might be used as interstage coupling for 100 to 300 nsec pulses.

Seek Leading-Edge Response

We are interested in the leading-edge transient response. The conventional equivalent circuit for this condition is shown in Fig. 1.

The transient response of this transformer is very easily calculated (see Millman and Taub, *Pulse and Digital Circuits*, pp 263-265).

The response to a unit step is:

$$h(t) = 1 - (1 + t)\ e^{-t}$$

where t is measured in units of 10^{-8} sec, and is shown in Fig. 2. (Note: In all figures, the amplitude has been normalized so that $h\ (\infty) = 1$.)

The transformer is critically damped, because $L_pC = L/R_L$, and, hence, the response to a unit step has no overshoot and no ripple. The rise time is about 33.5 nsec, and the delay to the half-maximum-amplitude point of the output is about 17 nsec.

Frequency-Response Solution

If we define

$$\alpha = R/(R + R_s),\ \tau = R_sC = L/R \qquad (1)$$

then, from Millman and Taub, the gain, A, and phase shift, ϕ, are

$$A = \sqrt{4\omega^2\tau^2 + \left(\frac{1}{\alpha} - \omega^2\tau^2\right)^2} \qquad (2)$$

$$\phi = \arctan \frac{2\omega\tau}{\frac{1}{\alpha} - \omega^2\tau^2}$$

where $\tau = 10$ nsec, and $\alpha = 0.9$.

Fig. 3 shows the gain, phase shift, phase error, and cosine of the phase error for the transformer as a function of w. The phase error, $\Delta\phi$, is defined by

$$\Delta\,\phi(\omega) = \omega \left.\frac{d\phi\ (\omega)}{d\omega}\right|_{\omega=0} - \phi(\omega) \qquad (3)$$

The phase error is the difference between the actual phase shift and the value that would result if phase shift were exactly proportional to frequency.

Were the phase error identically zero, all frequencies would be delayed by the same time and no dispersion would occur. In this event,

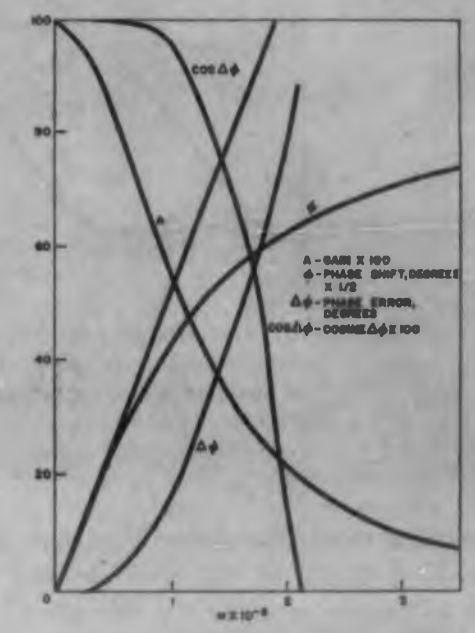


Fig. 3. The gain, phase-shift, phase error and cosine of phase error of the pulse transformer as a function of ω.

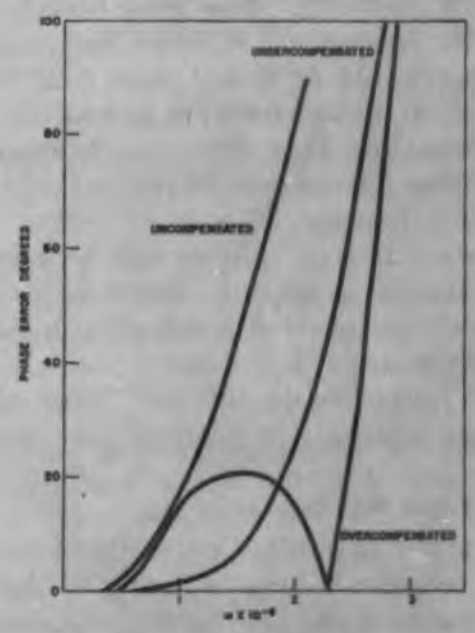


Fig. 4. Cascading a duopole (under- or over-compensated) with the pulse transformer makes phase error more linear and also increases frequency at which given phase error exists.

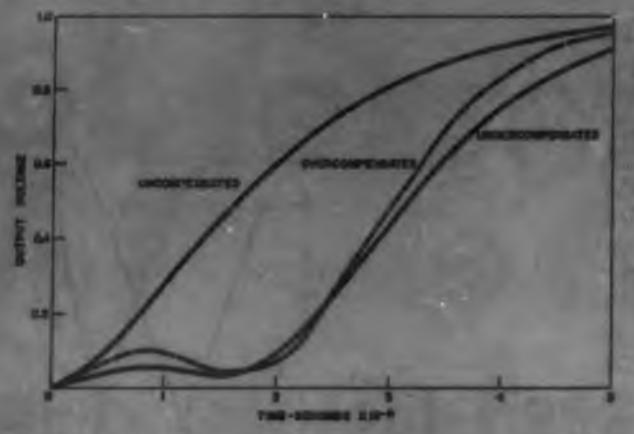


Fig. 5. Cascading a duopole (under- or over-compensated) with pulse transformer improves rise time of unit-step response but introduces a delay.

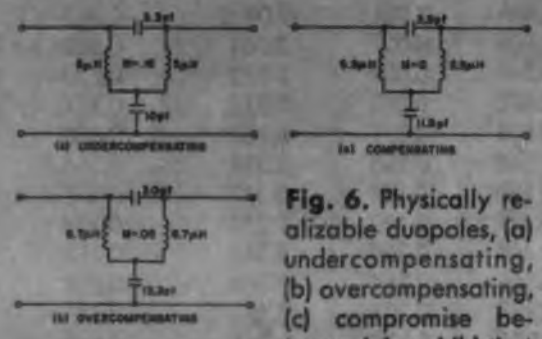


Fig. 6. Physically realizable duopoles, (a) undercompensating, (b) overcompensating, (c) compromise between (a) and (b) that eliminates mutual coupling.

the rise time would be determined only by the amplitude response of the network, and would be the minimum possible for the given amplitude response.

Zero Phase Error Impossible

Identically zero phase error is not possible for lumped parameter systems, although it may be closely approximated for practical purposes.

To simplify the equations, all times (t, τ) will be in units of 10 nsec, and all frequencies (ω, a, r) in units of 100 mega radians per sec.

Fig. 3 shows the phase error becomes quite large for frequencies at which the gain, A, is still appreciable. At 90 deg phase error the gain is 0.2. This situation results in poor rise time. The actual rise time, 33.5 nsec, is appreciably longer than the rise time determined only by the amplitude response, 20 nsec.

A single duopole section will be used as a phase-correction network. Reference to Fig. 3 shows the phase error of the pulse transformer is about 90 deg at $\omega = 2$ and is about 20 deg at $\omega = 1$. Hence the duopole must have about 70 deg excess phase shift between these points.

Most Errors Not Serious

As a first approximation to the desired network, consider a duopole having 90 deg phase shift at $\omega = 1$, and 270 deg at $\omega = 3$. The range of nearly optimum networks is quite wide, so errors due to non-optimum choices or to component drift are not serious.

Because a equals one-half the bandwidth between points of 90 deg and 270 deg phase shift, $a = 1$ in this case. The frequency of 180 deg phase shift is

$$\omega = \sqrt{a^2 + r^2}, \quad \text{so that} \quad r = \sqrt{3}.$$

Fig. 4 shows the net phase error of the pulse transformer and duopole. The duopole phase shift and phase errors are readily determined from the transfer function (substitute $s = j\omega$) and are

$$\phi = 2 \arctan 2a\omega/r^2 - \omega^2 \qquad (4)$$

$$\Delta\phi = \frac{4a\omega}{r^2} - \phi \text{ radians}$$

The resultant phase characteristic is much more linear than that of the pulse transformer alone; the frequency for a given phase error is increased by almost $\omega = 0.9$. Thus, the frequency for 90 deg error has been increased from $\omega = 2.1$ to $\omega = 2.75$.

Compensation Has Its Price

The phase error with the calculated duopole network is monotonic, i.e., phase error increases with frequency for all frequencies.

By overcompensating and accepting some extra phase shift at low frequencies, it is possible to reduce the phase error at higher frequencies. This usually results in improved rise time at the expense of ripple.

We may obtain overcompensation by increasing the duopole phase shift in the critical frequency range. With 90 deg phase shift at $\omega = 1$, as before, and 270 deg phase shift at $\omega = 2.5$, instead of at $\omega = 3$, the new duopole has $a = 0.75$, $r = \sqrt{2.5}$.

The phase error of the transformer and the second duopole is shown in Fig. 4. Note that the frequency for 90 deg error has been increased to $\omega = 2.85$, and that an error of 20 deg has been introduced at $\omega = 1.5$.

The transient response of the transformer alone and with each of the corrective networks is shown in Fig. 5. The rise time is materially improved with either network, but an additional delay has been introduced.

The response with the overcompensating network has a faster rise time and slightly less delay, but also has much more ripple. The peak ripple with the overcompensating network is about 10 of the final amplitude, and this may prove objectionable for some applications.

Mutual Coupling Used

Circuit values for the corrective duopoles are shown in Fig. 6. These values are obtained by substitution in Fig. 1 of the previous article. The undercompensating duopole has positive mutual coupling between the inductors and the overcompensating duopole has negative mutual coupling.

By choosing a duopole representing the average between the two already considered, and having $r = 2a$, the coupling may be eliminated.

The response with such a network would be an average of the responses of the other two networks. It is apparent that the network designer has a great deal of freedom.

The network responses are calculated by obtaining the differential equation for the duopole and solving it by means of difference equations. The technique is particularly easy for all-pass networks, and the following can serve as a model.

Solution Uses Difference Equation

For a duopole, the transform of the output is related to that of the input by:

$$H = \left(\frac{s^2 - 2as + r^2}{s^2 + 2as + r^2}\right) G \qquad (5)$$

By cross-multiplying and combining terms,

$$(s^2 + 2as + r^2)\ (G - H) = 4asG \qquad (6)$$

The transfer function is obtained directly from the differential equation of the network by substituting s for d/dt and s^2 for d^2/dt^2. Therefore by substituting back we obtain the differential equation:

$$(g - h)'' + 2a(g - h)' + r^2\,(g - h) = 4ag' \qquad (7)$$

where $'$ means d/dt.

This is an equation for the difference between the input and the output of any duopole in terms of the input waveform.

The difference solution is obtained by starting with the initial conditions at $t = 0$ (which here are $(g - h) = (g - h)' = (g - h)'' = g' = 0$,). Then select a suitable calculation interval, Δt, (the size of the interval depends on the accuracy desired) and systematically generate answers for time intervals after zero by applying the relation:

$$x(t + \Delta t) = x(t) + x'(t)\Delta t \qquad (8)$$

where x stands for $(g - h)$ or $(g - h)'$.

From the differential equation, calculate $(g - h)''$ at any value of t, after g', $(g - h)$ and $(g - h)'$ have been calculated for that particular value of t.

The first steps of the calculation for the undercompensating duopole are shown in Table 1. The time interval chosen is $t = 0.1$.

Input Minus Output Obtained

This procedure gives $(g - h)$ as a function of time, and h may be calculated by subtracting $(g - h)$ from g. The difference-equation procedure gives a solution delayed by half the sampling interval, Δt. Hence the obtained solution is not $(g - h)\ (t)$, but is $(g - h)\ (t - \frac{1}{2}\Delta t)$.

The response shown for the undercompensating duopole was calculated using $\Delta t = 0.1$ and that for the overcompensating duopole was calculated using $\Delta t = 0.2$. The duopole parameters were $a = 1$, $r^2 = 3$.

Time-Response Solution

From the previous discussion, it is evident that, while networks can be obtained without much difficulty using the frequency response approach, the calculations involved may become somewhat tedious, particularly if the designer is interested in calculating the time domain frequency response.

By using results established in the previous article (*ED*, Oct. 12, 1960), it is possible to avoid most of the calculations if the designer is interested only in approximate solutions in the time domain. The duopole's response to low frequency signals (frequency less than some w_o) is:

$$h_2(t) = g(t - 4a/r^2) + \frac{4a}{r^4}\,(1 - 4a^2/3r^2) \qquad (9)$$

$$g^{(3)}\,(t - 4a/r^2) - \ldots\ldots$$

where $g^{(n)} = d^n g/dt^n$

This equation gives the waveform at the output of the duopole in terms of the derivative of the input. As a first approximation, neglect all derivatives of the input waveform beyond the third.

In general, for band-limited inputs, this will lead to results that are quite erroneous near the beginning of the input waveform, but fairly accurate after $4a/r^2$ sec. This is indicated in the equation because it shows no output before $4a/r^2$ sec.

Optimum Parameters Obtained

Fig. 7 shows the input waveform, $g(t) = 1 - (1 + t)e^{-t}$–the pulse transformer output–and its third derivative, $(t - 2)e^{-t}$. By rewriting the duopole's response equation as

$$h_2(t) = g(t - d) + kg^{(3)}(t - d) \qquad (10)$$

where $d = 4a/r^2$ and $k = \dfrac{4a}{r^4}\,(1 - 4a^2/3r^2)$

we see we can alter h by changing the value of k. Thus, an optimum k, and hence an optimum network can be obtained with little computation. By choosing d, we can then find a and r.

Fig. 7 also shows that $g^{(3)}$ is very nearly zero for $t > 1.5 \times 10^{-8}$, so we expect the phase shift network to have little effect on the input waveshape, aside from the delay, beyond that point. It appears from experience that optimum networks have delays ranging from the time at which g equals $g^{(3)}$ to the time at which $g^{(3)}$ goes to zero. Here the delays range from about 1.1 to about 1.6.

We would expect the maximum effect of the corrective network to occur at about half this time. Therefore, select k so the output of the corrective network is zero at a time between 0.55 and 0.80.

The greater this time, the less the rise time of the corrected signal. The values of k that give zero network output between 0.55 and 0.80 lie between 0.15 and 0.36.

If the values $d = 1.33$, $k = 0.247$ are chosen, the resulting corrective network is the undercompensating network previously discussed. The values for the overcompensating network are $d = 1.2$, $k = 0.336$, and those for the network without mutual inductance are $d = 1.18$ and $k = 0.273$.

Fig. 8 shows the output of the undercompensating network calculated by solving the difference equation and also calculated from the time-response equation (Eq. 9). For $t > 4a/r^2$, the difference is fairly small. ■ ■

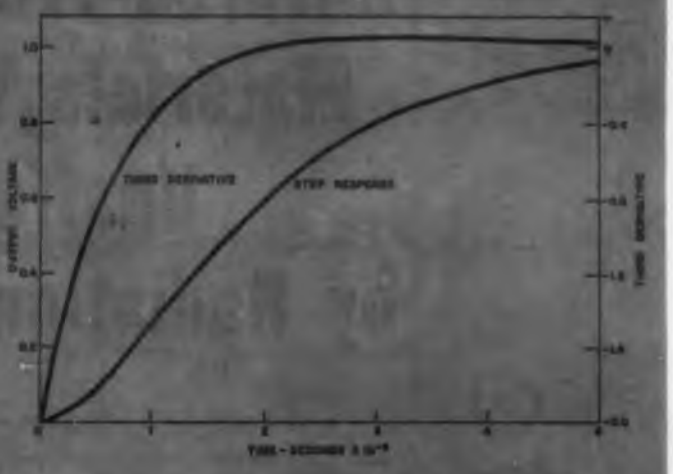


Fig. 7. Input to duopole is step response of pulse transformer because duopole is cascaded with transformer. Input and its third derivative figure in computing response of duopole.

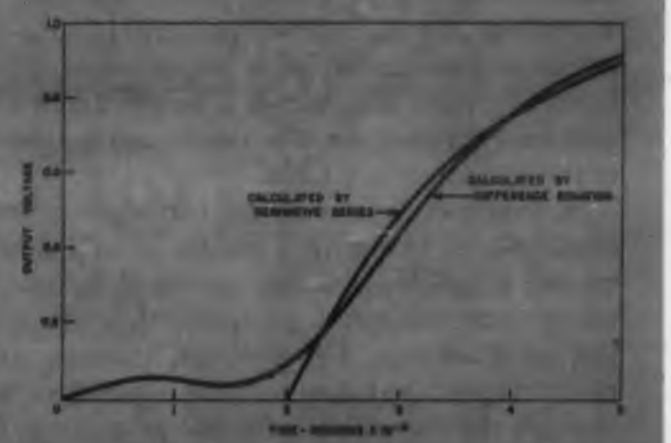


Fig. 8. Output of undercompensating duopole solved by derivative series and by difference equation. The difference between two solutions is small after time equal to delay associated with each term of derivative series.

Infrared-Transmission Materials Would be Unaffected by Radiation in Space

The safest assumption about infrared transmission materials in space would be that transmission efficiency is affected adversely by normal levels of radiation. However, tests, supervised by Dr. W. R. Langdon, and described here by Thomas E. Lusk, showed it would require more than a century of exposure for maximum, known radiation in space to affect the materials adversely.

Thomas E. Lusk
General Electric Co.
Ithaca, N.Y.

THE TRANSMISSION efficiency of 15 common infrared optical materials would not be affected adversely by exposure to the highest known levels of gamma radiation in space.

To affect the materials' transmission properties adversely would require their being exposed perpetually to the heaviest known gamma-radiation level in space for more than a century.

The infrared transmission properties of the 15 materials were tested after exposure to three levels of gamma radiation—0.975×10^4, 1.58×10^6, and 1×10^8 roentgens. The results are indicated in the accompanying table.

However, only four of the materials—germanium, silicon, Irtran *AB*-1 (similar to M_gF_2) and arsenic trisulfide—presently are used in space-vehicle infrared optics. In space, they are subject to irradiation by electrons, protons, and electrons-produced Xrays as the satellite passes through the Van Allen belts and solar flares.

The negligible effect of gamma radiation on these four materials is shown in detail in Fig. 1, a through d.

Different Radiations Have 'Same Effect'

Of course, the effects of gamma radiation are considerably different from those produced by electrons and protons. However, if the assumption is made that damage depends only on roentgen level, then the change produced by equal roentgen levels of gamma, electron, and proton radiation would be the same.

Approximately, a maximum of 100 roentgens per hour is encountered in the inner Van Allen Belt and the solar bursts, and 10 roentgens per hour in the outer belt. The solar bursts can be neglected in computing an approximate life time of materials in space, because the bursts usually exist only a few days a month.

Hence, a dose of 10^6 roentgens will be accumulated in about 1.1 years in the inner Van Allen belt. The damage produced in the laboratory by 10^8 roentgens will take about 110 years to develop in the inner belt. This also assumes the vehicle remains in the radiation belt all the time and that the infrared optics are exposed to the direction of radiation.

Radiation Source in Lab was Cobalt-60

The radiation-source for the laboratory tests was cobalt-60. The dose rate was 1.95×10^5 roentgens per hour. This rate did not produce appreciable heating in the samples, although the ambient temperature may have reached a maximum of 30 to 35 C because of absorption of radiation by the lead pig.

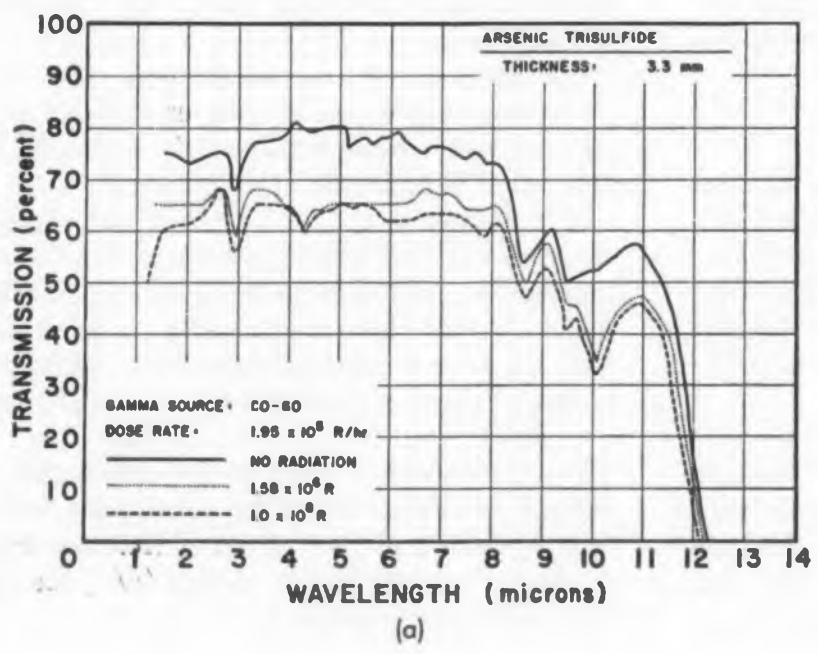
At least two samples of each material were tested (with the exception of silver chloride, a spinel and silicon-monoxide-coated single crystal silicon, where only one sample of each was available). Before the initial irradiation, the samples were optically polished so all samples of a particular material were of almost equal thickness.

Hence, when the infrared transmission between 1 and 14 microns was measured on a Perkin-Elmer Model 112 spectrometer, all samples of a particular material had the same transmission within the ±2 per cent reproducibility of the spectrometer.

The infrared transmission of all samples was determined before the initial irradiation and after each dose.

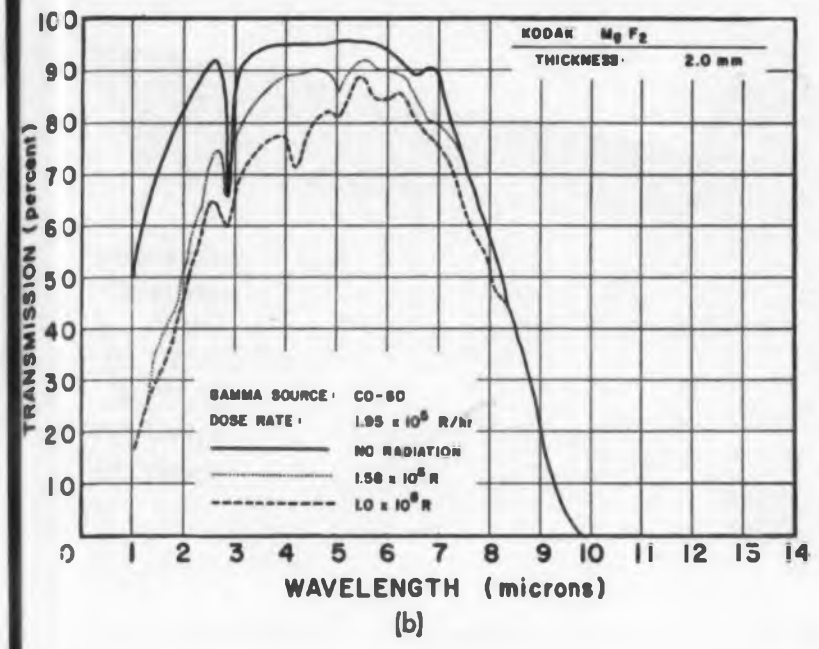
The measurements usually were made within five days after irradiation. (No attempt was made to determine the transmission within any specific time interval after irradiation.)

No transmission measurements were made at wavelengths shorter than one micron. ■ ■

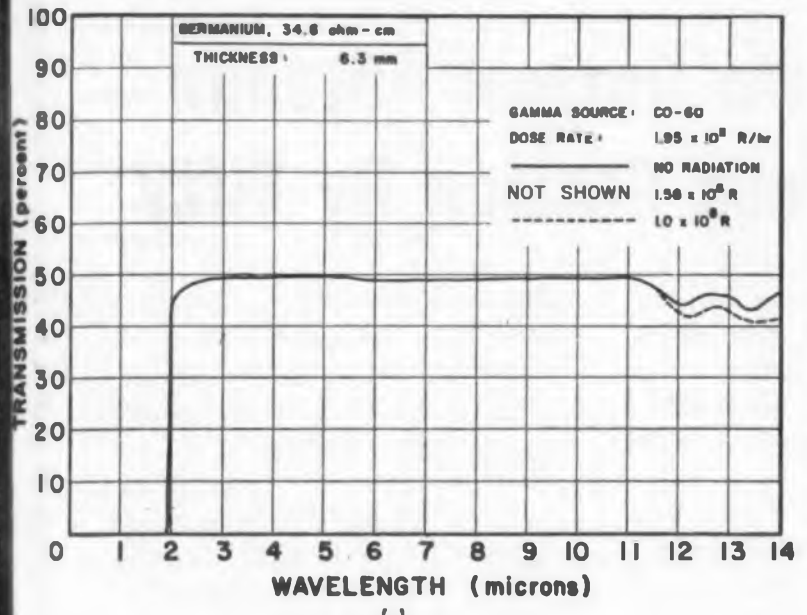


(a)

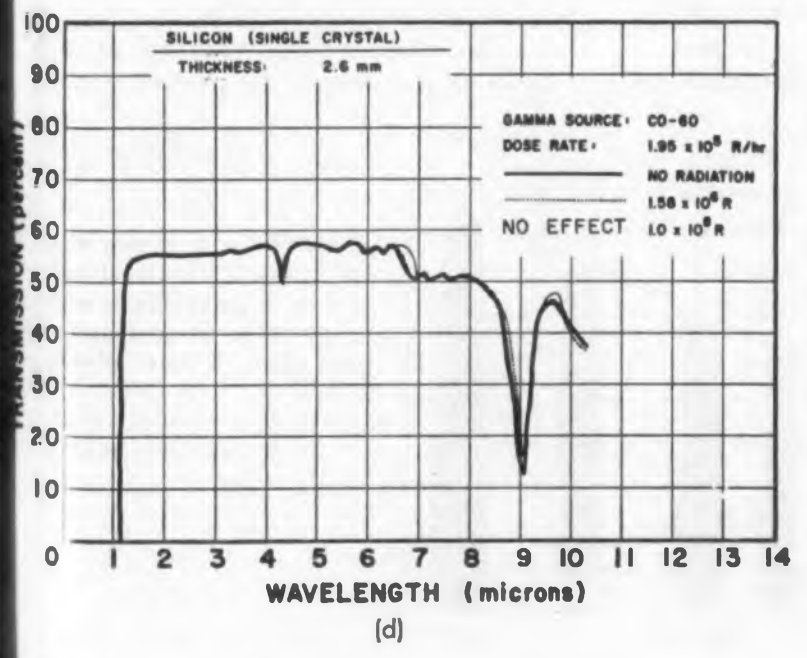
Fig. 1. Effect of high-level radiation on transmission efficiency of four materials presently used in infrared systems for space vehicles—(a) arsenic trisulfide, (b) magnesium fluoride (similar to the material known commercialy as Irtran AB-1), (c) germanium and (d) single crystal silicon. For highest known levels of space radiation to produce even these negligible effects would require materials to be exposed to radiation for more than a century.



(b)



(c)



(d)

Per Cent Change in Infrared Transmission Efficiency Due to Radiation

Material	Thickness	Radiation Level (Roentgens)	Infrared Wavelength in Microns													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Germanium Single Crystal (34.0 ohm-cm)	6.3 mm	10^8			0	0	0	0	0	0	0	0	0	−2	−2	−2
Silicon Single Crystal	6.3 mm	10^8		0	0	0	0	0	0	0	0	0	0	0	0	0
Silicon Boron doped	6.3 mm	10^8	−6	−4	−4	−4	−4	−4	−6	−5	−14	−14	−8	−8		
Silicon coated SiO for 4μ	2.5 mm	10^6		+14	+2	+1	−2	−5	0	0	0	0	0	0		
		10^8		+10	+1	+2	−8	−9	0	0	0	0	0	0		
Kodak 80-20 Arsenic modified Selenium	4.0 mm	10^8	0	−2	0	−1	−2	0	−2	−2	−2	−2	−2	−4		
Kodak MgF_2	2.0 mm	10^6	−32	−32	0	−6	−8	−4	−10	0	0					
		10^8	−32	−34	−6	−18	−14	−9	−13	−3	0					
Spinel	2.3 mm	10^8	−5	−4	−6	−4	−2	−20								
Corning $CaAl_2O_3$ #X-745 pm	2.0 mm	10^8		−5	0	−2	0	0								
Corning #0160 Glass	2.0 mm	10^8	−15	0	−2	+6										
Corning Pyrex #7740	2.1 mm	10^8	−10	−6	−8	−2										
As_2S_3	3.3 mm	10^6	−9	−10	−8	−15	−14	−12	−9	−8	−1	−14	−8	−2		
		10^8	−26	−14	−11	−16	−14	−15	−13	−11	−5	−16	−10	−4		
Mg O	5.0 mm	10^8	−10	−8	−4	−4	−4	−6	−2	0	0					
Lox-Grade Kel-F	2.3 mm	10^8	−6	−5	−14	0										
AgCl	6.3 mm	10^6	0	−4	−4	−2	−6	−14	+6	+21	+10	+6				
		10^8	0	−4	−4	0	−4	−10	−6	−2	−3	−3				
Sapphire	2.0 mm	10^8	−12	−2	0	−4	−4	−12								

DRAFTING TRENDS

In a typical application of the POST Diazo Materials Selector Chart, a draftsman, supervisor and reproduction specialist solve a special print-making problem in short order.

Solve unusual reproduction problems with new Diazo Selector Chart

Keeping up with rapid developments in graphic reproduction and communication techniques is a difficult job these days, even for the experts.

From the engineer's and draftsman's point of view, it's largely a matter of sorting out the specific information which helps him do a better job.

The new POST Diazo Materials Selector Chart does just that—provides a condensed, tabular reference piece that helps you anticipate the ideal diazotype prints for various needs before they occur. This convenient chart gives brief information on sensitized papers, intermediates and specialties in terse "what, when, why and where" style.

If you're concerned, for instance, with print distribution to different departments, units or groups, then prints on a variety of colored stocks might be the answer.

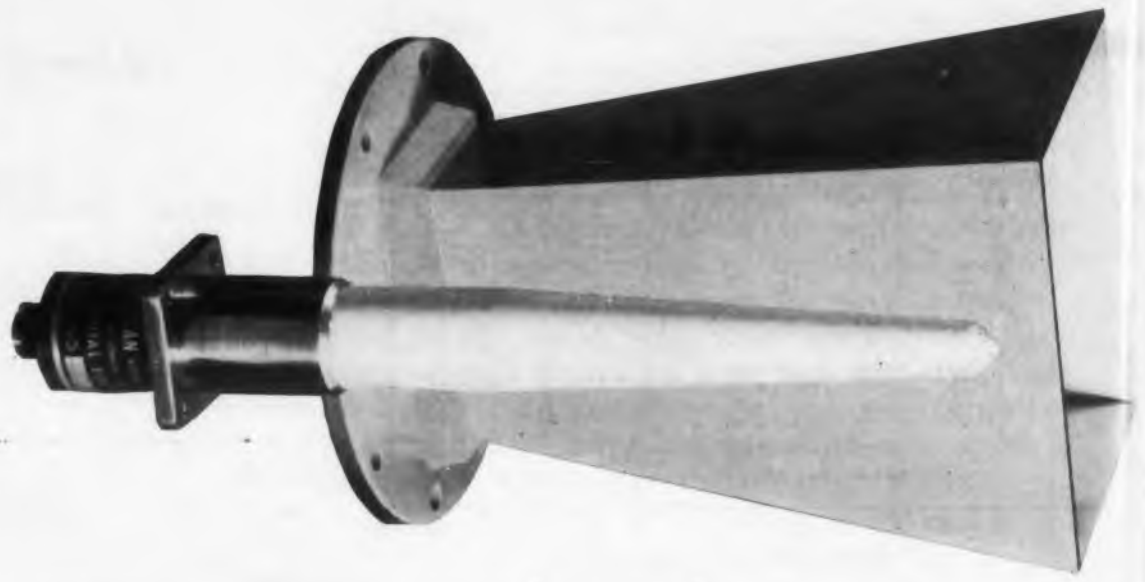
Increasing print production from diazo equipment with a lower-power light source . . . making legible prints from worn old tracings . . . even making copies from an opaque print . . . all can be handled by use of new POST 206M-14, a fast, extra-sensitive whiteprint paper.

Suppose a design conference calls for a poster, actual size, made from a large engineering drawing, rigid enough for display, tough enough for extreme handling and on-the-spot sketches? POST diazo-sensitized cardstock in 32 or 50 lb. weight can turn the trick on standard reproduction equipment, ammonia process or semi-moist. For many more helpful solutions to similar situations, ask for your personal file-size copy, of the POST Selector Chart, available from your POST dealer or Frederick Post Company, 3644 North Avondale Avenue, Chicago 18, Illinois.

POST

SENSITIZED PAPERS & CLOTHS • TRACING & DRAWING MEDIUMS • DRAWING INSTRUMENTS & SLIDE RULES
ENGINEERING EQUIPMENT & DRAFTING SUPPLIES • FIELD EQUIPMENT & DRAFTING FURNITURE

CIRCLE 57 ON READER-SERVICE CARD



Dramatic 50-to-1 reduction in cross-section is emphasized by this comparison with a standard horn, represented symbolically on the cover illustration.

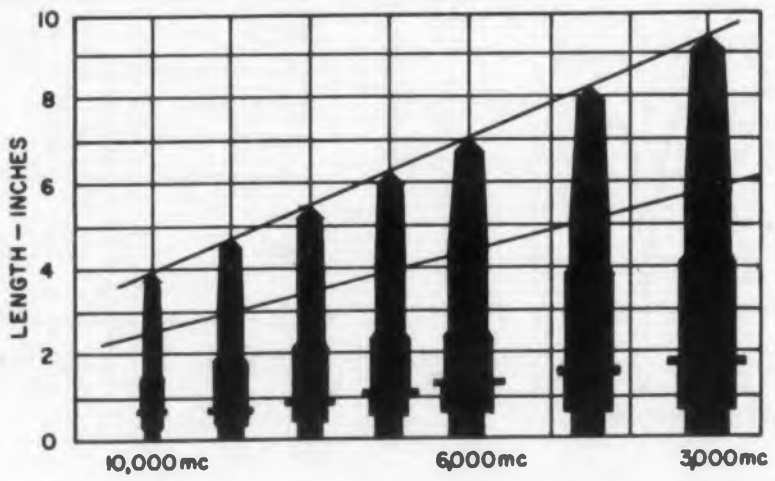
Dielectric Optical Antenna Cuts Cross-Section By Fifty

A NEW high-dielectric end-fire rod antenna duplicates the gain, directivity and other characteristics of a standard microwave horn while drastically reducing cross section to as little as 1/50 that of a horn.

The antenna's in-line coaxial connector allows missile and space-vehicle designers to fully exploit this aerodynamic advantage. The unit, developed and manufactured by Don-Lan Electronics Co., 1131 Olympic Blvd., Santa Monica, Calif., is said to be the first commercially available broadband rod antenna of this type and characteristics.

Much of the success of this novel design lies in the choice of advanced sintered materials. Beryllium oxide and aluminum oxide are used when higher temperatures are involved. Range *B* units are available for ranges up to 2000 F, while antennas can be supplied to operate at as high as 3,100 F. Lower cost materials are used in range *A* units, available for environments up to 300 F.

The extremely high and uniform density of these materials permits production machining tolerances to be held to 0.0001 in. These tight tolerances lead to beam-pattern repeatability as close as ±1 deg in a 50-deg pattern. The high dielectric constant of the material (in the



Antennas are available for 1,500-mc to 10,500-mc applications. Over-all length for 10-db gain varies from about 4 in. to about a foot.

range of $K = 15$) makes the small size and light weight possible (weight is 1/5 to 1/10 that of an equivalent standard horn).

Further bonuses arising from the choice of materials are the excellent dimensional stability over wide temperature and shock conditions, and negative moisture absorption. These characteristics lead to stable rf performance.

Available units cover the frequency range of 1,500 mc to 10,500 mc. As indicated in the graph, over-all dimensional scale is a function of frequency and gain desired. The vswr for any 5-per-cent bandwidth within this range is 1.30 to 1.0. Insertion loss is negligible, while efficiency is at least comparable to a standard horn.

The compact antenna lends itself to broad design flexibility. One unclassified application is in the Talos missile. Antennas are available with linear or circular polarization for multiple-element installations in small diameter missiles. The antenna has been adapted for multi-element phase or amplitude-monopulse systems. Additional size and weight saving is accomplished by eliminating the need for balanced mechanical mounting in compact search systems.

The unit can be attenuated electrically and can be cycled from linear to elliptical polarization at high speeds.

For a single-element antenna, price varies from $175 to $475, depending on quantity. Multiple arrays are priced by quotation. Most of these units are available from the manufacturer within 30 to 60 days, while some units can be delivered sooner.

For further information on this lens antenna, turn to Reader-Service Card and circle 251.

Electrocardiogram can be recorded on home-type magnetic tape recorder via Mnemotron pulse-frequency modulator/demodulator.

Low-Cost Analog Tape System Records or Plays Back Dc to 400 Cps

LOW-FREQUENCY data, even down to dc, can now be recorded accurately on conventional home tape recorders, thanks to a new device with the mnemonic name, Mnemotron.

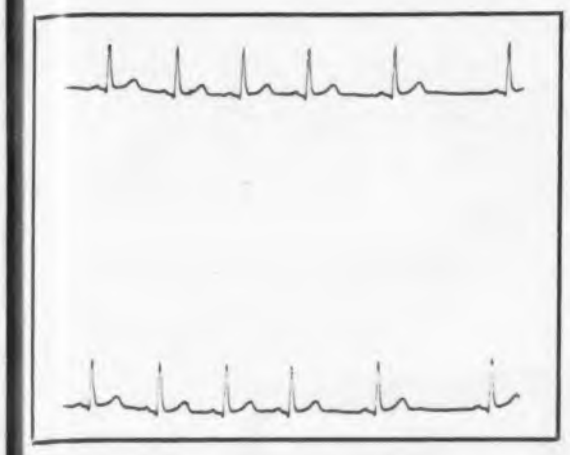
Manufactured by a company of the same name, Mnemotron Corp., 1 N. Main St., Spring Valley, N.Y., the M102 Analog Tape Recorder System is sensitive enough to resolve voltages as low as 6 mv. It can accept voltages as high as 3 v on one range and 10 v on the less sensitive range.

With appropriate transducers and preamplifiers, this recorder/reproducer system can record and play back variables such as pressure, temperature, strain, speed, and of course, any phenomena which can be measured with a dc meter.

Output from the instrument can be used as input to computer devices or as input to a scope. By viewing the output on a scope, an engineer can select those data he deems most useful for permanent recording on paper.

Input information can be in any form. It may, for example, be in the form of transients like those which might be de-

Information on tape is demodulated and transcribed onto paper by analog converter unit.



Electrocardiogram recorded directly on paper (bottom) and simultaneously recorded on magnetic tape and transcribed back to paper through Mnemotron units shows high accuracy (0.2 per cent full scale) of the modulator/demodulator.

rived from an electrocardiogram. The information is used to frequency-modulate a pulse carrier with a center frequency of 7,200 pps. With full modulation, this carrier can be driven from 4,000 to 11,000 pps. The frequency-modulated pulse train is delivered to, and recorded by a conventional tape recorder.

To retrieve the recorder information, one feeds the frequency-modulated pulse train from tape back into the Mnemotron. The usually distorted pulses from the pulse train are used merely as triggers in reconstituting the original pulses. The M102 converts the time-voltage integral of the pulses into varying dc-voltage levels which can be recorded on an oscillographic recorder.

By suitable selection of the record and playback tape speeds, one can expand or contract the time scale on the final record. Thus, one can extend the effective frequency response of oscillographic recorders or X-Y plotters.

The M102, a 2-channel converter, is offered alone (for $895), or with a companion tape recorder as a complete 2-channel analog tape recorder system (for $1,290). Delivery time for the 2-channel system is 15 to 30 days. Delivery time is longer and prices are higher (by about $450 per converter channel) for 4-, 6-, 7-, and 14-channel systems.

A Model M100A system is available for an additional $50 per channel. It allows one to record and play back simultaneously on the same channel.

For more information on these analog tape recorder systems, turn to the Reader-Service Card and circle 252.

NEW PRODUCTS

Covering all new products generally specified by engineers designing electronic original equipment. Use the Reader's Service Card for more information on any product. Merely circle number corresponding to that appearing at the top of each description.

Multimeter Expands Increments At Any Point In The Range

358

Type 5880 incremental multimeter permits increments of any range to be expanded and displayed on an external servo recorder. The instrument consists of a Simpson 270 multimeter, a suppressor power supply and an attenuator. The range is the same as that of the Simpson multimeter; typical accuracies are 1.5% for dc and 2% for ac. The servo recorder permits expansions of ±1%; the attenuator enables the expansion to be adjusted to any value from 1% to 100%. Applications for the unit are wherever a strip-chart recorder is used to display voltage, current or resistance.

Tensor Electric Development Co., Inc., Dept. ED, 1873 Eastern Parkway, Brooklyn 33, N. Y.
Price: $250.
Availability: 30 days.

Electrostatic Printer Tubes Translate Signals Into Printed Words

357

These electrostatic printer tubes can translate electronic signals into printed words and pictures on paper at the rate of 20,000 characters per second or more than 10,000 lines of computer information per min. The QV130 and the QV131 tubes have 3-in. matrices and were designed for short copy printing. The QV132 and the QV133 are 10-in. printer tubes and can print electronically stored or transmitted information on full page sheets. The tubes resemble flattened cathode-ray tubes with wire matrices across their faces. Tiny wires, 0.0001-in. thick and spaced 250 to the inch extend through the face of the tube. The varying cathode-ray beam current inside the tube passes through the matrix, depositing electrostatic charges on the paper as it passes against the tube.

Raytheon Co., Industrial Components Div., Dept. ED, 55 Chapel St., Newton, Mass.

Eight-Inch Ignitron Handles 100,000-Amp, 20-Kv Pulses — 356

A deceptively small ignitron, the GL-7703 is capable of passing and controlling a two-billion volt-ampere pulse. The tubes rating of a 100,000-amp, 20-kv pulse represents four times the power handling capacity of the GL-7171, up to now the most powerful ignitron produced by the manufacturer.

The new ignitron is simple in construction, and weighs less than 2 lb. The tube is 8-in. tall and has a 2-in. diam. A proprietary refractory metal is used for the anode in place of the usual graphite. This improved anode reduces fouling, while an oversize anode bushing gives the tube its large voltage-handling capacity. The usual pulse rate in capacitor discharge is 1 ppm. Half-cycle peak current is 60,000 amp for a 120-usec pulse and 100,000 amp for a 20-usec pulse. According to the manufacturer, the new tube will find use as a super crowbar for power supplies that require a means for rapid discharge of energy.

General Electric Co., Power Tube Dept., Dept. ED, Schenectady 5, N. Y.

Price: $145 ea.

Availability: From stock.

Tunnel and Backward Diodes For Computer Applications — 359

These germanium units meet the requirements of logic circuits and other computer applications. The backward diodes can also be used in low-level rectifier and detector circuits. Characteristics of the tunnel diodes are: peak current, 5 or 1 ma; peak-current tolerances, 2%, 5% or 10%; peak-to-valley ratio, 8:1; capacitance, 6 pf per ma; temperature range, −55 to +100 C. The backward diodes have these specs: shunt capacitance, 3 pf; forward voltage drop, 30 mv; leakage current, 400 mv. Forward voltage in the backward diode is 15% of the peak current of the companion tunnel diode.

Transitron Electronic Corp., Dept. ED, 168 Albion St., Wakefield, Mass.

Three Companies Offe

The two major advantages of the epitaxial transistor are the virtual elimination of the collector series resistance and a large decrease in the storage and turn-off times. The basic process in making epitaxial transistors consists of depositing a very thin layer, about 1/2-mil thickness, of high resistivity semiconductor material on a thicker substrate of very low resistivity material. Since the active part of the transistor is all within the high resistivity material, this process, in essence, provides a method for handling 1/2-mil thick semiconductor slices.

Rheem's RT409 Silicon Unit Is Similar To 2N697

The silicon epitaxial transistor, type RT409, i a 60-v collector breakdown unit and otherwis meets the general specifications of the 2N69 series. The typical collector-to-emitter saturatio voltage at 150 ma has been reduced by a facto of two. The V_{CE} for the RT409 is 0.35 as com pared to 0.7 for the 2N697. Compared unde similar test conditions, the typical storage tim for the epitaxial unit is less than 100 nsec, fo the 2N697 it is 400 nsec. Because the power di sipation is low, the RT409 may be operated a higher current levels. Other epitaxial transistor in the firm's line, to be announced soon, such a the 2N699, 2N699A, 2N657 and RT5004, will b made available at first in the TO-18, TO-5 an the firm's Microbloc packages.

Rheem Semiconductor Corp., Dept. ED, 35 Ellis St., Mountain View, Calif.

Price: *$170 ea for developmental units.*

Availability: *Six weeks after receipt of order.*

Offe itaxial Transistors

lotorola Offers 363
ow-Cost Type 2N834

This epitaxially grown silicon-mesa transistor, pe 2N834, gives increased performance on l device parameters. A comparison with stand- d silicon-mesa transistors indicates the epitaxial evices have higher breakdown voltage, higher equency response, lower storage time, and at e same time, lower saturation voltage and lower llector capacitance. Breakdown voltages are in e order of 90 v and storage time as low as 12 ec. Collector saturation voltage is reduced om 0.4 to 0.14 v, typical. At 50 ma saturation ltage is typically 0.28 v. They are capable of elivering 0.5-w power output with 10-db gain at mc. Current gain-bandwidth product is 500 c, collector capacitance is 2.0 pf.

Motorola Semiconductor Products, Inc., Dept. D, 5005 E. McDowell Road, Phoenix, Ariz.

ice: $18 ea in quantities of 100.

ailability: From stock.

lvania's Germanium 364
pes Resemble 2N702 and 2N711

Designated types SYL2300 and SYL2301 se epitaxial transistors are of the german- n diffused-base mesa type. They are electri- lly similar to conventional mesa transistor types N702 and 2N711, with improved performance saturation voltage and switching time. For uivalent transistor dimensions, the saturation a collector current of 50 ma is reduced by a tor of 3.5, typically 0.15 v at 50 ma for the itaxial units. Typical switching storage times reduced by a factor of 4.

Sylvania Electric Products, Inc., Dept. ED, 0 Third Ave., New York 17, N.Y.

ailability: Sample quantities immediately ilable, production quantities in November.

NEW PRODUCTS

Laboratory Oscilloscope 589

Vertical amplifier flat from 20 cps to 4.9 mc

Model 600 oscilloscope, for industrial and scientific applications, has a regulated power supply. A sweep frequency pulse on the panel terminal is for transformer ringing testing. Wide-band vertical amplifier is flat within 1 db from less than 20 cps to 4.9 mc. Two-range vertical sensitivity is from 20 mv per in.; horizontal amplifier response is uniform within 2 db from less than 20 cps to 200 kc. Linear sawtooth sweep is 10 cps to 100 kc. Input calibration voltage is 10 v, peak-to-peak. Power requirements are 105 to 125 v, 50 to 60 cps, 75 w.

Jackson Electrical Instruments Co., Dept. ED, 124 McDonough St., Dayton, Ohio.
Price: $335.
Availability: *Stock to 2 weeks.*

Tape Verifier and Duplicator 565

For punched tape

Model 1429, used in conjunction with tape readers and perforators, automatically verifies and duplicates error-free tapes in one operation. It can be used on up to eight channels in any code structure. Characters in disagreement are displayed for possible correction. The unit operates on 115 v at 60 cps, weighs 30 lb and is made for rack mounting.

Tally Register Corp., Dept. ED, 1310 Mercer St., Seattle 9, Wash.
Price: $850; fob Seattle.
Availability: 45 days.

Picture Tubes 511

Square corners expand viewing area

Nearly square corners on these 19- and 23-in. picture tubes have expanded their useful viewing areas to more than 95% of the area needed to display all the picture information transmitted. The 19-in. tube deviates no more than 15/16 in. from true flat. Both tubes use magnetic deflection with a diagonal deflection angle of 114 deg, are electrostatically focused, and require no ion trap.

Westinghouse Electric Corp., Electronic Tube Div., Dept. ED, PO Box 284, Elmira, N.Y.

Silicon Transistor 540

Has a minimum beta of 30

Type C106 symmetrical silicon transistor features a minimum beta of 30 in both directions and a maximum saturation resistance of 5 ohms at 10 ma collector current. The unit is designed for low-level applications, choppers, multiplexers, bi-directional switches and high-precision analog circuits requiring low saturation resistance with high "off" to "on" switching ratio.

Crystalonics Inc., Dept. ED, 249 Fifth St., Cambridge 42, Mass.

Oscillographic Recording Systems 514

Are direct-writing and photographic

These multi-channel recording systems combine the immediate readout of "direct-writing" and the high-frequency response of photographic recording. The direct-writing portion provides clear, inkless traces and is used to monitor events in the dc to 100 cps frequency range. The phographic recorder provides a frequency response to 500 cps. Trace overlap makes possible the recording of two events on a common base line.

Sanborn Co., Medical Division, Dept. ED, 175 Wyman St., Waltham 54, Mass.

NEW PRODUCTS

Variable Speed Drive 512

Fractional hp

This fractional hp variable speed drive features compactness and lightness. Speed ranges are from 1.2 to 4660 rpm with up to 10 to 1 variation and are available in 1/4, 1/2 and 3/4-hp ratings. Large diameter pullies are provided for cooler running, longer lasting belts. Electrical characteristics include: single phase; three phase; drip-proof; totally enclosed and explosion-proof. It is available with right-angle and helical gears.

Sterling Electric Motors, Inc., Dept. ED, 5401 Telegraph Road, Los Angeles 22, Calif.

Servo-Amplifier 515

For amplifying microvolts

Servo-amplifier, model SA-60C-4, is a compact, high-gain unit designed to amplify microvolts with stability. The unit will accept a low-level, balanced ac signal directly from a transducer. Specifications include: line voltage, 105 to 130 v; maximum voltage output, 140 v across 5 K at saturation with 90 μv input; power, 115 v ±10%, 60 cps, 1 phase, 50 w.

Schaevitz Engineering, Dept. ED, P.O. Box 505, Camden, N.J.

Pushbutton Switches 518

Have modular construction

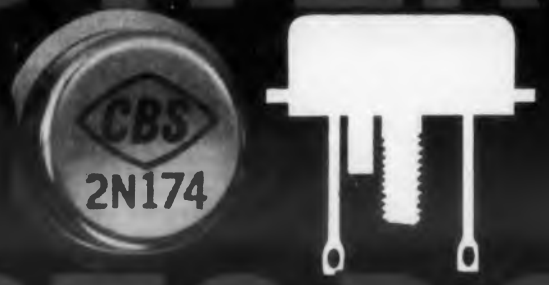
These are general purpose switches of modular construction that permit the use of two to 48 or more push-buttons in any array. Of light-weight construction, the switch has a life of 500,000 operations according to the manufacturer's claim. Any number of buttons in the general purpose switch can be interlocked. Each push-button can represent an 8 pst switch or a 4 pdt switch. Other combinations are available on request.

Telex Inc., Special Products Div., Dept. ED, 1633 Eustis St., St. Paul, Minn.

◀ CIRCLE 65 ON READER-SERVICE CARD

Now Added to Industry's Most Complete Line of Germanium Power Transistors

NEW CBS HIGH-POWER TRANSISTORS



Advantages

- High power output: up to 30 w Class A, 100 w Class B, 1000 w switching
- High voltages . . . high current gains . . . and high working currents
- Low-distortion ring emitter construction
- Hermetically welded JEDEC TO-36 male industrial case

Characteristics

All these CBS high-power transistors have: Max. dissipation, 150 watts* for a typical thermal resistance of 0.5° C/W; max. collector current, 15 amperes; junction temperatures, −65 to +100°C.

Type	Max. W. Diss.*	Max. Thermal Res°C/W	Max. V_{CBO}	Max. V_{CES}	h_{FE} (I_C = 5A) Min.	Max.
2N173	70	1.0	60	50	35	70
2N174	85	0.8	80	70	25	50
2N277	70	1.0	40	40	35	70
2N278	70	1.0	50	45	35	70
2N441	70	1.0	40	40	20	40
2N442	70	1.0	50	45	20	40
2N443	70	1.0	60	50	20	40
2N1100	85	0.8	100	80	25	50

*25°C base mounting temperature.

save costs • space • weight

You can now replace two 40-watt or four 20-watt paralleled power transistors with one CBS PNP high-power transistor. This one design change brings you important transistor . . . component . . . assembly . . . space . . . and weight savings. New economies become possible in power supplies and amplifiers and in high-power switching circuits.

Note the wide line of these CBS PNP high-power transistors, their pertinent characteristics and many advantages. Ask for complete technical data. Order these money-saving units today . . . at factory prices for quantities up to 1000 . . . from your Manufacturers Warehousing Distributor.

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CIRCLE 64 ON READER-SERVICE CARD

NEW PRODUCTS

AC Signal Amplifier 523

Has an operation life of 2,000 hr

All transistor ac signal amplifier model 853-001 has an operation life of 2,000 hr. It weighs 4.5 oz and was designed to amplify the output of a piezzo-electric, crystal type linear accelerometer to the level required by telemetry systems. Specifications are: gain, .5 to 50; input impedance, 300 megohms min; bandwidth, 2 cps to 100 kc; output impedance, 500 ohms max; output level, 2.5 v dc for biasing subcarrier oscillators and held to ±0.1 v over 0 to 100 C; limiting voltage, 6 v peak-to-peak.

Western Design Div. of U.S. Industries, Inc., Dept. ED, Goleta, Calif.

DC Power Supply 532

Uses transformer for current balance

Model P529A power supply uses a trimmer transformer to give a current balance of almost 100% from no-load to full-load conditions. It is an unregulated transformer-rectifier type and is completely static. Output is 26 to 31 v dc with a ripple voltage of 1 v peak, obtained from an input of 196 to 210 v, 300 to 420 cps. The power supply is rated at 100 amp, measures 10.5 x 5.5 x 15 in. and has an efficiency of 89%.

International Telephone and Telegraph Corp., Dept. ED, 67 Broad St., New York 4, N.Y.

Logic Inverter Circuits 520

Provide logic inversion with level restoration

These three transistorized logic inverter circuits are designed to provide logic inversion with level restoration. The T-136 is a dual inverter containing two identical inverter circuits; the T-137 is a buffered inverter circuit and the T-138 is a combination of 1/2 of the T-136 and the T-137. Each unit will operate at frequencies up to 250 kc. All

◀ CIRCLE 70 ON READER-SERVICE CARD

three units have power requirements of ±12 v dc.

They are packaged in containers 7/8 in. diam × 2-3/16 in. seated height and plug into standard 9-pin miniature tube sockets.

Engineered Electronics Co., Dept. ED, 1441 E. Chestnut Ave., Santa Ana, Calif.

Adjustable Meter Relays 519

Have external magnet meter movement

Model 29XA front adjustable meter relay has a dual adjust contact arrangement and an external magnet meter movement. Voltage and current rating for adjustable contacts is 500 mw, 5 to 15 v dc on resistive or diode protected inductive loads. Mechanical adjustment is within two angular degrees. Non-locking contacts may be positioned along the instrument scale arc by means of an external front adjusted gear drive.

Simpson Electric Co., Dept. ED, 5200 W. Kinzie St., Chicago 44, Ill.

Transistorized-Relay Drivers 536

Will operate most general purpose relays

These two transistorized-relay drivers will operate most of the general purpose relays now available. They will switch a resistive load at frequencies up to 1 kc at currents up to 400 ma and at voltages up to +30 v for the T-139 and +45 v for the T-141. These drivers must be provided with diode clamping to protect against back surges when used to operate relays. The turn-on signal is —3 v nominal, turn-off is —11 v. nominal. Both units have the same power requirements, ±12 v dc. They are packaged in containers measuring 7/8 in. diam x 2-3/16 in. seated height and plug into standard 9-pin miniature tube sockets.

Engineered Electronics Co., Dept ED, 1441 E. Chestnut Ave., Santa Ana, Calif.

CIRCLE 71 ON READER-SERVICE CARD ➤

NEW PRODUCTS

EIR Meter 574

Current range is 10^{-9} to 10 amp

Model 810 EIR meter has a current range of 10^{-9} to 10 amp ±2% dc and ±3% ac. Resistance range is 10 ohms to 10 meg, center scale, with 5% accuracy. Voltages can be measured from 1 mv to 1 kv ac ±3% over the range of 20 cps to 1 mc and from 1 mv to 1 kv dc ±2%. Input impedance is 10 meg. The instrument requires 117 v ac ±10% at 50 to 60 cps, weighs 18 lb and can be supplied in rack and cabinet models.

Smith-Florence, Inc., Dept. ED, 4228 23rd Ave. W., Seattle 99, Wash.

Price: *$445.*

Availability: *60 days.*

Sine-Wave Power Supply 590

Provides regulated 117 v ac at 1 kva

This transistor-regulated sine-wave power supply, designated model PS3210 Sineverter, provides a 117 v nominal regulated output at 1 kva. The unit is not damaged by overload, short-circuit or open-circuit operation. Line regulation is better than 6%; load regulation, better than 5%. Frequency is 60 cps ±1%. Efficiency is 70% min. Power input is 105 to 125 v dc. Unit is designed for rack mounting, measures 15 in. high and 17-1/2 in. deep. Weight is 180 lb.

Power Sources, Inc., Dept. ED, Burlington, Mass.

Price: *$1995 ea.*

Availability: *30 days.*

Pressure Switch 586

Activated by 5 to 300 psig

The model 6266 pressure switch can be preset to actuate in the 5 to 100 psig range with a tolerance of ±1 psig. Operating temperature is −65 to +180 F. The switch can endure a 300% overpressure and can mount directly on pressure fittings or built into pressure-fitting hardware. Housing is stainless steel. Diaphragm is non-corrosive, and is secured by a welded seam around its circumference. Current rating is 2 amp at 28 v dc or 110 v ac. Device measures 1.5-in long and 0.75-in. wide, and weighs 2 oz.

Aero Mechanism, Inc., Dept. ED, 13918 Saticoy St., Van Nuys, Calif.

Price: $40 to $60, 10 to 1,000 components.
Availability: 45 days.

Grid Circuit Tester 566

For all TV tubes

The GCT-9 tester offers complete coverage of all TV tubes, including voltage amplifiers, power output and heater-type diodes. All tubes are checked with the dc testing process. The unit also provides for the cathode continuity check and complete inter-element short test. It makes up to 11 simultaneous tests.

Seco Electronics Inc., Dept. ED, 5015 Penn Ave. S., Minneapolis, Minn.

Price: $32.95 to $34.95, depending on case.

NEW PRODUCTS

L-Band Transmitter 575

For airborne and ground use

Model 2701 transmitter has a frequency range of 1,650 to 1,680 mc, fm modulated with a minimum power output of 800 mw. It contains an integral power supply and operates from an input of 0.7 amp at 29 v from —55 to +72 C. Size is 5-1/2 in. long and 3-5/16 in. in diameter.

R S Electronics Corp., Dept. ED, 435 Portage Ave., Palo Alto, Calif.

Availability: *Made on order for 30-day delivery.*

Variable Delay Lines 572

Delay is 2 to 10,000 μsec

These continuously variable delay lines have bandwidths of up to 500 kc. Reproducibility and linearity of setting is 0.1%. Jitter is less than 1 nsec. Both military and commercial units can be furnished.

Ferranti Electric Inc., Dept. ED, 95 Madison Ave., Hempstead, L. I., N. Y.

Availability: *90- to 120-day delivery.*

Trimmer Potentiometers 579

Measure 1/2 in. in diameter

Models 140 and 150 are designed for trimming, control and servo applications. Model 140 is 0.3-in. long, weighs 0.1-oz and has a standard resistance range from 50 to 10 K. Model 150 is 0.6-in. long, weighs 0.15-oz and has a resistance range of 20 to 70 K. These bushing mount units have a standard linearity tolerance of ±1% or ±0.5% on special order. Servo mount, ball-bear-

ing units, having a linearity of 0.5%, can also be furnished.

Spectrol Electronics Corp., Dept. ED, San Gabriel, Calif.

Price: Model 140, $10; model 150, $12 (in bushing mount design).

Availability: From stock.

Power Relay 577

Multi-pole type

This 115-v, 400-cps relay with self-wiping contacts continuously handles 10 amp loads at 28 v dc and 115 v ac. It is available with up to 3 pdt contacts, an octal plug and a clear polystyrene cover. Dimensions are 1-3/8 x 2-1/16 in. The dpdt type is for 8-pin mounting and the 3 pdt type, 11-pin.

Kurman Electric Co., Dept. ED, 191 Newel St., Brooklyn 22, N. Y.

Price: $8.95 for spdt type; $11.45 for 3 pdt type.

Availability: Six-week delivery.

Voltage Comparator 404

Has dynamic range of 0.1 mv to 1,000 v

Model 465 voltage comparator operates as a high-low limit alarm over a wide input range. It indicates whether an applied voltage is over, between or below preset tolerance limits. Its range of from ±0.0001 to ±1,000 v makes it applicable to go/no-go type problems encountered in military and industrial systems. The unit can be used to operate lights, alarms, or relay closures for missile check-out systems, production line testing of resistors, transistors or other electronic components.

Cohu Electronics, Inc., Kin Tel Div., Dept. ED, 5725 Kearny Villa Road, San Diego 2, Calif

NEW PRODUCTS

Modular Silicon Rectifier Columns 588

Deliver up to 1,000 w of power per cu. in.

These silicon rectifier columns deliver up to 1,000 w of power per cu in. of volume. They are available for voltages from 10,000 to 120,000 v, with current capacity ranges from 1 to 50 amp. Complete columns can be operated in air, or in gaseous or liquid coolants. Applications include long-range radar transmitters, high-voltage dc resistance welders, induction heaters and pulse modulators.

International Rectifier Corp., Dept. ED, 1521 E. Grand Ave., El Segundo, Calif.
***Price:** Dependent on requirements.*
***Availability:** On request.*

X-Y Recorder 592

High-speed type

Model 560-RX-Y digital plotter accepts data from all digital computers and can be driven by punched-paper tape and punched-card data processors. Applications include monitoring industrial processes, evaluation of processed flight test data, statistical surveys and analysis of time varying systems by digital differential analyzers. It provides up to 200 incremental steps per sec on each axis; Z-axis modulation can be maintained at up to 10 operations per sec. Input power is 125 w.

California Computer Products, Inc., Dept. ED, 8714 Cleta St., Downey, Calif.
***Price:** $3,300.*

Transitron

introduces

an exciting new device for simpler, more reliable, more economical switching circuitry

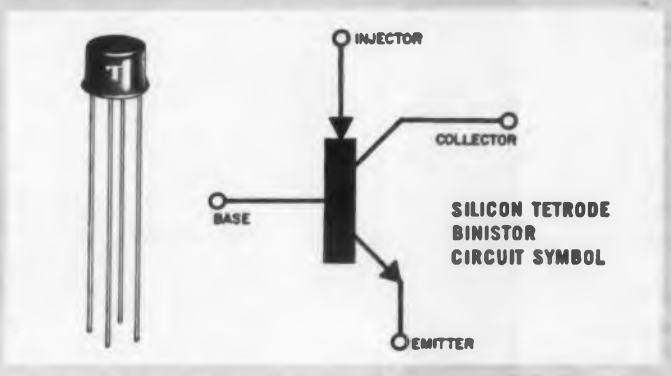
BINISTOR

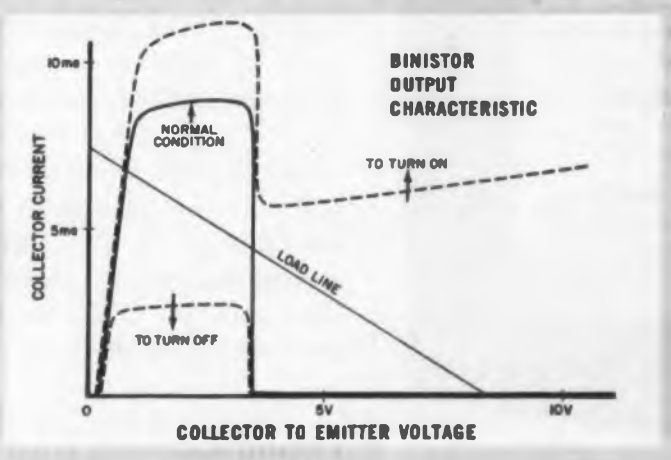
(BY-NIS-TOR)

The Silicon NPN Tetrode binistor is a new component and a new concept for the circuit designer!

The key parameters of this bi-stable, negative resistance device are determined by external circuitry in contrast to existing devices. The significant reduction of peripheral circuitry results in outstanding savings in cost, space, weight and solder connections. For example, a typical flip-flop requires at least 13 components versus only 4 in an equivalent binistor stage. Very large current and voltage gains are realized in both on and off directions. Inputs and output are compatible in level with typical transistor and diode circuits. The tetrode binistor can operate from −80°C to +200°C.

To learn more of this important new development — THE BINISTOR — and how it works — write for Bulletin No. TE-1360.





CONDENSED SPECIFICATIONS TRANSITRON BINISTOR

Typical Turn-off Current Gain	50 @ 15ma Collector Current
Operating Collector Current Range	50μa to 15ma
I_j critical	0.5ma @ 5ma Collector Current
Operating Temperature Range without Temperature Compensation	−65°C to 150°C

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NEW PRODUCTS

DC Amplifier 351

Common mode rejection is 180 db at dc

Type 1-104 floating differential dc amplifier offers common mode rejection of 180 db at dc and 130 db at 60 cps, with up to 1,000 ohms line unbalance. It is designed to amplify dc signals from strain gages, thermocouples, and bridge-type transducers. It provides complete isolation of input signal from amplifier output and chassis ground. Stability is 5 mv over a six-month period.

Neff Instrument Corp., Dept. ED, 2211 E. Foothill Blvd., Pasadena, Calif.
Price & Availability: *$800; 30-day delivery.*

Linear Potentiometer 352

Life is better than 25,000,000 cycles

Model 34LP linear-motion potentiometer is made of conductive plastic material that provides the unit with a life in excess of 25,000,000 cycles. The unit has Teflon insulated leads. Terminals can be mounted on the case by special order. Resistance values of 50 ohms to 1 meg can be supplied. Case length is 1-3/4 in.

New England Instrument Co., Inc., Dept. ED, 1334 Main St., Waltham, Mass.
Availability: 60 days.

Liquid Cooling Unit 618

For radar transmitting tubes

Model D/SCU-1000 liquid cooling unit provides cooled, purified water to high-powered radar transmitting tubes. It has other applications in which the coolant is purified water. Packaged in a fully enclosed, drip-proof cabinet, the unit has a built-in meter for instantaneous

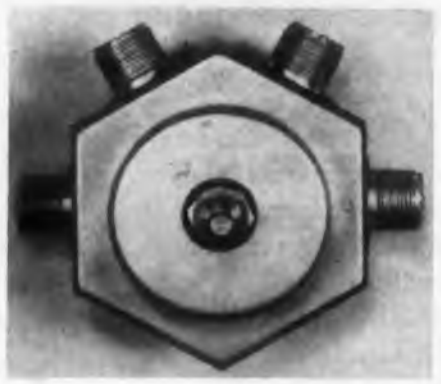
reading of resistivity of input and output water. The filter cartridge can be replaced without stopping the operation of the equipment.

Budd Lewyt Electronics, Inc., Environmental Systems Section, Dept. ED, 43-22 Queens St., Long Island City 1, N.Y.

Price & Availability: *Prices from $4,000 to $6,000; delivery 90 days after order received.*

Coaxial Switches 353

For radio frequencies to 30 mc



These multi-position coaxial switches are designed for radio frequencies to 30 mc. Model 550A handles up to 1 kw of modulated power with a maximum of 45-db crosstalk. It selects any one of five transmitters, antennas, exciters or other devices. Model 551A two-pole, two position unit is for switching equipment in or out of series connections. Both switches can be used with 52- or 70-ohm coaxial lines.

Barker & Williamson, Inc., Dept. ED, Bristol, Pa.

Pressure Transducers 355

Have ranges up to 0 to 5,000 psi

These industrial pressure transducers are available in full scale ranges of 0 to 0.05 psi through 0 to 5,000 psi. They operate from 115 v ac at 60 cps. Temperature range is —65 to +160 F. They weigh 9 lb, including housing, and measure 4-1/2 x 8-5/8 x 3-3/16 in.

Ultradyne, Inc., Dept. ED, P. O. Box 3308, Albuquerque, N.M.

Price & Availability: *$232 to $314; 30-day delivery.*

CIRCLE 80 ON READER-SERVICE CARD

NEW PRODUCTS

Miniature Chopper 747

Drive is 6.3 at 60 cps

Weighing 9 g, model 30 chopper is for printed circuit use. Characteristics are: drive, 6.3 v at 60 cps; dwell, 175 deg avg; phase, 25 ±10 deg; and balance, within 15 deg. Jewel bearings are used.

Airpax Electronics, Inc., Cambridge Div., Dept. ED, Cambridge, Md.
Availability: 2 to 6 weeks.

Miniature Brakes, Clutches 619

Rated at 1.5 lb-in.

These miniature brakes and clutches, designed for power drives rated up to 1.5 lb-in., are less than 1 in. in diameter and 7/8 in. long. They are designed for aircraft components, data processing equipment, and similar equipment requiring rotary drives which cycle automatically or remotely. These units have stepless torque modulation and operate from a variety of actuating devices. They operate directly from 28 to 90 v dc.

Warner Electric Brake and Clutch Co., Dept. ED, Beloit, Wis.

Marker Generator 354

Provides pulses of 10 μsec and 1 msec

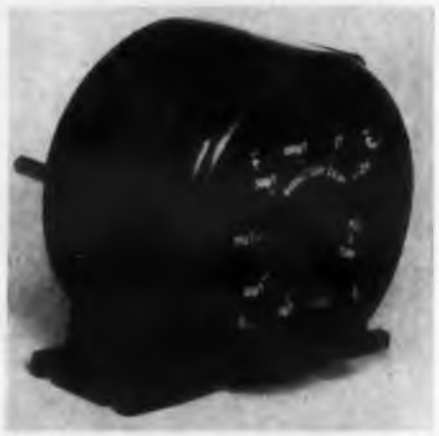
Model LOO MG 1 marker generator uses crystal control to provide a 10-μsec and a 1-msec pulse to accurately calibrate the sweep of an oscilloscope. Weighing 8 oz, the unit operates on its own 9-v battery. No warm up time is necessary.

Johnson Electronics, Inc., Electronics Div., P. O. Box 1675, Casselberry, Fla.

NEW PRODUCTS

Step-Function Speed Reducer 740

Torque capacity is to 50 oz-in.



This step-function speed reducer is available with either a single-geared reduction ratio or a continuously variable, friction-type speed change of limited ratio. Torque capacity is up to 50 oz-in.; speeds are to 1,500 rpm, continuous, and 3,000 rpm, intermittent; and size is 4.5 in. in diameter and 3 in. deep. Designated models 00140 through 00144, the units provide ratios of up to 1,000:1. They can be used in oscillators, tuning condensers and other devices.

Barry Controls Inc., Insco Co., Dept. ED, Hollis St., Groton, Mass.

Microwave Radio Equipment 748

Range is 11,000 to 15,000 mc

Model MW-601 microwave radio system provides terminal circuits for lower frequency systems entering congested areas. A temperature control chamber is provided for the klystron. Both the transmitter and receiver have ferrite devices to protect the transmitter klystron from effects of mismatch. Model 52A-1MW transmitter, shown, has an output of 100 mw, a frequency stability of ±0.05%, and a nominal deviation of ±3 mc. Model 54A-1MW receiver has a tangential threshold sensitivity of —117 dbw, a noise figure of 15 db max, an if of 70 mc, and an if bandwith of 15 mc at 3 db points.

Collins Radio Co., Dept. ED, P.O. Box 1891, Dallas 21, Tex.

Rechargeable Battery 377

Capacity is 1,000 ma

The D style 2-v battery can be recharged 1,000 times. Although wet-cell construction is used, the unit is guaranteed not to leak if left in a radio or similar equipment for a year or longer. The two-cell charger, also offered, is equipped with indicator lights.

Beamco Associates Inc., Dept. ED, 8 E. Spring St., Ardmore, Pa.

Price & Availability: *$1.97 for battery in quantities of 48 and up; $2.98 for charger. Delivery is from stock.*

Ceramic Capacitors 378

Come in values of 47 pf to 0.01 μf

These axial lead units are usable at a full rated voltage of 200 v to 150 C. Uses are in airborne and ground system equipment. The units are available in tolerances of 5%, 10%, 20% and GMV tolerances. Sizes are from 0.1 x 0.125 x 0.075 in.

King Electronics Inc., Dept. ED, 915 Meridian Ave., South Pasadena, Calif.

Availability: *Immediate.*

Tantalum Capacitors 381

For missile applications

These P-type tantalum capacitors are intended for missile, airborne, and similar applications up to 125 C. At maximum temperature and rated working voltage the units provide 2,000 hr of service. They are guaranteed to altitudes of 80,000 ft and will withstand 20-g acceleration from 50 to 2,000 cps. Capacitance values range from 1.75 to 330 μf at dc working voltages of 85 v for operation to 125 C and 125 v at 85 C working temperature.

International Telephone and Telegraph Corp., Components Div., Dept. ED, 815 San Antonio Road, Palo Alto, Calif.

Price & Availability: *From $2 to $7 in quantities of 1,000; available from stock.*

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NEW PRODUCTS

Trimming Potentiometer 434

Measures 1/3 in. in diameter

Measuring 1/3 in. in diameter and weighing 1 g, model 80 trimming potentiometer is a single-turn unit designed for printed circuits. It is sealed to meet requirements of MIL-STD-202A and MIL-E-5272C. Some specifications of the unit are: diameter, 0.345 in.; height, 0.28 in.; resistance range, 50 ohms to 10 K; tolerance ±5%; noise, 100 ohms ENR per NAS-710; power rating, 1 w; shock, 50 g; vibration, 30 g to 2,000 cps; load life, 1,000 hr.

Spectrol Electronics Corp., Dept. ED, San Gabriel, Calif.

Price & Availability: *$6 ea for 1 to 9 units; from stock.*

Variable Bandpass Filters 741

For af use

Designed for audio frequency use, type A103 continuously variable bandpass filters have no vacuum tubes, transistors or power supplies. Four major types are offered. Group 1 is step variable with a center frequency from 50 cps to 1,000 cps. Group 2 has a continuously variable center frequency from 50 to 2,000 cps. Group 3 has a center frequency continuously variable from 280 to 5,200 cps and group 4, center frequency continuously variable from 40 cps to 10 kc.

Ad-Yu Electronics Laboratory, Inc., Dept. ED, 249-259 Terhune Ave., Passaic, N.J.

Adhesive Tape 460

Specially etched Permacel 423 Teflon-film adhesive tape accepts printing. It is compatible with epoxy resins and electrical varnishes, and adheres to itself. The material is suitable for continuous operation at temperatures from −150 to +500 F. Electrical strength is 8,500 v and insulation resistance is 2,000,000 meg.

R. S. Hughes Co., Inc., Dept. ED, 4515 Alger St., Los Angeles 39, Calif.

Price & Availability: $21.97 for 36 yd of 1-in. tape; from stock.

IF Transformer 461

This miniature, bobbin-constructed unit has a can dimension of 0.25 in. and a height of 29/64 in.

Radio Industries, Inc., Dept. ED, 666 Garland Pl., Des Plaines, Ill.

Crimping Tool 466

The CT-3050 is for insulated and non-insulated terminals and connectors. It cuts and strips wire, shears bolts and screws, and crimps all terminals in wire ranges 22 through 10.

Waldom Electronics, Inc., Dept. ED, 4625 W. 53rd St., Chicago 32, Ill.

Indium-Clad Aluminum 463

These preforms are for use in forming alloy junctions in germanium semiconductor devices. The indium cladding melts first at 400 C.

Accurate Specialties Co., Inc., Dept. ED, 340 Hudson St., Hackensack, N. J.

Harness Assemblies 464

These harness assemblies, for applications to 1,600 F, are available in a wide range of sizes and materials.

Harco Laboratories, Inc., Dept. ED, 77 Olive St., New Haven, Conn.

Indicator Lamps 491

The Tec-Lites, miniature neon transistor-driven indicator lamps, operate on low voltages and provide a minimum life of 25,000 hr. The units are shock-resistant.

Transistor Electronics Corp., Dept. ED, 3357 Republic Ave., Minneapolis 26, Minn.

Voltmeters and Ammeters 498

Type KX-251 100-deg indicating instruments have ranges of 20 μa to 50 amp and 35 mv to 800 v. They can be used in magnetic fields of up to 500 gausses.

Westinghouse Electric Corp., Dept. ED, P. O. 2099, Pittsburgh 30, Pa.

NEW PRODUCTS

Linear-Motion Pot 417

Fits in hydraulic actuators

Model 159 tubular pot was designed for internal installation in hydraulic actuators and other telescoping assemblies. The 1/2-in. diameter case with concentric actuating shaft is O-ring sealed against contamination from hydraulic fluids and high-humidity conditions. Standard travel ranges are 1 to 5 in. Resolution is 0.001 in.

Bourns, Inc., Dept. ED, 6135 Magnolia Ave., Riverside, Calif.

Availability: *Made to customer specs.*

Miniature Toroidal Inductors 581

For printed-circuits

The firm has expanded its line of miniature toroidal inductors to include the following types: MM-5, 20 mh, 20 ma dc max; MM-6, 30 mh, 16 ma; MM-7, 60 mh, 11 ma; MM-8, 120 mh, 8 ma; MH-5, 10 mh, 22 ma; MH-6, 15 mh, 18 ma; MH-7, 25 mh, 14 ma; MH-8, 40 mh, 11 ma. Units are 7/16 in. OD and 1/4 in. high and weigh 0.07 oz. Hermetically sealed, they have a temperature range of −55 to +100 C. Terminal spacing is 21/64 in. MIL specs are met.

United Transformer Corp., Detp. ED, 150 Varick St., New York 13, N. Y.

Availability: *From stock.*

Half-Wave Rectifier 419

Piv is 1,000 v

This 10-amp, 1,000-piv rectifier is designed for control applications requiring a half-wave rectifier. Type 664L has a lug base; type 664P has bracket base and flying leads for panel mounting. Specifications are: filament voltage, 2.5 v; filament current, 25 amp; peak anode current, 120 amp; and condensed mercury temperature limits, −40 to +100 C.

National Electronics, Inc., Dept. ED, Geneva, Ill.

Price: *$26.*

Availability: *From stock.*

Integrating Motor Tachometer 716

Has high output-to-null voltage ratio

This size 15 integrating motor tachometer has high output-to-null voltage ratios and remains accurate from —55 to +80 C. No warm-up time is required at any temperature within the operating range. No heaters, mechanical thermostats, amplifiers or external heat sources are used, resulting in less weight and power drain on the over-all system.

United Aircraft Corp., Norden Div., Dept. ED, Jericho Turnpike, Commack, L.I., N.Y.

Silicon Varactor Diodes 699

Cut-off frequency is 120 kmc

Type MA-4297 silicon mesa varactor diodes have a cut-off frequency of 120 kmc. Shunt capacitance is about 0.4 pf and series lead inductance is about 2×10^{-9} h. Low-capacitance units used in 5,500-mc receivers that are equipped with parametric amplifiers achieve stable over-all receiver noise figures of 2.2 db for ±10 mc bandwidth. Stable over-all receiver noise figure is under 1.8 db for 3,000-mc radar receivers using parametric amplifiers.

Microwave Associates, Inc., Dept. ED, Burlington, Mass.

Availability: Experimental quantities, immediate.

X-Band Isolator 388

Measures 1/2 in. long

This X-band isolation model XM2, is 1/2 in. long. It has a minimum isolation of 20 db and a maximum insertion loss of 0.3 db at 9375 ±25 mc. VSWR is 1.2 max. The center frequency can be modified within the X-band.

E & M Laboratories, Dept. ED, P.O. Box 2427, Van Nuys Station, Van Nuys, Calif.

Price & Availability: $65 to $175 depending on quantity; units are made to order.

CIRCLE 94 ON READER-SERVICE CARD ➤

NEW PRODUCTS

NPN Power Transistors 706

Rated at 60 w

These four diffused-silicon, npn power transistors, types 2N1487 through 2N1490, dissipate 60 w at a mounting-flange temperature of 25 C. Temperature range is −65 to +175 C. Types 2N1489 and 2N1490 transistors have beta ratings from 25 to 75 with saturation resistance of 0.67 ohms max measured at 1.5 amp. Units are hermetically sealed in welded cases conforming to the JEDEC TO-3 outline. The collector is in electrical contact with the case. Applications are in power coverters, power-supply regulators, relay replacements and controls, and dc and servo amplifiers.

Silicon Transistor Corp., Dept. ED, 150 Glen Cove Road, Carle Place, L.I., N.Y.

Price & Availability: *$50 to $75; three week delivery.*

Plug-In Sweep Generator 713

For alignment applications

This plug-in sweep generator is designed for alignment of if stages and wide-band amplifiers. No power cables or batteries are required. The device has separate center-frequency and sweep-width controls. Marker input, synchronization and blanking, variable sweep rate and 10^4 short-term stability in center frequency are provided.

Teltronics, Inc., Dept. ED, 277 Main St., Nashua, N.H.

Price & Availability: *$98.90; delivery from stock in small quantities.*

Insulated Jack 467

No. 4351 insulated jack is for use in quick and tight patchwork panels. It mates with the firm's plugs having pin diameters of 0.045 in.

Cambridge Thermionic Corp., Dept. ED, 445 Concord Ave., Cambridge 38, Mass.

Inertial Dampers 468

Model 1D-15-100, size 15, inertial damper can be used in high-performance instrument servo loops. The units, also available for sizes 11 and 18, work equally well with 60- or 400-cps servo motors.

Industrial Control Co., Inc., Dept. ED, Central Ave. at Pinelawn, Farmingdale, N. Y.

Plastic Instrument Cases 469

The interior compartments of these ABS thermoplastic, custom-designed instrument cases are specially formed to hold various shapes and sizes of electronic instruments.

Hollywood Plastics, Inc., Dept. ED, 4560 Worth St., Los Angeles 63, Calif.

Decade Scaler 470

Model N-240 3.5-in. scaler is for use in analytical scintillation and proportional counting systems. Pulse-pair resolution is 1 μsec, with a continuous repetition rate of up to 250,000 cps.

Hamner Electronics Co., Inc., Dept. ED, P.O. Box 531, Princeton, N. J.

Rosin Flux 471

The RU series activated rosin flux is for electronic use where non-conductive, non-corrosive flux residues are required.

Fusion Engineering, Dept. ED, 17921 Roseland Ave., Cleveland 12, Ohio.

Wire Stripper 473

The Glo-Melt stripper is for on-the-job or bench work; a foot control is optional. Stripping of all plastic wire including Teflon is accomplished. A Nichrome cutting element is used.

American Electrical Heater Co., Dept. ED, 6110 Cass Ave., Detroit 2, Mich.

Thyratron Trigger System 476

Type SP-504 is for triggering the 1237, 1754, and the SGR-2 thyratrons. It is small in size and is mechanically rugged.

Axel Electronics, Inc., Dept. ED, 134-20 Jamaica Ave., Jamaica 18, N. Y.

Series Motor 496

Type TW, for special purpose applications where fractional-horsepower motors are required, has removable brushes for quick, easy replacement.

Redmond Co., Inc., Dept. ED, Owosso, Mich.

NEW PRODUCTS

Mercury Plunger Relay 714

Will handle 100 amp at 115 v

The type 100 mercury plunger relay will handle 100 amp at 115 v ac. Mercury-to-mercury contacts are hermetically sealed; an inert-gas atmosphere quenches arcs to provide cool operation. The relay is suitable for motor and lighting control, heating power and other high-current applications.

Ebert Electronics Corp., Dept. ED, 212-26 Jamaica Ave., Queens Village, N.Y.

Price & Availability: *From $32.50 to $21.20, depending on quantity; delivery is 1 to 2 weeks.*

Printing Scalar 711

For high-speed counting systems

The type N-276 scalar is designed especially for use in systems where high speed and automatic operation are needed. It is intended for use in conjunction with the firm's type N-803 printing timer. Preset counts from 10 to 500,000 are provided. At the end of the preset count or time, an optional printer prints the scalar display and the instrument automatically starts counting again. The device has a pulse-pair resolution of better than 1 μsec, a repetition rate of 1 mc, and a display of six electronic decades. Sensitivity is ±4 v min. Dimensions are 3-1/2 x 19 x 13-1/2 in.

Hamner Electronics Co., Inc., Dept. ED, P. O. Box 531, Princeton, N.J.

High-Voltage Test Set 379

Produces 5 ma continuously at 50 kv

Designed for dielectric testing and leakage-current measurement at high voltage, the model S50-5DC test set provides 5 ma continuously at 50 kc. The high-voltage tank is oil-filled, weighs 90 lb and occupies less than 1 cu ft.

Peschel Electronics, Inc., Dept. ED, Towners, Patterson, N.Y.

Price & Availability: *$1,200; delivery is 10 days.*

High-Gain Power Transistors 389

For high-frequency applications

These npn diffused-silicon power transistors, types 2N1661 and 2N1662, have high gain and are designed for high-frequency power handling. Collector-to-emitter voltages are 80 and 100 v, respectively. Collector current is 2 amp max; beta frequency, 25 mc min; power output, 85 w. The units have applications in regulated power supplies, power switching, amplifiers, oscillators, core drivers and servo amplifiers.

Raytheon Co., Semiconductor Div., Dept. ED, 215 First Ave., Needham, Mass.

Price & Availability: *2N1661, $67.50; 2N1662, $90; delivery from stock.*

Extension-Plunger Slide Switches 382

For unconventional mountings

These extension-plunger slide switches are designed for applications where conventional panel mounting is inconvenient. Model SW-726X switch is a dpdt device with detent and a contact rating of 0.5 amp at 125 v, ac or dc. Also available are spst, spdt and dpst switches with detent, and spst and spdt switches with spring return.

Continental - Wirt Electronics Corp., 26 W. Queen Lane, Philadelphia 44, Pa.

Availability: *Immediate.*

CIRCLE 101 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Regulated Power Supplies 707

Rated 300 to 500 v, 0 to 500 ma, dc

The output for model RR 550 dc power supply is 300 to 500 v at 0 to 500 ma. Line and load regulation is 0.1%. Filament output is 6.3 v, 15 amp. Input is 105 to 125 v, 55 to 400 cps. The device is rack mounted; panel height is 5-1/4 in. and depth is 14-1/4 in.

Trans Electronics, Inc., Dept. ED, 7349 Canoga Ave., Canoga Park, Calif.

Price & Availability: *$310 without meters; $350 with meters. Delivery is from stock.*

Transistorized Power Supplies 710

Provide 12 v at 5 amp

Model PS111M transistorized power supply, one of a series, has the following specifications: output, 12 v dc at 0 to 5 amp; transient response, 50 mv or less for 50 μsec or less square-wave load; no line transients; line regulation, 0.1%; load regulation, 0.25%; stability, 0.5% or 50 mv for 24 hr; ripple, 1 mv rms. Device measures 19 x 5-1/4 x 10 in., weighs 15 lb. Input is 105 to 125 v, 60 to 400 cps.

Valor Instruments, Inc., Dept. ED, 13214 Crenshaw Blvd., Gardena, Calif.

Price & Availability: *$395; two weeks.*

Film Resistors 422

Are rated at 1 and 1/2 w

Types C-20 and C-32 resistors have resistance ranges of 56 ohms to 150 K and 56 ohms to 470

K, respectively. Other specifications are: derating, full load at 70 C ambient to zero at 150 C; load life, change in resistance of 1% and 1.5% after 1,000 hr operation at 70 C; temperature coefficient, ±150 ppm per deg C from −55 to +150 C; and noise level, 0.1 mv per v of applied signal.

Corning Glass Works, Dept. ED, Bradford, Pa.

***Price:** Type C-32 with 5% tolerance, 6.1 cents in quantities of 5,000; type C-20 with 5% tolerance, 5.9 cents.*

High-Gain Amplifier 362

Bandwidth is 0.1 to 320,000 cps

Model 72 amplifier is a low-noise, high-gain, wide-band unit useful in research and development work, both as an amplifier and a noise source. Nominal bandwidth is 0.1 cycle to 320 kc. Gain is adjustable in 3 db steps from 100 to 10,000. Noise is less than 3 μv; distortion, less than 0.5%. With an auxiliary input, gain is 500,000.

Shapiro and Edwards, Dept. ED, 1130 Mission St., South Pasadena, Calif.

***Price & Availability:** $1950; stock to 45-day delivery.*

Solid-State Switches 418

For airborne and missile uses

These solid-state switches are designed for airborne and ground-control missile applications and aircraft uses. Model EA 154, for example, operates from an input of 110 v ac at 400 cps and is rated at 2 amp at 28 v dc. It stands temperatures from −40 to +160 F, 25 g shock for 10 msec, 10 g vibration from 5 to 500 cps, and humidity, salt spray and fungus. It meets MIL-E-4790.

Thermador Electronics, Dept. ED, 715 S. Raymond Ave., Alhambra, Calif.

NEW PRODUCTS

Subminiature RF Tubes 359

Have high transconductance with low heater power

Two subminiature rf-amplifier tubes, types CK6611 and CK6612, have mutual conductances of 1,000 and 3,000 μmhos at filament powers of 25 and 100 mw, respectively. Plate voltage is 30 v max. Operating life-time is over 5,000 hr. Units are designed to stand shock, vibration and fatigue conditions.

Raytheon Co., Industrial Components Div., Dept. ED, 55 Chapel St., Newton, Mass.

Price & Availability: *CK6611, $9.95; CK6612, $12.45. Delivery from stock.*

Parametric Amplifiers 408

For all microwave frequency applications

These reactance diode parametric amplifiers are designed for applications at all microwave frequencies. The heart of the line is the gallium arsenide, variable reactance diode which gives improved noise performance over a wide range of temperatures. Typical models include: model S-21, S-band tunable from 2.7 to 2.9 gigacycles, has ratings of 3 db over-all noise figure (double sideband) with 15 db gain over a 15 mc bandwidth; model C-11, C-band tunable from 4.4 to 5 gigacycles, has a 3 db over-all noise figure (double sideband) with 15 db gain over a 20 mc bandwidth; model L-11, tunable from 0.9 to 1.2 gigacycles, has a noise figure of 1 db (double sideband) with 16 db gain over a 50 mc bandwidth.

Texas Instruments Inc., Dept. ED, 6000 Lemmon Ave., Dallas 9, Tex.

Miniature Lights 465

Series MCL indicators are for commercial data processing and industrial control system applications. Six different types offered are neon or incandescent lamps, pin or wire lead terminals, and square or round lenses.

Transistor Electronics Corp., Dept. ED, 3357 Republic Ave., Minneapolis 26, Minn.

Metal Film Resistors 484

This is a flat sided version of the firm's cylindrical, axial-lead resistor. Three of the units fit into an area that would ordinarily accommodate two cylindrical units. Temperature coefficient of resistance is 25 ppm per deg C.

Ohmite Manufacturing Co., Dept. ED, 3645 W. Howard St., Skokie, Ill.

Fastener 474

Series 12F 1/4-turn fastener is for light covers, small sub-assemblies, and miniature black boxes. They use rivets 0.062 in. in diameter; rivet spacing is 1/2 in.

Camloc Fastener Corp., Dept. ED, 61 Spring Valley Road, Paramus, N. J.

Terminals 485

The Tabon terminals for quick connect-disconnect applications are available in chain form for rapid machine crimping. Offered in a wide range of wire and insulation sizes, the terminals are self-wiping and self-cleaning.

Malco Mfg. Co., Dept. ED, 4025 W. Lake St., Chicago 24, Ill.

Radio Filters 472

Designed for installation in aircraft these units are light and compact. They come in hermetically sealed drawn-steel containers, have high Q inductors, and use low power factor capacitors.

Aerovox Corp., Cinema Engineering Div., Dept. ED, 1100 Chestnut St., Burbank, Calif.

Instrument Ball Bearings 505

Made in R2, R3 and R4 sizes, the MPB R series uses a stainless steel retainer. They are suitable for use in servos, generators, small motors, synchros and gyros.

Precision Bearings, Inc., Dept. ED, Keene, N. H.

Capacitor Package 504

The Vu-Paks are clear plastic tubes packed with electrolytic twistmount capacitors. They are re-usable.

Pyramid Electric Co., Dept. ED, Darlington, S. C.

NEW PRODUCTS

Refrigeration Unit 420

Dissipates 65.3 w

This Peltier cooling device dissipates 65.3 w of heat to the ambient air at 140 F at sea level. In so doing, temperatures are maintained below 110 F. The Peltier modules require 20 amp at 5.5 v dc for cooling. When used with the firm's temperature controller, this device can also be used to heat by reversing the current.

The Garret Corp., AiResearch Manufacturing Div. of Los Angeles, Dept. ED, 9851 Sepulveda Blvd., Los Angeles, Calif.

Environmental Test Fixture 407

Is resonant-free below 2,000 cycles

An environmental test fixture that is resonant-free below 2,000 cycles has been designed for testing specimens in three mutually perpendicular axes, simultaneously. It may be used for vibration, shock and acceleration testing. The transmissibility factor does not exceed 1.10 up to 2,000 cps, giving accurate transmission of input with no amplification. Available in two sizes, the smaller size has a capacity of 6 x 6 x 4-1/2 in. with a weight capacity of up to 6 lb; the larger type has a capacity of 12 x 12 x 9-1/2 in. and a weight capacity up to 25 lb. The T-type fixture is made of cast magnesium.

Avco Research and Advanced Development Div., Dept. ED, 201 Lowell St., Wilmington, Mass.

Push-Button Switches 387

Momentary-contact type

This line of 400-1 miniature, momentary-contact, push-button type switches are rated at 1/2 amp and 115 v ac. It stands a dielectric test of 1,000 v. Nipple mounting is standard. Terminals are solder type. The switch is suitable for control of electronic equipment, television sets, audio equipment, computers and relays.

Alcor Manufacturing Co., Dept. ED, 4444 W. Roosevelt Road, Chicago 24, Ill.

Price & Availability: *$0.40 in quantities of 5,000; delivery is 15 days.*

Beam Pentode 383

For high-voltage applications

This beam pentode is designed for use in high-voltage pulse amplifiers and high-voltage shunt regulator applications. Designated type 7239, the tube has a type 9KH base. The nine-pin miniature device has a plate dissipation of 4 w and a peak cathode current of 85 ma. Maximum plate voltage is 2200 v and screen voltage is 200 v.

General Electric Co., Dept. ED, Schenectady 5, N.Y.

Price & Availability: *$8.75; from stock.*

Plug-In Relay 386

Has indicating lamp

The series 1210-N plug-in relay has an indicating neon lamp that lights when the coil is energized. Failure to light is an indication of a fault. The unit is applicable in relay banks, mass relay installations and at intermediate switching points. The device has an eight-pin octal plug for dpdt and an 11-pin plug for 3 pdt. Contacts are rated at 8 amp, 115 v ac. The unit measures 2-22/32 x 1-3/8 x 1-3/8 in.

Guardian Electric Manufacturing Co., Dept. ED, 1550 W. Carrol Ave. Chicago 7, Ill.

Price & Availability: *DPDT, $6.30; 3PDT, $7.70; available from stock.*

CIRCLE 110 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Null Voltmeter 427

Range is 300 mv to 300 v

This transistorized, battery or line-operated null voltmeter has full-scale ranges of 300, 30, and 3 v, and 300 mv. The device measures the in-phase fundamental components of small ac signals, particularly the null or error signals common to suppressed-carrier control systems, with an accuracy of 1-1/2% of full scale. Reference, input, and power-input circuits are isolated from each other and chassis ground to eliminate ground-loop effects.

Hydel, Inc., Dept. ED, 223 Crescent St., Waltham, Mass.

Price: *$1100.*

Availability: *8 to 10 weeks.*

Beam Power Pentode 425

Rated at 400 w

The type PL-175A beam pentode, rated at 400 w, is directly interchangeable with the type 4-400A tetrode. A specially designed vane-type supressor grid is said to provide increased efficiency, lower distortion and greater output. In class AB_1 operation, the tube delivers 790-w usable power. In class-C service, the tube provides 960-w power with 1.4 w driving power.

Penta Laboratories, Inc., Dept. ED, 312 Nopal St., Santa Barbara, Calif.

Price: *$50 ea for 1 to 25 units; $35 ea for 25 or more.*

Availability: *From stock in small quantities.*

igh-Voltage Relays 743

Weigh 1 oz

Able to switch 3,000 v, the Mini-c R-5 relay weighs 1 oz and easures 2 in. long and 3/4 in. in ameter. It handles up to 750 va th a maximum contact rating of amp. Contacts are sealed in a gh vacuum. The relay stands ock, vibration, and temperature tremes and meets Mil specs.

Resistron Laboratories, Inc., Dept. D, 2908 Nebraska Ave., Santa onica, Calif.

ailability: From stock in sample production quantities.

-Band Detector 724

For systems monitoring

This miniature X-Band detector ount, model 1046, is intended for ystems monitoring and has a mini-um dc output of 0.5 v across 10 K r 1 mw rf, 7500 to 8500 mc, into e sub-miniature connector. The tal unit is enclosed by 1 x 1 x 1/2 in. Weight is 3.5 oz.

Radar Design Corp., Dept. ED, O. Box 38, Syracuse 11, N.Y.

ice & Availability: Prices are: 1 9, $82 ea; 10 to 49, $74 ea; 50 to 9, $64 ea; prices include the N23C crystal. Available 30 days fter receipt of order.

haft Encoders 728

Analog to digital

These analog-to-digital shaft encoders have passed life tests in excess of 10,000 hours at average slew speeds of 500 rpm and maximum slew speeds of 3,000 rpm. They are available in 6, 7, 8, 9, 10, 13, 15, 17 and 19 bit models. This line of shaft encoders has a constant thickness design for the brushes, single brush contacts for each bit, and low friction, low surface wear coding discs. Readout accuracies of ±1/2 a digit are maintained in excess of 10,000 hours.

Guidance Controls Corp., Dept. ED, 110 Duffy Ave., Hicksville, L.I., N.Y.

NEW PRODUCTS

Mica Capacitors 360

Measure 5/16 x 1/4 x 1/8 in.

The series DM-10 silvered mica capacitors measure 5/16 x 1/4 x 1/8 in. They are available in values from 1 to 360 pf, rated from 100 to 500 wvdc. Operating temperature is up to 150 C. Units are encased in phenolic and are suitable for printed-circuit applications.

Electro-Motive Manufacturing Co., Inc., Dept. ED, Willimantic, Conn.

Availability: Large quantities, made to order, are delivered in 30 days; limited quantities from stock.

Laboratory DC Power Supply 429

Provides 0 to 20 v at 5 amp

This laboratory power supply, model PS-1235, provides 0 to 20 v, continuously adjustable, at a rated current of 5 amp. Load current can be limited to a maximum of either 1 or 5.5 amp to protect components in the load circuit. Ripple is less than 2 mv. Voltage regulation is better than ±0.1% or ±5 mv, whichever is greater, for full load or rated line change. Input is 105 to 125 v, 60 cps. The device has low internal impedance and fast recovery time. It measures 7 x 9.5 x 10.6 in., and weighs 19 lb.

Power Instruments Corp., Dept. ED, 235 Oregon St., El Segundo, Calif.

Price: $280.

Availability: 3 to 4 weeks.

Test Point Jacks 497

The Kwik-Term line includes both lug and turret styles. Standard contact and terminal material is gold flash over silver-plated beryllium copper. Probe diameters range from 0.041 to 0.09 in.

Cannon Electric Co., Dept. ED, 3208 Humbolt St., Los Angeles 31, Calif.

Terminal and Pull Box Enclosures 486

JIC enclosures with factory installed terminal blocks are for use as full boxes and junction boxes on all types of OEM machinery and signal systems. They are suitable for use where wiring must be protected from dust, dirt, oil, water and coolants.

Keystone Manufacturing Co., Dept. ED, 23328 Sherwood Road, Warren, Mich.

Transistor Holder 488

This three-pin holder is designed to eliminate holding failures of transistors undergoing shock, vibration and environmental tests. Made of heat resistant materials, it can be used to hold transistors undergoing tests at 260 C.

Jupiter Electronics, Inc., Dept. ED, 225 E. 144th St., New York 51, N. Y.

Hot-Junction Thermocouples 494

These single-wire thermocouples have unbroken mineral oxide insulation and sheath continuity for use under extremes of pressure and temperature, corrosive conditions and physical stresses.

Conax Corp., Dept. ED, 2300 Walden Ave., Buffalo 25, N. Y.

Accelerometer Switches 508

These units make accurate measurements of the shocks that critical missile components and other sensitive parts receive in shipping. The units are multi-range. A typical device has three sets of contacts, closing at 1, 2 and 3 g.

Humphrey, Inc., Dept. ED, 2805 Canon St., San Diego 6, Calif.

Resin Mixer 502

The Multi-Rez-Processor proportions, dispenses and mixes epoxy and polyurethane compounds. The Teflon is the only part of the unit to enter the reactive resin mix.

CPM Special Machinery Corp., Dept. ED, 324 Butler St., Brooklyn 17, N. Y.

Overtravel Switch 509

Type 14-324 heavy-duty, snap-action switch is rated at 20 mp and has a mechanical life of over 10,000,000 cycles. Standard type is spdt with double .002-in. contact gaps.

Illinois Tool Works, Licon Div., Dept. ED, 6606 W. Dakin St., Chicago 34, Ill.

NEW PRODUCTS

Transistor Tester 416

Beta calibration accuracy is ±1%

Model 200 transistor tester provides for measuring beta at different collector-current reference levels and incorporates an I_{co} test leakage reading on a 200-μa meter. The instrument has separate sockets for npn and pnp transistors. Beta calibration accuracy is ±1% and current meter accuracy is ±2%.

Westmore, Inc., Dept. ED, Fanwood, N. J.

Price: *$67.50.*

Availability: *One week.*

Telemetering Pulse Separator 409

For PAM decommutation systems

The TPS-100-B telemetrics system, capable of decoding a 100% non-return to zero commutated wave train into a standard IRIG return to zero wave train, has a high degree of stability and synchronization. Frame rates are from 20 to 7200 pps. It is designed to operate where bit channels total 30, 45, 60 or 90 per frame. Decommutation rate variations of ±20% do not affect system synchronization. After 20 min warm-up, the system is stable within 0.20% over an 8 hr period.

Telemetrics, Inc., Dept. ED, 12927 Budlong Ave., Gardena, Calif.

Transistorized Crystal Oscillator 411

Output amplitude is 8 v peak-to-peak

The T-311 crystal oscillator has an output amplitude of 8 v peak-to-peak, from —11 v to —3 v. Frequency stability is ±0.001% max under the maximum combined variations of temperature

supply voltage and load with crystal in oven. The unit contains four germanium pnp transistors, two as a Butler crystal oscillator circuit, one for squaring and one as an emitter follower. A type H-160 crystal acts as a coupling impedance between the two stages of the Butler circuit. The T-311 covers the frequency range of 250 kc to 1 mc.

Engineered Electronics Co., Dept. ED, 1441 E. Chestnut Ave., Santa Ana, Calif.

Microwave Fault Alarm System 421

Reports 11 or 17 fault conditions

This transistorized fault alarm for microwave systems reports 11 or 17 different fault conditions from as many as 30 remote stations. Tones can be set within one of five ranges from 1 to 30 kc. Indication is by means of lights on the front panel. Each unit is housed in a plug-in module measuring 1.5 x 7 x 18 in. and requiring 20 w of power.

Collins Radio Co., Texas Division Sales, Dept. ED, 1930 Hi-Line Drive, Dallas 7, Tex.
Availability: 90 days.

Three-turn Potentiometer 406

Over-all length is 1-31/64 in.

The three-turn design of this potentiometer results in a housing length of 1-31/64 in. The basic design for the 205 series was developed originally for the military, but is now available commercially as well. Major specifications of the 205-3T potentiometer are: resistance range, 10 to 50,000 ohms; linearity, zero biased or independent; linearity accuracy, ±0.5% to 0.1%; weight, 3.2 oz; mechanical rotation, 1080 deg +15 —0 deg; electrical rotation, 1080 deg +14.4 —0 deg.

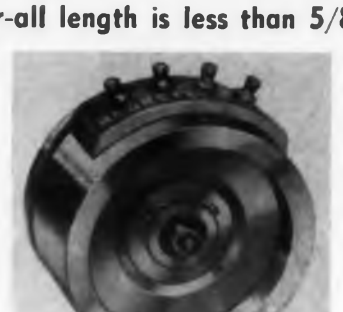
Amphenol-Borg Electronics Corp., Borg Equipment Div., Dept. ED, 120 S. Main St., Janesville, Wis.

CIRCLE 118 ON READER-SERVICE CARD

NEW PRODUCTS

Recentering Magnetic Clutch 415

Over-all length is less than 5/8 in.



This re-centering magnetic clutch has an over-all length of less than 5/8 in. It has a cavity for potentiometer winding, synchro winding or switches to facilitate marriage of clutching with the function to be performed. Recentering spring torque is not applied until the clutch is disengaged, keeping operational torque to a minimum. Dual winding coil permits 12 or 24 v operation.

Magnetec Corp., Dept. ED, 7232 Eton Ave., Canoga Park, Calif.

Solid-State Counter-Timer 412

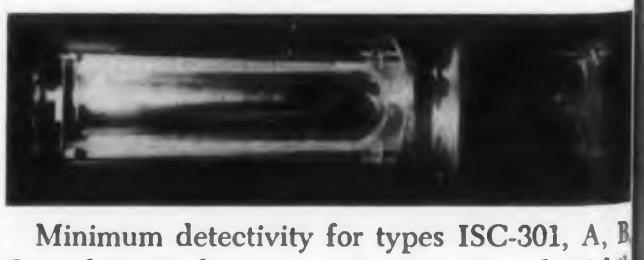
For dc to 20 mc applications

This dc to 20 mc counter-timer is completely transistorized, direct reading and combines the functions of a counter, time interval meter and frequency period meter. Heterodyning techniques are not used. It is available with either the standard vertical decade number panels or inline Nixie readout. Power consumption is 50 w and weight is 27 lb. Sensitivity is 0.25 v rms; input impedance is 25 K per v. Output information from each DCU will operate digital printers, punches and other data processing equipment.

Computer-Measurements Co., Dept. ED, 12970 Bradley Ave., Sylmar, Calif.

Photovoltaic IR Detectors 435

Have military and industrial applications



Minimum detectivity for types ISC-301, A, B, C, and D IR detectors is 3, 6, 9, 12 and 15 bil-

lion cm per w, respectively. Minimum impedance for the units is 500, 1,000, 2,000, 3,000 and 4,000 ohms. They operate in excess of 30 min with one filling of liquid nitrogen. Cryostats are available for operations with gaseous nitrogen. Applications include search, track, guidance, reconaissance and spectroscopy.

Philco Corp., Lansdale Div., Dept. ED, Lansdale, Pa.

Price & Availability: Ranges from $500 for ISC-301 to $1,700 for ISC-301D; 60 to 90 days.

Transistorized Relay 426

Input impedance is 250 K

This transistorized relay, model T-681, is said to have high input sensitivity through 250 K impedance. Device operates to 120 F. Device measures 3 x 4 x 5 in., and weighs 30 oz. Power requirements are 110 v ac; contact load is 1,500 w max.

Precision Thermometer and Instrument Co. Dept. ED, 1434 Brandywine St., Philadelphia 30, Pa.

Price: $75.

Availability: From stock.

Digital Comparator 433

Provides 100,000 operations per sec

This programable, solid-state, unit is capable of comparing measurement numbers at rates as high as 100,000 per sec. Intended for use as part of a checkout system, the device accepts digital information from an analog-to-digital converter, as an example, and compares it with preset high and low tolerance limits. It then gives the correct answers in terms of Go, No Go Hi, or No Go Lo. Circuitry is laid out in the form of etched-card modules that fit into a standard 19-in. rack-mounted chassis with a 5.5-in. panel height.

Leach Corp., Dept. ED, Compton, Calif.

Price & Availability: About $2,000; immediate.

NEW PRODUCTS

Constant-Power Tubes 424

Plate dissipation rating is 20,000 w

The 7806 high-vacuum triode is for use as an oscillator at frequencies up to 30 mc in industrial, dielectric and induction heating applications. Type 7807 is a water-cooled version of the 7806 forced-air cooled tube. Some specifications are: dc plate voltage, 12,000 v; dc plate current (loaded), 4.5 amp; dc grid current (loaded), 0.9 amp; power input, 54,000 w; and plate power output, 39,000 w.

Amperex Electronic Corp., Power Tube Div., Dept. ED, 230 Duffy Ave., Hicksville, L.I., N.Y.
Price: *Type 7806, $795; Type 7807, $584.*
Availability: *From stock.*

Oscillographic Recording System 744

Has a response of 0 to 5,000 cps

Combining model 650 recorder and model 658-3400 amplifier, this recording system provides direct readout of events in the range of 0 to 5,000 cps within 3 db. Mirror galvanometer inserts may be added to the recorder to provide it with up to 24 channels. Chart width is 8 in. The amplifier, consisting of 8 channels of identical circuitry, has a maximum sensitivity of 7.2 ma per mv input, an input resistance of 100,000 ohms. Common mode performance tolerance is ±500 v max and rejection is at least 140 db for dc.

Sanborn Co., Industrial Div., Dept. ED, 175 Wyman St., Waltham 54, Mass.

Pin and Socket Contacts 500

These contacts are offered in both crimp and solder type for a variety of wire sizes. Typical specs for size 16 type are: 5 amp, 5 mv drop; 10 amp, 15 mv drop; socket contacts machined from grade A phosphor bronze; pin contacts machined from high-conductivity commercial bronze; gold-alloy plating over silver.

General Products Corp., Dept. ED, Union Springs, N. Y.
Availability: Immediate.

Tape Connectors 501

These units provide for electrical continuity, positive gripping and strain relief by means of one cam adjustment. Multiple barbed contacts are forced through the conductive metal.

Digital Sensors, Inc., Dept. ED, 6443 N. Figueroa St., Los Angeles 42, Calif.

Molded Knobs 506

This series includes four standard sizes: 5/8 in. high and 23/32 in. in diameter, 21/32 in. high and 29/32 in. in diameter, 11/16 in. high and 1-1/4 in. in diameter, and 3/4 in. high and 1-3/4 in. in diameter. They may be equipped with special shaft holes.

Rogan Brothers, Dept. ED, 8025 N. Monticello Ave., Skokie, Ill.

Pulse Tube 503

Type XD-5 forced-air cooled triode switches 30 amp at 40,000 v with a duty of 0.03. Anode voltage is 35 kv, grid voltage is −5,000 v dc, pulse width is 90 μsec, and peak power output is 1.2 mw.

Nuclear Corp. of America, Central Electronics Manufacturing Div., Dept. ED, 2 Richwood Place, Denville, N. J.
Availability: Immediate.

Jacks 475

Series J6 is smaller, lighter and claimed more reliable than conventional telephone and short-frame jacks. It uses only a few parts which are locked in place to a rigid molded body.

Carter Parts Co., Dept. ED, 3401 Madison St., Skokie, Ill.

Stepping Switch 478

Type 200 is available with up to 8 cams providing 30, 32, or 36 tooth ratchets. Operating speed is up to 60 steps per sec, self-interrupted, or 30 steps per sec, remote-impulsed. It can be used as a memory device, as a replacement for interlock relays or in applications where control of a sequence of operations is necessary.

C. P. Clare & Co., Dept. ED, 3101 Pratt Blvd., Chicago 11, Ill.

NEW PRODUCTS

Excess Temperature Cut-Out 490

The Pyrotac, an instrument that automatically protects against excess temperature and provides continuous temperature indication, is offered in two types. Model N-30 does not shut off upon line voltage failure and model N-34 does shut off in this condition.

Illinois Testing Laboratories, Inc., Alnor Instrument Co., Dept. ED, 420 N. LaSalle St., Chicago 10, Ill.

Component Holders 489

Series II holders use a stainless-steel, type 302 spring for jaw movement and tension. Only finger pressure is needed to open the jaws for insertion of leads as large as banana plugs. Applications include: prototype-circuit design, Wheatstone and other null-balance bridge instruments; capacitance, resistance and other measuring equipment.

Jupiter Electronics, Dept. ED, 225 E. 144th St., New York 51, N. Y.

Stand-Off Terminals 510

A complete line of terminals set in molded phenolic, melamine, or ceramic is offered. Ceramic types are gold over silver plate; others are silver-plated with cadmium-plated bases. Miniature, insulated stand-offs can also be furnished.

Goe Engineering Co., Dept. ED, 219 S. Mednik Ave., Los Angeles 22, Calif.

Gold-Bonded Contacts 493

The use of gold in these contacts eliminates surface formation of various sulphides and oxides, which create circuit resistance. A break-through process, rather than plating, is employed.

Contacts Inc., Dept. 1100 Silas Deane Highway, Wethersfield, Conn.

Availability: Some types in stock; others can be made to customer specs.

Print-Punch Equipment 480

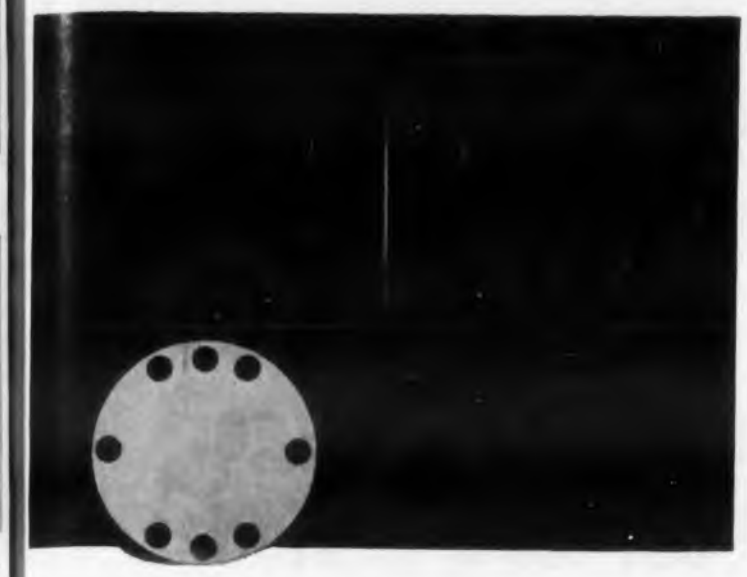
Designed for use with the firm's Recomp digital computer, this equipment consists of two table-top units, a 10-key input keyboard and the paper-tape punch.

North American Aviation, Inc., Autonetics, Dept. ED, 9150 E. Imperial Highway, Downey, Calif.

Kits of Silicon and Germanium Slices 499

This kit consists of five slices of material in each of the ten most commonly-used resistivity ranges. All slices are 0.02 in. thick and measure from 3/4 to 1 in. in diameter.

Tang Industries, Inc., Dept. ED, 49 Jones Road, Waltham, Mass.



New Transducer Package

... WITH ONLY ONE MOVING PART

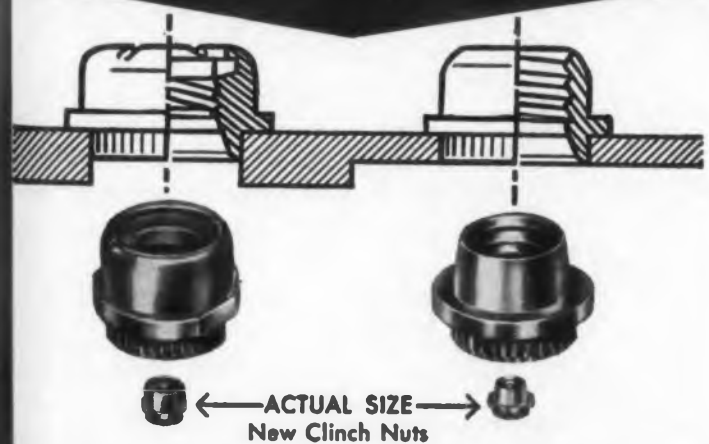
The stiff metal diaphragm shown above is the only moving part in the new Ultradyne DCS-4 DC/DC pressure transducer package. It has a stable DC output to ± 1% despite supply changes from 25 to 30 volts DC. Weighs only 9 ounces. Eliminates amplifiers and drift problems. Write, wire or phone for complete specifications.

ULTRADYNE
INCORPORATED
P.O. BOX 3308 ALBUQUERQUE, NEW MEXICO

A Member of The Condec Group

CIRCLE 133 ON READER-SERVICE CARD

New ESNA miniatures flush mount in thin stock



When space requirements are tight, one of these two new ESNA miniature clinch nuts may be just what you're looking for! They are easily flush mounted in sheet as thin as .030".

Type NCFM clinch nut for temperatures up to 350°F, has special nylon locking insert which will not gall screws or create the cadmium flaking so damaging to electrical circuitry. Type LHCFM is an all-metal nut with an elliptical crown locking device capable of withstanding up to 550°F.

Detailed dimensional drawings on these two new miniature nuts, plus full data covering necessary installation tools are now available. Write Elastic Stop Nut Corporation of America, Dept. S8-1057, 2330 Vauxhall Road, Union, N. J.

ELASTIC STOP NUT CORPORATION OF AMERICA

CIRCLE 134 ON READER-SERVICE CARD

Power Supply 479

Model P-1 is for high-intensity gas-discharge tubes such as are used in high-speed photography. The unit is housed in an encapsulated container and is suitable for use in aircraft, missiles and satellites. Dimensions are 2-3/8 x 3 x 5-3/4 in.

Cubic Corp., Dept. ED, 5575 Kearny Villa Road, San Diego 11, Calif.

Slip Ring Assembly 483

This assembly is of concentric-ring type construction and for switching from positive to negative for sine and cosine functions in radar antenna mounts. Switching is accomplished within 20 min. of arc. Phasing accuracy is 0.2 min, electrical, and 0.005 sec, mechanical.

Breeze Corp., Inc., Dept. ED, 700 Liberty Ave., Union, N. J.

Metal Cabinets 481

Single or sectionalized units can be furnished for communications equipment, computers, electronic testing units, production control units and other devices. Shelving, roll shelves, racks and other constructions can be furnished. Cabinets are made of cold rolled steel.

Anetsberger Brothers, Inc., Dept. ED, 110 N., Anets Drive, Northbrook, Ill.

Power Supply 507

Model F1002A contains four isolated supplies that may be connected in many combinations for computers or transistorized equipment. Voltages range from 1 to 15 v dc for each output with currents of 2, 4 and 8 amp. Regulation is better than 0.1% for lone and load.

Anders Electric Products Inc., Dept. ED, Brook Road, Needham Heights 94, Mass.

Insulating Tape 477

Type CDF Level-Wrap tapes, made of silicone rubber, come in widths from 1 to 1.5-in. and in thickness from 0.02 to 0.08 in. at the apex and 0.007 to 0.008 in. at the edges. It offers: good thermal stability, Corona resistance, moisture resistance and high resiliency.

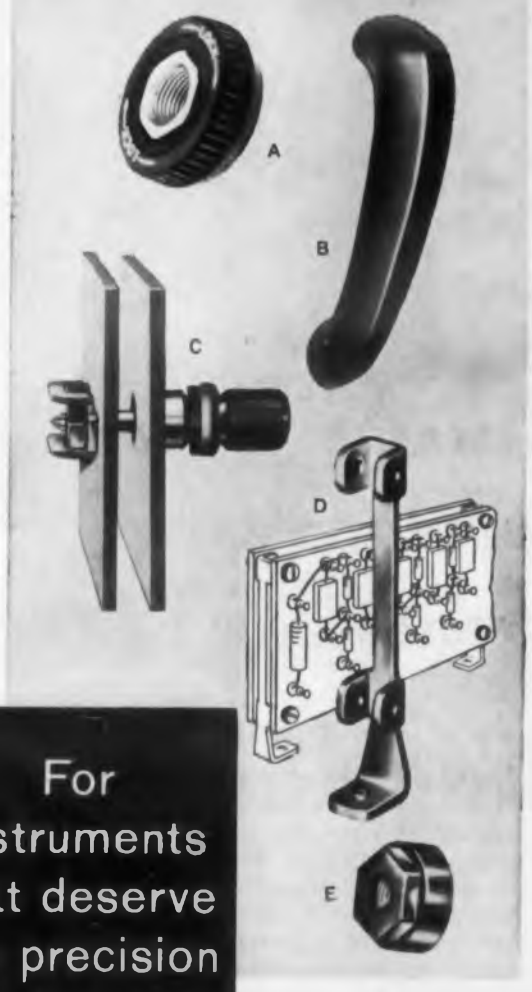
Continental-Diamond Fibre Corp., Dept. ED, Newark, Del.

Toggle Switches 487

Meeting MIL-S-3950A and MIL-S-6745, this line of toggle switches incorporates a barrier configuration between terminals. This design increases leakage paths and provides a safety factor in case of a loose connection. Models for all common circuit characteristics can be furnished.

Kulka Electric Corp., Dept. ED, 633-643 S. Fulton Ave., Mount Vernon, N. Y.

SPECIFY RAYTHEON PANEL HARDWARE



For instruments that deserve the precision engineered look

A. non-slip knob locks
B. contour-grip pull handles
C. convenient captive hardware
D. printed-circuit terminal board brackets
E. one-piece nylon shaft locks

FREE FOLDER IS YOURS for the asking. Tells more about panel hardware and gives specifications on control knobs, test jacks, binding posts, fuse clips. Write Raytheon Company, 55 Chapel St., Newton, Mass.

RAYTHEON COMPANY
Industrial Components Division
55 Chapel Street, Newton, Mass.

CIRCLE 135 ON READER-SERVICE CARD

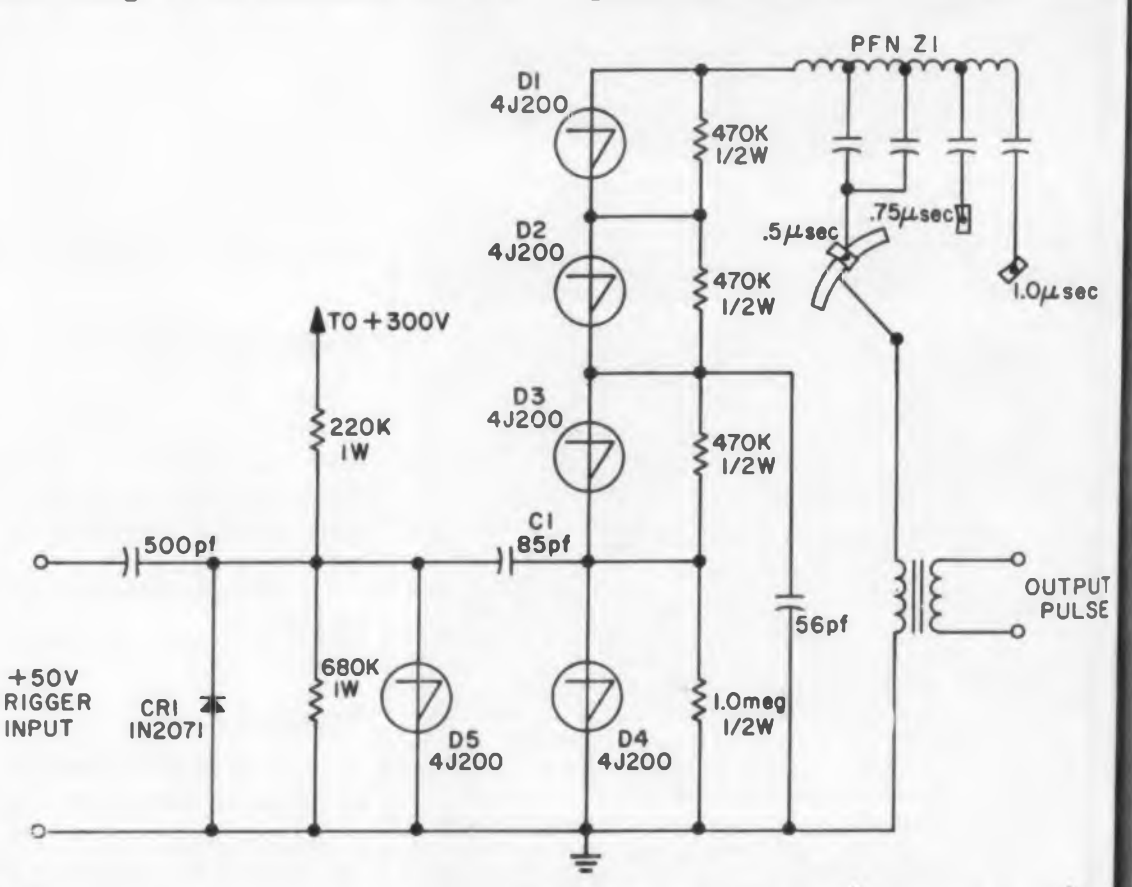
Pulser Uses 50-V Trigger To Short Four 200-V Diodes

SWITCHING diodes in a pulser manufactured by Burmac Electronics Co., Inc. of Rockville Center, L.I., N.Y., posed an interesting problem. The solution, developed by Burmac's president Steve Delligatti, proved even more interesting.

The switch, shown in the schematic, consists of four 200-v, four-layer diodes, *D1*, *D2*, *D3*, and *D4* in series. Due to resonant charging of the capacitors in the pulse-forming network *Z1*, the maximum voltage on the four-diode switch is almost twice the power supply voltage, or 600 v.

To allow for variations in charging voltage and shorting voltage of the diodes, four 200-v, four-layer diodes were used in series. Attempts to use only three resulted in a tendency of the switch to "free-run" at a rather high frequency; it acted as a relaxation oscillator.

Now, here lies the problem. Under quiescent conditions, with no trigger pulses applied to the switch, the voltage



A 50-v pulse can short four-layer diode *D5*. This shorts the 680-K resistor across it. Voltage across this resistor drops suddenly to zero, resulting in a large negative pulse transmitted through *C1*. The negative-going pulse shorts *D3*, and the remaining four-layer diodes in the string quickly break down.

across it stabilizes at 300 v. A 50-v trigger could not short the switch. It would have been necessary to interrupt the supply voltage, then reapply it while the trigger pulses were present. The transient double voltage on the switch would then permit its being shorted.

But it was desired that the supply voltage be applied continuously, if at all possible, and the switch be ready to respond to random triggers of all spacings down to considerably less than 100 μsec. To meet this objective it was necessary to short the switch with only 300 v across it.

The normal shorting voltage of these four-layer diodes is 200 v. However, the literature cautions that with high rates of voltage rise, the diodes can short at reduced voltage. Thus, if a large trigger were applied—one large enough to short one of the diodes in the string—the sudden voltage increase across the others should cause an avalanche.

To supply this large trigger, another four-layer diode, *D5*, is used. Tied by a voltage divider to the regulated 300-v supply, this diode is easily shorted by a 50-v positive pulse. When it shorts, the voltage across it is suddenly pulled down to zero, causing a negative pulse of about 200 v to be coupled through *C1* to the junction of *D3* and *D4*. Hence, *D3* (not *D4*), is the first diode shorted by the trigger pulse, followed, probably, by *D1* and *D2*, then finally *D4*.

Unfortunately, negative transients fed back through *C1*, tended to cause failure of *D5*. To preclude this, silicon diode *CR1* was added. It removes any negative spikes which might appear. ■ ■

DESIGN DECISIONS

'Flat' and Eccentric-Magnet Speakers Conserve Space in TV, Portable Radio

Minimizing the space requirements of loud speakers was the problem solved by these two designs.

The 4-in. speaker for portable radios, Fig. 1, has an over-all thickness of 3/4 in. The eccentric permanent-magnet speaker, Fig. 2, conserves space at the front of a TV cabinet, as shown in Fig. 3. The magnet is mounted at the rim of the speaker. Both speakers are made by Audax.

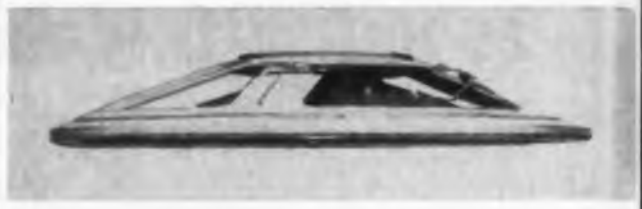


Fig. 1. "Flat" speaker for portable radios has over-all thickness of 3/4 in.

Fig. 2. Eccentric-permanent-magnet speaker has magnet mounted near rim.

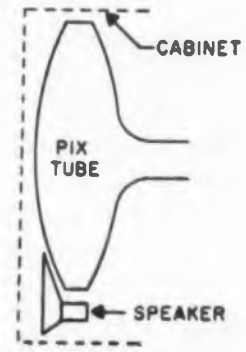


Fig. 3. Eccentric-permanent magnet speaker conserves space at front of TV cabinet.

Computer Logic Cards Shaped To Fit Curved Missile-Contour

Logic cards for a missile-borne computer were shaped so the computer could fit into a 60-deg sector of the missile's circumference. The plane of the cards was normal to missile's axis. Hence, mounting-leads of components within the sandwich were parallel to direction of missile's thrust.

Estimation of External Surface Case Temperature Rise For Closed Electronic Equipment

J. R. Baum
Senior Staff Member
Mechanical Engineering Laboratory
Military Electronics Div.
Motorola, Inc.
Scottsdale, Ariz.

IN MILITARY equipment packaging, it is often desirable to house electronic devices in closed cases for protection against dust, humidity and low pressure. Since the initial analysis of anticipated case heat dissipation, required during the initial packaging study, can be tedious and lengthy, a nomogram is presented to provide a preliminary estimation tool.

Only the ambient altitude and unit surface power dissipation density need be known to determine the anticipated surface temperature rise over ambient. The assumptions and approximations required to simplify the complex relationships include:

1. Case is closed and unlouvered.
2. Air is the surrounding medium.
3. Average electronic "black box" configuration and dimension are known.
4. External surface of the package and surroundings are painted.
5. Free convection and radiation take place only from the case surface.

When preliminary estimates are completed, a more detailed study can then be undertaken to establish accurate thermal analysis information for final design considerations.

The procedure for use of the nomogram is as follows:

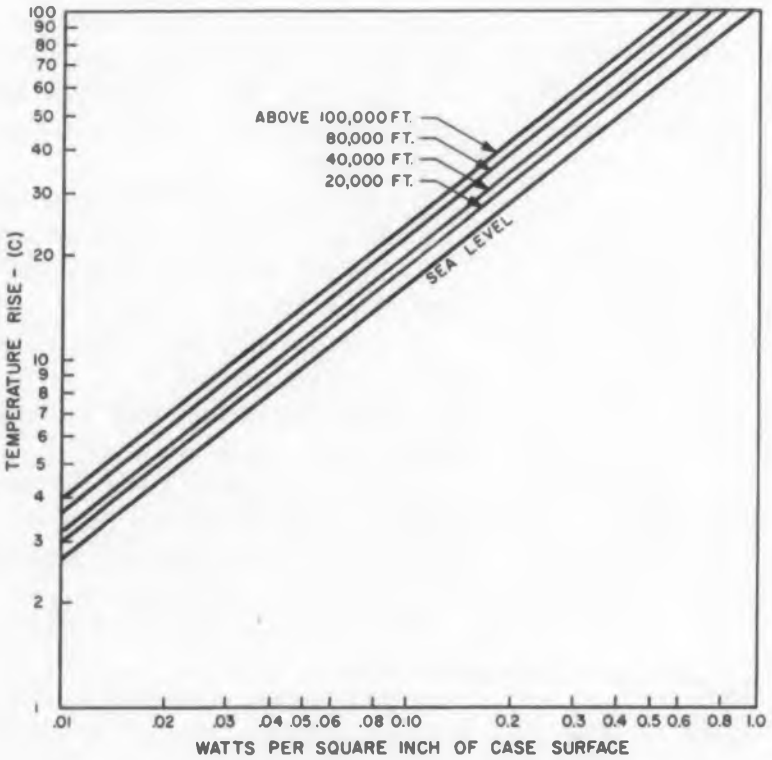
1. Determine amount of heat (in watts) to be dissipated by the case. For a closed unit with no special external cooling provisions, this would be the total unit power input.
2. Determine surface power density in watts per square inch by dividing the heat dissipated by the total exposed external surface dissipation area (including ribs, etc.).
3. Enter the nomogram with this value and the

(Continued from p. 131)

appropriate altitude and read the resultant temperature rise of unit case surface over the ambient.

4. The reverse procedure can be used to determine the allowable power density for a given temperature rise.

A rough estimate of the unit internal ambient can be made by doubling the temperature rise obtained above and applying it to the external ambient. The result would be conservative where the components have a good conductive path to the case and would be realistic for the typical situation where they are thermally isolated from the case with no special internal cooling provisions. ■ ■



Estimated surface temperature rise for closed electronic equipment with no external cooling provisions.

NEW LITERATURE

Waveguide Stand 261

This two-page bulletin describes the 370 universal waveguide stand which accommodates all waveguide sizes in the frequency range of 2.6 to 40 kmc. All waveguide sizes are listed in their respective frequency ranges and the proper RG waveguide type numbers are given. PRD Electronics, Inc., 202 Tillary St., Brooklyn 1, N.Y.

Power Supplies 262

The company's ME series of transistorized power supplies are listed and briefly described in this two-page data sheet. Included are performance specifications, data on trouble-shooting instructions, and data on pre-tested plug-in modules for simplified maintenance and parts stocking. Mid-Eastern Electronics, Inc., 32 Commerce St., Springfield, N.J.

Diodes and Rectifiers 263

Listed in this 18-page booklet are diodes and rectifiers made by Texas Instruments, Inc. Available from off-the-shelf are: a photo device; silicon rectifiers; high conductance general purpose silicon diodes; silicon controlled rectifiers; silicon computer diodes; voltage regulator diodes; and power regulators and double anode clippers. Lafayette Radio, 165-08 Liberty Ave., Jamaica 33, N.Y.

IR Detector Measurement 264

Model ISL 302 infrared detector measurement console is described in this six-page booklet. The illustrated booklet covers uses of the equipment including: photoconductive, photovoltaic, photoelectromagnetic and pyroelectric detector measurements, in addition to measurement of thermistor bolometers and ac thermocouples. A block diagram of the equipment is included. Infrared Industries, Inc., Box 42, Waltham 54, Mass.

Photovoltaic Cells 265

Called "Photovoltaic Cells For the Precise Measurement of Light," bulletin No. GEZ-3005, eight pages, offers a complete description of these sensors for applications where light is used to perform a control function. It includes graphic data on spectral sensitivity, exposure effect, temperature characteristics, current output, internal resistance and other factors. Dimensions for all available calls, and typical circuits for single and multiple cell applications are given. General Electric Co., Schenectady 5, N.Y.

NEW LITERATURE

Instrument Bearings 266

A series of technical data sheets contains dimensional specifications and load factors for the firm's type R2, R3, and R4 instrument bearings made to ABEC class 7 tolerances. Miniature Precision Bearings, Inc., Keene, N.H.

Timing and Data-Processing Systems 267

These three data sheets describe: the firm's model 26211 airborne time code generator which is a compact, transistorized unit with an accuracy of one part in 105; the model ZA-23833 search and control system for Ampex FR-100 tape recorders for searching PAFB or EGTR time-code reference tapes; and the model ZA-25159 computer format converter for converting AN/FPS-16 radar data into IBM 704 magnetic tape or NRZ format. Electronic Engineering Co. of California, 1601 E. Chestnut Ave., Santa Ana, Calif.

Heat-Shrunk Tubing 268

Thermofit tubing, an irradiated modified-polyolefin insulation sleeving which shrinks to a preselected diameter when exposed to heat, is described in these two brochures. Brochure No. 203-4 lists properties, test data, weights, sizes, and various applications. Brochure No. RT-2000 describes applications in harnessing and splicing, and outlines fabrication techniques. Raychem Corp., Oakside at Northside, Redwood City, Calif.

Electronic Cables 269

Bulletin No. DM-S-6015, six pages, describes and illustrates a line of electronic cables suitable for high-temperature and radiation applications. Included are control cables, instrument probe cables, airframe, missile, and satellite cables, instrumentation cables, communication cables, TV camera cables, and computer cables. Anaconda Wire & Cable Co., 2201 Bay Road, Redwood City, Calif.

Thermocouples 270

This six-page bulletin, No. P1281A, describes Armorox thermocouples. The metal-sheathed, ceramic-insulated construction of the thermocouples is explained, and typical applications are cited. Physical specifications are tabulated. The Bristol Co., Waterbury 20, Conn.

Terminal Strips 271

This 12-page brochure, "Guide Book to Thermal Strips," contains drawings and tables on standard terminal strips made up from universal, external "T", Wire-Grip, tear-drop, Wrap-A-Wire, and subminiature lugs. Mandex Manufacturing Co., Inc., 2614 W. 48th St., Chicago 32, Ill.

Test and Sensing Components 272

This vest-pocket guide and wall chart is intended to help the design engineer choose test and sensing component. The chart contains complete specs on panel lights, switches, fuseholders, test prods and jacks, and molding materials. Alden Products Co., 117 N. Main St., Brockton 64, Mass.

High-Current Power Supplies 273

High-current power supplies and variable-voltage transformers are described and illustrated in this four-page brochure. Electronic applications include capacitor forming, electrolytic refining, magnet powering, tube testing and aging, and supply for computers and checkout systems. Glenn Pacific Power Supply Corp., 703 37th Ave., Oakland 1, Calif.

Pulse Generators 274

A series of 9-kw solid-state pulse generators is described in this two-page bulletin. Circuit-design information, tabulated specifications, and dimensional drawings are included. Magnetic Research Corp., 3160 W. El Segundo Blvd., Hawthorne, Calif.

NEW LITERATURE

Permanent Magnet Alloy 275

This four-page, illustrated brochure describes properties and applications of a copper-nickel-iron ductile permanent-magnet alloy of the generic Cunife type. Applications include timer motors for appliances, speedometers, aircraft instruments, and various electronic equipment and control systems. Watkins-Rogers, Inc., 685 Pallister, Detroit 2, Mich.

Plastic Materials 276

A line of plastic materials, including molding and extruding materials and resins applicable in the electronics field is described in this 12-page booklet. Applications of the plastics are indicated, and properties are listed or tabulated. Monsanto Chemical Co., Springfield 2, Mass.

Servo Motor 277

The firm's type 5752-03 inertially damped servo motor for high-temperature applications is described and illustrated in this two-page data sheet. Electrical, mechanical, and physical characteristics, outline drawings, and performance curves are included. John Oster Mfg. Co., Avionic Div., Racine, Wis.

Resonant Modes 278

This two-page bulletin, No. 5A, describes a method of obtaining crisp photographs of vibrations. The method enables a still camera to photograph resonant modes detected in a frequency sweep. Full instructions and examples are provided. Chadwick-Helmuth Co., 427 E. Duarte Rd., Monrovia, Calif.

Special-Purpose Capacitors 279

Feed-thru, trimmer, transmitting, flat-plate, discoidal, precision, high-voltage, disk, and tubular capacitors are described and illustrated in this 20-page catalog, No. 42-407. Electrical specifications and dimensional drawings are given for each type. Centralab, 900 E. Keefe Ave., Milwaukee 1, Wis.

Tubing Connectors 280

Connectors for plastic tubing intended to conduct compressed air, fluids, and gases are described and illustrated in this two-page bulletin, No. 125. Male and female end connectors and panel-mount connectors are included. Devices quickly connect and disconnect manually. Breco Div., Perfecting Service Co., 332 Atando Ave., Charlotte 6, N.C.

RF Coaxial Plugs 281

The firm's series BNC rf coaxial plugs are described in this 16-page booklet. The plugs, designed for small coaxial cables, are lightweight and weather proof. The catalog includes nomenclature, a mating functional diagram, assembly instruction, and drawings and specifications. Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif.

Stepping Switches 282

Forty-page, two-color catalog, No. 202, contains data on construction features, circuitry, and performance characteristics of spring-given, cam-operated, and direct-drive stepping switches. Mounting accessories, sealed and dust-cover enclosures are pictured and described. C. P. Clare, 3101 Pratt Blvd., Chicago 45, Ill.

Heavy Tungsten Alloys 283

This eight-page bulletin describes heavy tungsten alloys with densities of 17 to 18.5 g per cu cm. Properties, applications, fabrication methods, and available sizes and shapes of three grades are given. The firm's engineering services and facilities for applying the materials are also outlined. Kennametal Inc., Latrobe, Pa.

Snap Action Switches 284

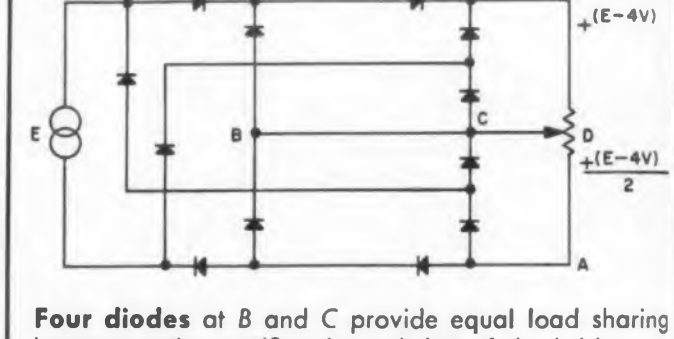
A line of snap action switches is described in this 12-page folder. Heavy-duty limit switches, compact sealed switches, explosion-proof switches, precision snap-action basic switches, and manually operated, door interlock, mercury, and proximity switches are illustrated and briefly described. Micro Switch, Freeport, Ill.

IDEAS FOR DESIGN

Get $10.00 plus a by-line for the time it takes you to jot down your clever design idea. Payment is made when the idea is accepted for publication.

Four Extra Diodes Insure Load Sharing in High Voltage Bridge

Equal load sharing between series rectifiers in high voltage, full wave bridge circuits can be easily attained by using only four extra diodes. When connected as shown, the extra diodes eliminate the need for complex RLC matching circuits in any of the legs. Such matching is especially necessary when high frequencies, in the tens or hundreds of kilocycles are applied to the bridge. At these frequencies the junction switching and peak inverse loads depend on



Four diodes at *B* and *C* provide equal load sharing between series rectifiers in each leg of the bridge.

matched resistance, capacitance, and leakage characteristics of each diode.

Referring to the figure, if points *B* and *C*, and if necessary a third equipotential point *D* bisecting the load are joined, each diode will switch at precisely the same moment. Also, the two diodes in each leg will share inverse and forward peak voltages.

Considering one end *A* of the load as zero reference potential, and each diode as having a forward voltage drop '*V*', it can be shown that the potentials

$$V_{AB} = V_{AC} = V_{AD} = 1/2(E - 4\text{ v})$$

As an economy measure, resistors can be substituted for the four extra diodes at *B* and *C*.

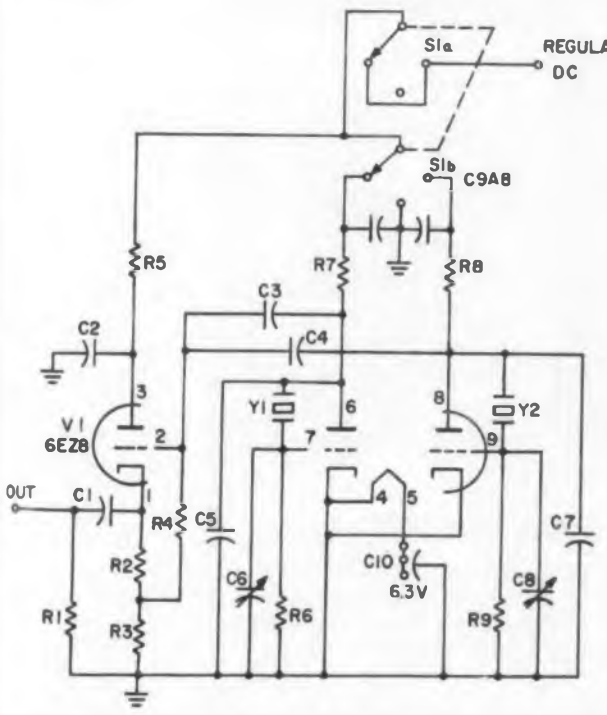
Patrick F. Howden, Systems Engineer, Consolidated Systems Corp., Monrovia, Calif.

Dual Frequency Oscillator Built With 6EZ8 Tube

A dual frequency, low impedance source was required for upper and lower sideband carrier re-insertion. The frequency selector switch had

to be remote, stray radiation and leakage were not permissible and the printed circuit usable space was 2-3/4 sq in. Selection of a crystal within an oscillator circuit was not possible; the required long rf shielded leads interfered with the oscillator operation in different ways, depending on the type of oscillator circuit. Since the usable space and economy rejected the use of several tubes, a rather new comer among the electron tubes, the 6EZ8 was selected.

The 6EZ8 is very similar in characteristics to the 12AT7 and is well suited to low power oscillator circuitry. Since low impedance output was required, one section is used as a cathode follower stage and the two other sections as individual oscillators. Selection of the operating oscillator is determined by switching the dc plate supply. This eliminates all rf leads. The coupling between each oscillator and common cathode follower is assumed constant. The fact that the rf plate impedances are coupled through *E3 — C4* required a circuit having a minimum of such impedance to avoid shunting effect or interaction. A modified Pierce oscillator was selected. Grounded cathode operation was necessary because of the common cathode and filament connections.



Dual frequency, low source impedance oscillator uses 6EZ8 tube in modified Pierce circuit.

Georges M. Cnudde, Engineer, Sierra Electronic Corp., Div. of Philco Corp., Menlo Park, Calif.

PATENTS

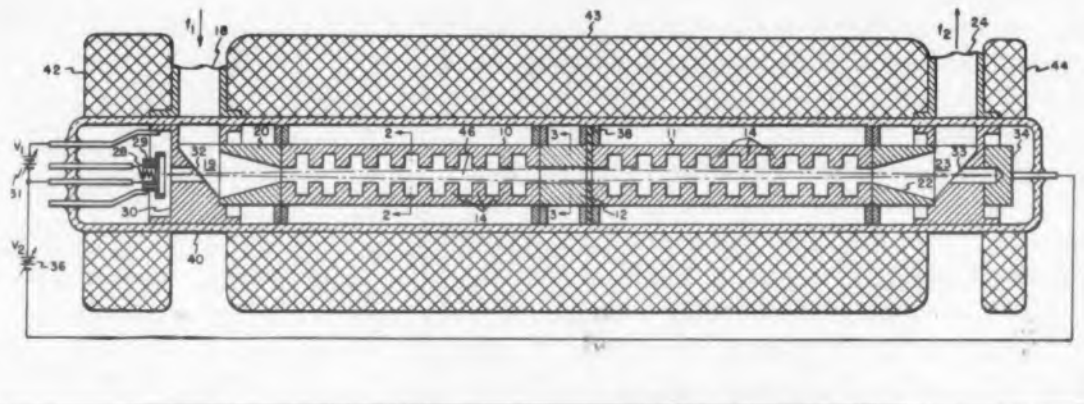
Benjamin Bernstein

Frequency Shifting Apparatus

Patent No. 2,933,639. P. M. Lally. (Assigned to Sperry Rand.)

Frequency is changed in a cyclotron TWT by causing interaction of the electron beam and the wave at separate axial velocities of the beam.

The electron beam, originating at cathode *28*, accelerates through the slow wave structure *14*, and propagates a transverse electric field at the first frequency. Due to the axial-magnetic field generated by solenoid *43*, the beam orbits in a helical path at cyclotron frequency. Drift space *12* isolates slow wave structure *11*. The beam is then accelerated at a second potential to induce a wave at a second frequency in the slow wave structure. This signal is coupled out through waveguide *24*.



Transmitter-Receiver for Radio Location

Patent No. 2,943,188. L. George, W. Knott and D. Kerr. (Assigned to Ultra Electric, Inc.)

Designed for use in a homing-type radio locating system, the transmitter-receiver uses a one-tube squegging oscillator, that generates bursts of rf energy that can be pulse modulated.

Variable Artificial Transmission Lines

Patent No. 2,943,276. E. Lovick. (Assigned to Lockheed Aircraft Corp.)

The device consists of tubular dielectric members, a conductive core and a helical winding around the outer wall of the dielectric members. The inductance and capacitance of the circuit are varied by rotating the conductive cores.

Folded Dipole Having a Direct Current Output

Patent No. 2,943,189. L. R. Crump. (One half assigned to G. T. Morris.)

The two wires of the folded dipole are connected at their ends to one another, so that the distance between wires is small compared to the shortest wavelength used. One wire is broken at its midpoint and diodes are inserted in the wire back to back. A capacitor is connected from a point between the diodes to the midpoint of the other wire. The signal is taken from across the capacitor.

Instrument Linearizer

Patent No. 2,943,207. N. W. Burlis and M. J. Reinert. (Assigned to Custom Engineering and Development Co.)

This system improves the linearity of voltages proportional to data derived from nonlinear measuring instruments. Input data are displayed on an oscilloscope. The display falls onto a photo tube. The photo tube voltage is fed back negatively to the input. A transparent calibration curve on an opaque background is mounted between the photo tube and the oscilloscope face. This curve is the reference that the input voltage is made to align itself with.

RUSSIAN TRANSLATIONS

J. George Adashko

Limiting Values Of Active Resistances In RC Phase-Shift Generators

IN ANALYZING RC phase shift generators it is usually assumed that the input resistance of the phase shift network is considerably greater than the output resistance of the amplifying stage. Consequently, formulas for the frequency and for the self-excitation conditions usually disregard the effect of the internal resistance of the vacuum tube and the resistance of the plate load.

Townsend (*Electronic Engineering*, Vol. 22, No. 265, pp 116-117, March, 1950) did derive formulas for the frequency and for the attenuation with allowance for the amplifier parameters. In the present article we will derive formulas for the limiting values of the active resistances of the phase-shifting network below which the RC generator cannot become excited.

Self-Excitation Conditions of RC Phase Shift Generators

The RC phase shift generator can be represented as a cascade connection, for which the a-matrix is known, of an amplifier and a phase shifting network, Fig. 1. With the feedback loop open, the self-excitation condition can be determined by assuming the attenuation of the overall network to be less than unity.

The amplifier matrix is

$$[a'] = \begin{bmatrix} -\frac{1}{SR_a} & -\frac{1}{S} \\ 0 & 0 \end{bmatrix}. \quad (1)$$

where S is the transconductance, and

$$R_a = \frac{R'_a R_i}{R'_a + R_i} \quad (2)$$

By multiplying the matrix of the amplifier and the matrix of the phasing network, still specified in general form, we obtain

$$[a] = \begin{bmatrix} -\frac{a_{11}}{SR_a} - \frac{a_{21}}{S} & -\frac{a_{12}}{SR_a} - \frac{a_{22}}{S} \\ 0 & 0 \end{bmatrix}. \quad (3)$$

Assuming that the element a_{11} of matrix (3) is less than unity, we obtain, after transformation, a general formula for self-excitation.

$$-a_{11} - a_{21}R_a < SR_a. \quad (4)$$

Three-Element RC Phase Shift Generator

For a three-element phase-shifting network, Fig. 2, the a-matrix can be determined by mul-

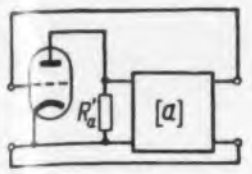


Fig. 1. RC phase-shift generator can be represented by an amplifier and a phase-shifting network.

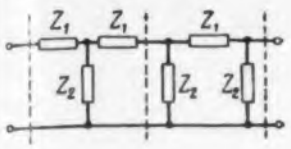


Fig. 2. Dotted lines separate individual units in this three-element phase shifting network.

tiplying the matrices of the separate four-terminal network. That is,

$$[a] = \begin{bmatrix} 1 + Z_1Y_2 & 2Z_1 + Z_1^2Y_2 \\ Y_2 & 1 + Z_1Y_2 \end{bmatrix} \begin{bmatrix} 1 + Z_1Y_2 & Z_1 \\ 2Y_2 + Z_1Y_2^2 & 1 + Z_1Y_2 \end{bmatrix}.$$

After multiplication we get

$$[a] = \begin{bmatrix} 1 + 6Z_1Y_2 + 5Z_1^2Y_2^2 + Z_1^3\,Y_2^3 & 3Z_1 + 4Z_1^2Y_2 + Z_1^3\,Y_2^2 \\ 3Y_2 + 4Z_1Y_2^2 + Z_1^2\,Y_2^3 & 1 + 3Z_1Y_2 + Z_1^2\,Y_2^2 \end{bmatrix} \quad (5)$$

Substituting the elements of the matrix (5) into the general formula (4) for the self-excitation condition, yields

$$-(1 + 6Z_1Y_2 + 5Z_1^2\,Y_2^2 + Z_1^3\,Y_2^3) - (3Y_2 + 4Z_1Y_2^2 + Z_1^2Y_2^3)\,R_a \leqslant SR_a. \quad (6)$$

For a phase-shifting network with R in the parallel legs, the impedances of the network of Fig. 2 are

$$Z_1 = \frac{1}{i\,\omega\,C};\ Z_2 = R. \quad (7)$$

After substituting Eq. 7 in Eq. 6, separating real and imaginary parts, and setting the latter equal to zero, we obtain

$$\omega_0 = \frac{1}{RC\sqrt{6 + 4\,\frac{R_a}{R}}} \quad (8)$$

$$(SR_a - 29)\left(\frac{R}{R_a}\right)^2 - 23\,\frac{R}{R_a} - 4 > 0. \quad (9)$$

Eq. 9 yields the condition for the gain

$$SR_a > 29, \quad (10)$$

since for positive values of R/R_a, inequality (9) can be satisfied only if Eq. 10 is satisfied.

The positive root R_{min}/R_a of Eq. 9 determines the limiting value of the resistance of the phasing network, below which the generator will not be excited. In designing an RC generator, when the gain and the resistance R_a (Eq. 2) are specified, the resistances of the phase-shifting network must be chosen to satisfy the condition

$$\frac{R}{R_a} > \frac{R_{min}}{R_a} = \frac{23 + \sqrt{65 + 165SR_a}}{2\,(SR_a - 29)}. \quad (11)$$

Fig. 3 (curve 1) plots a curve of R_{min}/R_a as a

function of the gain product SR_a.

For a phase-shifting network with the capacitance in the parallel leg, the impedances of the circuit of Fig. 2 are

$$Z_1 = R;\ Y_2 = i\,\omega\,C. \tag{12}$$

After suitable transformations we obtain

$$\omega_0 = \frac{1}{RC}\sqrt{\frac{6\frac{R}{R_a}+3}{\frac{R}{R_a}+1}}; \tag{13}$$

$$(SR_a - 29)\left(\frac{R}{R_a}\right)^2 + (SR_a - 38)\frac{R}{R_a} - 12 \geqslant 0; \tag{14}$$

$$\frac{R}{R_a} > \frac{R_{min}}{R_a} = \frac{38 - SR_a + \sqrt{(SR_a)^2 - 28SR_a + 52}}{2(SR_a - 29)}. \tag{15}$$

Fig. 3 (curve 2) plots R_{min}/R_a versus the gain.

Four-Element RC Phase Shift Generator

The matrix of the four-element phase-shifting network, using the same notation as in Fig. 2, has the following form

$$[a] = \begin{bmatrix} 1+10Z_1Y_2+15Z_1^2\,Y_2^2+7Z_1^3\,Y_2^3+Z_1^4\,Y_2^4 & 4Y_2+10Z_1Y_2^2+6Z_1^2\,Y_2^3+Z_1^3\,Y_2^4 \\ 4Z_1+10Z_1^2Y_2+6Z_1^3\,Y_2^2+Z_1^4\,Y_2^3 & 1+6Z_1Y_2+5Z_1^2\,Y_2^2+Z_1^3\,Y_2^3 \end{bmatrix}, \tag{16}$$

The self-excitation condition becomes

$$-(1+10Z_1Y_2+15Z_1^2\,Y_2^2+7Z_1^3\,Y_2^3+Z_1^4\,Y_2^4) - (4Y_2+10Z_1Y_2^2+6Z_1^2\,Y_2^3+Z_1^3\,Y_2^4)\,R_a \leqslant SR_a \tag{17}$$

For a phase-shifting network with the resistance in the parallel leg, Eq. 7, we obtain

$$\omega_0 = \frac{1}{RC}\sqrt{\frac{7\frac{R}{R_a}+1}{10\left(\frac{R}{R_a}+1\right)}}; \tag{18}$$

$$(49SR_a - 901)\left(\frac{R}{R_a}\right)^3 + (14SR_a - 1210) \times \left(\frac{R}{R_a}\right)^2 + (SR_a - 470)\frac{R}{R_a} - 56 \geqslant 0, \tag{19}$$

For a capacitance in the parallel leg, Eq. 12, we obtain

$$\omega_0 = \frac{1}{RC}\sqrt{\frac{10\frac{R}{R_a}+4}{7\frac{R}{R_a}+6}}. \tag{20}$$

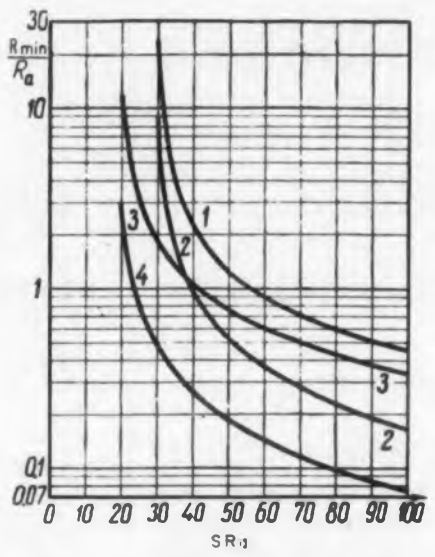


Fig. 3. The ratio R_{min}/R_a as a function of gain, SR_a.

$$(49SR_a - 901)\left(\frac{R}{R_a}\right)^3 + (84SR_a - 1.756)\left(\frac{R}{R_a}\right)^2 + (36SR_a - 1.108)\frac{R}{R_a} - 224 \geqslant 0. \quad (21)$$

From Eqs. 19 and 21 we obtain the well known condition for the selection of the gain

$$SR_a > 18.4 \quad (22)$$

Here the polynomials (Eqs. 19 or 21) have one positive root, which determines the minimum value of the ratio R/R_a. Fig. 3 shows a plot of R_{min}/R_a (parallel R—curve 3, parallel C—curve 4) versus the gain, obtained by solving cubic Eqs. 19 and 21 by one of the standard methods.

Conclusions

1. From a comparison of the curves of Fig. 3 for parallel R and parallel C networks one can see that, other conditions being equal, the parallel RC generator is excited at lower values of R/R_a.

2. Starting with a gain of 38 and greater, the RC generator with a four-element parallel R phase-shifting network is excited at larger values of R/R_a than the RC generator with a three-element parallel C network.

3. When the gain exceeds a definite value (differing with the type of network), the resistance of the phase-shifting network can be smaller than R_a.

4. In the design of RC generators one must choose such a value of R, that the ratio R/R_a, for a chosen gain, be greater than the minimum R_{min}/R_a, as given in Fig. 3.

5. The formulas for frequency agree with those given by Townsend.

Translated from "Limiting Values of Active Resistances of Phase Shift Generators," Garmash, Elektrosvyaz', *No. 6, June, 1960, pp 24-27.*

STANDARDS AND SPECS

Sherman H. Hubelbank

Adjustable Wirewound Resistors: Styles Madified In MIL-R-19365

Resistor styles have been modified by the C amendment of MIL-R-19365 to correspond to the fixed resistor styles in spec MIL-R-26C. The resistance tolerance has been reduced from +10% to +5%. The 24-number decade for standard resistance values has been adopted. The quality assurance provisions have been revised to incorporate standard paragraphs on responsibility for inspection. Latest packaging information has been incorporated. Adjustable wirewound power resistors, MIL-R-19365C, 18 March 1960.

Electrolytic Capacitors: New Voltage Rating Substituted In MIL-C-3965B

Amendment 1 to spec MIL-C-3965B has deleted the 18-v rating and substituted a 20-v rating. A requirement for visual examination has been added after life test. The insulating sleeve requirements for testing have been revised. Requirements for brackets have been added for the bathtub styles. The appendix has been changed to match the addition of new styles and the changed number of specimens necessary. MIL-C-3965B, Amendment 1, Fixed Electrolytic (Tantalum) Capacitors, 16 April 1960.

Mil Spec Covers Five New Plastic Sheets for Printed Wiring

Five new types of plastic sheets have been added to MIL-P-1394 by the "B" revision. Rigid tolerance classes have also been established for thickness, and warp or twist, in addition to normal tolerances. The quality assurance sections have been modified to incorporate the latest paragraphs on responsibility for inspection. MIL-P-1394B, Plastic Sheet, Laminated, Copper Clad (For printed wiring).

Feed-Through Capacitor Spec Is Completely Revised

MIL-C-11693 has been completely recast. The "B" issue also supersedes MIL-C-19080 (SHIPS). The military standard format has been changed to the detail format. The type designation has been changed to delete the identification of terminals. Current rating is now identified by a letter

symbol instead of a number symbol. The scope of the spec has been broadened to cover additional dielectric materials, such as paper-plastic, metalized paper, and metalized plastic. Fifteen new-style capacitors have been added. MIL-C-11693B, Capacitors, Feed Through, Radio-Interference Reduction, AC and DC (Hermetically sealed in metallic cases).

Air Force Issues Materials and Processes Specs

Issued monthly by the Air Force, USAF Specification Bulletin 23, provides a list of material and process specs, and other closely related specs. These specs are approved for use in the construction and maintenance of Air Force equipment and accessories. The primary purpose of the bulletin is to provide a check-list to insure that correct issues of applicable publications and specs are being used in manufacture. *Copies can be obtained from: Commander, Wright-Patterson Air Force Base, USAF Engineering Specifications and Drawings Branch, Administrative Services Office, Attn: EWBFE, Wright-Patterson Air Force Base, Ohio. Be sure to reference the contract number or bid.*

RF Filters: Eight New Types Added To MIL-F-15733

The most significant change to MIL-F-15733 has been the deletion of all six types of filters listed in MIL-F-15733C and the addition of eight new styles. Two of the new styles are tubular; the other six are bathtub type. The tubular types have current ranges from 1 to 30 amp at 100 v dc, and 1 to 50 amp at 400 v dc (125 v ac). The bathtub types have ranges from 1 to 50 amp at 100 v dc, 400 v dc (125 v ac), and 600 v dc (250 v ac). The type designation has been expanded to include symbols for current rating, insertion loss characteristic, terminal identification, operating temperature range, and vibration grade. This spec also supersedes MIL-F-18344A (SHIPS). Radio Interference Filters, MIL-F-15733D.

Coax Connector Adapters: General Requirements Listed In MIL-A-27434

MIL-A-27434 is a new spec covering the general requirements for weatherproof, between series, rf, coaxial connector adapters having a nominal impedance of 50 ohms. These connectors are intended for use in rf applications up to 10,000 mc. Adapter connector types established by this spec are: UG-564/U, UG-565/U, UG-635/U, UG-636A/U, and UG-637/U. MIL-A-27434, Adapters, Connector, Coaxial, Radio Frequency, Between Series, General Specifications For, May 10, 1960.

YOUR CAREER
NEWS AND NOTES

Electrical engineers received the highest starting salaries of 1960 graduates from Lehigh University.

The electrical engineers averaged $540 per month, a 7-per-cent increase over the 1959 average starting salary. However, according to the University's placement office, the greatest demand by employers was for mechanical engineers.

The 48 electrical engineers who were graduated had a total of 717 interviews with prospective employers, the placement office said.

° ° °

The National Science Foundation has awarded 500 summer fellowships to secondary-school teachers of science and mathematics.

The recipients will work on individually planned summer programs of graduate study and research for six to 12 weeks. The Foundation will pay tuition, fees, travel expenses, and dependency allowances.

The recipients come from 45 states and the District of Columbia. A total of 226 awards went to mathematics instructors, 173 to teachers of the biological sciences, 55 to physical-science instructors and 46 to general-science instructors.

° ° °

The Datex Corp., Monrovia, Calif., has found that engineers' writing problems were in organization and planning. The company's engineers, however, disagree.

The engineers, according to Datex, listed their major writing problems as deficiencies in vocabulary, grammar, composition, spelling, and sentence structure.

The engineers surveyed spent an average of 7 per cent of their time writing, according to the company. The company said studies have shown that "most engineers write grammatically. Despite their feeling to the contrary, their college training and experience (plus the usual reading) have given them vocabularies more than adequate to handle any engineering writing job."

° ° °

The Engineering Manpower Commission is trying to find out again what engineers are earning.

The commission's fourth survey of earnings is expected to cover more than 200,000 engineers employed in private industry, the government and education.

The last survey, conducted in 1958, indicated that engineers' salaries jumped an average of 6.5 per cent annually between 1953 and 1958.

Electronics men in the Chicago area often seek career advice from a woman.

She is Barbara Ann Seibert, an employment counselor with Drake Personnel, Inc., who specializes in helping electronics engineers and executives find better jobs in the industry.

"Those first months weren't easy," Miss Seibert said. "Many employers at first refused to deal with me when they found that B. A. didn't stand for Bart or Bert."

Although she now is well established in the personnel guidance field, she still uses only her initials in correspondence with men she hasn't met.

Her advice to job seekers: first pick the geographic area in which you are interested. Then decide on the size and type of company you want to work for. In addition, she said, consider whether you prefer to work with components or systems.

° ° °

By 1970, technical and professional employment will rise by 40 per cent, the largest change of any working group, according to a pamphlet compiled by the Labor Department.

The pamphlet, "Manpower—Challenge of the 60's," deals with expected changes in the nation's population and labor force in the next decade. It may be obtained from the U.S. Government Printing Office, Washington, D.C.

ENGINEER-IMPROVEMENT COURSES AND SEMINARS

Below are courses and seminars intended to provide the engineer with a better knowledge of various specialties. Our grouping includes several different types of meetings: National Courses—those held on conescutive days and intended to draw attendees from all geographical areas; One-Day Seminars—one-day intensive seminars which move from city to city; and Regional Lectures —regional symposia or lecture series which generally run one night a week for several weeks.

Linear Metrology Course

An intensive 70-hour, four-week course in Linear Metrology is being offered to qualified personnel by MetroLonics, Inc. The course, beginning Oct. 3 will utilize the complete facilities of MetroLonics. Subjects to be covered include Necessity for Standards, Derivation of Standards, Human Factors in Precision Measurement, Type of Instruments, such as Comparative and Absolute Instruments and Sources of Error. Instructors will be MetroLonics' experts headed by John A. Harrington, vice president for technical operations and an internationally recognized metrologist. For further information write: MetroLonics, Inc., 2201 N. Hollywood Way, Burbank, Calif.

Cyrogenic Engineering Course

An intensive two-week short course on Cyrogenic Engineering will be held Oct. 31-Nov. 11, 1960 sponsored by Engineering Extension and Physical Science Extension, University of California, Los Angeles. This course is an introduction to cyrogenic engineering. It is intended for the engineer unfamiliar with low-temperature techniques, who finds that he must employ some of these techniques in his design and research work. A prerequisite for the course is a bachelor's degree in engineering or physical science, including a course in elementary thermodynamics. For further information write: Engineering Extension, Room 6266, Engineering Building Unit II, University of California, Los Angeles, Calif.

PAPER DEADLINES

Convention Program Chairmen have issued the following deadlines to authors wishing to have their papers considered for presentation.

Oct. 1: Deadline for complete manuscripts for the **Fifth Midwest Symposium on Circuit Theory** to be held **May 7 and 8, 1961,** at Allerton Park and the Urbana campus of the **University of Illinois.** Send manuscripts to: *Prof. M. E. Van Valkenburg, Guest Editor, Dept. of Electrical Engineering, University of Illinois, Urbana, Ill.*

Oct. 10: Deadline for titles and abstracts (100 to 200 words) of papers, in duplicate, for the **URSI-IRE** fall meeting to be held **Dec. 12-14** at the **Boulder Laboratories** of the National Bureau of Standards, Boulder, Colo. The following commissions are planning to hold one or more technical sessions in addition to their business meetings. Commission 2—Tropospheric Radio Propagation, Irwin H. Gerks, Chairman; Commission 3—Ionospheric Radio Propagation. L. A. Manning, Chairman; Commission 4—Radio Noise of Terrestial Origin, William Q. Crichlow, Chairman; Commission 6—Radio Waves and Circuits, John I. Bohnert, Chairman. At the top of each abstract, give your name in the form you prefer, your affiliation, and your complete address. Send abstracts to: *Chairman, Commission ———(Appropriate one from above), c/o A. H. Shapley, CRPL, National Bureau of Standards, Boulder, Colo.*

Nov. 15: Deadline for 100-word abstracts and 500-word summaries for the **Winter Convention on Military Electronics,** sponsored by the Institute of Radio Engineers on Military Electronics, **Feb. 1, 2 and 3, 1961** in Los Angeles. Send abstracts and summaries to: *Dr. John J. Myers, Hoffman Electronics Corp., Military Products Div., 3717 S. Grand Ave., Los Angeles 7, Calif.*

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2-WAY RADIO COMMUNICATIONS

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- Systems engineering
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- Selective signaling
- Transistor applications
- Crystal engineering
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- Design of VHF & UHF FM communications in portable or subminiature development
- Microwave field engineers
- Transistor switching circuit design
- Logic circuit design
- T.V. circuit design engineering
- Home radio design
- New product design
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