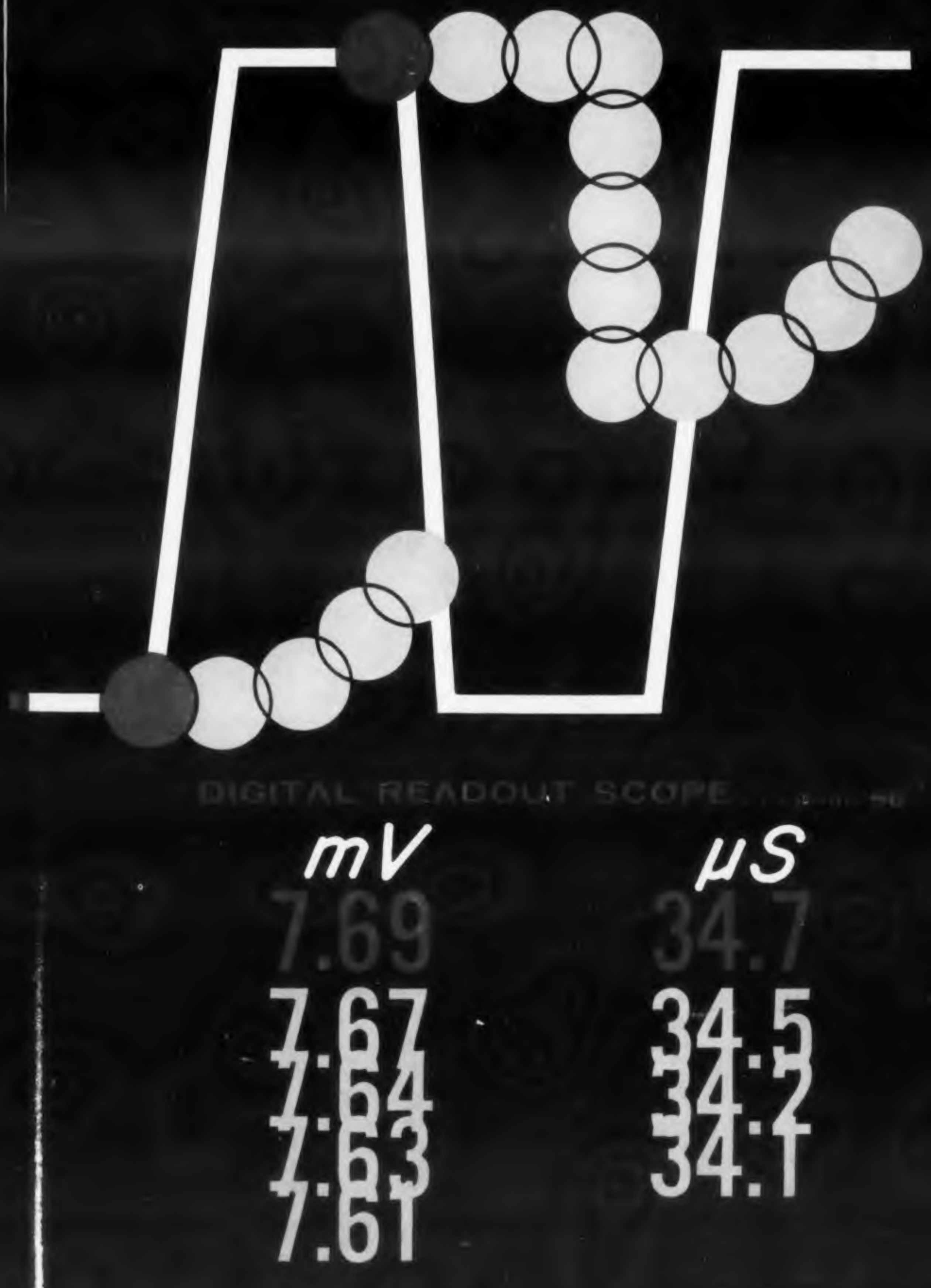
ELECTRONIC DESIGN

JANUARY 2, 1960



DIGITAL READOUT SCOPE . . .

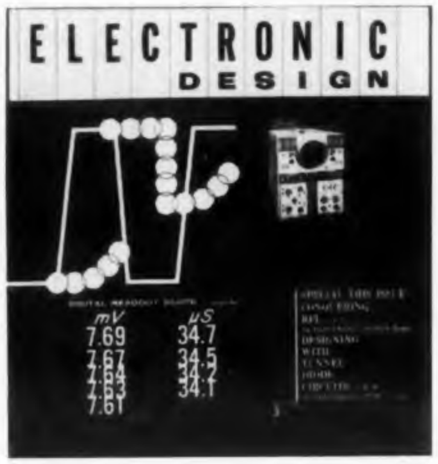
SPECIAL THIS ISSUE:

CONQUERING RFI . . . p. 24

An *ELECTRONIC DESIGN* Report

DESIGNING WITH TUNNEL DIODE CIRCUITS . . . p. 50

An *ELECTRONIC DESIGN* First



COVER: Digital readout, joystick positioning, and electronic switching in X, Y, and Z axes are just a few of the features of this new oscilloscope. On the cover, our artist has shown his impression of the movement of the indexing and scaling dots, set up for digital readout of the waveform amplitude.

Selected Topics In This Issue

RFI—Peril to Progress

Formerly scorned as a minor imperfection, radio frequency interference (RFI) now looms as a major peril to electronic progress. Because of the disturbances that result from interference, an impasse has been reached in the quest for higher sensitivity and greater reliability. The question many design engineers are now asking is, "How can RFI be effectively eliminated?"

Aware of the urgency of the problem, *ELECTRONIC DESIGN* is pleased to present a revealing Special Report on the subject. Howard Bierman, after contacting experts in various phases of interference work, has organized their findings into a series of articles dealing with the latest developments made in the field. Beginning in this issue, developments in the critical areas of design precautions, trouble-shooting, and measurement techniques are presented and discussed in detail. The series will continue in subsequent issues.

A First!
Tunnel Diode Circuits

Since tunnel diodes first made their appearance on the electronic scene, engineers have been interested in possible practical applications of the devices. This issue contains the first article ever to appear on practical tunnel diode circuits. Authors are U. S. Davidsohn, Y. C. Hwang, and G. B. Ober of General Electric Co. Designing With Tunnel Diodes, Part I of a two-part series, begins on page 50. Part 2, which will appear in a subsequent issue, deals with measurement of tunnel diode characteristics.

Selected Topics In This Issue (Cont.)

CIRCLE 2 ON READER-SERVICE CARD ➤

CONTENTS FOR FEBRUARY 3, 1960 VOL. 8 NUMBER 3

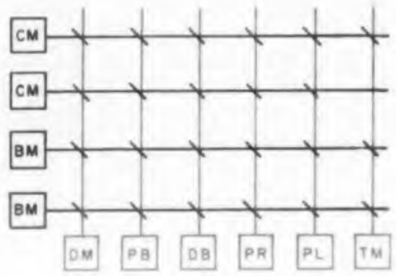
ELECTRONIC DESIGN Hayden Publishing Co., Inc., 830 Third Avenue, New York 22, N. Y.

Coming in the Next Issue

Paul Wrablica, industrial designer, begins a series of articles dealing with the introduction of human factor engineering in industry. No longer concerned with product appearance alone, industrial designers are focusing on the need to modify equipment to more functional styling. At the same time, serious consideration must be given to the human operator who will work with the product. Meet Paul Wrablica in our next issue and follow him through a series of articles in which he describes this fresh approach to knobs, panels, housings, and other electronic components.

ELECTRONIC DESIGN is published bi-weekly by Hayden Publishing Company, Inc., 830 Third Avenue, New York 22, N. Y., T. Richard Gascoigne, President; James S. Mulholland, Jr., Vice-President & Treasurer. Printed at Hildreth Press, Bristol, Conn. Accepted as controlled circulation at Bristol, Conn. Additional entry, New York, N. Y. 34,058 copies this issue.

Computer Networks Are on the Way



How two types of elements are connected in Thompson Ramo-Wooldridge's polymorphic computer. At left are control modules and buffer modules. These connect with subordinate drum modules, peripheral buffers, display buffers, printers, plotters, and tape modules. If required, other computer elements can be similarly connected—high-speed buffers, Flexowriters, analysis consoles and control consoles.

DATA-PROCESSING scientists are wondering whether it's time to take a "system" look at current computing needs. Sometime soon, they reason, computers will have to be teamed to keep capacity abreast of increasing demands for data processing.

Computers and translators linked in a network could handle more work more efficiently and economically than the same equipment operating independently.

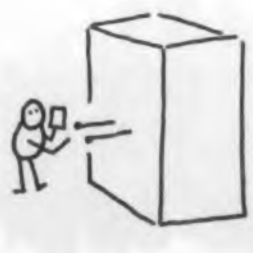
Some of the first steps toward computer networks have been taken: data-processing centers are in operation and more are being organized; digital computers have been linked by microwave radio, and the first "polymorphic" computer is nearing completion.

The polymorph, being developed by Thompson Ramo-Wooldridge, Inc., is made of many small modules of a few basic types that can organize themselves in different ways to do different jobs.

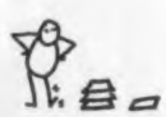
The first of these systems, the RW-400, is being built for the military at Dr. Simon Ramo's Intellectronics Laboratory, Canoga Park, Calif.

It has two kinds of controlling elements: a digital computer and a buffer module. These are connected by a central "switchboard" to drum modules, peripheral buffers, display buffers, printers, plotters, tape modules, translating devices, high-speed buffers, Flexowriters, analysis consoles and control consoles.

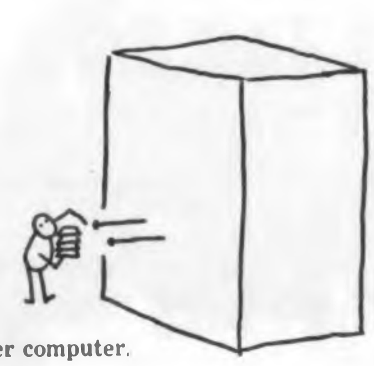
If you have a problem to be computed . . .



You take it to a computer.

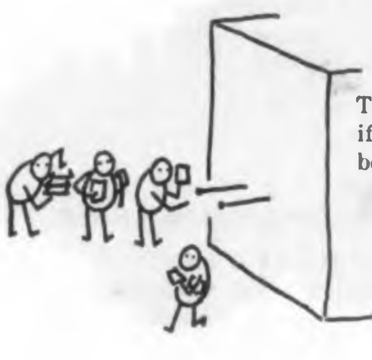


And as the problem gets bigger . . .



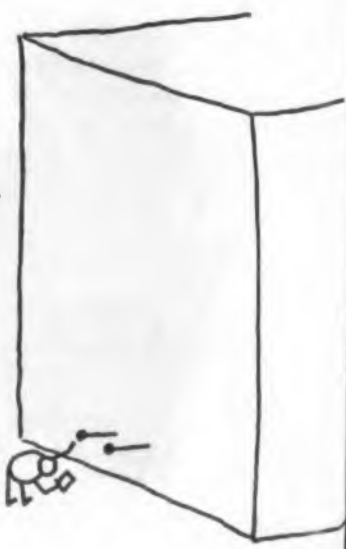
You need a bigger computer.

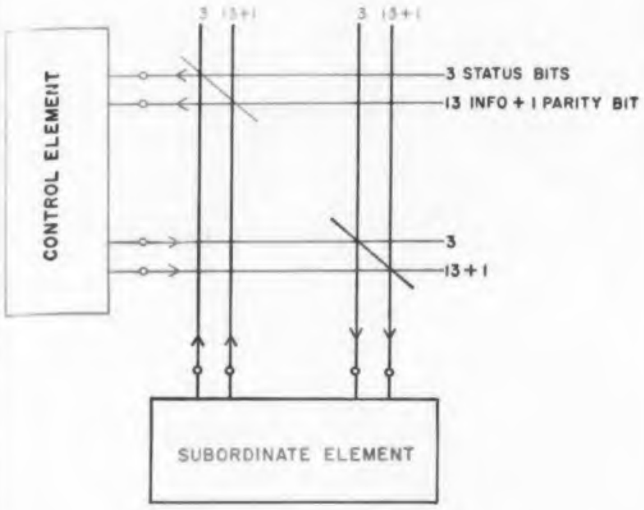
And as more and more guys have problems to solve . . .



They take turns on the computer. Which is fine if the computer is fast enough. Which it can be if it is big enough and expensive enough.

But as the number of guys and the number of problems increase, the machine gets huge—and . . .

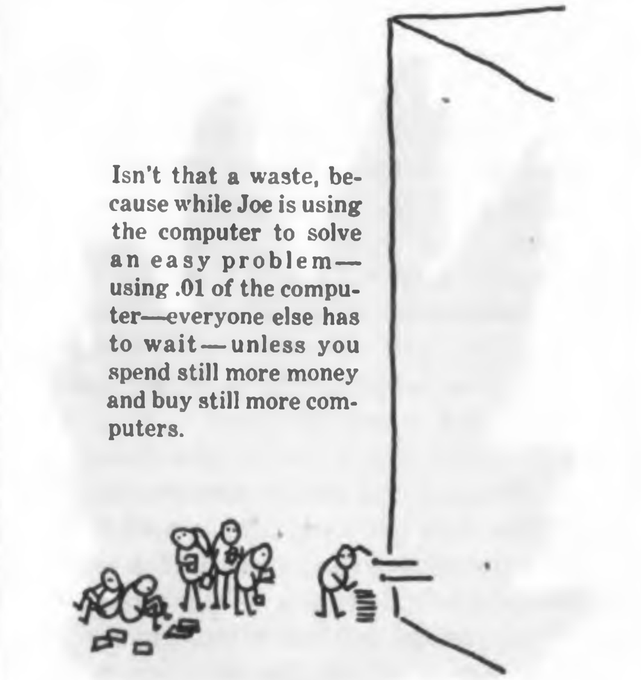




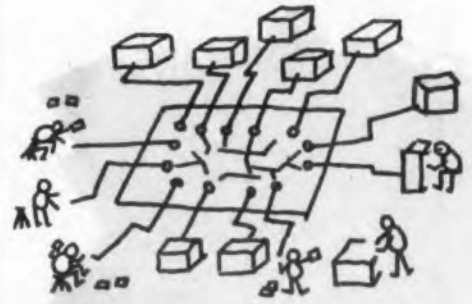
The polymorphic computer being built for the military can transmit 13 information bits, one parity bit and three status bits to and from each control element and each subordinate element.

The switchboard is a transfluxor matrix capable of 5-μsec switching. Through the switchboard, controlling elements—those with "dials" on their "telephones"—can talk to any subordinate component.

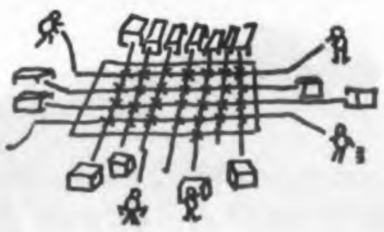
The central exchange matrix is not a bus bar: the computer doesn't have to "talk" to many different devices simultaneously. It needs only to communicate with one line, and there can be as many simultaneous conversations as there are



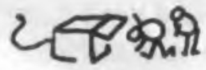
NEWS



So the users all wish they could divide the huge computer into little pieces and make a flexible, loose "switchboard" connection, distributing the control and the memory and the arithmetic and everything else. Then they can all use it at once, with switching combining a large or small collection of computer units, as the case may require.



Then if users get the busy signal too often, they buy more capacity and connect the added components to the system—or connect new "subscribers" as they move in—or add more displays, so they can see what they have.



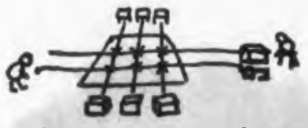
And, if one piece quits, it's no great catastrophe—they switch over to another.

controlling devices. All elements talk in one common language in the switchboard complex.

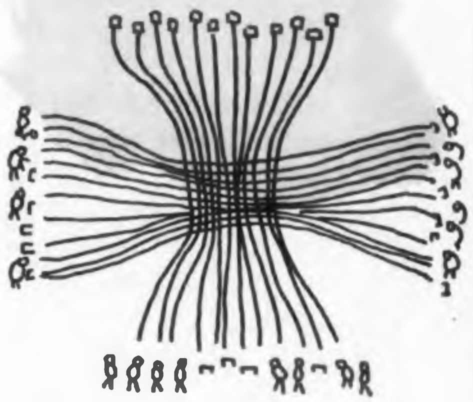
Polymorphic computers have large memories, useful because a minimum-size system installed as a starter can be expanded easily later. There are more profound implications. One is that with two buffer modules, the computer effectively has an infinite memory, says E. E. Bolles, associate head of the Digital Control Dept. at Intellectronics Laboratory. Normally, with a program that requires much data, the data are pulled in and worked on until they are complete; then more data are pulled in and processed.

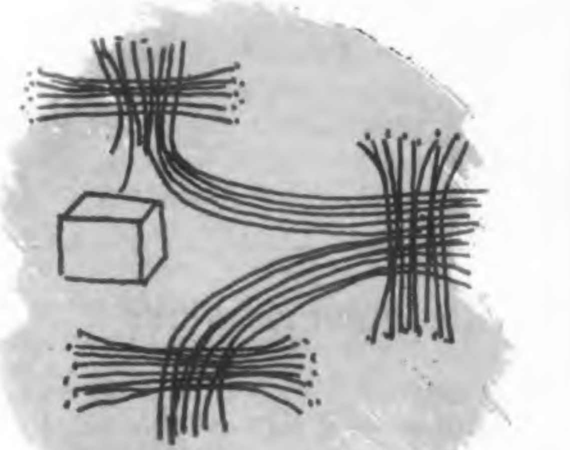
With a polymorphic computer having two buffers, the computer module can start by operating on the data gathered and supplied by one buffer, while setting the second buffer to gathering the next batch of data. When the computer is finished with the first batch, it ties to the second buffer memory and sets the first to sorting and accumulating data.

Therefore two intelligent buffer modules



And now—when you put together a complex of human brains and electronic boxes—you can start with a few components. When you need more and can afford them, you can build to a big, or even a really, really big system without over-investing early or throwing anything away. So you save money and all the while have better reliability and multiple use and better access.





You can't even join two complexes—or three or four—by means of switching like a telephone system, connected in a giant computer as an element. If the "super-system" scale justifies, you can also keep some lines private by opening some switches permanently, so some information won't be available to "nosy" subscribers.

switching in and out, interpreting and sorting data to help the computer operate most efficiently, give the system what amounts to a very large memory.

In systems with more than one computer module, one is assigned the job of master. It then assigns tasks and subtasks to the other controlling elements, as well as to the subordinate elements. In this way different computers can be working on different problems or all working on subtasks of the same problem.

The polymorphic system that Thompson Ramo-Wooldridge is readying for the military comprises

And so now you see, it wasn't exactly a computer you wanted but a group of guys with brains and a group of electronic "brains," consoles and displays —all connected in varying ways and growing together, so that the combine can do more per dollar than each group alone in processing information and reaching conclusions.

And that's all there is to the data-processing approach known as "polymorphic" (many shaped) or "multiple-mode" or the "matrix concept" or maybe just the common-sense switchboard idea in data-processing systems.

one computer module, two buffer modules, a printer, a plotter, three tape units and a drum storage unit.

Thirteen information bits and one parity bit can be transmitted either to or from the module. Three additional "status" bits go along with the information, to give the receiving module advice on how reliable the information is.

This means that the transmitting module's best information about the validity of the information is sent as status bits. If a tape breaks, for example, along with the noise of the break comes status information that alerts the computer elements. *(Continued on opposite page)*

The Language Problem in Computer Networks

In a paper delivered at the Northeast Electronics Research and Engineering Meeting in Boston last year, Jerry Rothstein of Edgerton, Germehausen & Grier, Inc., discussed some aspects of computer networks. Here, in simplified form, are some of his observations on communication among computers:

For computers to cooperate, they must "speak" the same language. Very often this requires an intermediate "translator," which accepts the output of one system and changes it into a form suitable for use by the other system.

A translator can be considered part of either of the two computers, or all three elements can be viewed as a single system. Similarly existing systems can be broken down into many subsystems.

For n computers capable of individual operation, each with its own language and with co-operation required between every pair, there would have to be $(n-1)$ one-way translators at each computer to permit any computer to understand any other.

There would be $n(n-1)$ translators required altogether. If a common language were devised, however, each computer would need two one-way translators ($2n$ altogether), namely, those to translate its language to the common language and back again. Two-way translators could, of course, replace a pair of one-way translators in either case.

The common language is important because computers in existence speak different languages, and it is not likely that all computers of the future will speak the same language. A computer is generally built with some particular class of problems in mind. The language chosen is appropriate to that class of problems. The economies inherent in an appropriate choice are too large to be sacrificed to a common language.

Fortunately computer languages have sufficiently simple and similar logical constructions to make translator design a soluble problem.

Unlike machine translation of natural languages, translation between computer languages is feasible in practce aind not just in princple.

If one of the elements breaks down, the computer is not disabled. The element's task is simply distributed among other elements. Clearly this means better reliability without duplicating the whole system.

For the time being, Thompson Ramo-Wooldridge believes, the principle use of polymorphs will be for command-control systems. These have large enough problems to make the system a necessity. Air-traffic control, air defense and other large systems will also probably be polymorphs. For industry, the company sees the possibility of a network of computers communicating with one another by central exchanges and digital data-transmission links.

In one form or another, computer networks seem only a matter of time. Some problems within the reach of programers' capabilities, and others soon to be, are too large for individual computers and too important to be excluded from the schedule of problems to be analyzed automatically.

Jerome Rothstein of Edgerton, Germehausen & Grier, Inc., put the problem this way to an audience of computer specialists at the Northeast Electronics Research and Engineering Meeting:

"In economic science the labor expended in treating data absorbs so many man-hours that relatively few penetrating questions are ever formulated, let alone answered. In public health and vital statistics there are dozens of hypotheses worth testing and mountains of data in hospitals, insurance companies and elsewhere that should be processed by high-capacity computer systems. Worldwide weather prediction and literature searching are other giant but vital problems that will probably be solved only by new approaches to data processing.

The chief technological problem of computer co-operation reduces to one of organizing a number of independent computers into a cooperating network without prejudice to their ability to operate independently when desired."

CIRCLE 9 ON READER-SERVICE CARD ➤

NEWS

Direct-View Battery TV Due

Fully transistorized, direct-view portable TV set made by Sony Corp. will be marketed in Japan next month and in the U.S. within eight months. It has an 8-in. screen and weighs 13 lbs with its 2-lb battery. This model, to be priced at about $200 on the Japanese market, operates on 100-v, 60-cycle ac or on a self-contained, sealed-type rechargeable 12-v battery, using 15 w of power. Battery is a 3 amp-hr unit and lasts about 2 1/2 hr.

1959 Electronics Sales Reach All-Time High of $9.2 Billion

Total 1959 factory sales for the electronics industry established an all-time high of $9.2 billion, reported David R. Hull, president of the Electronic Industries Association, releasing the official EIA totals for 1959. He added that the industry is expected to pass the $10 billion mark in 1960.

"Manufacturers of consumer products made a substantial comeback from the 1958 recession with a 1959 sales total of $2.05 billion, or $450 million better than last year," Mr. Hull stated. "The 1959 figure of $1.1 billion for replacement parts, tubes, and semiconductors is $240 million higher than 1958. Industrial and military products set new highs with totals of $1.55 and $4.5 billion. These were, respectively, $170 and $400 million over 1958."

U.S. Leads in Semiconductors Says Solid-State Conference Chairman

Assisted by heavy financial backing from government agencies, the U.S. is well ahead of Japan, Russia and the rest of the world in solid-state technology, believes A. P. Stern, chairman of the 1960 Solid-State Circuits Conference, which is about to open in Philadelphia.

Mr. Stern, manager of General Electric's Electronic Components and Applications Laboratory, also told ELECTRONIC DESIGN that he thinks it's time for companies engaged in microminiaturization to co-operate in an evaluation of all microminiature programs.

The situation in microminiaturization is disturbing because of confusion in goals and nomenclature, Mr. Stern stated. He would like to see a schedule set up for each program, against which progress could be measured. This would permit, Mr. Stern said, concentration on the most promising work and elimination of many programs.

About 2500 engineers are expected to attend the conference, which will be held Feb. 10, 11, and 12. Over 43 papers, arranged for by program chairman T. J. Lynch of Bell Labs, will be presented.

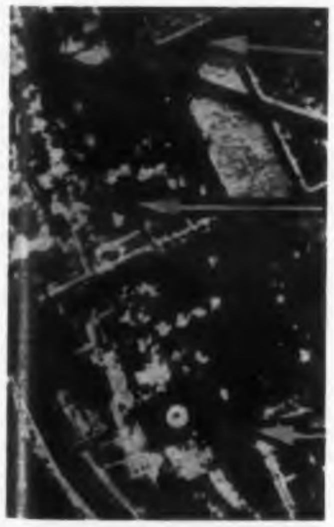
Radar With 0.02-Musec Pulse So Sharp It Tracks People

A new magnetron that packs 25 kw of 8-mm power into a 0.02-μsec pulse has been developed for airport surveillance radars and other applications. Resolution of the tube in a millimetric radar system is so sharp that traces of people and of vehicles as small as jeeps can be displayed clearly.

Amperex Electronics, which is distributing the Philips-designed tube, reports that range and azimuth resolution of 4.5 yd at 1000 yd has been achieved.

The new magnetron, Type 7093, achieves the rise-time of 600 kv per μsec needed for a 0.02-μsec pulse.

"The short pulse length enables a radar to detect objects as close as 10 or 12 ft from the antenna," Amperex reports. "This makes the tube ideal for small-craft harbor vehicles and airport surveillance applications."



Jeep

Aircraft

People

Map-like ppi presentation, using new tube, shows people walking on airport apron and jeep rounding corner and heading along runway.

A technician probes radiated interference from an aircraft hoist in the Los Angeles laboratory of Sprague's Interference Control Field Service Dept.

Improved Service For Radio Interference Control

Fast-growing Department of Sprague Electric Company Greatly Expands its Measurement, Control, and Consulting Engineering Facilities to Provide Fast Service.

Contractors responsible for the design and manufacture of electric/electronic equipment and weapon systems which must conform to military interference requirements will get a major assist from Sprague Electric's expanded industry service in the field of r-f interference and susceptibility.

The service includes: interference and susceptibility measurements up to frequencies of 10,000 mc; complete analysis of all test results; and comprehensive recommendations of appropriate control techniques to bring about a suppression system having the lowest weight, the lowest cost, and the greatest reliability.

Sprague's consulting service applied at the design stage already has proven to be the best approach to interference and susceptibility control. Experienced Sprague engineers invariably save valuable time in the preparation of test plans and their subsequent approval. Sprague engineers prefer to work from the design conception, analyzing original schematics and equipment drawings. This permits them to recommend optimum shielding, isolation, and decoupling techniques before cases and layouts are finalized. Space allowances for suppression components can be made with proper attention to economy of weight and cost.

Once the equipment reaches the prototype stage, Sprague specialists will conduct tests either in the manufacturer's own plant or in one of Sprague's interference laboratories. Sprague will also direct compatibility tests on end equipment or complete weapons systems, and recommend solutions to any integration problems which might develop.

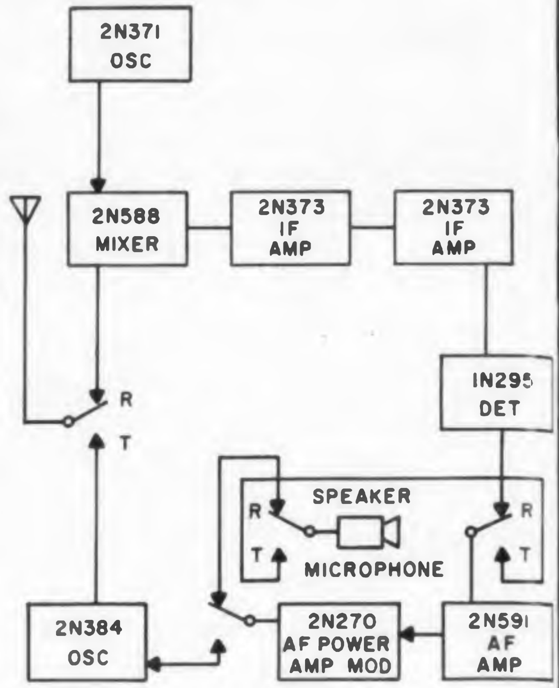
Sprague Interference Control Laboratories are located on the Pacific Coast, in the Mid-West, and on the East Coast. These laboratories are staffed by top interference and susceptibility control specialists, and are equipped with the most advanced instrumentation and model shop facilities.

For further information, write to Interference Control Field Service Manager, Sprague Electric Co. at 12870 Panama Street, Los Angeles 66, California; 224 Leo Street, Dayton 4, Ohio; or 347 Marshall Street, North Adams, Massachusetts.

CIRCLE 11 ON READER-SERVICE CARD

Three Approaches To Low-Pri

Micro-Pak Citizens' set made by Micro Electronics has a transmitter with a crystal-oscillator-driven, class-C power amplifier. Power output is 15 mw for 60-mw input. Signals off by ±20 kc from operating frequency are attenuated 45 db. Sensitivity of single-conversion, superheterodyne receiver for useful audio output is 0.5 μv. This provides audio power output of 50 mw.



AM transceiver, Radio Manufacturing Engineer's 4303, also uses only one transistor in the rf portion of the transmitter. The 2N384 operates a crystal-controlled oscillator with 90-mw input. The local oscillator is continuously tunable between 26.965 and 27.255 mc. To switch circuits from receive to transmit, the operator uses a multipole switch, coupled to the press-to-talk button, instead of a relay.

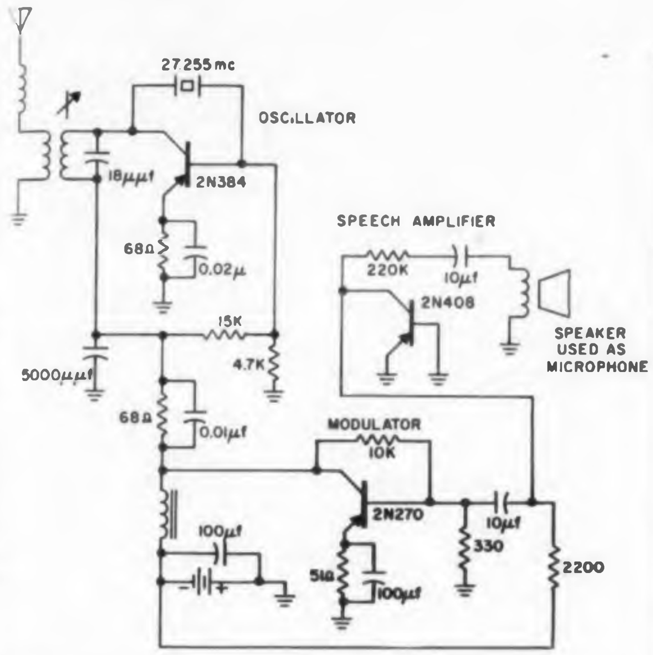
Designers Producing $100 Citizens

THE popularity of Citizen's Radio is triggering design of a new class of communications equipment—walkie-talkie sets that retail for about $100, less than half the price of standard portable transceivers.

Designers are hitting the $100 target by keeping circuits simple, leaving out frills, and by going to single-frequency operation.

Three low-priced sets have already been introduced, and manufacturers are reported developing similar devices in anticipation of a huge market. Available at present are:

- A 27-mc transceiver made by Radio Manufacturing Engineers, Inc., with seven transistors and two diodes. Only one transistor is used in the rf portion of the transmitter. To reduce components, the designers made the receiver audio amplifier double as the transmitter modulator system. The built-in loudspeaker also serves as the microphone.
- A WEPhone transceiver manufactured by Wightman Electronic Engineering Co., with seven transistors and one diode. The WEPhone's designers provide a modulator system independent of the receiver audio amplifier. The receiver is a single-conversion superheterodyne designed for single-frequency operation. With appropriate crystals, it can receive and transmit on any frequency in the 27-mc Citizens' band.
- The Micro-Pak, a more elaborate low-priced transceiver developed by Micro Electronics. It has squelch operation, more complex circuitry than the other sets and a price tag of more than $100. Receiver sensitivity for useful audio output is reported to be 0.5 uv. Receiver drain is 20 mw and transmitter drain, 70 mw.



WEPhone transmitter developed by Wightman Electronic Engineering is paired with a single-conversion, superheterodyne receiver. The 2N384, used as a crystal-controlled oscillator, constitutes the transmitter rf section. This stage is modulated by the 2N270, which is driven by the 2N408 speech amplifier. The loading coil feeds a 48-in. antenna. Standby drain is 7 ma and transmitting drain, 17 ma. The set can operate anywhere in the 27-mc band with appropriate crystals.

Transceivers

The Federal Communications Commission requires that sets for unlicensed operation transmit between 26.77 and 27.27 mc, restrict power input to the final rf stage to 100 mw or less, use a single-element antenna not more than 5 ft long, and attenuate emissions outside the 26.97-27.27-mc band by at least 20 db.

In addition to meeting these requirements, Citizens' equipment designers must meet these needs of the market:

- Transmitter range of at least one mile.
- No transmitter tuning adjustments for the user to make.
- Selectivity ample to avoid adjacent channel interference and adequate to permit reception from a similar unit one mile away.
- Small, light equipment operated by self-contained batteries.

Despite the limitations, designers are delivering sets that give surprisingly good performance for the stringent requirements under which they must operate. ■ ■

NEWS

Gallium Arsenide Tunnel Diode Has 60-to-1 Peak-Valley Ratio

Latest from the tunnel diode labs is General Electric's announcement of a tiny gallium arsenide device with these features:

- Peak-to-valley current ratio of 60 to 1, 5 to 10 times that of previously described tunnel diodes;
- The ability to handle current densities ranging from 5,000 to 10,000 amp per sq cm, roughly the capability of No. 12 gage copper wire, and four times that of germanium tunnel diodes. Current densities handled by germanium tunnel diodes range from 0.4 to 0.45 v per sq cm.
- Voltage swing of from 0.9 to 1.1 v.
- Resistance to temperatures up to 500 C.

Gallium arsenide, the company believes, performs better than any other tunnel-diode material tested so far, and may prove the ultimate material.

Company spokesmen report that the best peak-to-valley current ratio of germanium so far observed is 14 to 1. Silicon diodes have exhibited no greater than 6-to-1 ratios.

GE expects to have samples ready for circuit designers in six months; these will cost an estimated $75 each.

NEWS BRIEFS . . .

. . . **THE INSTRUMENT SOCIETY OF AMERICA** will collect and publish a "comprehensive compendium" of up-to-date information on all known transducers. Expected publication of the first volume is January 1961.

. . . **A NEW WATT-MEASURING DEVICE,** the Hall multiplier, developed by Westinghouse Corp., operates as a watt transducer, converting ac watts to a dc millivolt signal. In control circuitry, the unit has a response speed in microseconds, compared with a time constant of about one second for a thermal converter, Westinghouse reports. Two versions have been designed: one provides an unfiltered dc current output in the milliampere range; the other produces a filtered dc millivolt output.

. . . **THE AMERICAN POWDER METALLURGY INSTITUTE** has been formed for metallurgists and "anyone having a bona fide interest in powder metallurgy." Address of the new organization is 60 E. 42nd St., New York 17, N.Y.

. . . **LUNAR GLOBES** showing the moon's far side as photographed by the Soviet's third cosmic satellite have been constructed at the Moscow Planetarium and are being readied for mass production.

. . . **TELEVISION SETS AND ANTENNAS** currently cause more than 4% of lightning-originated fires, reports the Lightning Protection Institute.

. . . **WESCON** (Western Electronic Show and Convention) will be held in Los Angeles' new Sports Arena in 1960, Wescon's board of directors reports.

. . . **ELECTRONIC SYSTEMS** engineering and electronic cabling contracts in excess of $500,000 have been awarded to Pacific Automation Products, Inc., by Lockheed Missile Systems Div., Convair, Fischbach & Moore, and Sperry-Utah. An initial Lockheed contract is for work on the Samos-Midos reconnaissance satellite program. The contract includes systems integration and systems engineering on Lockheed's satellite tracking and data-acquisition station.

. . . **DIGITAL AND ANALOG** airborne magnetic tape recorders will be designed by Oliver-Shepherd Industries, Inc., Nutley, N.J., under a $215,000 contract from Airborne Instruments Laboratory.

. . . **RELIABILITY** of communication equipment could be greatly improved if designers could use principles believed to underlie operation of the brain and nervous system, according to Kenneth W. Jarvis, a panel chairman at the Winter General Meeting of the AIEE. He told an audience of computer engineers: "Scientists have long been aware of the remarkable powers of the human brain and nervous system to utilize astonishingly small quantities of sense data to arrive at reliable decision regarding the external world. It seems that one factor in this remarkable capacity is that parallel sensory paths are utilized and their outputs compared at various levels. Most probable values of the sense data are computed and cross-compared, resulting in a high degree of reliability. In essence, operation is parallel rather than serial."

Correction

Two captions were transposed on pages 3 and 4 of the Dec. 23, 1959 issue of ELECTRONIC DESIGN. The drawing on page 3 actually shows a Centralab flip-flop wafer; the schematic on page 4 illustrates a module made by Arthur Ansley Manufacturing Co.

NEWS BRIEFS...

. . . **A MATHEMATICAL FORMULATION** that predicts microwave absorption in ferrites is being evaluated for the Diamond Ordnance Fuze Laboratories by the National Bureau of Standards. NBS reports that prediction could cut the testing required to determine behavior and properties of ferrites. The work could also lead to more effective use of existing materials and to easier synthesis of new materials.

. . . **ENGINEERS JOINT COUNCIL** will invite foreign scientists to this country in the next six months to broaden engineering teaching and research. The scientists will exchange information with educational groups here and will receive an opportunity to visit engineering society meetings and non-university research organizations.

. . . **A COMPUTER** able to operate at 500,000 operations per second is under development at the University of Illinois. The unit will provide high-speed storage for nearly 250,000 bits of information.

. . . **"RESEARCH AND DEVELOPMENT** expenditures by industry, government, universities and private laboratories will rise to more than $20 billion annually over the next seven or eight years, against $10 billion today," predicts Donald C. Power, chairman and chief executive officer of General Telephone and Electronics Corp.

. . . **SCIENTISTS AND ENGINEERS** employed by American companies totaled 780,000 in January, 1959, the National Science Foundation reports. A foundation survey found that industry accounted for two-thirds of the scientists and engineers employed in the nation. The other third work for government agencies, educational institutions and non-profit organizations, or are self-employed.

. . . **A TECHNICAL ADVISORY COMMITTEE** of university scientists has been established by Daystrom, Inc., to aid in long-range R&D planning. The committee will review the programs of all Daystrom divisions and provide them with the latest research information.

. . . **RECIPIENT** of the annual National Reliability Award for the best technical paper delivered at the Fifth National Symposium on Reliability and Quality Control in Washington was H. G. Friddell of the Boeing Airplane Co. His paper, "System Operational Effectiveness (Reliability, Performance, Maintainability)", included a procedure for obtaining an operational-effectiveness value for systems.

...GENERAL CHAIRMAN for next year's reliability symposium will be W. T. Sumerlin of the Philco Corp. He succeeds C. M. Ryerson of the Radio Corporation of America.

...1959 ANNUAL AWARD of the IRE Professional Group on Reliability and Quality Control was presented jointly to J. A. Connor and H. L. Wuerffel in "recognition of their contributions to the profession." The citation recalled their work in report TR 1100, which included an assemblage of guiding principles, data and graphs for the design of reliable electronic equipment. Mr. Wuerffel, a systems engineer, is in the reliability analysis and measurement engineering section at RCA. Mr. Connor is manager of the Reliability and Component Engineering Dept., Communications Div., Hughes Aircraft Co.

PRICES AND AVAILABILITY...

... TANTALUM POWDER, both "Lo-Cap" and "Hi-Cap," has been reduced 15 per cent in price by the Kawecki Chemical Co. of Boyerton, Pa. The powder is now available at $49.80 a pound in minimum 200-pound shipments.

...MULLARD, LTD., London, has developed an S-band Faraday rotation circulator with an insertion loss of less than 0.2 db. The circulator's low insertion loss represents an increase of less than 14 K in noise temperature. The circulator provides an isolation of more than 30 db in any unwanted transmission path. Bandwidth is about 30 mc. An S-band ferrite switch also developed by Mullard, and designed for a maser amplifier, has an insertion loss of 0.3 db. The device is designed for switching between two waveguide outputs, isolation between the paths being greater than 20 db. Bandwidth is 100 mc and switching time is less than 100 μsec.

...SILICON-CONTROLLED rectifiers have been reduced 20 to 40 per cent in price by General Electric Co., Liverpool, N.Y. The new prices range from $18.50 to $95 each on the eight models in the 16-amp line; from $14 to $71 each on the eight types in the 10-amp line, and from $24 to $114 each on the seven devices in the inverter series. All prices are for production quantities to original-equipment manufacturers.

Is your company making changes in prices or availability of its products? Send the details to *ELECTRONIC DESIGN*, 830 Third Ave., New York 22, N.Y.

WASHINGTON REPORT

Ephraim Kahn

. . . **RECORD R&D** spending is planned by the Government during the fiscal year that starts July 1. The Defense Dept. alone will be ready to commit $5.8 billion, while the National Aeronautics and Space Administration contemplates $600 million worth of R&D. The Federal Aviation Agency will allot $56.2 million, much of it for electronic development and modernization of air-traffic-control and navigation systems. President Eisenhower's new budget includes a request for total Government R&D spending of $8391 billion, 5 per cent more than was requested for the last fiscal year. Basic research accounts for $600 million of this.

. . . **ELECTRON TUBE** procurement procedures proposed by the Air Force as purchasing agent for the military have been submitted to the Defense Department for approval. If they satisfy the Assistant Secretary for Supply and Logistics, the Air Force will first compile total military requirements of types of tubes used by all the services, work out a buying schedule and place contracts. Expectations are that the Air Force will be ready to do its first buying before March 31.

. . . **BIDDING MODIFICATIONS** for military electronic contracts have been urged by J. K. Sprague, president of Sprague Electric. He suggests weighting bids by grading manufacturers on the quality of their products and their past records in meeting military specifications. At present, he asserts, producers of top-quality items must compete on a straight price basis with those "who have not demonstrated a capability for producing to the required standards."

. . . **COMPONENT RELIABILITY** is the keystone of a successful weapons system, says the Navy's chief of development, Vice Adm. J. T. Hayward. Components "have been overlooked completely" in the glamor of many large systems, he charges, adding that "the results have shown we should have paid more attention to our homework on the components." He notes, too, that reliability starts with "the lowest component" and that "all the quality control in the world" cannot compensate if engineering and design are inadequate.

. . . **JAPANESE COMPETITION** may soon make itself felt in color TV sets. A major incursion of the U.S. market is believed planned. The competitive weapon is believed to be a 21-in. color set priced to retail in the U.S. market at less than $300 (with a short margin for the seller). Production capacity is expected eventually to exceed 500,000 sets a year.

. . . **MACHINE TOOLS** owned by the Government and furnished to defense contractors will be audited by the General Accounting Office. Investigators have already found a number of cases in which tools furnished for defense work are being used improperly for production of civilian goods. The GAO will put "particular emphasis on the adequacy and effectiveness of controls exercised by the military department to assure that the use of such tooling does not give one contractor a competitive advantage over another and that adequate rental or other consideration is received by the Government for the tooling."

. . . **R&D MANAGEMENT** may become a primary job for the Advanced Research Projects Agency. The object would be to help the Defense Department avoid "uneconomic development of obsolescent weapons systems, procurement of unnecessary hardware, and undesirable misuse of resources." Another project for the agency is exploration of advanced concepts and theories that will enable it "to identify and make contributions of a conceptual nature to the basic technical problems vital to national defense, which may not now be receiving adequate attention by the scientific community."

. . . **DEFENSE-MATERIALS** research should be subject to "maximum coordination" among Government agencies, states the Joint Congressional-Defense Production Committee. Defense needs for materials that can withstand extremes of temperature, corrosive conditions, and great pressures have far outstripped civilian technology. The Congressmen note that there exist theoretical designs "which are dependent upon new or improved materials in order to move forward to construction."

. . . **RETALIATORY FORCES** must be "economical enough to support without undue drain on the Treasury," according to the director of the Navy's Guided Missile Div. Endorsing "a modest force of approximately 45 Polaris submarines" as the keystone of U.S. defense, Adm. K. S. Masterson nevertheless asserted that the U.S. should never become completely dependent on a single weapons system.

IDEAS FOR DESIGN—*ENTRY BLANK*

To the *Ideas-For-Design* Editor of ELECTRONIC DESIGN —
830 3rd Ave., New York 22, N.Y. • PLaza 1-5530

Here is my design idea for possible publications in your *Ideas For Design* department. I can expect $10 for this idea if accepted for publication.

(Ideas suitable include: *1.* new circuits or circuit modifications, *2.* new design techniques, *3.* designs for new production methods, *4.* clever use of new materials or new components in design, *5.* design or drafting aids, *6.* new methods of packaging, *7.* design short cuts, or *8.* cost saving tips)

STATEMENT OF THE PROBLEM—

MY SOLUTION. AND WHY—(Please be explicit. Include sketches or photos that will help the idea across)

Name____________________

Title____________________

Company____________________

Address____________________

(Place illustrations on separate sheet if necessary)

MEETINGS

Calendar of Events

February

- 3-5 1960 Winter Convention on Military Electronics, PGME, Ambassador Hotel, Los Angeles, Calif.
- 10-12 7th Annual Solid-State Circuits Conference, IRE, AIEE, Hotel Sheraton, Philadelphia, Pa.
- 11-12 7th Annual Cleveland Electronics Conference, IRE, ISA, AIEE, Engineering and Scientific Center, Cleveland, Ohio.
- 11-13 1st Annual Electronics Representatives Association, Drake Hotel, Chicago, Ill.
- *14-18 Annual Meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Sheraton Atlantic Hotel & Statler-Hilton, New York, N.Y.
- 16-18 1st National Symposium on Nondestructive Testing of Aircraft & Missile Components, SRI, Hilton Hotel, San Antonio, Tex.
- *19-23 3rd International Electronic Parts Show, Paris, France.
- 25-26 Scintillation Counter Symposium, PGNS, AIEE, AEC, NBS, Washington, D. C.

March

- 6-9 Gas Turbine Power and Hydraulic Conference, ASME, Hotel Rice, Houston, Tex.
- 21-24 IRE National Convention, All PG's, Waldorf-Astoria Hotel and New York Coliseum, New York, N.Y.
- 23-26 Electrical Industry Show and Lighting Exposition, EMEA, Shrine Exposition Hall, Los Angeles, Calif.
- 24-25 1st Annual Symposium on Human Factors in Electronics, IRE, New York, N.Y.
- 29-31 22nd Annual American Power Conference, Illinois Institute of Technology, Hotel Sherman, Chicago, Ill.

April

- 3-8 6th Nuclear Congress, N. Y. Coliseum, New York, N.Y.
- 6-8 Structural Design of Space Vehicles Conference, ARS, Biltmore Hotel, Santa Barbara, Calif.
- 18-19 3rd Annual Conference on Automatic Techniques, ASME, IRE, AIEE, Cleveland-Sheraton Hotel, Cleveland, Ohio
- 19-21 International Symposium on Active Networks & Feedback Systems, Department of Defense Research Agencies, Polytechnic Institute of Brooklyn, IRE, Engineering Societies Bldg., New York, N.Y.
- 20-22 1960 Southwestern IRE Conference, Shamrock Hilton Hotel, Houston, Texas
- 20-22 National Symposium on Manned Space Stations, IAS, NASA, Ambassador Hotel, Los Angeles, Calif.

*Includes meetings described herewith

Annual Meeting of American Institute of Mining, Metallurgical, and Petroleum Engineers, Feb. 14-18

A special forum on Navy Materials problems, constituting a new concept of communication between military and civilian scientists and presenting high defense officials as spokesmen will be a major feature of the Annual Meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Current critical program areas will be discussed and will include the following: "Thermoelectric Materials," B. D. Rosenbaum, Bureau of Ships; "Semiconductors," W. W. Scanlon, Naval Ordnance Laboratory; and "Effect of Radiation on Magnetic Materials," E. I. Salkovitz, Naval Research Laboratory.

The national convention will run five days, beginning Sunday, February 14. The Metallurgical Society Forum will be held at the Sheraton-Atlantic Hotel on February 15. The Society of Mining Engineers of AIME and the Society of Petroleum Engineers of AIME will hold concurrent sessions at the Statler-Hilton Hotel.

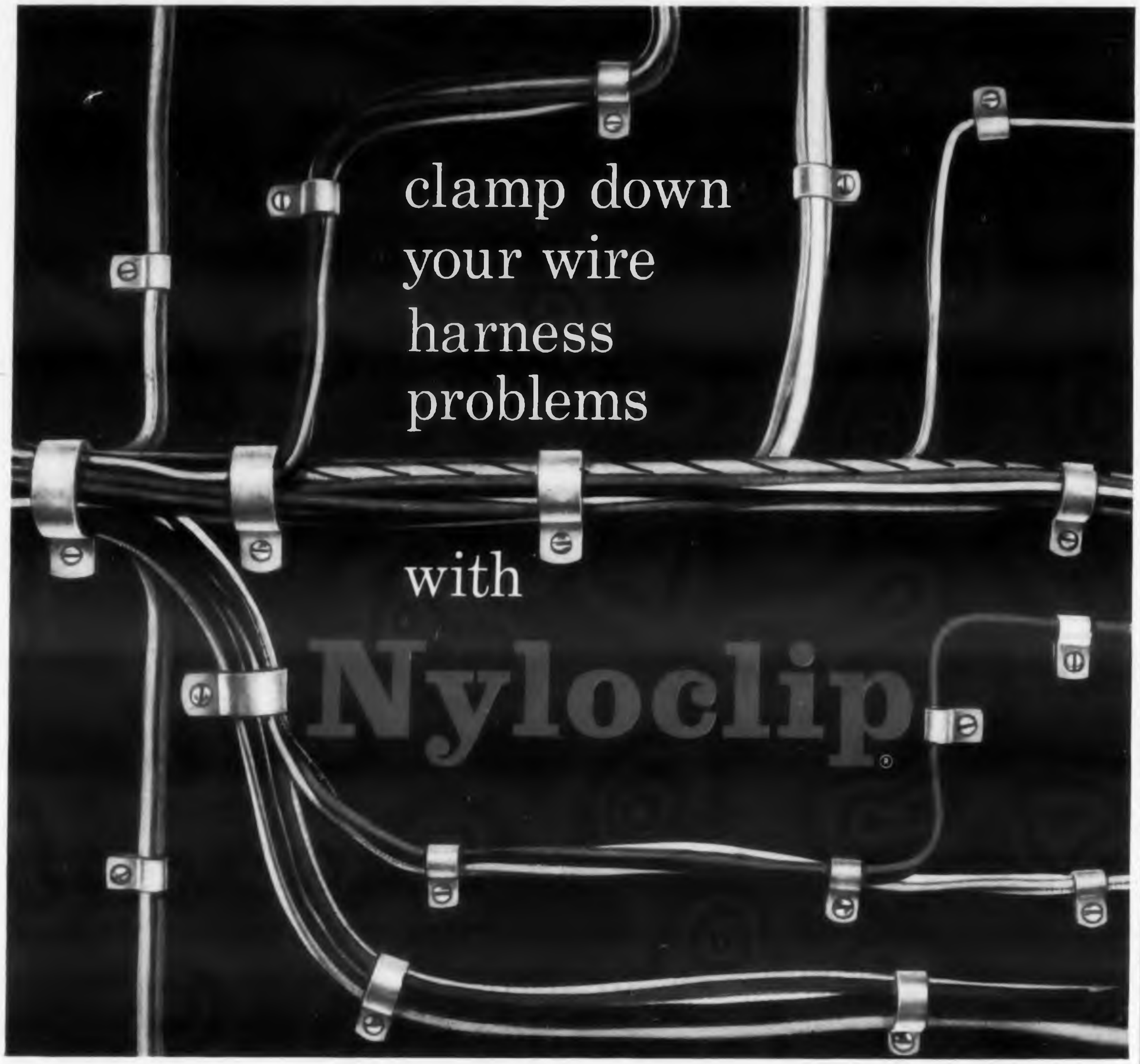
3rd International Electronic Parts Show, February 19-23, Paris, France

The 3rd International Electronic Parts Show, for electronics specialists, will present a full range of elements used in the construction of radio-electrical and electronic appliances. Many new exhibitors from all countries will be taking part alongside the larger international firms. The show is organized by the National Federation of French Electronics Industries, 23 rue de Lubeck, Paris 16, France.

7th Scintillation Counter Symposium, Feb. 25-26

The objective of the Scintillation Counter Symposium is to bring together those interested in scintillation counters for the purpose of exchanging information on advanced techniques, recent equipment developments and new components. The meetings are on a high technical level and treat both the theoretical and practical aspects of the field. The symposium will consist of four sessions of a half-day each treating the following topics: scintillators, photomultipliers and associated electronics, scintillation track imaging, and astrophysical and space applications of scintillation counters.

The symposium to be held at the Hotel Shoreham in Washington, D.C. is sponsored by the American Institute of Electrical Engineers, the Atomic Energy Commission, the Institute of Radio Engineers, and the National Bureau of Standards. Committee Chairman is G. A. Morton, Scintillation Counter Symposium Committee, RCA Laboratories, Princeton, N.J.



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CIRCLE 22 ON READER-SERVICE CARD

(Advertisement)

NEW PRODUCT

Versatile Crimped Connector For Miniature Coax Cable

A highly versatile crimp-type snap-locked modular HYFEN® connector for miniature coaxial cable has been introduced by the Omaton Division of the Burndy Corporation, Norwalk, Connect. This modular HYFEN offers the facility of simple removal of individual snap-locked contacts or gang disconnect.

Both inner and outer contacts are crimped to the conductors, simplifying a previously complicated and difficult process. In addition this process eliminates many of the parts formerly used, and also eliminates any heat in the connection process. The result is a reliable coax connection, easily and quickly installed.

The new plug-and-receptacle unit will presently connect RG195U and #24 shielded miniature coax cable. Connectors for other sizes of miniature coax will be available soon.

Connector frames, of die-cast anodized aluminum, accommodate three, five, or eight inserts, snapped in from either front or back. Inserts for coax cable, of glass-filied diallyl phthalate, accommodate up to 21 contacts. A plug or receptacle insert may hold male or female contacts, or they may be intermixed. Coax cable inserts and standard wire inserts (35 contacts) may be mounted in the same frame.

Contacts can be crimped to cable ends either before or after the harness is in place. Engaging and disengaging forces of low magnitude make it easy to insert, remove, and replace contacts and inserts individually for flexibility and economy in circuit changes and checks.

Burndy Corporation, Norwalk, Connect.

CIRCLE 23 ON READER-SERVICE CARD

EDITORIAL

U. S. Must Demand Radio-Frequency Interference Control

Just how important is the problem of radio-frequency interference?

On boarding an airliner at Chicago last fall, I, along with all the passengers was reminded over the PA system that all portable radios were to be turned off during flight. It was World Series time, however, and several passengers could not resist "sneaking a listen" from transistor radios concealed under their jackets.

Departure was delayed. Soon the stewardess announced that take-off was impossible; the flight engineer was picking up extraneous signals. Again the passengers were requested to cooperate, and this time they complied. The trip proceeded.

Could serious consequences or a major disaster have resulted if just one avid fan decided to check the score? How scornful can we become of the seriousness of radio-interference? Already missile failures, loss of key communication in defense links, computer errors and blanked radar screens demonstrate the havoc resulting from radio-frequency interference.

Considerable engineering effort has been expended to create receivers with less than one-tenth microvolt sensitivity. Similar zeal has been applied to engineer sharp-pulse, high-power transmitters, complex military systems, and high-speed computers.

At the same time the number of electronic devices for office, home and industry is increasing. But these achievements only aggravate the problem of RFI; each new device is a potential source of interference.

All major countries except the U. S. impose close restriction on radiation and have engineering teams checking and locating RFI sources. While U. S. military agencies limit and control interference in defense equipment and installations, the Federal Communications Commission ruling on non-military devices does not make it mandatory that the manufacturer produce interference-free devices. Instead the consumer or user is responsible for controlling interference!

Why approach the problem from the wrong end? Interference complaints pile up under this system, and only the most flagrant can be checked and corrected through the limited facilities of the FCC.

It is up to the Government to insist on strict interference-control by the manufacturer. The sooner the better!

Howard Bierman

RFI

Radio Frequency Interference

An *ELECTRONIC DESIGN* Staff Report
Howard Bierman
Associate Editor

Causes and Effects

Suppression Techniques

Measurement Methods

Prediction Approaches

Trouble Shooting Procedures

MOUNT a costly, highly sensitive receiver near equipment containing pulse and switching circuits, relays and oscillators and what do you have? An expensive and impressive guarantee of unreliable and ineffective performance—unless pains have been taken to eliminate radio-frequency interference.

Years ago many design engineers who were cautioned on the need for RFI suppression inquired, "Why bother?" After viewing missile failures, listening to garbled communications and inspecting blanked radar screens, their question has now changed to, "How can RFI be effectively eliminated?"

Interference Sources

Before attempting to eliminate it, however, let's examine its nature.

Radio interference may be defined as any electrical disturbance that causes undesirable response or malfunctioning of electronic equipment. Basic sources of interference include:

- Sine-wave signals from transmitter harmonics, diathermy or oscillator leakage.
- Wide-band output from bearings, belts or fluorescent fixtures.
- Impulse or sharp-pulse waveforms from high-voltage supplies, ignition systems or switching transients.

Basic Phases of RFI Efforts

Interference control and suppression may be basically subdivided into four categories:

- **Prediction—by careful analysis and examination of circuit parameters, equipment characteristics and operating frequency, it is possible to predetermine the location and level of interference. Steps can then be taken to allocate frequencies and separate systems for minimum interaction.**
- **Early design precautions—by keeping RFI in mind during each phase of development, interference-free "building blocks" can be tied together in a final package relatively free of RFI.**
- **Trouble-shooting—crowding many systems in a small area, such as aircraft, submarines or remote base shacks, often poses problems due to mutual interaction. Cables may require rerouting or power line feeds additional filtering. Individual shielding enclosures may also be necessary. Rapid and direct pin-pointing of trouble spots is a must for effective trouble-shooting.**
- **Measurement techniques—methods of measuring and tolerable limits must be established and followed. Standards set by the military are presently adhered to, since the Government is the biggest buyer of electronic equipment.**

'Brute Force' Vs Planned Attack

Two basic methods of attack are possible. First is the "Christmas tree" approach of hanging chokes and capacitors on equipment previously designed without regard to RFI. This is expensive, creates additional size and weight problems and is conducive to inefficiencies since it is generally applied in a frenzied haste.

Preventive design steps in the early stages of equipment or system development offer a second means of control, one more professional and intelligent. Careful evaluation of shielding needs, late developments in components and circuit layout can be coupled with previous experience in RFI problems to meet even the most rigid specs. By carefully guarding interference leakage at individual stages of progress, the possibility of overall deterioration at the project's completion is drastically reduced. Also, a steady, well-planned suppression program is always more efficient than the last-minute "brute-force" remedy.

This does not mean that final touchup will be unnecessary; minor modifications often arise due to interaction when several units are interconnected. But such changes are obviously more readily applied than those resulting from designs devoid of RFI forethought.

Growth of RFI 'Missionaries'

The military was introduced to the destructive effects of RFI during World War II. Radar and communication transmitters created havoc with nearby receivers, airborne equipment and sensitive instrumentation. Messages were distorted or lost completely, radar displays were blanked out, and tragic losses were directly attributed to interference.

Consequently specifications were prepared by the military branches, and tolerable limits with methods of measurement were outlined. Unfortunately only a handful of engineers were experienced in the rather ticklish task of locating and controlling RFI. Government manuals were distributed as an aid to the design engineer confronted with curbing RFI on a crash-program basis.

A giant step in the dissemination of RFI suppression techniques and measurements was made in 1954 through the organization of the First Conference on Radio Frequency Interference, jointly sponsored by Government agencies and the Armour Research Foundation of the Illinois Institute of Technology. In 1957 the Professional Group on Radio Frequency Interference was established within the IRE. More recent conferences have since been sponsored by the Government, the Armour Foundation and the IRE group. From these meetings, heavily attended by engineers from all parts of the country, important advances have been announced. Suppression techniques have been presented as an extremely helpful guide to design engineers, and moves have been launched to standardize measurement definitions and methods.

Rigid Specifications Demanded

Almost every piece of electrical equipment now purchased for military use must comply with rigid specifications. Generators, hand tools, motor vehicles and table radios are typical potential interference sources; each could conceivably disrupt communications, computer accuracy or telemetry—hence the rigid specs. Needless to add, electronic equipment must pass a wide variety of tests to qualify as trouble-free. As difficult as these specs may appear, experienced RFI engineers realize that careful consideration during initial design offers the means to success.

RFI Elimination a 'Must'

To escape chaos, complete control of RFI will be a necessity in the coming years. More computers, TV sets, electronic toys, space vehicles, communication links, machinery and countless other devices will be crammed into an already crowded spectrum. Or, as Rexford Daniels, president of Interference and Testing Laboratory, Inc., put it: "Mankind can no longer hope to operate a micro-volt civilization in a millivolt environment." ■ ■

There's More Ahead — ELECTRONIC DESIGN RFI Series Will Appear in Several Issues

Thousands of design engineers are directly or indirectly involved in suppressing radio frequency interference. Because editorial material for the engineer seeking theoretical and practical RFI information is somewhat limited, ELECTRONIC DESIGN invited specialists in the field to prepare a series of special RFI articles.

Interference-control engineers, who have spent years trying to get other engineers to heed their warnings, responded with enthusiasm. The opportunity to "spread the word," many felt, would help hammer home the serious message predicted at recent IRE conferences:

"Unless interference control is completely effective, communications and electronic automation will be severely limited in operation and reliability."

ELECTRONIC DESIGN's RFI report will include articles covering the important phases of interference work: prediction, preventive design, troubleshooting and measurement. The articles will appear in several issues. Following are the titles and authors of the articles devoted to RFI:

RFI—Today and Tomorrow

● RFI—AN UP-TO-DATE SURVEY, R. Schulz, Armour Research Foundation.

FCC CONTROL OF RFI, J. Deitz, Federal Communications Commission.

RFI IN SPACE VEHICLES, J. Lee, Melpar, Inc.

Prediction Techniques

METHODOLOGY OF INTERFERENCE PREDICTION, W. Floyd of Melpar, Inc.

Bailey, Georgia Institute of Technology.

PREDICTION OF RECEIVER INTERMODULATION, C. E. Blakeley, Georgia Institute of Technology.

PREDICTION OF TRANSMITTER INTERMODULATION, R. N.

Preventive Design and Trouble Shooting

● CHECKLIST OF RFI, L. W. Thomas, Navy Bureau of Ships.

RFI GASKETING, O. P. Schreiber, Technical Wire Products, Inc.

● OPTIMUM SHIELDING DESIGN, A. Albin, Filtron Co., Inc.

DISSIPATIVE FILTERS FOR SWITCHING CONTACTS, R. Schulz, Armour Research Foundation

GENERATION OF HIGH-POWER SIN^2 VIDEO PULSES, A. F. Standing, Avco Corp.

● INTERFERENCE TROUBLE SHOOTING, T. H. Herring, Boeing Airplane Co.

Measurement Techniques

GOVERNMENT SPECIFICATIONS AND MEASUREMENT TECHNIQUES, A. R. Kall, Ark Engineering Co.

CALIBRATION OF RADIO NOISE INTERFERENCE METERS, M. J. Rodriguez, Polarad Electronics Corp.

● appearing in this issue.

RFI
An Up-to-Date Survey

R. B. Schulz, H. M. Sachs, G. C. Vallender
Armour Research Foundation of
Illinois Institute of Technology
Chicago, Ill.

With government agencies insisting on tighter RFI control, design engineers are becoming increasingly aware of the need for interference reduction in early design stages of equipment and systems. Since many interference-suppression devices, components and techniques have been innovated recently, this roundup of the latest in RFI developments brings the design engineer up-to-date in all important phases of a relatively new field.

WITH THE ever-increasing number of electronic system installations, interference problems associated with operation of electronic devices in close proximity have multiplied drastically. Missile failures, communication jamming and radar blanking are but a few of the direct catastrophies traced to radio-frequency interference.

To maintain a semblance of order and intelligence in the growing chaos of spurious signal radiation, considerable research and development efforts have been devoted to the suppression and control of RFI. Recent advances in communication and radar systems plus latest instrumentation techniques are presented to acquaint the design engineer with the up-to-date "state-of-the-art" picture.

CommunicationsSystems

Theoretical and experimental investigation of the interference problems in the area of communications systems has shown that a major cause of interference is receiver intermodulation. Intermodulation is defined as the production of a signal at a receiver response frequency by the mixing of two undesired signals in the receiver's rf amplifier and/or converter stages. Receiver intermodulation susceptibility can be decreased by improved if-circuit dynamic range, improved rf preselection, and use of if-circuit bandwidths no greater than necessary for information-handling requirements.

Rf-circuit dynamic range can be improved by the extensive utilization of agc circuits. Although other specialized circuits can be used, agc is the simplest method of implementation.

Rf preselection can be obtained by active or passive devices which reduce the bandwidth of rf stages. The state-of-the-art is such that coupling networks and cavities can be produced which

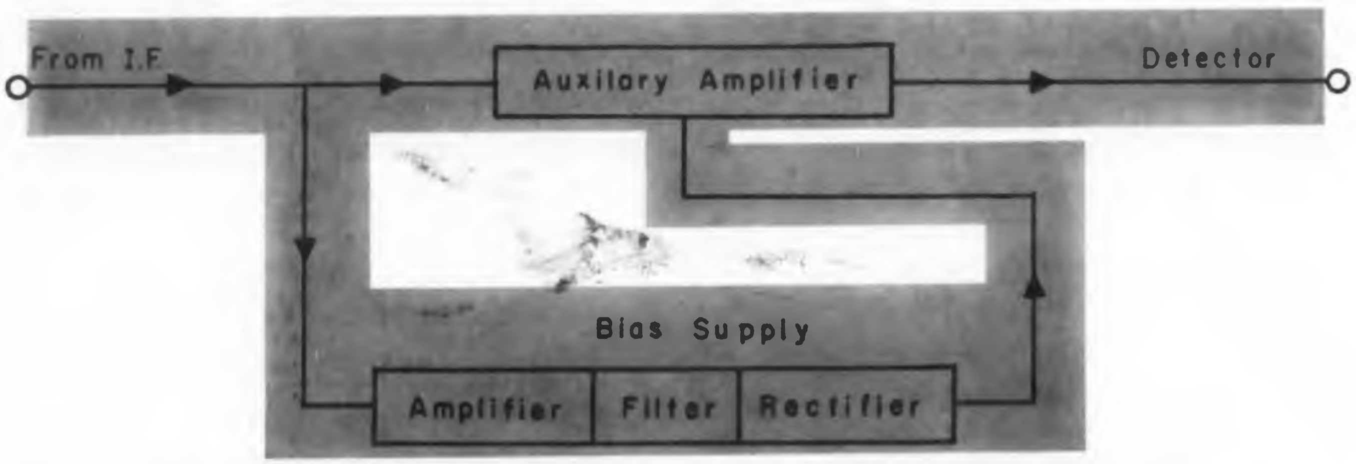


Fig. 1. Block diagram of a variable-gain device which permits if-bandpass control. Desired signals cannot pass through bias-supply filter and therefore no rectified bias voltage appears to cut off the auxiliary amplifier. Undesired signals are passed by the filter and develop sufficient bias to cut off the auxiliary amplifier to prevent output to the detector stage.

Dick Schulz has devoted the past 15 years to the task of keeping RFI under control. He became involved in interference work as a research associate at the University of Pennsylvania, followed through as a consultant in private practice and joined ARF in 1955. He holds several patents on RFI suppression devices and has authored and delivered numerous papers on the subject. ARF Conferences on Radio Interference Reduction and Electronic Compatibility are well-known for high quality papers and presentations—Dick is one of the active organizers responsible for their success and popularity.

provide improved selectivity; however, the major problem lies in the "ganged tracking" of tunable rf and converter circuits. Within the past year, narrow-band cavities have been used in uhf equipment, resulting in improved off-frequency rejection, even though tracking techniques require further development.[5(k)] In addition to reducing intermodulation effects, preselection also helps in reducing local oscillator radiation.

The third intermodulation-reduction technique requires the use of if-circuit bandwidths that are minimized with respect to the various modes of intelligence transmission. An example is the different number of sidebands required, and hence different bandwidths necessary, for voice and cw operation. A second example is a search receiver where a wide if-circuit bandwidth is needed to search a given band as rapidly as possible to find a desired signal; afterwards, a narrow bandwidth is used to reduce the sensitivity of the receiver to near-channel distracting signals.

In present-day systems, mechanical and crystal filters are being used to provide necessary bandwidth. Recently, circuits have been devised which make possible an electronically controllable bandpass for if amplifiers. One method[14] provides a change in bandpass as high as 20 to 1 in a 30-mc strip with very little change in the on-frequency gain. The circuits varies the bandwidth by adjusting the bias of a control tube. The output of this stage results in an effective change of circuit Q in a narrow-band amplifier stage.

The block diagram for a variable-gain circuit is shown in Fig. 1.[5(a)] The signal from the last stage of the if amplifier is fed into both the unity-gain auxiliary and bias-supply amplifiers. When the incoming signal is at the center frequency of the if system, it passes through the auxiliary amplifier to the input of the second detector. The stop-band filter after the bias-supply amplifier prevents the signal from reaching the bias-supply rectifier. If the signal is not at the if center frequency, it is amplified in the bias-supply amplifier, passed by the stop-band filter, rectified and fed as a negative voltage to the auxiliary amplifier. By adjusting the gain of the bias supply amplifier, the circuit allows control of the if bandpass. Some information can be lost if the desired and undesired signals appear simultaneously. To minimize the loss, the recovery time of the circuit must be small.

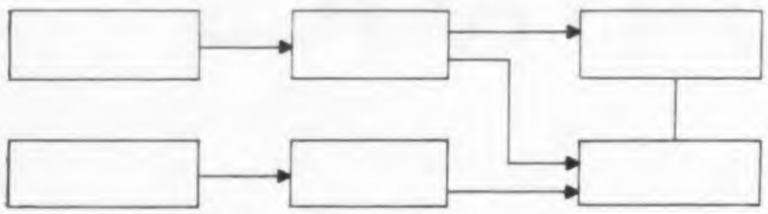


Fig. 2. Block diagram of a gating arrangement to eliminate interference from antenna side lobes.

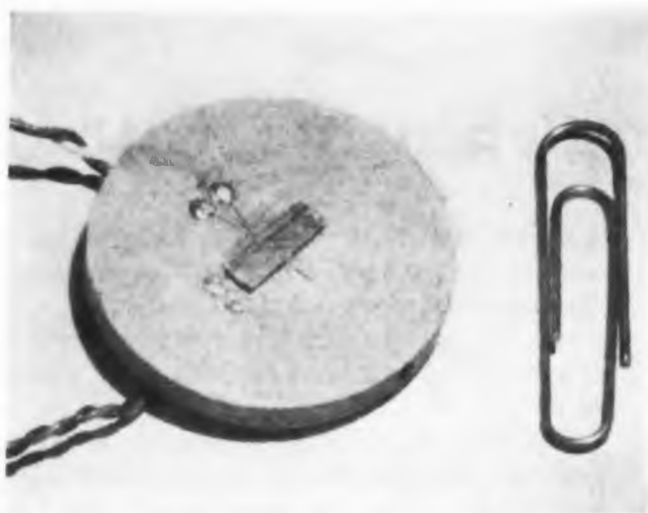


Fig. 3. Hall-effect sensor on a ceramic mount.

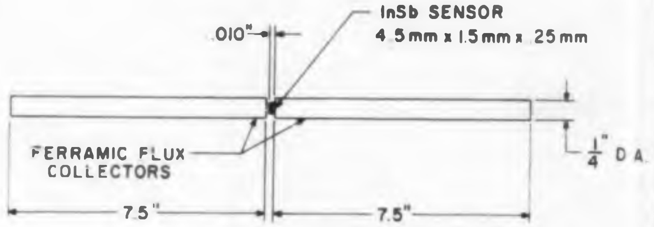


Fig. 4. Sensitivities better than 10^{-6} oersted are possible with Hall-effect sensors using flux collecting rods.

Radar Systems

In recent years, many methods have been proposed and investigated to reduce the effects of rf interference relative to radar systems. These include blanking techniques, moving-target indicators, pulse length and/or interpulse length selection, pulse compression, pulse shaping, noise correlation, delay-line video integration, and others.[15] A discussion of all these techniques would fill many pages; therefore, only a few will be mentioned.

Intra-Site Systems

One of the most serious problems confronting radar operators is intra-site radar interference. The problem is very critical at air fields and long-range radar sites where several radars of different pulse-repetition rates are being operated. Two basic methods are used to reduce the interference.

In the first method, all the radars at a site are synchronized. The technique requires all radars to operate at the same or at a multiple of the pulse-repetition rate of the slowest. If all radars are operated at the same repetition rate, all mutual interference will be eliminated. In the case of synchronized high- and low-repetition-rate radars, interference will appear as fixed range targets.

The second method, which is proving more successful, is receiver blanking. A pre-knock pulse from the interfering radar is sent to the victim. This pulse is used as the trigger to blank the victim receiver for the duration of the interference period. The effect of target return loss due to blanking reduces the range of the radar.[5(b)] However, a very weak relationship exists between the number of returns lost and the decrease in range. Therefore, a reasonable degree of blanking will not have a serious effect upon the efficiency of the radar.

Interference received via antenna side lobes can be eliminated by the system shown in Fig. 2. The overall gain of the secondary channel is adjusted so it is more than that of the primary receiver at any side lobe, but less than the primary receiver at the main lobe. In operation, the signal passes through both channels; if the output of the primary channel is the larger, no gate is generated and the signal is applied to a presentation system. However, if the secondary channel produces the larger signal, a gate is generated to blank the video.

Table I. Commercial and military RFI equipment.

Parameter	Stoddart NM-40A AN/URM-41	AN/URM-85*	Empire Devices NF-105 AN/URM-7	Polarad FIM	Stoddart NM-60A AN/URM-42	Empire Devices NF-112
Frequency Range	30 cps - 15 kc	150 kc - 1000 mc	150 kc - 1000 mc	1 - 10 kmc	1 - 10.7 kmc	1 - 15 kmc
Sensitivity						
CW	1.5 - 10 µv @ 10^5 ohms	1 µv	1 µv	20 µv @ 50 ohms	5 - 15 µv	10 µv @ 50 ohms
Noise	(20 db S/N ratio)	1/BW µv/mc	1/BW µv/mc			10/BW µv/mc
Bandwidth (6 db)	13 - 90 cps			5 mc	1.5 mc	1 and 5 mc
Calibration	400 cps sine wave	Impulse	Spot sine wave and impulse	Sine-wave	Impulse	Impulse
Detecting Circuits	Avg, QP, Peak, RMS		Avg, Peak	Avg, QP, Peak	Avg, QP, Peak	Avg, Peak
Antenna System	Loop and rod	Dipoles, loop, rod, discone	Rod, dipoles, loop, discone	Omni-directional and directional	Omni-directional and directional	Horn
Spurious Response Rejection	−55 db			−60db	−60 db	
Image Response Rejection	−60 db				−60 db	

* For information on special heads see Reference 5 (k).

Pulse Shaping

Energy distribution resulting from the high-amplitude sidebands associated with rectangular pulses can cause interference to other nearby radars and communications-electronic systems. Reducing the amplitude and/or number of these sidebands allows operation of more equipments without mutual interference within a given frequency band.

One technique for reducing the rf spectrum bandwidth is the use of shaped pulses. Theoretical investigations have shown that an ideal shape is the gaussian shape;[16] however, the major obstacle to the use of this shape pulse is its generation at high power levels. The cosine-squared shape is a somewhat more practical pulse shape to produce, and offers good narrow-spectrum characteristics. The major obstacle to the use of shaped pulses is the inability to modulate high-power microwave tubes.

Instrumentation

Recent development work on radio-interference field-intensity meters has been concerned largely with improved accuracy of measurement and an extended frequency range. The major efforts in the latter case have been in the 30 cps to 15 kc and the 1- to 15-kmc regions. Present system development efforts include improved calibration methods and application of miniaturization techniques. Some of the latest commercially available and military interference-measuring equipments are tabulated in Table I.

Pickup Devices

In order to measure conducted radio interference, a clamp-on type rf transformer has been developed by Stoddart Aircraft Radio Company (Model 91550-1). The transformer serves as an accessory for use with interference instrumentation over the frequency range of 14 kc to 100 mc. It measures rf current up to 1 amp with power line currents (dc or ac) of up to 350 amp.

The need for greater accuracy in the measurement of interference fields has accelerated research and development work in another area of special probe design. One device presently under development uses the Hall effect to measure magnetic fields[17] in the range of 30 cps to 15 kc. A sensor based on this principle has the advantage of being small (Fig. 3), gives good signal-to-noise ratio and has a sensitivity which is independent of frequency down to zero frequency. The output of the Hall device is fed into a low-noise preamplifier to increase the level of the signal at the input of a noise meter. Present sensitivities are of the order of 10^{-4} oersted for the Hall-element alone, and less than 10^{-6} oersted for the element with flux-collecting rods added to it (see Fig. 4).

Increased sensitivity is possible using refined techniques.

Thermistor Bridge

The accuracy of amplitude calibration of radio-interference/field-intensity meters frequently suffers because the input impedance of the instrument may vary with frequency and may not provide a matched load for the calibration generator being used as a known source. Consequently, the voltage across the interference meter input terminals may not be that indicated by the generator output controls. Even for cases of proper loading of the signal generator, its output may be incorrect due to a change in its calibration since its previous calibration check.

A calibration instrument containing a thermistor bridge is being developed to measure the rf voltage directly across the terminals of the interference meter.[6(b)] In order to achieve 5-mv sensitivity with good stability, temperature compensating thermistors are used in the bridge proper. When the bridge is used with coaxial attenuators in a special measurement procedure, the overall calibration instrument is useful to 50 mv.

White Noise Generator

Inconsistencies had been noted in the calibration of random noise generators. A generator is presently being developed as a laboratory standard source of noise from which other types of noise generators can be calibrated.[18] The generator, which is useful up to 1000 mc, uses the basic Nyquist relation to determine the noise power available from a heated resistor. This noise power is proportional to the resistor temperature, a quantity which can be controlled and measured.

Traveling-Wave Tubes

There are many advantages which can be obtained by employing an rf amplifier in a microwave interference meter. In a recent paper by J. L. Smith,[6(c)] the particular advantages of a low-noise traveling-wave tube for this purpose are presented. A TWT with low-noise figure and adequate amplification will make the overall system noise figure independent of the properties of the mixer crystal. In addition, such an amplifier has the ability to saturate, and will provide the crystal mixer protection during periods of rf overload.

The tube can provide 40 to 60 db of isolation between the instrument input and its local oscillator. TWTs have been built with 3- to 4-db noise figures. When such units become commercially available, they should be well suited for use in microwave interference-measuring equipments.

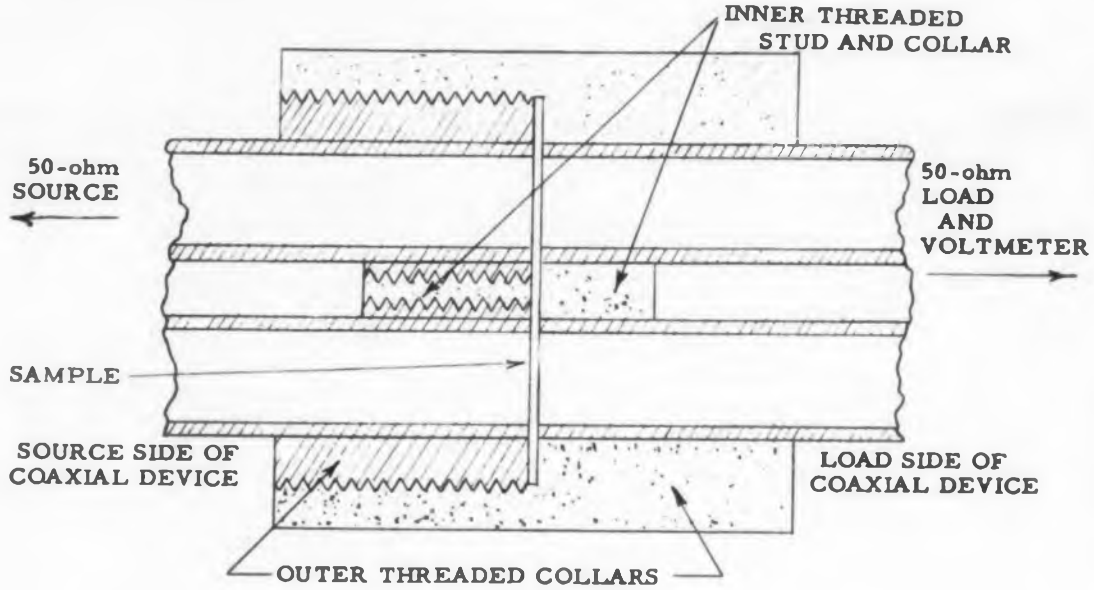


Fig. 5. Construction of a coaxial device to measure the shielding performance of conducting materials.

Shielding Measurements

In order to measure the performance of conducting materials as shield against electromagnetic radiation, a coaxial testing device was recently developed.[6(d)] Within the coaxial structure, the field of a TEM mode has an impedance equal to that of a plane wave. When such fields are incident upon a lamina inserted in the sample-receiving portion of the device (Fig. 5), the measured ratio of the transmitted-to-incident waves is a measure of shielding performance for plane-wave impedance fields.

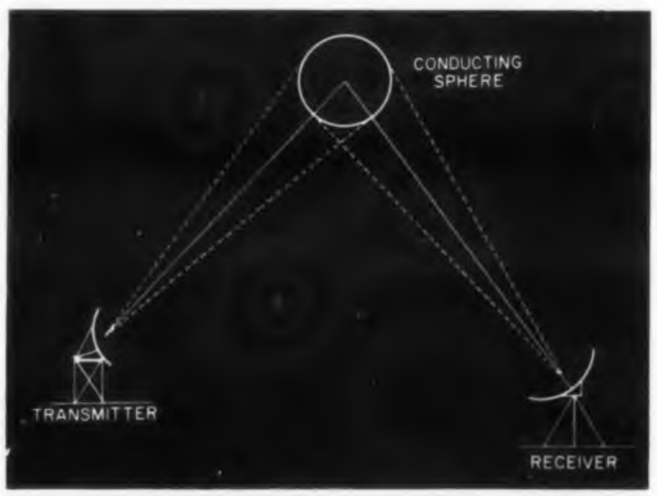


Fig. 6. (right) One technique of obtaining antenna-pattern data involves the use of a reflecting target from which radiated energy is redirected to ground and recorded.

When the shielding material is used as the walls of an enclosure, the effects of power inlets, metallic junctures, and other imperfections will cause the shielding capability of the room to be less than might be predicted on the basis of material alone. New techniques have been investigated for evaluating the performance of complete shielded enclosures over the frequency range of 14 kc to 10 kmc.[6(g)] Tests at three different portions of this spectrum are suggested.

At 15 kc, large transmitting loops which surround the enclosure are used to immerse it in a low-impedance field. An average indication of shielding effectiveness is obtained by the use of a pickup loop in the center of the room.

In the mid-frequency range, the shielded enclosure is illuminated by radiation from a half-wave antenna at the enclosure's lowest natural resonant frequency, which generally occurs in the region of 20 mc to 100 mc. The field inside the shielded enclosure is detected by a short-dipole antenna.

Tests near 9 kmc include the illumination of the shielded enclosure by plane waves from a high-energy source. The effect of shield separation, in the case of doubly shielded rooms, and the size of perforation openings, in the case of screening-type material rooms, were investigated.

These techniques are presently being examined as a basis for revision of military specification MIL-STD-285, and also as a basis for an IRE specification on techniques for measuring shielded enclosures.

RF Leakage of Transmitters

Substitution techniques are certainly not new, but their application to the measurement of interference radiated from cabinets and external wiring of high-power transmitters is a novel approach.[6(e)] The transmitter is operated into a well-shielded dummy antenna to obtain only case and wiring radiation. The substitute power is an rf signal source used in conjunction with a dipole antenna located at a distance within three feet of the transmitter. Thus, essentially the same path is utilized between either the transmitter or the substitute rf signal source and a receiver or sensitive frequency-selective voltmeter operated at some remote point. If the substitute power and the received power ratios are measured, the transmitter power can then be determined at the measurement frequency, which could be a harmonic. The technique is independent of local topography because path loss is automatically taken into account. A suitable site is limited principally by the availability of sufficient remote points which lie in the distant or radiation field.

Antenna Pattern Measurements

In the microwave region, the antennas used confine much of the energy to a relatively narrow beam. However, there are still many side and back lobes which can contain sufficient gain to give rise to serious interference problems. To be able to predict interference levels, it is necessary to obtain information on the three-dimensional antenna-gain characteristics. This information is required for all spurious and harmonic frequencies as well as the fundamental frequency of operation.

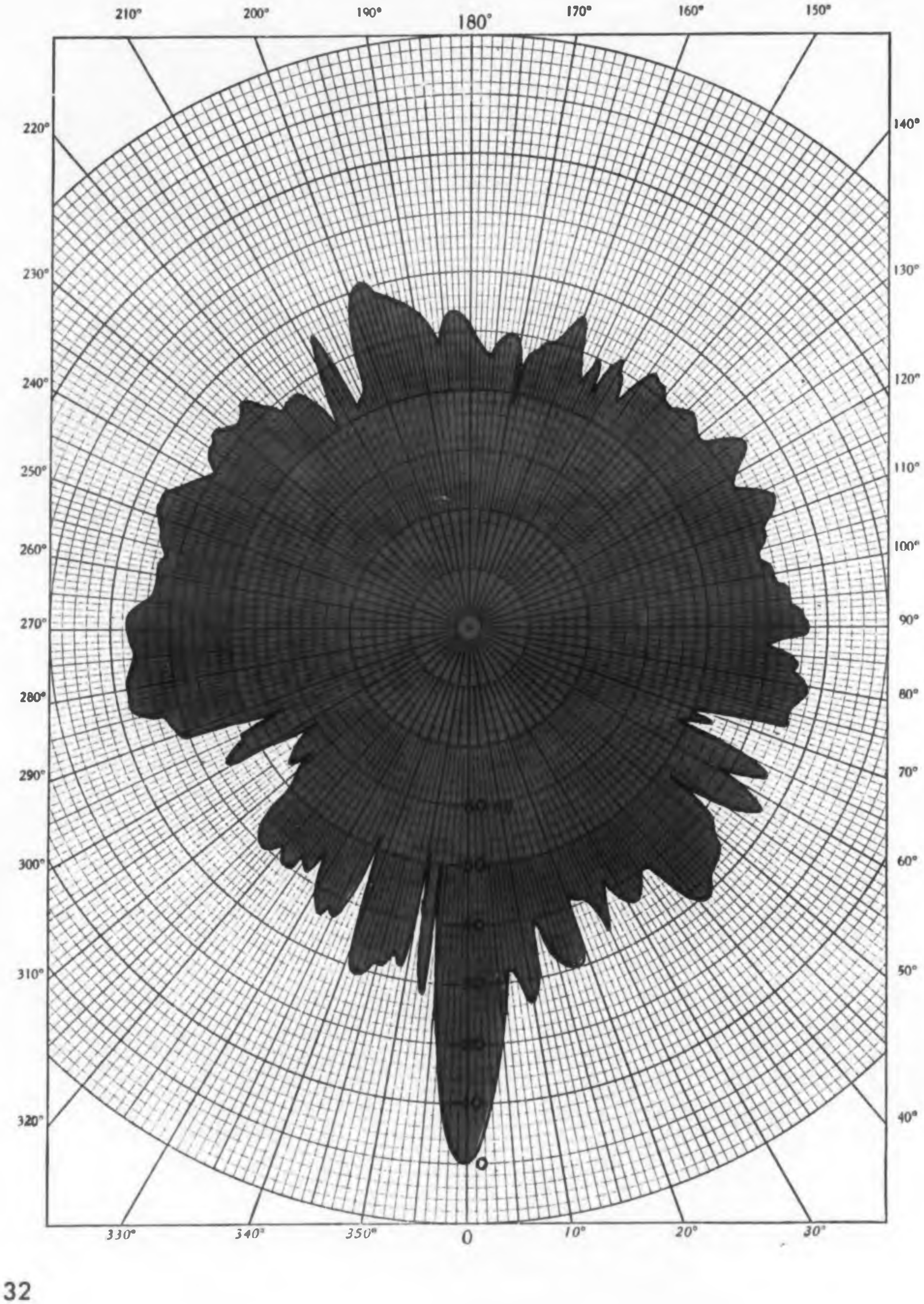
Various methods have been considered to obtain the necessary pattern data. These include:

- An airborne platform flying a predetermined course through the antenna-radiation field. From an operational standpoint, the method is costly and very difficult to implement.
- Space-probing with a mobile antenna mast moved to various locations (and heights) around a transmitting antenna. This method also has disadvantages as far as cost and implementation is concerned, as well as the additional effect of pattern distortion. Complete hemispherical patterns are not possible.
- A modeling technique, where scale-model antennas are used at an adjusted frequency of operation. It is not possible to build models which are scaled exactly in physical or electrical characteristics. Scaled analysis at other than the fundamental system operating frequency has not been attempted.
- Mounting the antenna whose pattern is to be measured on a special platform which, in turn, can be oriented so that the antenna will effectively be laying on its side. Then azimuthal pattern cuts with respect to the platform can be related to elevation cuts of the antenna. In addition to requirements im-

posed on a platform, one must be able to interpret the recorded patterns in terms of the actual antenna orientations.

- Use of a reflecting target from which the antenna radiated energy may be redirected toward the ground[5(f)] and there recorded. (See Fig. 6.) A field-intensity meter is used in conjunction with a highly directional antenna to measure the reflected signal. This approach is currently being evaluated.
- Representation of the statistical distribution of antenna gain, instead of the gain characteristic itself. Fig. 7 shows the normal representation of antenna gain versus azimuth for a given antenna. Fig. 8 shows the statistics of the pattern of Fig. 7, that is, the probability that the gain of the antenna in any particular direction (where any direction is equally likely) is above a specified level.[22,23] It is hoped that this approach will lead to considerably simpler methods of obtaining and describing three-dimensional antenna characteristics.

New communications-electronics applications in radar, radio astronomy and the reception of weak signals emanating from orbital vehicles and space probes have led to the development of very large, high-gain electronically and mechanically steerable antennas. At the same time, more emphasis has been placed on decreasing antenna side lobes and reducing major-lobe beamwidths. These large gains and physical sizes may require modification of the above methods before the gain information can be obtained.



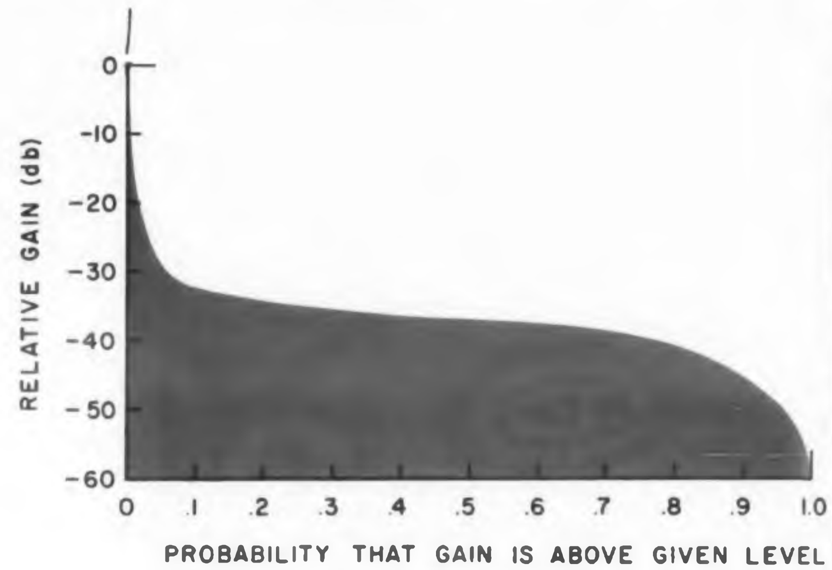


Fig. 8. (above) Statistical distribution of the antenna gain shown in Fig. 7.

Fig. 7. (left) Typical pattern of antenna gain vs azimuth.

Table II. Shielding Effectiveness Factor (SEF) data, for coaxial cables at 350 mc, show good agreement between a new triaxial technique and the free space method.

Type of Cable		Free-Space Method (Electric Field Basis)	Tri-Axial Tester
RG-59/U	(S)	1.2×10^{-3}	2×10^{-3}
RG-8/U	(S)	8.5×10^{-4}	9.2×10^{-4}
RG-29/U	(S)	7×10^{-4}	1.1×10^{-3}
RG-158/U	(D)	8×10^{-5}	1.8×10^{-4}
RG-6/U	(D)	1.3×10^{-5}	1.1×10^{-5}
RG-55/U	(D)	9×10^{-6}	1.0×10^{-5}
RG-13/U	(D)	8×10^{-6}	7.3×10^{-6}
RG-X9B	(D)	8×10^{-6}	1.2×10^{-5}
RG-5/U	(D)	1.3×10^{-5}	1.1×10^{-5}
RG-9/U_a	(D)	1.3×10^{-5}	—
RG-9/U_b	(D)	5×10^{-6}	9.4×10^{-7}

(S) - Single Braid
(D) - Double Braid

Components

Within the past few years, many advancements have been made in the development and evaluation of components. Again, the list is extremely long and only the most recent and useful will be discussed at this time. These include areas of microwave filters, rf coaxial cables, semiconductors, ferrites, and low-noise components.

Filters

Filters have been developed, for operation in the S-band microwave region,[24] with a harmonic rejection ratio of 60 db and are capable of handling approximately 1 megawatt of peak rf power. It has been noted that, on the average, the strongest harmonic of a transmitter is 45 db below the output of the fundamental; thus, application of such a filter would reduce the maximum harmonic output to 105 db below the fundamental. It is expected that present developmental effort will reduce the level to —150 db by the mid-sixties. One program, in progress to develop high-powered filters, is also investigating the sources which generate spurious and harmonic frequencies, and considering methods for decreasing these undesired outputs.

Rf Coaxial Cable

A study has been undertaken by Robl and Schatz to define the shielding effectiveness of braided coaxial cable.[25] The triaxial measurement system which has been used previously provides information for frequencies below 350 mc. At higher frequencies, measurements are more difficult and the complex results are often hard to interpret. With the new technique, measurements are made of the leakage fields from a short-circuited coaxial cable radiating as a monopole antenna above a ground plane, and the results are compared with a theoretical analysis of radiation due to a current source having the same distribution as the current within the coaxial cable. A Shielding Effectiveness Factor (SEF) has been defined as the ratio of the experimentally determined leakage field to the theoretical calculation, for a given current. For perfect shielding, the SEF is zero and for no shielding it is one. In the far field, either the electric or magnetic fields can be used as a reference for SEF. Table II provides SEF data for the axial component of the electric field. The data shown in column three, which was taken using a triaxial technique, shows good agreement with the free space method.[26]

Silicon Diodes

Radio-interference measurements performed on silicon diodes show that their noise output is extremely high—far in excess of military specification MIL-I-6181C. An oscillogram of diode current shows that interference is produced by a large reverse-current spike. In an investigation by Nichols,[5(h)] two different diodes were evaluated, and it was found that the IN337 was a much better unit than the IN345 from a radio-interference standpoint. Nichols also gave some important "rules of thumb" to help the design engineer to select the proper diode:

- Select a diode which will operate at the lowest current density in proportion to the manufacturer's maximum rated current.
- Select a diode with the highest rated working and peak inverse voltage.
- Use the lowest possible switching rate. This approach is contrary to normal application since the maximum switching rate, that is a three-phase bridge over a simple bridge, is usually preferred to reduce ripple and the need or subsequent ripple filtering. However, in most applications, the audio filter and rf filter combined will be smaller in size than the ripple capacitor-rf filter for the higher ripple frequency. .
- Select diodes with the slowest recovery time.
- After several diodes have been selected on the above basis, they should be measured to determine which is the best diode from an rf standpoint.
- Corrective measures for reduced rf output can be taken, as shown in Fig. 9. All of the circuits or component additions reduce both the current spike and/or present a low impedance load to the high frequency oscillations of the current spikes.

Circuits *A* and *C* should be used for currents under 1 amp while circuit *C* is preferred as the power line frequency is increased. The capacitors shown are in addition to the normal electrolytics used to regulate ripple. Foil or pellet types of tantalum capacitors can be used for both rf bypass and ripple filter. Table III gives the range

Fig. 10A. Power-transmission line wrapped with high-mu tape to attenuate RFI radiation.

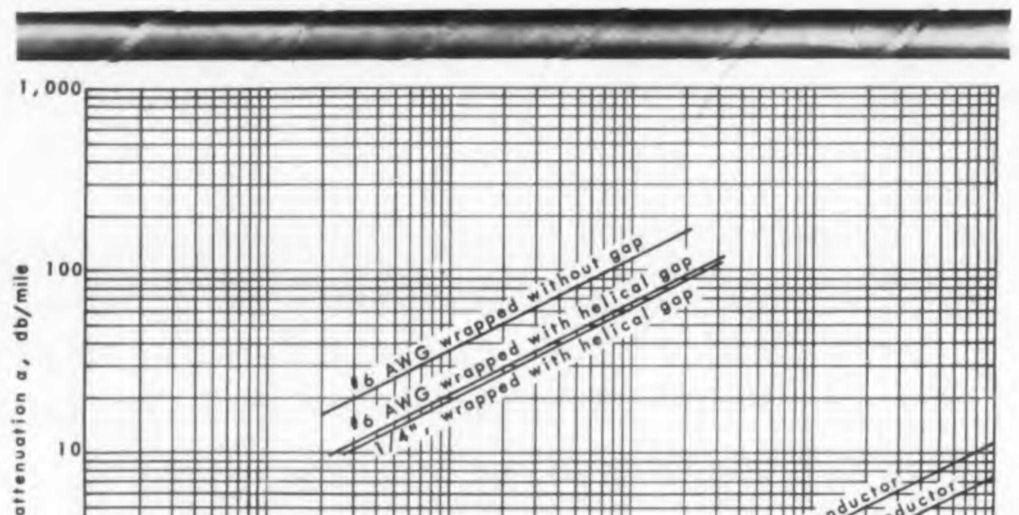


Fig. 10B. Measured data on experimental power-line conductors wrapped with high permeability tape.

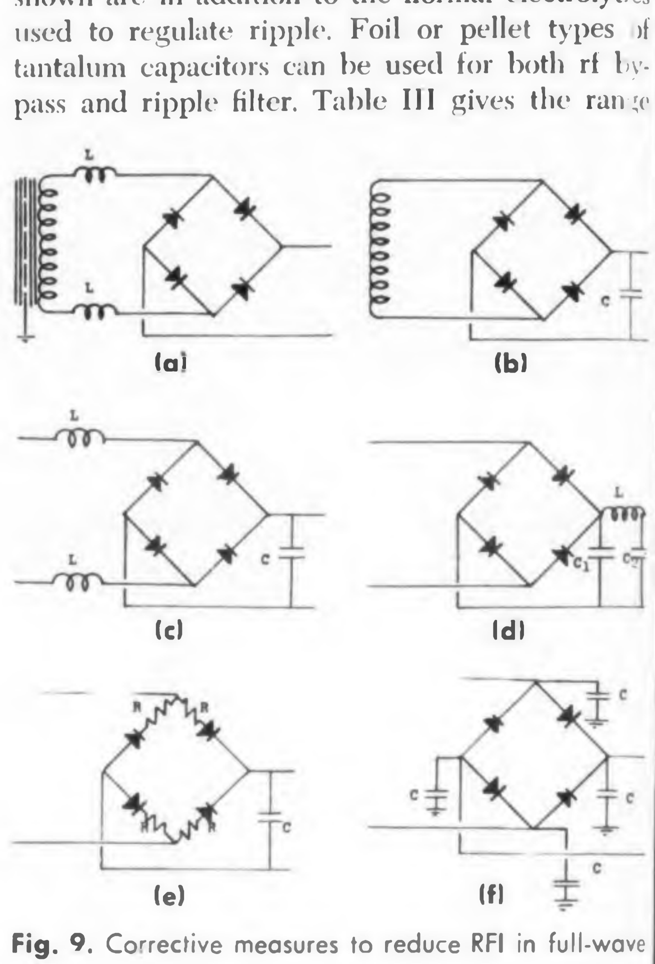


Fig. 9. Corrective measures to reduce RFI in full-wave bridge rectifiers.

Table III. Component values for the corrective circuits shown in Fig. 9.

Fig. 9	Component	60 cps	400 cps
A	L	100 to 300 μh	250 to 750 μh
B	C	0.1 to 0.5 mfd	0.1 to 1.0 mfd
C	L C	100 to 300 μh 0.1 to 0.5 mfd	250 to 750 μh 0.1 to 1.0 mfd
D	C_1 C_2 L	0.1 to 0.5 mfd Ripple capacitor Ripple and rf inductance	0.1 to 1.0 mfd
E	R	1 to 10 ohm	1 to 10 ohm
	C	—	0.05 to 0.25 mf
F	C	0.05 to 0.25 mfd	0.05 to 0.25 mfd

Table IV. Basic characteristics of recent low-noise devices.

Techniques	Frequency Range	Typical Operation: Noise Figure	Gain	Band Width	Remarks
A. Maser	300 MC to 30 KMC	Nearly ODB	13 DB	67 MC @ 6 KMC	Super Cooling Needed
B. Parametric					
1. Ferrite	1.5 KMC Up	?	60 DB	2 MC @ 6 KMC	Electromagnet Needed
2. Semiconductor Diode	Up to 10 KMC	<2 DB	20 DB	2 MC @ 6 KMC	Most Advanced Design
3. Electron Beam	600 MC to 12 KMC	<2 DB	30 DB	150 MC @ 600 MC	In Early Development Stages
C. Low Noise TWT	1 KMC to 12 KMC	2 DB	25 DB	2 KMC @ 2 KMC	Significant Improvement over Past Performance

of values required for effective suppression. Whenever possible, electrostatically shielded transformers[1] should be used to reduce radio interference conducted along the ac lines.

Ferrites

Recent investigations into the use of ferrites for low-frequency filter systems have been undertaken, since the combination of high permeability and dielectric constant cause the propagation velocity of electrical energy within the ferrite to be much lower than that in air. The reduced propagation velocity allows resonance within small structures. This property permits small ferrite shapes to be combined with capacitors for use in miniaturized radio-interference filters. Such filters should be additionally effective because of the loss characteristics[5(i)] of ferrites.

Despite the apparent advantage of ferrites as the dielectric in coaxial filters, results of investigations have not yet arrived at practical units.[5(j)]

The application of a high-permeability SiFeMg tape to a transmission line, as in Fig. 10A, can result in high attenuation of radio-frequency energy in the range of interference frequencies normally encountered on power transmission lines.[6(h)] Analysis of conductors coated with a high-permeability material shows a large increase in skin-effect losses at frequencies above the power transmission frequency. Experimental data made on three conductors wrapped with a thin, high-permeability tape is shown in Fig. 10B. A small helical air gap was formed in the wrapping of two of the transmission lines to reduce saturation effects which might occur on lines distributing power. The attenuation measured on these lines was about half that of the fully wrapped line, but gave much lower standing wave ratios and a low characteristic-impedance phase shift. The attenuation of these lines was large compared to the attenuation of a bare line. It is expected that high-permeability tape coatings with a gap will prove to be a useful and practical technique for reducing interference on power transmission lines.

Low-Noise Devices

During the past several years, radically new types of microwave amplifiers have been developed. These include low-noise traveling-wave tubes; masers; diodes, electron beam, and ferrite parametric amplifiers noted in Table IV. In the very near future, these extremely low-noise devices will find applications in communications and radar equipments, and may impose problems in equipment compatibility.[6(g)] Even before such problems are treated, the significant improvement in the noise level of these devices over conventional components will require the investigation of new and refined methods of improving the electromagnetic environment. ■ ■

RFI

Up-to-Date Survey *cont.*

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RFI Check-List

It is often possible, in the design stages of exotic and complex equipment, to overlook basic factors which may not affect performance but lead to flagrant interference problems. Excessive costs, time delays and "sweat and tears" are expended to remedy the situation. The check-list presented should be scanned as a reminder during early design considerations where RFI is most efficiently reduced.

Leonard W. Thomas
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Washington, D. C.

AN OUNCE of prevention is worth a pound of cure"—Perhaps radio-frequency interference suppression and control engineering is the most flagrant example of this old cliché.

Top experts engaged in RFI suppression quickly point out the easy road to freedom from interference.—"To avoid interference, don't generate any." Vast amounts of energy, time, and money are expended in searching out RFI offenders in equipment: often, outlandish cost and size increases accompany the final steps of eliminating interference sources.

A remarkable number of interference problems arise in early design stages due to simple oversights and forgotten basic engineering theory. In an effort to recall the more important, although seemingly obvious, areas and sources of potential interference, the following check-list has been prepared from the "Standard Inspection Procedures for Interference Control", compiled for the Dept. of the Navy, Bureau of Ships, Electronics Division.

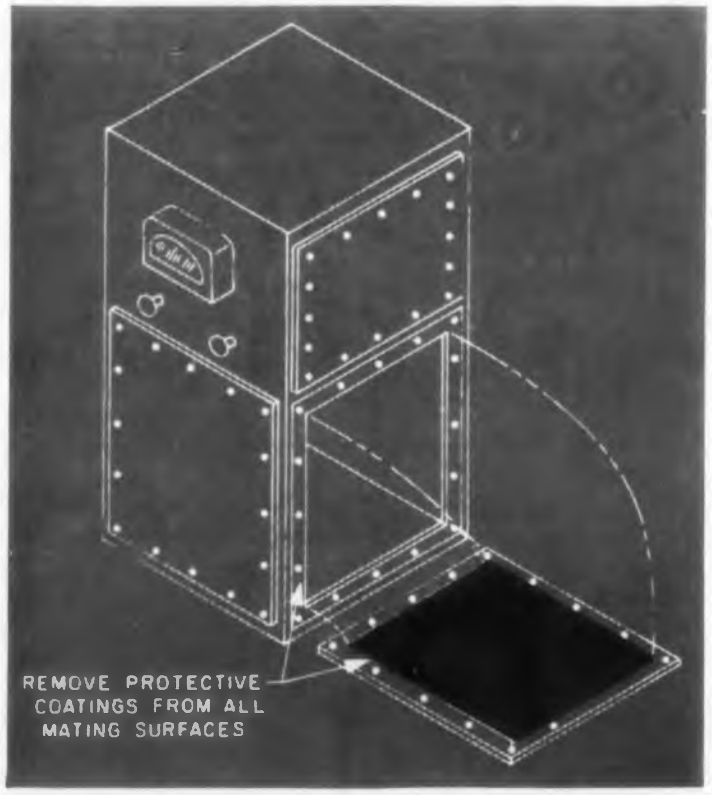

Fig. 1. Protective finish must be removed to achieve reliable metal-to-metal contact essential for shielding.

Preliminary General Check-List for Equipment

- The chassis or frame must be grounded or a means of grounding must be provided.
- Shockmounts must be by-passed with ground straps.
- Whenever a metal-to-metal contact is required for shielding or grounding, the insulated protective finish must be removed (Fig. 1).
- All openings for access, ventilation and case-mounted components shall be shielded to prevent case leakage. (See Fig. 2).
- Blower motors should be ac non-commutating types.
- All access doors should be metal textile or finger strip type, as shown in Fig. 3.
- Drawer- and door-locking devices must provide firm pressure against metal gaskets.

Communication Transmitters

- Heaters should be wired with twisted or isolated leads. (Field report data point to heater wiring as a major RFI culprit.) Two heater leads should be used and twisted together to cancel interference fields. The practice of using one "hot" lead and the other connection grounded should be avoided. Examples are illustrated in Fig. 4.
- Isolate the oscillator stage from other stages.
- Use interstage decoupling networks to reduce transfer of undesired harmonics and spurious radiations.
- To avoid undesired signal transfer to the high power stage of a transmitter, use link or parallel-tuned circuits.
- Apply parasitic suppression devices such as plate and grid resistors or chokes.

Communication Receivers

- Keep local oscillator power at a minimum level.
- Decouple oscillator heater and B supply sources.
- Isolate the oscillator from the antenna by rf amplifiers or preselectors.
- Use a shielded oscillator compartment when necessary.

Radar Transmitters

- Magnetrons should be contained in a shielded

enclosure located as close to the pulse transformer as possible.
- Keep the pulse transformer close to the pulse cable entry. Rf shielding integrity must be maintained where the waveguide enters the cabinet.
- Direct coupling of the waveguide into the magnetron should be made whenever possible.
- The "keep-alive" voltage should be isolated and decoupled.

Radar Modulators

The square wave pulse used to fire the magnetron is the major source of interference from radar equipment. In many cases, the sharp leading edge of this pulse may shock excite the magnetron into oscillating at more than one frequency. In addition, the modulator pulse can shock and often overdrive the input stages of radio receivers, resulting in severe interference.
- The pulse network shall be isolated and all leads associated with the pulse network should be decoupled.
- The pulse transformer should be isolated so that the magnetic field of this transformer will be prevented from modulating the thyratron keyer tube.
- The grid despiking network shall be isolated and all leads associated with this network shall be decoupled.
- The pulse cable inside the thyratron-shielded enclosure and inside the pulse-transformer-shielded enclosure should be kept to a minimum length.
- A multiple-shielded pulse cable should be used to prevent pulse circulating ground currents. Multiple-shielded cable is a triaxial cable with the two inner shields of the cable connected to the thyratron cathode at one termination and to the low side of the pulse transformer at the other termination.
- The blower motors and the motor-driven pulse rate mechanisms should be synchronous type ac motors. If dc motors must be used, these motors should be designed with interference reduced to acceptable levels.
- Sharp projections in high-voltage circuits are possible sources of corona or arcing and thus are potential sources of interference. Construction with sharp projections therefore should be avoided.
- Sharp bends should be avoided in high-voltage wiring. The possibility of insulation breakdown is increased and, in the case of coaxial cable, the characteristic impedance of the cable may be changed and the attenuation increased.

Antenna Control Unit

This unit generally contains thyratron-rectifier circuits for the antenna servo system and antenna drive motors. Many of the interference problems could be eliminated through the use of an ac servo system and the possibility of using ac should be fully investigated.

Particular attention given to the following items will greatly aid in designing an antenna control unit with low interference levels.
- The thyratron-rectifier circuits should be isolated from other circuitry.
- The thyratron-filaments leads shall be decoupled at their entry to the tube base shield. The tube-base shield should be constructed in a manner which will provide complete shielding of the thyratron-tube base.
- The output leads from the thyratron to the antenna motor should be decoupled. These output leads can be decoupled without affecting antenna rotation.
- The antenna control unit should not be used as a terminal box for wiring not associated with this unit. The practice of using the antenna control unit as a terminal box for wiring from other sources only complicate the problem of providing complete isolation of the thyratron.
- Pulse and rf rotary joints should be thoroughly shielded.

Pulse Generators

- Waveforms in the pulse-generator circuits should be checked for unnecessary spikes. The presence of these spikes may not affect the operation of the circuit but may produce interference.
- Pulse-circuit wiring should be kept as short as possible.
- Return for the pulse stage should go to the cathode of the stage rather than to ground in order to reduce pulse ground currents.
- All pulse energy should be fed to succeeding stages in coaxial leads where possible. Precautions should be taken to guard against distortion of the waveform introduced by the capacitance of the coaxial cables.

Radar Receiver

In the radar receiver, as in the communication receiver, the principle area of concern is the oscillator unit. Parasitic oscillations are not uncommon in receivers and every effort should be made in the design stages to prevent them.

Radar Indicator

Unless special precautions are taken, the radar indicator may be the source of many magnetic fields which can be serious interference problems. The problem is primarily that of isolating the fields at their sources. If attention is given to the following design principles, interference from the indicator unit can be kept within allowable limits.
- Control and power leads must be decoupled by the use of feed-through bypass capacitors.
- The deflection coils for the cathode-ray tube must be isolated.
- Glass or plexiglass with a coating of conductive material should be used to cover the opening for the indicator-tube face. This, in conjunction with the indicator case, provides a continuous shield for the indicator.
- The range-oscillator coils and the coils used in the blocking oscillator must be individually isolated to confine the magnetic field to the coil producing that field.
- The rf high-voltage power supply should be isolated. Input and output leads must be decoupled at their entry into the shielded enclosure isolating this power supply.
- All stages of the indicator should be decoupled

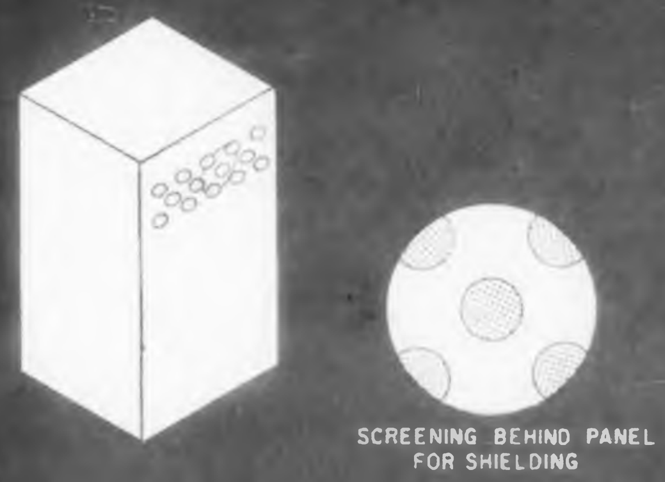

Fig. 2. Recommended procedure for shielding panel openings.

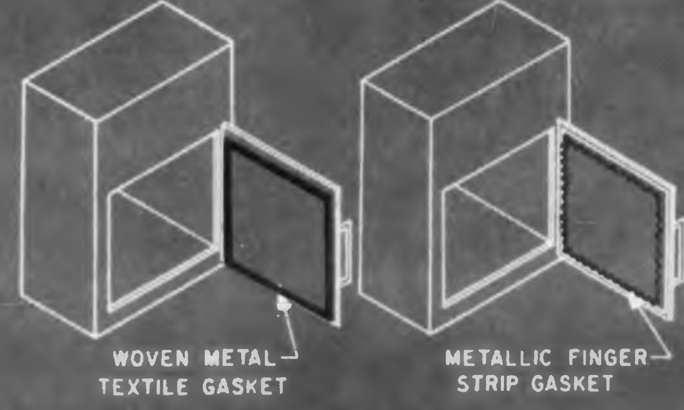

Fig. 3. Access doors should be metal-textile or finger-strip type to reduce RFI leakage.

Check List

to prevent interference signals from being conducted between stages.

DC Machines

Among rotating electrical equipment, the principle offenders as a source of interference are dc machines. In the design of dc machines (either generators or motors), care must be taken to minimize the effects of the commutation process. This is essentially a switching process in which high currents are continuously switched. The problems of good interference-free design are then, in reality, the problem of good commutator design.

- Commutation transients can be reduced by use of interpoles. A more rapid change in the armature-coil current at the beginning of the commutation period is achieved, reducing the steepness of the transient at the end of the commutation period.
- Compensating windings produce the same effect as interpoles but to a smaller degree. Field distortion is also minimized.
- A greater number of armature coils and commutator bars can reduce interference by lessening the current broken per bar.
- The use of laminated brushes will reduce arcing and interference by lowering the resistance presented to the approaching commutator bar and raising the resistance presented to the receding bar. This would favor the load-current flow in the approaching bar and introduce a higher resistance in the coil undergoing commutation, thereby reducing circulating currents.
- Commutation interference can be caused by the generation of thermo-electric voltage which is proportional to current density in the contact areas. With an increase in current density, greater heat is generated in the contact resistance with a resulting rise in temperature of the brush and commutator surfaces. Since current density is the important factor, large brush surface areas should be used. However, if to obtain low current density it becomes necessary to make the brush size excessive, grooving and rapid wear of the commutator surface may occur. General design practice calls for a current density of 55-65 amps per sq. in. at full load for graphite-carbon brushes and 65-90 amps per sq. in. for metal-graphite brushes. Use of the design figures should give a brush which has good "wear" qualities as well as low-interference generation properties.
- Proper mechanical design and construction will reduce inherent interference. Electrical and me-

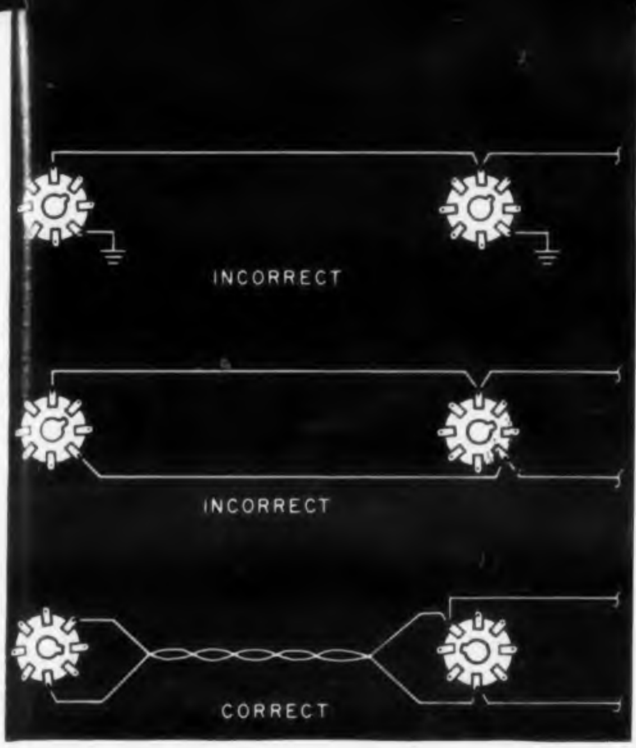

Fig. 4. Examples of proper and poor heater wiring techniques.

chanical symmetry, accuracy of machined parts and good quality control will aid in eliminating the dc machine as a source of interference.

AC Generators

Ac rotating equipment as a source of interference does not present nearly the problem as do dc machines. The principle problem lies with ac generators. This problem is that of the prevention of harmonic generation and the prevention of resonant conditions within the circuits associated with the ac generator.

- If in the design of an ac generator, the designer considers the criteria of obtaining a pure sine-wave output as one of his most important design objectives, the resulting product will present very little difficulty as a source of interference.
- A sinusoidal distribution of the flux around the armature is necessary.
- Mechanical and electrical symmetry cause cancellation of even order harmonics; electrical pole pieces and uniform winding of the armature will provide symmetry.
- In three-phase alternators, the use of "Y" or star connection with a grounded neutral will cause the third harmonic to be present in the voltage from any phase to neutral. The use of delta connections will cause the third harmonic and its multiples to be cancelled within the machine.
- By making the number of armature slots per pole pair an odd number, tooth ripples can be eliminated.

AC Motors

Induction and synchronous motors are practically free of interference sources. These sources

Checklist

when they do exist can generally be traced to mechanical failures. Loose laminations in the armature and pole pieces, and loose or faulty slip ring or brushes may cause interference. An exception is that several instances have arisen where

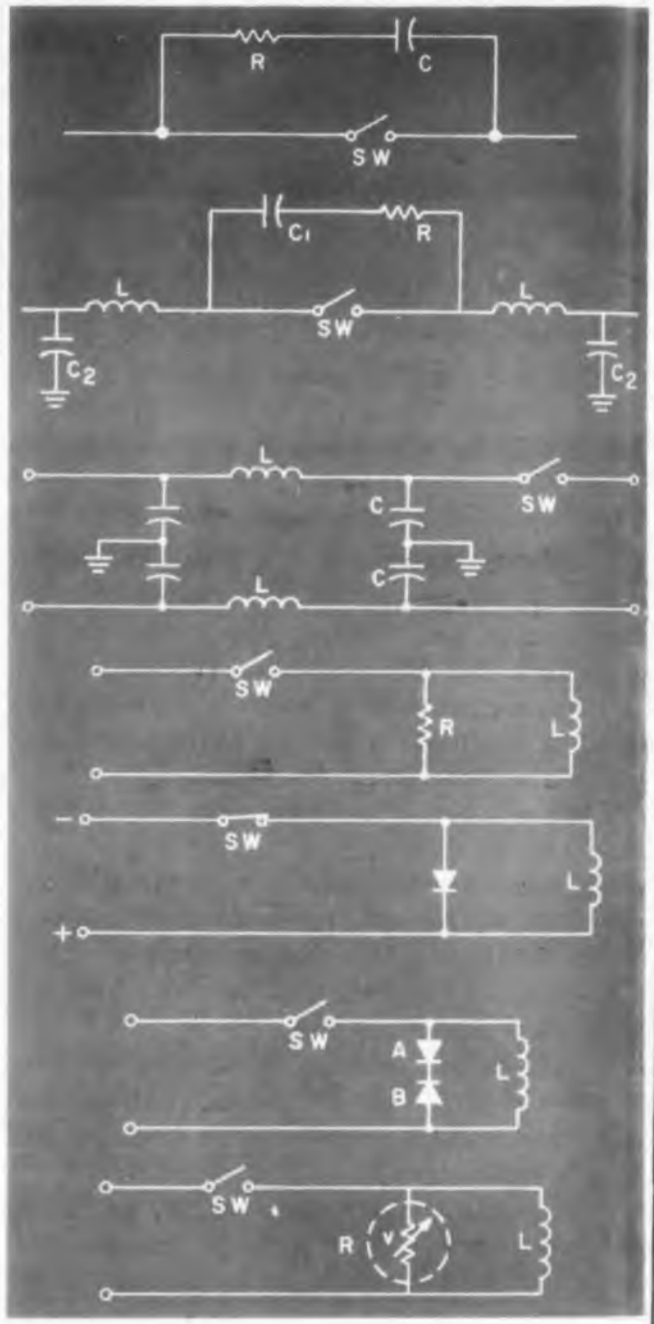

Fig. 5. Various methods used to reduce arcing due to switch and break transients. (a) simple RC network (b) low-pass filter added to RC network (c) double-pi filter (d) high resistance across an inductive circuit (e) rectifier used in place of the high resistance in (d) for dc applications (f) back-to-back rectifiers and (g) negative-voltage characteristic resistors.

high-speed rotating electrical machinery (above 2000 rpm), employing antifriction (ball or roller) bearings, has exhibited an impulsive type of radiated interference, the frequency distribution of which was related to that length of shaft which was a quarter wavelength. Such interference has been termed "bearing static", and research is continuing one means for its control or reduction.

Electrical Contacts

■ Many methods are available to reduce the arcing that occurs when a switch or contact makes or breaks. There is no single method of interference reduction which is universally applicable, so various methods which can be used are given in Fig. 5; these methods can be used either singly or in combination, depending upon the particular case upon the interference reduction required.

■ If the methods shown in Fig. 5 do not sufficiently reduce interference levels, shielded enclosures and shielded leads should be employed. The addition of feed-thru capacitors in the input and output leads of the shielded enclosure may be required. The mechanical design or a relay should be such as to prevent chattering or bouncing of the contacts.

Power Supplies

■ The most common type of interference associated with electronic power supplies results from high impedances in filters. If the power-supply filter impedance is low for rf as well as for power line frequencies, this trouble is reduced. Additionally, line filters and electrostatically shielded power transformers are recommended.

■ Gas-tube rectifiers are prone to generate interference. In addition to line filters and electrostatically shielded transformers, hash-suppression chokes are required in the plate and cathode leads of these rectifier tubes.

■ Electronically regulated power supplies should be provided with decoupling circuits to prevent oscillations in the regulator. Long lead lengths should be avoided in plate and grid circuits.

Gas-Tube Equipment

The category of gas-tube equipment includes such items as rectifiers, sweep generators, electronic switching devices, relay controls, modulators, and pulse generators. Unless the proper steps are taken in the design of this type of equipment, serious interference problems may result. Isolation and decoupling are of prime importance in circuits employing gas tubes.

■ The heater supply of a gas tube should be well decoupled and isolated. The output leads should be isolated and decoupled to prevent interference from being conducted and radiated along those leads. ■ ■

RFI

Interference Trouble-Shooting with Clamp-On-Devices

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Magnetic clamp-on devices are well adapted for the electronic installation trouble-shooter who must cope with the characteristic inaccessibility of interconnecting circuit terminations, generally with a lack of detailed knowledge of the installation. Many practical problems are described and their solution outlined.

INTERFERENCE resulting from magnetic coupling is difficult to reduce by shielding; proper cable bundling and re-routing are generally the most effective means of suppression. Clamp-on ammeters and injectors permit rapid and convenient radio-frequency interference measurements without the need to clip wires or open cable harnesses.

Clamp-On Devices

A clamp-on device is an incomplete transformer. The ferro-magnetic core may be easily opened to admit one or more turns of wire, thus completing the transformer. When the clamped wire is the primary, the device is termed a "clamp-on ammeter" and when the clamped wire is the secondary, a "clamp-on injector". Clamp-on ammeters measure current and clamp-on injectors inject voltage. Used separately or together these devices can perform many measurement and analysis functions.

The physical size of clamp-on devices is determined by the amount of iron needed, the size of the largest cable to be clamped, and the over-all rule that compactness is essential if the full potential of convenience is to be realized. A bulky unit that cannot be clamped around cables in tight places is of little use.

Ammeters

Clamp-on ammeters operate on various principles. Some operate on the principle of the "current transformer", used in accurate high-power measurement wherein the secondary is heavily loaded so as to minimize the range of core flux changes. Others use an unloaded (vtvm load) secondary. Rf clamp-on ammeters work into a 50-ohm load. Also, there are dc clamp-on ammeters which make use of various ingenious principles.

Those ammeters having a nearly unloaded secondary coil will have a voltage output heavily dependent on frequency. Rf units are of this type and the impedance reflected into the line is very low. Clamp-on ammeters with unloaded secondaries will reflect a reactive impedance into the line. Clamp-on ammeters other than those of the "current transformer type do not need low reluctance cores because close coupling is not required.

Two properties of clamp-on ammeters are common to all types and are the basis of their utility in trouble-shooting. First is the ability to sense a current without opening the circuit under test. The advantage of this property in testing installed systems is quite evident. Second is the ability to perform a vector addition of all currents which are simultaneously linked and to thus read the net current. Using this property, one can, in a single measurement, determine whether two currents are complementary (whether or not they differ by exactly 180 deg in phase and are otherwise identical). This property makes it possible to determine if all wires of a circuit are included in a given bundle. This knowledge is often useful in locating the path taken by either an interference producing current or by a sensitive circuit.

If a current is contained entirely in a bundle (the smaller the better) it will cause less interference and/or will be less susceptible to interference than if it is spread out over a wide area. Used as a simple ammeter, the clamp-on ammeter can accurately measure interference producing current. Comparison of this measurement with previously established limits will give an indication of whether or not a given current is causing trouble.

Injectors

Clamp-on injectors as discussed here may be used in two ways. With the jaws closed around a wire (N turns may be taken), a known flux Φ is caused to link the wire resulting in an induced voltage in the wire

$$V(Volts) = 2\pi f n\Phi \text{ (webers per sec)}$$

This voltage can be calibrated in terms of the energizing current, or, almost as conveniently, a wire turn may be taken around the core and lead to a monitoring voltmeter which reads the injected voltage directly. The accuracy with which the injected voltage is measured depends on the degree to which the region surrounded by the core is free of flux. Moving the wire around in the core space should not change the amount of voltage induced in the wire by more than a percent or so. If the injector is linked around all wires of a circuit, and if structure is not carrying part of the circuit, then no amount of flux linkages will induce a voltage in the circuit. This is a good test of the actual path taken by a circuit.

When the clamp-on injector is applied to a

After RFI trouble-shooting the interior of a bomber literally "wallpapered" with wiring, Mr. Herring became a dedicated interference control engineer. During the past eight years devoted to this work, he (and others) have been plagued with designers who don't know or don't care what paths their interference may take. With clamp-on devices, lengthy and costly checks can be accelerated without extensive studies of circuit configuration or system details; splicing wires is unnecessary.

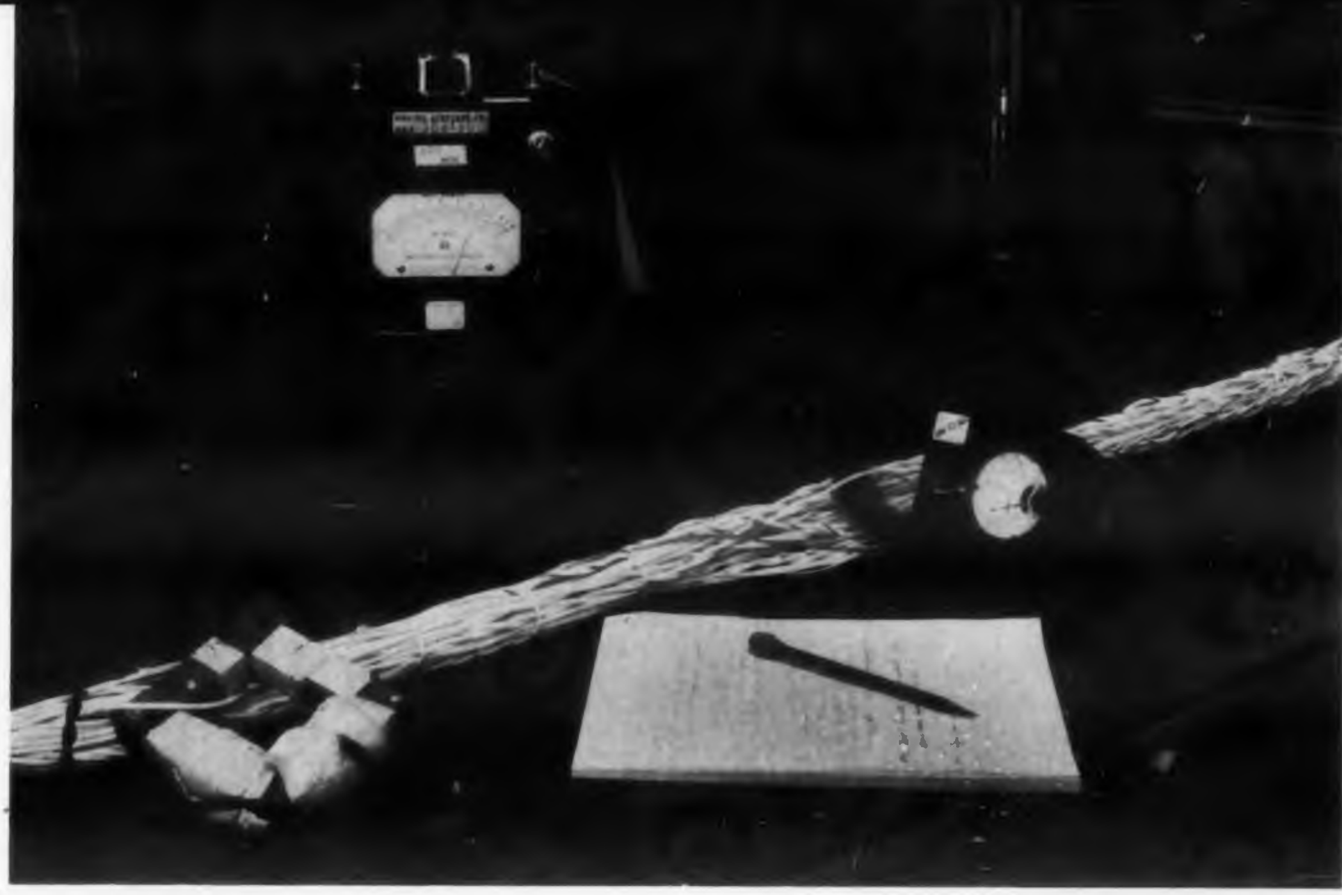

Fig. 1. For impedance or continuity measurement, an af injector (left) has ten monitor turns fed to a voltmeter. The clamp-on ammeter at the right reads the resulting current.

cable with the jaws open, the flux is no longer concentrated in a well-defined path but spreads out over a wide region. Thus the number of lines linking the cable under test is not known. However, this mode of operation is very useful for rapid qualitative analysis of cables which are well tied, or in a sheathing, and which are not to be cut open. Only with the jaws open can flux be threaded between the wires of the cable without untying the cable. This usage approximates actual wire coupling since actual wire coupling is strictly an "air-core" transformer situation. Cables which do not respond to the closed-jaw test may respond to the open-jaw test and may in practice be quite susceptible. Thus, with the clamp-on injector, we have both an accurate producer of flux linkages and a handy qualitative source of diffused flux.

For audio-frequency injectors, a magnetic circuit of reluctance comparable to that of a good power-transformer core is required. The iron should be able to handle at least 200 amp-turns of excitation. The phase of the injected voltage can be controlled by energizing the injector from the system power supply.

Applications

Typical problems which are tailored to the use of clamp-on devices are grouped into categories of:

(a) measurement of interference sources
(b) threshold determination
(c) circuit pathfinding and
(d) re-routing recommendations.

Measurement of Interference Sources

Problem: Several bundles of wires are suspected of generating interference in the audio-frequency band. Locate the wire or wires at fault.

Approach: Select a clamp-on ammeter responsive to the frequencies of interest and clamp each bundle. Readings below 0.5 amp generally indicate innocence. Untie the guilty bundle and clamp individual wires. The best fix is to twist together together the complementary wires—if both are available.

Problem: An rf noise source has been located, but the means of coupling to the affected equipment is not known.

Approach: To tell whether the wires to the source are carrying the interference, clamp them with an rf ammeter. Compare the readings with the limits given in specification MIL-I-26600. Generally, readings within these limits indicate innocence.

Threshold Determination

Problem: The ripple on a dc reference voltage is suspected of causing trouble. The ripple is measured at 100 mv rms, 60 cps. Is the ripple really causing any trouble?

Approach: Control the ripple by injecting additional ripple and check the system for any change in the observed trouble. Use a closed-gap injector energized at 60 cps with a monitor turn around the iron. The monitor turn is connected to an ac voltmeter which can read 100 to 500 mv. Inject, if possible, either in or exactly out of phase with the ripple. If phase cannot be controlled, simply inject several times the 100-mv existing ripple so that the injected ripple dominates.

Problem: A wire connected to a sensitive equipment is suspected of being sensitive to interference at 50 kc. The wire cannot be cut or opened and is shielded. What is the threshold sensitivity of this wire?

Approach: Use a closed-jaw injection energized at 50 kc having a monitor turn connected to an ac voltmeter. Inject increasing amounts of voltage until an equipment response is obtained.

Problem: A system shows signs of interference. Cable coupling is suspected as the cause. Is this a reasonable supposition?

Approach: Energize an injector to its maximum rated number of ampere turns (with the jaws open) at the frequency or frequencies of interest. At power frequencies, about 1000 lines of flux in the gap is a good figure. Apply the open gap to each cable of the system. If there is no response, then cable coupling is not involved. The injection flux should be a few times larger than any actual flux linkage which could exist. If both wires of a two-wire sensitive circuit are linked by the injection flux lines, less voltage is induced than if most of the injection flux threads between the wires. Hence, the injector would be moved around a bit to cover both these possibilities. (To estimate the actual flux linkages which could exist, assume the worst case, that is, both the source circuit and

Fig. 2. Only a few minutes time is required to locate current carrying wires using a clamp-on ammeter.

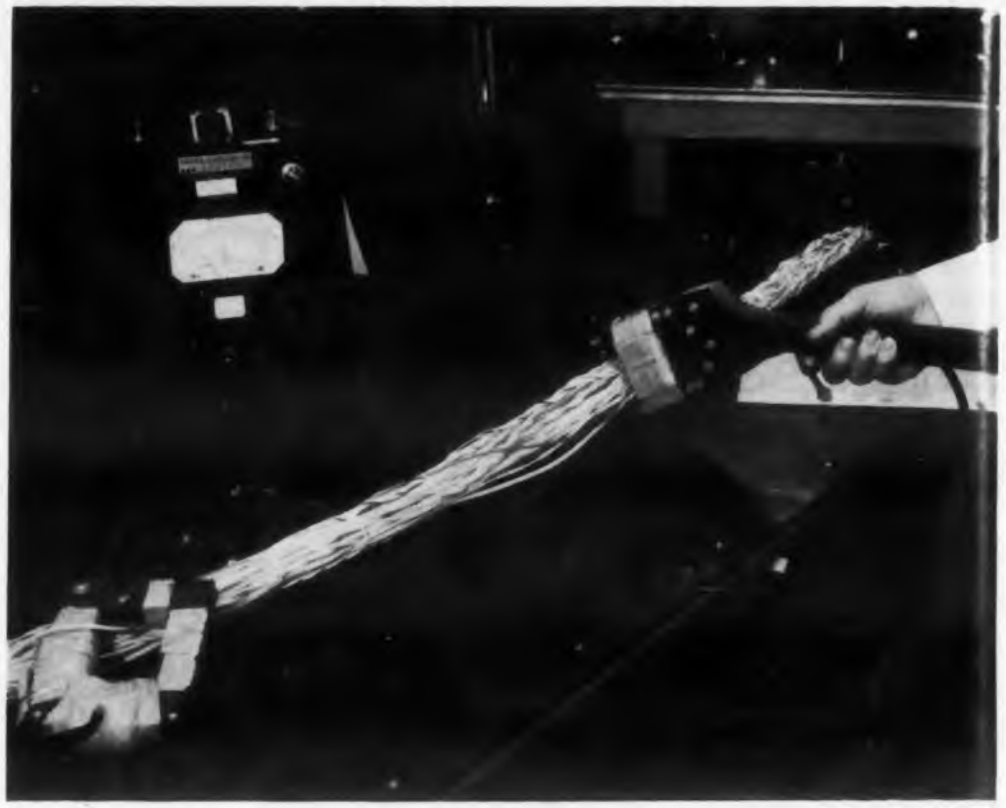

Fig. 3. For threshold determination, an open jaw injector (at right) is threading 400 cps flux through the cable at simulated environmental level. The injector (at left) is being used as an ammeter to detect the resultant RFI current flowing in a signal return wire of a sensitive circuit.

sensitive circuit consisting of single wires with structure return, spaced an inch apart. This situation has a coupling of about 200 linkages per 10 ft/amp.).

Circuit Pathfinding

Problem: A circuit is known to be highly sensitive. Can this be corrected, or is it an intrinsic property?

Approach: Use an injector to determine whether the circuit is confined to as small a space as possible. If it is not so confined, then considerable improvement can be gained by this confinement. Use a closed-jaw injector on the cable at the signal frequency and apply a very large injection voltage. Lack of circuit response shows that the circuit is confined to the cable. A response will prove that an additional, possibly remote, circuit path exists. Locate this path, if any, and re-route it with the circuit cable. (If this path is structure, one is confronted with a somewhat classic problem.)

If one is working with a non-energized system, the above approach can be used if a clamp-on ammeter is placed on the signal return wire or around the entire bundle. Either location should show no response if the circuit is complete in the bundle. The lack of response should be equivalent to an isolation resistance of 1 megohm.

Problem: A bundle is known to contain a power circuit, or at least part of it. Is the circuit completely contained in the bundle, and if not, where is the rest of it?

Approach: The clamp-on ammeter will read zero if the circuit is complete (all wires of the circuit linked). If not complete, clamp all likely bundles for the missing wire while cycling the power circuit on and off. If this search fails, structure is probably carrying the rest of the current. Any power bundle which has a clamp-on net current reading over 0.5 amp is a potential source of interference. If the clamp-on reading is 0, the bundle may still have an appreciable induction field, but twisting will reduce it greatly.

Problem: A continuity check is being made on a circuit, and/or the loop impedance of a circuit is to be determined.

Approach: Inject a small ac voltage at a convenient location by clamping one wire of the circuit and use a clamp-on ammeter nearby (but not too near) to measure the induced current.

Re-Routing Recommendations

The problem of re-grouping wires and of re-routing the groups in order to reduce interference is basically a mutual inductance (M) calculation problem. One starts with the flux sensitivity threshold (in webers) (Φ_t) of the sensitive circuit. If the voltage threshold (V_t) was measured, then $\Phi_t = V_t \div 2\pi f$. The aim is to reduce the flux linkages to a figure less than Φ_t by reducing the effective width of the sensitive circuit (proper bundling, choice of cable type, twisting), reducing the effective width of the source circuit (proper bundling, choice of cable type, twisting) and by increasing the separation between the circuits. The following method is suggested:

Consider a model pair of circuits, each of two wires, with the circuits in parallel planes spaced a distance X apart. Let the width of the sensitive circuit be D_v and that of the source circuit be D_s. With proper choice of parameters, this model configuration is equivalent to the actual case. The mutual inductance, or flux linkages per ampere, of the model arrangement is easily figured by handbook methods. All one needs to know to solve the problem is the flux threshold of the sensitive circuit, Φ_t, the "noise" producing current I_s, the coupled length L, the existing values of D_v and D_s and the minimum values of these latter quantities which can practically be obtained.

Clamp-on devices can measure all five existing quantities, I_s, Φ_t, L, D_s and D_v. The first two are obtained directly from ammeter and injector data. The circuit widths D_s and D_v are obtained through the "Circuit Pathfinding" methods previously described in which the paths of the current and return current are located. When the ammeter reads 0 around a bundle, one merely assumes the circuit width to be the width of the bundle; if one knows that the circuit is twisted, then a width of approximately 0.02 in. may be assumed. The coupled length L, common to both source and sensitive circuits, likewise is found by the "Circuit Pathfinding" methods. To solve the problem one first assumes that D_s and D_v are reduced to a minimum by bundling and twisting. Then, calculate the flux linkages Φ. If Φ is still too large, increase the separation X until the calculated Φ does not exceed Φ_t.

Actual Field Problem

An airborne air data computer was reported to give inconsistent output. The interference engineer who was called in knew only that the computer used a signal carrier frequency of 400 cps (the same as the aircraft's power system), that three "black boxes" were involved, and that the interconnecting cables were numbered CA-30, CA-121, CA-122 and CA-60.

The engineer first selected a clamp-on injector to use in finding the sensitive cable, if any. He energized the injector at 400 cps to a standard number of ampere-turns, energized the computer, opened the jaws of the injector about 1 in. and started to probe the computer cables. It was found that two cables, CA-121 and CA-122, produced computer responses many times more intense than those of the other cables. Next, completely closing the magnetic circuit around each cable in turn, the engineer obtained large and equal responses from each cable. No response was obtained when the injector was closed around both cables simultaneously.

By these three steps, the engineer had located the sensitive cable, and further, had learned that the sensitive circuit was divided, with signal "high" in one cable and signal "return" in another cable, and that the circuit was entirely contained in these two cables. To check that electrostatic coupling was not involved, a wire energized to 110 v, 400 cps, was laid parallel to the computer cables in turn; no response was obtained.

To locate the source of the interference, the interfering circuit was identified by systematically turning aircraft circuits on and off until computer response was obtained. The culprit proved to be the wing-flap-position indicating circuit. Location of the interfering wires was made evident immediately by using a clamp-on ammeter (on the 5-amp range) on all aircraft cables in the vicinity of cables CA-121 and CA-122. The path taken by the interfering wires was traced by having a person cycle the flap-indicator power on and off while the trouble-shooter worked along the interfering cable with the clamp-on ammeter. The interfering current was found to be contained in a single cable. Since the ammeter had a non-zero reading with its jaws shut, the return current was, in part, returning by some other (evidently remote) path. The investigator now knew the precise path taken by all wires of the sensitive circuit and he knew that the interference was magnetically coupled from a cable carrying a net, unbalanced, 400-cps current. It was then a simple matter to specify the re-cabling and re-routing required. ■ ■

RFI

Optimum Shielding of Equipment Enclosures

Electromagnetic shielding may be applied to radiating devices to prevent escape of rf energy from an enclosure or may be used in receivers to minimize extraneous pickup. The factors influencing shielding material selection and the use of design curves to determine shield thickness are discussed.

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RADIATING equipment is shielded to limit the transmission of spurious signals which may cause objectionable interference to nearby devices; receiving equipment is housed in shielded cabinets to minimize pickup of external rf fields which might produce direct or heterodyne interference and render communication useless.

Shielding Theory

One concept of shielding theory is that an rf field is produced by a wave which impinges on the shield, which in turn induces a current in the shield; the induced current is in a direction opposite to the original current. An opposing magnetic field results, which reduces the transmission of energy.

The classical shielding theory relates a shield to a transmission line.[1] An rf field is reflected and attenuated in passing through a metal. See Fig. 1. This is analogous to propagation of traveling waves on a transmission line. It is possible, by consideration of the transmission-line analogy, to compute the attenuation and reflection which will be experienced at each surface of the shield, and in passing through the shield.[2]

The relationship is shown in Eq. 1:

$$S = R + A \tag{1}$$

where:

S = total shielding efficiency (db)
R = total deflection loss (db)
A = dissipation or absorption loss (db)

These losses depend on the frequency involved and the thickness of material. Losses are also functions of material resistivity, permeability, and conductivity; reflection losses are related to the electromagnetic field characteristics. Since these losses vary with the characteristic "wave impedance" of the field, they may also vary with distance.

Low impedance or magnetic fields occur in the vicinity of coils or small loop antennas. (An rf field has both electric and magnetic components; the ratio of the components is what permits description as either an "electric" or "magnetic" field.) Since reflection losses for magnetic fields are small for most materials, the shielding depends primarily on absorption losses. High impedance or "electric" fields are easy to shield against, since large reflection losses are easily obtained. The absorption loss, which is essentially independent of the wave impedance, is the same for both electric and magnetic fields.

Material Selection

Figs. 2 and 3 show typical values of reflection and absorption losses for selected shielding materials (copper and iron). It is seen that at reasonably high frequencies, the dissipation of the field by absorption loss in metals of reasonable thickness is by far the most important factor in shielding. Reflection losses play only a minor role in this regard.

For the electric or high-impedance field, the

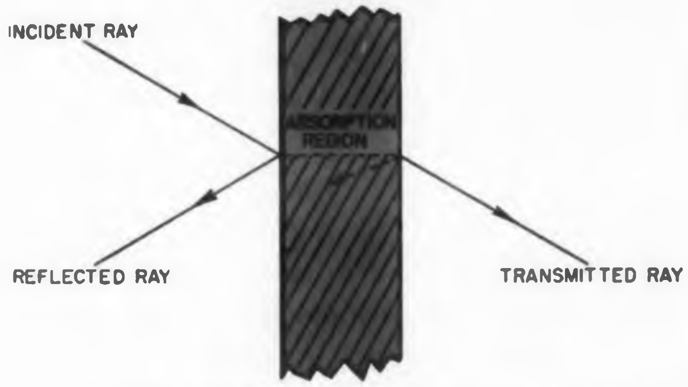

Fig. 1. Reflection and absorption in an rf shield.

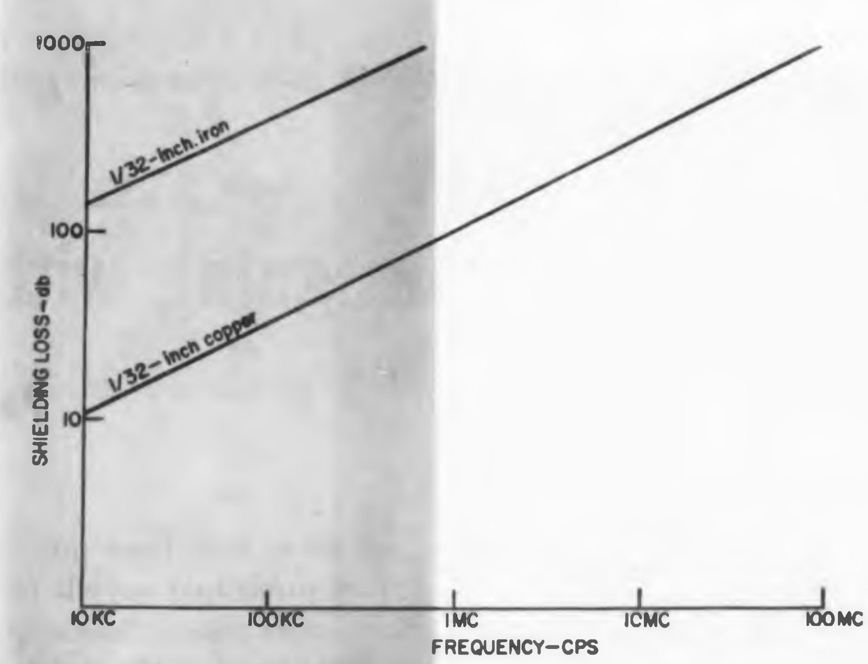

Fig. 2. Attenuation due to dissipation or absorption losses.

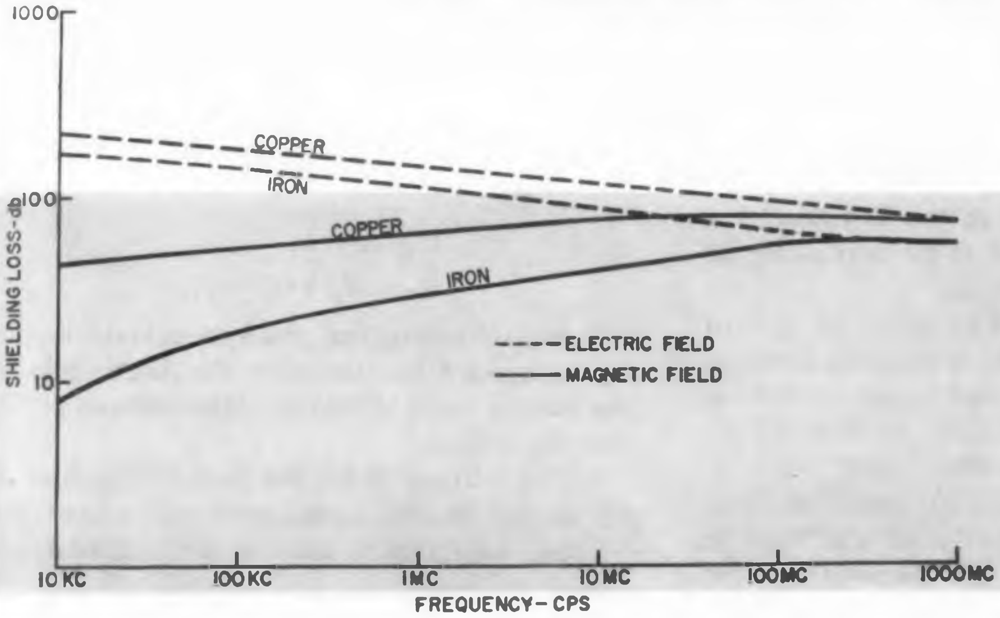

Fig. 3. Attenuation due to reflection.

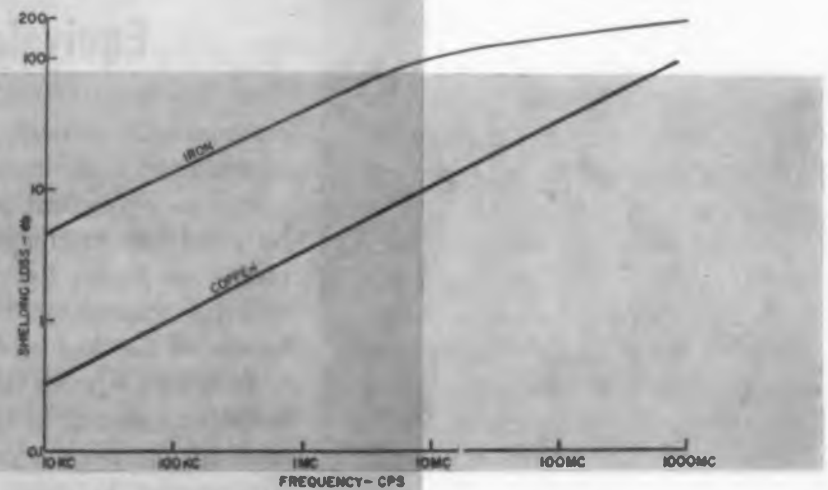

Fig. 4. Dissipation loss for one-mil thickness material.

shielding due to reflection increases at lower frequencies. Highly conductive materials, such as copper, aluminum, or magnesium give the best results. The shielding for low-impedance (magnetic) fields decreases at lower frequencies.

Both the reflection and absorption losses are small at low frequencies and the shielding problem is thus severe. Since magnetic materials, such as iron or Mu-Metal, have high permeability at low frequencies, they are more effective as shields. However, the resulting increase in absorption loss is obtained at the expense of a reduction in reflection losses.

This suggests the following general rules for selection of shielding materials:

- Good conductors (copper, aluminum, magnesium) should be used for high-frequency shields.
- Magnetic materials (iron, Mu-Metal) should be used for low-frequency shields.

Although seldom practical for equipment shields, composite layers of copper-iron are used in commercial shield enclosures. Such shielded rooms provide optimum performance over a wide frequency range.

Design Procedure

As a rule of thumb, any shield which is structurally sound will be thick enough for shielding at radio frequencies. This approximation does not hold at audio-frequencies or for critical applications; however, Fig. 4 shows representative values of absorption loss per mil thickness of material. By multiplying the thickness and the absorption loss factor, and then adding the reflection loss, the total shielding effectiveness can be computed.

For example, suppose it is necessary to determine the shielding effectiveness for magnetic fields at 100 kc, using 0.025 in. copper.

Procedure: From Fig. 3, the reflection loss at 100 kc is 50 db. The corresponding dissipation loss for 1 mil copper, as obtained from Fig. 4, is 1 db. Hence, from Eq. 1:

$$S = R + A$$
$$R = 50 \text{ db}$$
$$A = \alpha t = 1 \times 25 = 25 \text{ db}$$

Therefore,

$$S = 50 + 25 = 75 \text{ db}$$

When it is necessary to provide a given degree of shielding, say 60-80 db, reference to the curves permits quick estimates of the required material and thickness. In most applications, however, it is required to reduce the interference field to some specified level. By measuring the field without the shield, and comparing with the specific limits, the shielding requirements can be determined. ■ ■

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Designing with Tunnel Diodes

Part I

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Three experts have pooled their talents to write this first practical design article on tunnel diodes published anywhere. In Part 1, these GE authors discuss characteristics of the tunnel diode, operational limitations imposed on the designer by these characteristics and their effect on circuitry stability. In order to include some special examples of practical amplifier design, the article is somewhat longer than usual. Part 2 will describe methods of measuring tunnel-diode characteristics.

With the advent of the tunnel diode[1, 2, 3] the circuit designer has been supplied with a new tool which promises to be extremely valuable in producing entirely new circuit characteristics; or which will simplify the design of present special circuitry.

Inspection of the voltage-controlled negative-conductance characteristics shown in Fig. 1 (as distinguished from the current-controlled negative-resistance devices; such as the unijunction transistor, the controlled-rectifier, the 4-layer and avalanche switching devices, etc.) suggests applications as oscillators, mixers, autodyne converters, logic switching and storing elements, detectors and feedback elements in operational amplifiers.

As with any component, the eventual applications of the device are limited by the ingenuity of the circuits engineer, who is in turn limited by the reproducibility of the components in his circuit complex.

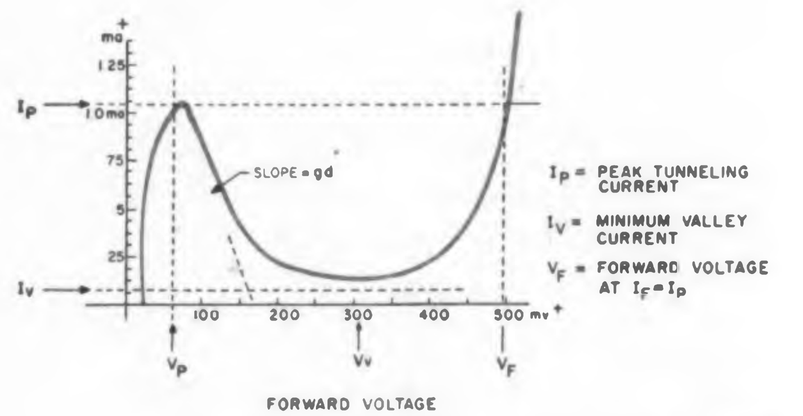


Fig. 1. Negative conductance characteristic of the tunnel diode.

Equivalent Circuit

As has been mentioned in the literature[3, 5] a reasonable equivalent circuit of the device may be represented as shown in Fig. 2.

For an equivalent circuit to be useful it must be physically meaningful for a range of frequencies (even if only for a limited range), so that we will be able to mathematically predict the response of the device within this range.

In order to prove that our equivalent circuit is, in fact, an analog of the device, we shall have to measure the parameters of the device at different frequencies. However, measurements of a two-terminal active element are complicated by the obvious requirement that the device "hold still" to be measured. We must insure that the tunnel diode will not oscillate in the measuring circuit; and for this reason we shall first consider the circuit-stability requirements.

Stability Criteria

Successful linear operation of a tunnel diode depends critically on the stability of the complete system; including, in particular, the internal impedance of the bias supply and the source impedance of the signal, if any. In the following we shall examine the condition of stability either as a sinusoidal oscillator or as an amplifier. The basic circuit can be reduced to that shown in Fig. 3, where R_l represents the load resistance; R_g, the generator resistance; L, the sum of the inherent lead inductance of the diode, l_s and the load inductance l_l; C, the diode capacitance; $-g$, the diode negative conductance at the specified bias current and voltage.

Fig. 3b is the equivalent of Fig. 3a, with the following substitutions:

$$L = l_l + l_s$$

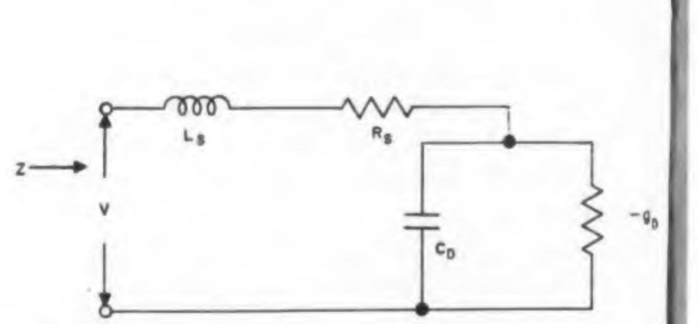
$$R_T = R_g + R_l + R_s$$

It is well known that the system stability can be determined by examining the distribution of the poles or zeros of the circuit determinant in the complex S-plane.[4]

Suffice it to say that if the zeros of $Z(s)$ seen at "X" of Fig. 3b, fall in the right half side of the S-plane, the system is instable and nonlinear operation results. Further nonlinear analysis will not be considered. If the zeros fall on the real frequency axis, the system will have a "free" sinusoidal oscillation. If the zeros are in the left half side of the S-plane the system is stable.

Now the input impedance is given as

$$Z_{(s)} = \frac{S^2 LC + (R_T C - Lg) S + (1 - R_T g)}{SC - g}$$



L_s = LEAD INDUCTANCE
R_s = BULK RESISTANCE
C_D = DIODE BARRIER CAPACITANCE
g_D = NEGATIVE TUNNELING CONDUCTANCE

Fig. 2. Equivalent circuit of a tunnel diode.

and zeros are

$$S = -\frac{1}{2}\left(\frac{R_T}{L} - \frac{g}{C}\right) \pm \sqrt{\frac{1}{4}\left(\frac{R_T}{L} - \frac{g}{C}\right)^2 - \frac{1 - R_T g}{LC}}$$

Then S will have a negative real part only if both

$$\frac{R_T}{L} - \frac{g}{C} > 0$$

$$\text{and } 1 - R_T g > 0$$

or it may be written

$$\frac{Lg}{C} < R_T < \frac{1}{g}$$

This is the condition for stable operation, and is shown graphically in Fig. 4.

Free Oscillation

The condition for free oscillation requires the real part equal to zero, namely

$$\frac{R_T}{L} - \frac{g}{C} = 0 \qquad (\omega = 2\pi F)$$

and then $\qquad \omega_0 = \left(\frac{1 - R_T g}{LC}\right)^{\frac{1}{2}}$

Evidently, one cannot change the frequency by changing one of the four variables alone and still maintain free oscillations.

Amplifier

For amplifier design, we are interested not only in stability, but also in the gain and the frequency bandwidth. This can best be explored by examining the Nyquist plot of the input impedance (impedance is used here for convenience; one can equally use admittance analysis if he wishes)[4].

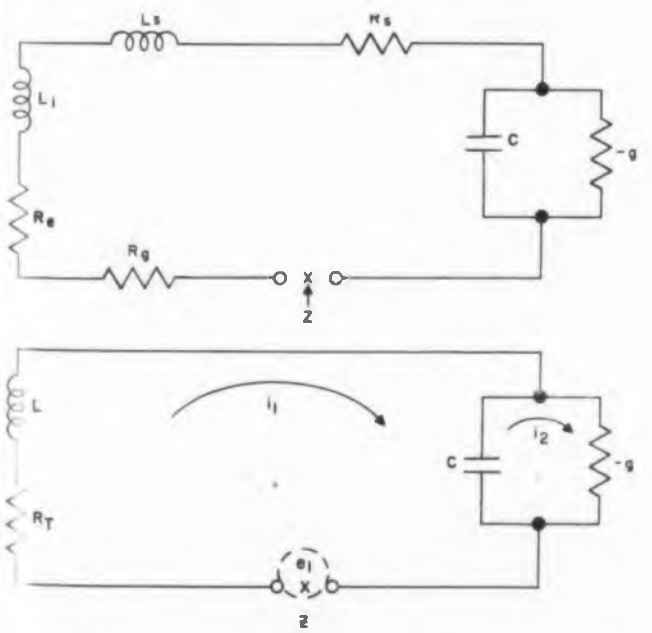


Fig. 3. Basic circuit of an oscillator or amplifier. With substitutions for L and R_T, (b) becomes equivalent of (a).

Table 1—Number of Positive Encirclements (P-N) of the Origin of the Plots in Fig. 5.

Case	P-N	P	N	Stable
1	−1	1	2	No
2A	−1	1	2	No
2B	+1	1	0	Yes
3	0	1	1	No
4	0	1	1	No

Note: P = Number of poles and N = number of zeros in the right half of the "S" plane.

The input impedance $Z(s)$ on the real frequency axis of the contour integration in the S-plane is obtained by substituting jW for S. Thus (replacing ω by W):

$$Z(W) = \frac{W^2 R_T C^2 - (1 - R_T g)\, g}{W^2C^2 + g^2} + j\,\frac{W\,(L\,g^2 - C) + L\,C^2W^3}{W^2C^2 + g^2}$$

$$= R_T - \frac{g}{W^2C^2 + g^2} + jW\left(L - \frac{C}{g^2 + W^2C^2}\right)$$

The Nyquist plots for the above are shown in Fig. 5.

As given by Bode,[4] the number of times the plot encircles the origin in the positive direction (counterclockwise) is equal to the difference of the number of poles minus the number of zeros in the right half of the S-plane. By inspection of the equation for $Z(s)$ we see there is one pole in the right side of the S-plane, when

$$S = +\frac{g}{C}$$

and the number of zeros can be obtained as shown in Table 1.

The only stable case is 2(b), Fig. 5. Fig. 6 is an enlarged picture of 2(b).

Defining two critical frequencies:

$W_1 = W_R$ is the frequency at which the real part

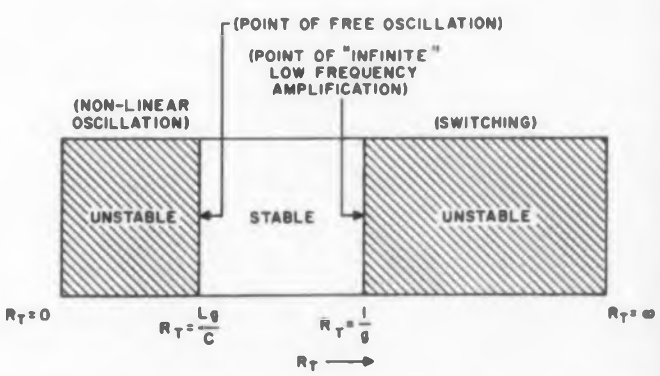


Fig. 4. Condition for stable operation shown graphically.

of $Z(W) = 0$
$W_2 = W_X$ is the frequency at which the imaginary part of $Z(W) = 0$

then

$$W_R = \frac{g}{C}\sqrt{\frac{1}{g\,R_T} - 1}$$

and

$$W_X = \sqrt{\frac{1}{LC} - \frac{g^2}{C^2}}$$

In general, three possible conditions may exist, provided:

$$\left.\begin{matrix} W_R \\ W_X \end{matrix}\right\} \neq 0$$

1. $W_R = W_X$
2. $W_R > W_X$
3. $W_R < W_X$

When $W_R \leqslant 0$, the device can only be a switch since $R_T \geqslant |1/g|$. When $W_X \leqslant 0$, the device can only operate as a nonlinear relaxation oscillator.

For the sake of clarity, these three conditions are compared graphically in Fig. 7 in S-plane, Z-plane, and a plot of effective negative "R" and reactance vs frequency to show the direct correspondence of these methods of presentation. (One may consider the effective negative resistance as an energy source driving the reactances of the circuit; when this source disappears at increasing frequencies the entire circuit becomes passive.)

Circuit Stability Limitations

From the preceeding we have shown that the circuit will be stable when:

$$\frac{Lg}{C} < R_T < \frac{1}{g}$$

or:

$$1 < \frac{1}{R_T g} < \frac{C}{Lg^2}$$

so that when $L < R_T C/g$ we can have a stable amplifier.

Power Gain

Several definitions of Power Gain have come into common usage. Some of these are:

(1) Transducer gain:

$$G_T = \frac{P\ load}{P\ available\ from\ the\ generator}$$

(2) Insertion gain:

$$G_i = \frac{P\ load\ with\ network\ inserted}{P\ load\ with\ only\ generator\ and\ load\ connected}$$

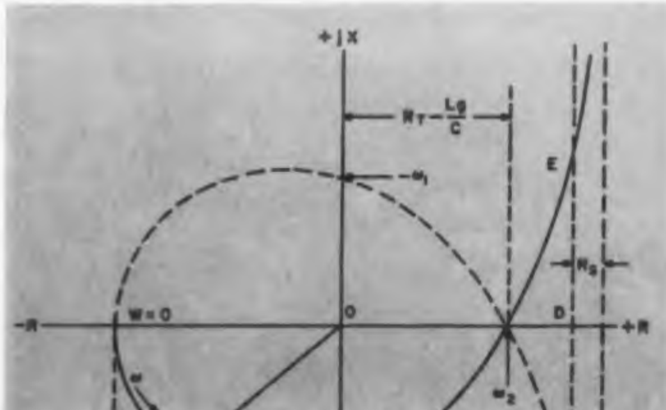


Fig. 6. (above) Enlarged version of the only stable case, 2(b), of Fig. 5.

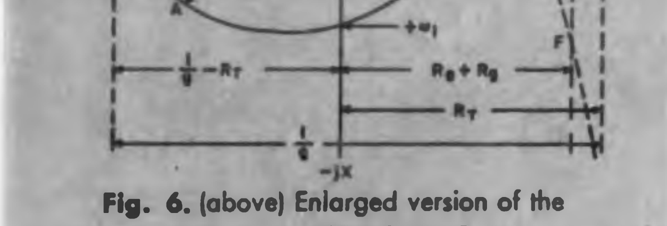


Fig. 8. Series circuit, right, compared with its parallel counterpart.

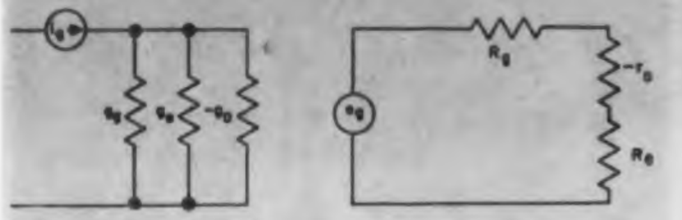
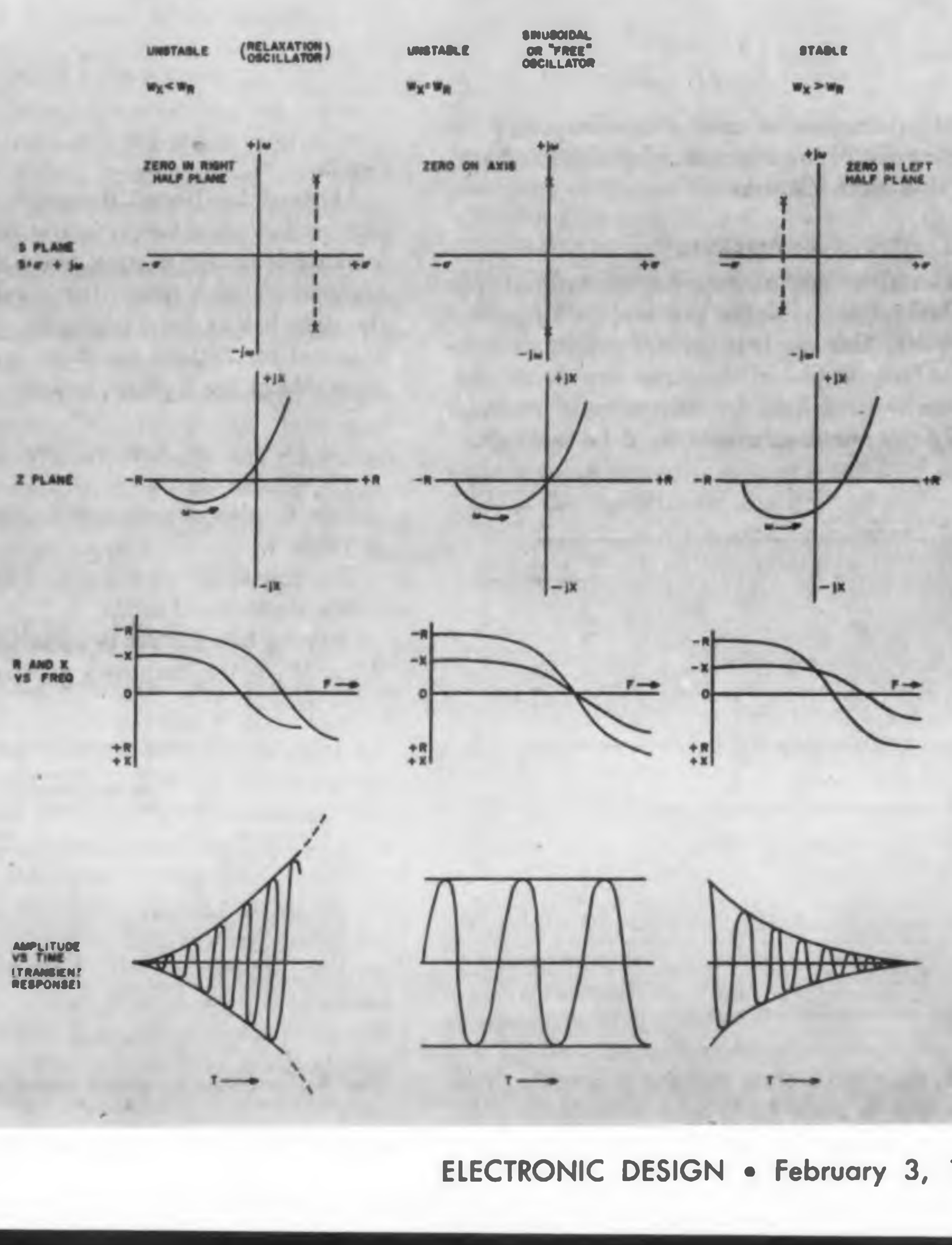
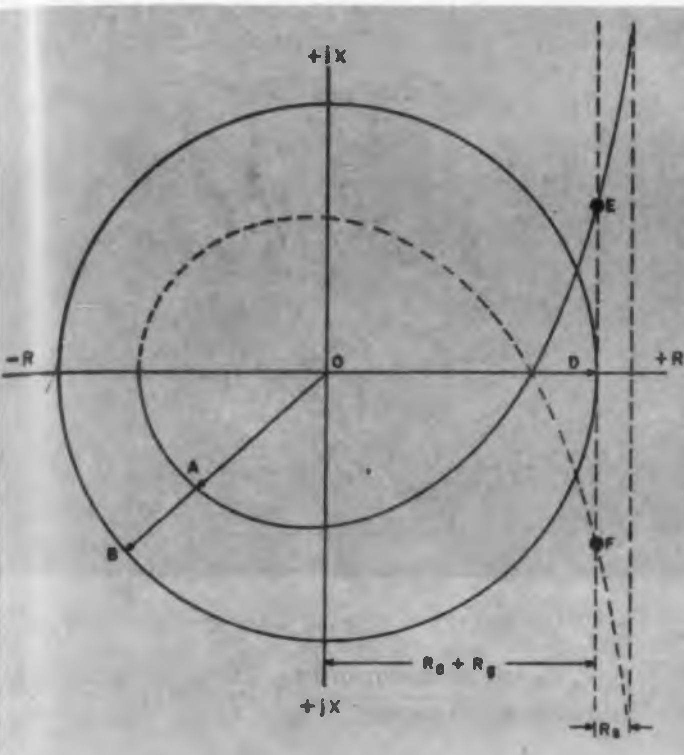


Fig. 9. Basic circuit to determine power gain.

Fig. 7. (below) Comparison of three possible conditions which may exist.





$\frac{OB}{OA}$ = CURRENT AMPLIFICATION

Fig. 10. Vector diagram illustrating power gain.

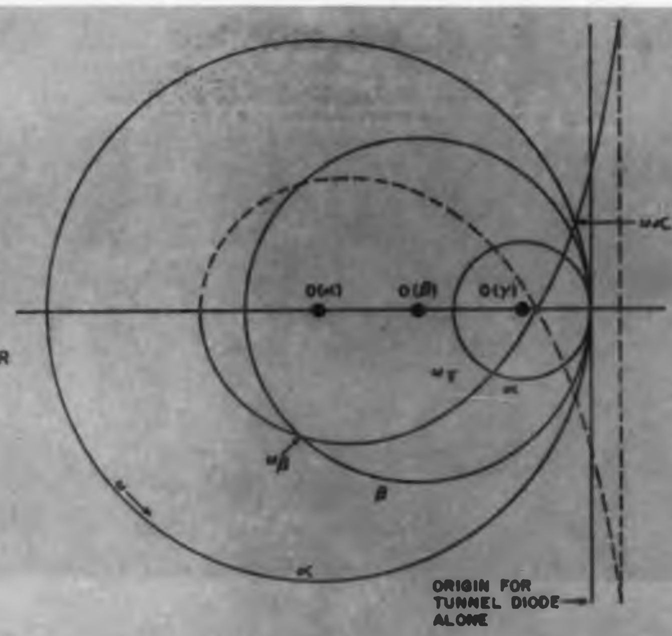


Fig. 11. Process by which circuit may be changed to increase gain at a particular frequency.

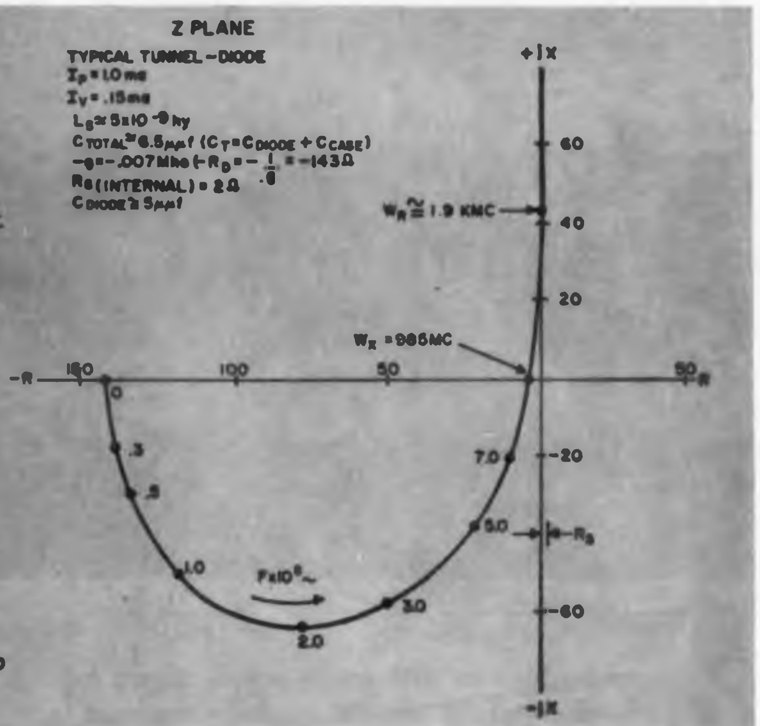


Fig. 12. Characteristics of a typical tunnel diode.

(3) Maximum available gain:

$$G_{MA} = \frac{P \text{ available from output}}{P \text{ available from generator}}$$

(Complex conjugate match at input and output)

(4) Effective operational gain or efficiency:

$$G_e = \frac{P \text{ load}}{P \text{ delivered by generator}}$$

Definition 3 is normally used to describe 4-terminal active elements and does not seem to be particularly useful for a 2-terminal device.

Definition 4 ceases to be meaningful when the net resistance or conductance of the complete network is negative; since in this event the generator is absorbing power from the network instead of delivering power to it. (One must remember that a negative resistance or negative conductance is a source of energy.)

For the sake of simplicity in measurement and calculations, and because the definition agrees with a practical method of using the device, we will define power gain in terms of insertion gain in preference to transducer gain.

It should be noted that while the authors have treated the series-insertion amplifier for the purpose of illustration, a similar approach to the stability and design procedures may be applied to the parallel amplifier.

A comparison of the series circuit shown in Fig. 8 with its parallel counterpart is shown in Table 2 (assuming no reactances).

Let us consider the circuit shown in Fig. 9 and the power in the load with no diode in the circuit (switch closed).

As shown in Fig. 10, a vector such as OA represents the $Z(jW)$ at any frequency. Vector OD is the series resistance of the load and generator. E and F are the limits at which the negative resistance contribution of the diode is equal to zero. Then the current-gain in the load is inversely proportional to the ratio OA to OD that is:

$$\left|\frac{i_1}{i_o}\right| \alpha \frac{OD}{OA}$$

Where i_o is the current in R_l with shorted diode and where i_1 is the current in R_l with diode in the circuit.

Since the current flowing $|i_o| = \frac{e_g}{|Z_o|}$

then $$P_{l_o} = |i_o|^2 R_l = \frac{e_g^2 R_l}{|Z_o|^2}$$

with the switch open $|i_1| = \frac{e_g}{|Z_T|}$ and $P_{l_1} = \frac{e_g^2 R_l}{|Z_T|^2}$

where $|Z_T|$ = magnitude of the total loop impedance, including the tunnel diode. Defining the power gain ("insertion" power gain) then

$$G = \frac{P_{l1}}{P_{lo}}$$

$$G = \frac{\dfrac{e_g^2 R_l}{|Z_o|^2}}{\dfrac{e_g^2 R_l}{|Z_o|^2}} = \frac{|Z_o|^2}{|Z_T|^2} = \left|\frac{Z_o}{Z_T}\right|^2$$

For the sake of simplicity and for purposes of illustration:

$$Z_g = R_g,\ Z_l = R_l,\ Z_o = (R_l + R_g)$$

With the simplification stated, we see that $|Z_T|$ may be determined by constructing the tunnel-

Table 2—Comparison of Parameters of Series and Parallel Circuits of Fig. 8.

	Insertion Gain	Available Gain
Series	$\left[\dfrac{R_l + R_g}{R_l + R_g - r_d}\right]^2$	$\dfrac{4 R_l R_g}{(R_l + R_g - r_d)^2}$
Parallel	$\left[\dfrac{g_l + g_g}{g_l + g_g - g_D}\right]^2$	$\dfrac{4 g_l g_g}{(g_l + g_g - g_D)^2}$

Ratio of: $\dfrac{G \text{ insertion}}{G \text{ available}} = \dfrac{g_g}{4g_l}\left(1 + \dfrac{g_g}{g_l}\right)^2 = \dfrac{R_g}{4R_l}\left(1 + \dfrac{R_l}{R_g}\right)^2$

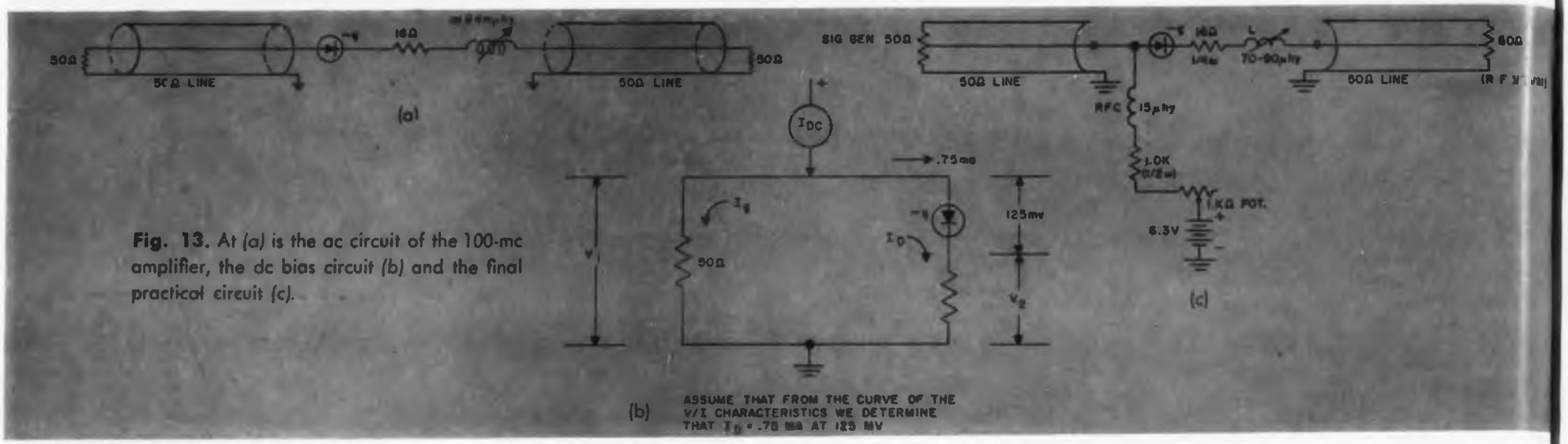


Fig. 13. At (a) is the ac circuit of the 100-mc amplifier, the dc bias circuit (b) and the final practical circuit (c).

diode characteristics with frequency as shown in Fig. 10, offsetting the original origin by the magnitude of $R_l + R_g$ and comparing the square of the vectors from the new origin, of Z_T and $(R_l + R_g)$ at the desired frequency. In Fig. 11 we illustrate a process by which the design of the circuit can be changed to emphasize the gain at a particular frequency.

A set of circles corresponding to different $(R_l + R_g)$ values are superimposed on a diode characteristic with the centers $o(\alpha)$, $o(\beta)$, $o(\gamma)$ located inside the loop to insure stability. We can see that circle γ intercepts the diode characteristics at $\pm W\gamma$. Above this frequency the current amplification is positive, while below this frequency the amplification is negative. For circle α, the intercepts are at $\pm W\alpha$. This means that current amplification is positive for all frequencies up to $W\alpha$.

Amplifier Design Procedure

Let us consider the characteristics of a typical tunnel-diode with the specifications and response shown in Fig. 12.

Example 1:

Required: 100-mc amplifier to operate between two 50-ohm transmission lines.

Let:

$$R_T - \frac{g}{g^2 + W^2C^2} = 0,$$

Then:

$$R_T = \frac{1}{g\left(1 + \frac{W^2C^2}{g^2}\right)}$$

for

$$\frac{C}{g} = \frac{5 \times 10^{-12}}{7 \times 10^{-3}} = 7.15 \times 10^{-10},$$

$$\left(\frac{C}{g}\right)^2 = 51 \times 10^{-20}$$

$$\frac{W^2C^2}{g^2} = 39.4 \times 10^{16} \times 51 \times 10^{-20}$$

$$= 3.94 \times 5.1 \times 10^{-2} = 0.21$$

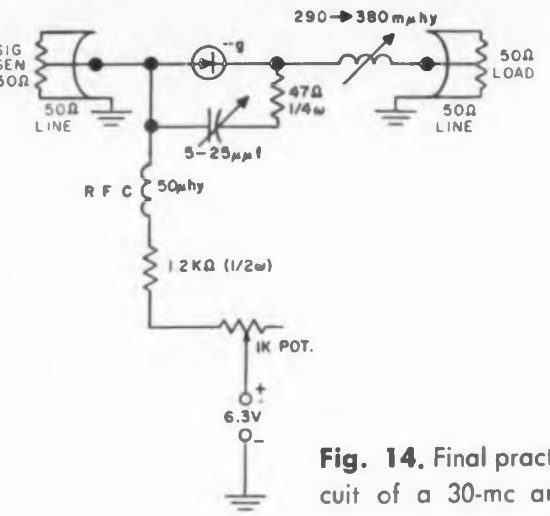


Fig. 14. Final practical circuit of a 30-mc amplifier.

$$\therefore R_T\,(\text{required}) = \frac{143}{1.21}$$

$= 118\Omega$, $R_T - (R_l + R_g + R_S) = 16\Omega$ (to be added)

$$\text{and } L = \frac{R_TC}{g} = 1.18 \times 10^2 \times 7.15 \times 10^{-10}$$

$$= 8.43 \times 10^{-8} = 84.3 \text{ m}\mu\text{hy}$$

Therefore: the ac circuit is as shown in Fig. 13a, and for dc bias, Fig. 13b.

$$V_2 = 7.5 \times 10^{-4} \times 66 = 49.5 \text{ mv}$$

$$\text{therefore } V_1 = 125 + 49.5 \text{ mv} \cong 175 \text{ mv}$$

$$\text{so that} \quad I_g = \frac{175}{50} \text{ ma} = 3.5 \text{ ma}$$

$$\text{and} \quad I_{DC} = I_g + I_D = 4.25 \text{ ma}$$

Assume we wish to use a 6.3-v battery, then

$$R_B = \frac{6.12}{4.25} \times 10^3 = 1.44\ K\Omega$$

We should decouple the dc supply from the amplifier by at least a 10 K-ohm inductor.

$$L_B > \frac{X_L}{W} \approx \frac{10^4}{6 \times 10^8} \approx \frac{10 \times 10^{-5}}{6} \approx 15\ \mu\text{hy}$$

or: (allowing for battery changes), the final practical circuit is shown in Fig. 13c. Experimental results obtained were:

$$f_o = 100 \text{ mc},\ G = 32 \text{ db, bandwidth} \cong 20 \text{ mc}$$

When L was increased so that $G = 40$ db, bandwidth was approximately 8 mc but very nonsymmetrical.

Example 2:

Required: A 30-mc amplifier to operate between two 50-ohm transmission lines. Following the procedure in Example 1:

$$R_T = \frac{1}{7 \times 10^{-3}\ (1 + 39.5 \times 9 \times 10^{14} \times 51 \times 10^{-20})}$$

$$R_T = \frac{143}{(1 + 0.018)} \cong 140.5\Omega$$

Now this is entirely too close to $|T/-g|$ for reasonable stable dc operation.

We can approach this problem from a different aspect and attempt to increase the parallel capacitance, thereby reducing g/C. However, Fig. 12 shows us that W_X internal $< W_R$ internal; and therefore merely paralleling the tunnel-diode with a capacitor will inevitably cause oscillation. *Therefore:* Consider the stability requirement of the device at very high frequency.

Assuming that the distributed inductance of socket and leads (including capacitor leads) is in the order of 30 mμhy.

with $l = 3 \times 10^{-8}$ hy,

$$W_X' = \left(\frac{1}{3 \times 10^{-8} \times 5 \times 10^{-12}} - 2 \times 10^{+18}\right)^{\frac{1}{2}}$$

$$= (6.67 - 2)^{\frac{1}{2}} \times 10^9$$

$$f_x' \cong \frac{2.2 \times 10^9}{6.28} = 350 \text{ mc}$$

If we add a new R'_T in series with the capacitor such that

$$R_T' > \frac{Lg}{C_D}, \left(\frac{3 \times 10^{-8} \times 7 \times 10^{-3}}{5 \times 10 - 12} = \frac{21}{5} \times 10\right)$$

> 42 ohms, the second loop will also be stable at 350 mc.

To be safe let us use $R'_T = 47$ ohms. Since $W_X \ll W_c$ internal we can neglect l_s.

Now the required $C_{Total} = \frac{g}{W}\left(\frac{1}{gR_S} - 1\right)^{\frac{1}{2}}$

$$= \frac{7 \times 10^{-3}}{1.88 \times 10^{8}} \sqrt{0.43}$$

$$\therefore C_T = 3.73 \times 10^{-11} \times 0.655 = 24.4\ \mu\mu f.$$

$$C_{Reg} = C_T - (C_D + C_{strays}) \cong 24.4 - 6.5 \cong 18\ \mu\mu f$$

$$X_c \text{ at } 30 \text{ mc} = \frac{1}{1.88 \times 10^{8} \times 1.8 \times 10^{-11}}$$

$$= \frac{1}{3.38 \times 10^{-3}} = 296\Omega \cong 300\Omega$$

$$X_c \text{ at } 350 \text{ mc} = \frac{1}{2.2 \times 10^{9} \times 1.8 \times 10^{-11}}$$

$$= \frac{1}{3.96} \times 10^{2} \cong 25\Omega.$$

Since $X_c = 6.3\ R'_T$ the apparent capacitance will only be reduced by about 3 per cent or 1/2 μμf at 30 mc.

From the proceeding we can now design the 30-mc amplifier:

With $R_T = 100$ ohms, $C = 24\ \mu\mu f$, $g = 0.007$ mho then

$$L\ total = \frac{R_T C_T}{g} = \frac{10^{4} \times 2.4 \times 10^{-11}}{7 \times 10^{-3}} = 0.343\ \mu hy.$$

$$L\ total = L_1 - L\ strays \cong 300\ m\mu hy.$$

The same procedure as in Example 1 is now followed for the dc supply and decoupling rf choke and Fig. 14 shows the practical amplifier circuit. Results were: $G = 32$ db at 30 mc for bandwidth of 10 mc.

Alignment

To align the amplifier, one first reduces L_1 to its minimum value. A 0.1 mv signal at 30 mc is injected and the generator is "rocked" in frequency while adjusting C_1 for a peak at 30 mc. L_1 is then increased until the required gain is obtained. The generator should be turned off at this point to check that the amplifier is not oscillating. (Otherwise one must reduce L_1 slightly, and/or increase C_1 slightly). Since the amplifier becomes critical in adjustment when more than 30 to 50 db of G_1 are required, it is not recommended for higher-gain operation.

One precaution in the use of this amplifier must be mentioned. From the characteristic curve of Fig. 1 one sees that the peak linear current excursion is approximately 0.5 ma. Therefore the peak-to-peak voltage across the 50-ohm output must be less than 25 mv for linear operation (that is, $e_{out} \leqslant 8.5$ mv rms).

Since we can obtain over 30 db of gain, then the maximum input voltage to the amplifier is in the order of 0.5 mv.

It is to be noted that the solution of the quadratic equation for the g/C ratio required, results in two values; namely:

$$\left(\frac{g}{C}\right) = \frac{1}{2CR_T} \pm \sqrt{\frac{1}{4C^2R_T^2} - W^2}$$

and $$C\ maximum \leqslant \frac{1}{2WR_T}$$

also if given a specific C (provided $C \leqslant 1/2WR_T$) the permissible values of g are:

$$g = \frac{1}{2R_T} \pm \sqrt{\frac{1}{4R_T^2} - W^2C^2}$$

so that for a 6-1/2 μμf C total, $|1/g| = 125$ ohms or 500 ohms which implies that a 1.0-ma unit or a 0.25-ma unit of the same capacitance may be used.

Since the amplifiers are bilateral, a possible application for those described is as a low-level "repeater" amplifier in transmission lines. ■ ■

Part 2 of this article will appear in a subsequent issue of Electronic Design, *and will discuss measurement of tunnel-diode characteristics.*

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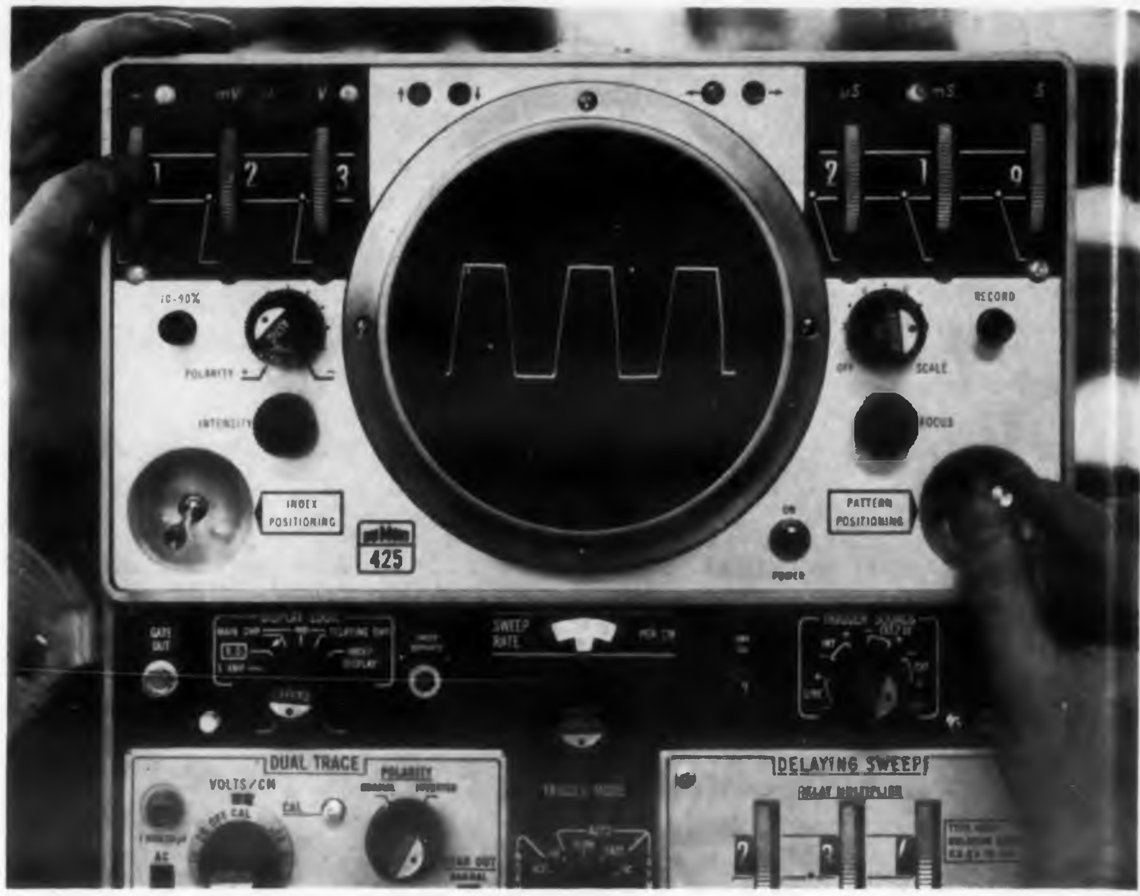


No guesswork needed to read voltage and time on the DuMont 425.

Digital Readout Scope

DIGITAL readout of voltage and time, joystick positioning controls, and modular construction are but a few of the features which make the 35-mc, 50-mv/cm DuMont 425 a most unusual oscilloscope.

Manufactured by Allen B. DuMont Laboratories of Clifton, N. J., the 425 provides unambiguous, accurate voltage and time readings from even the most complex waveforms. Of its many novel features, the most unusual is the digital readout.

Joystick Positioning

To measure the peak-to-peak amplitude of a complex waveform, for example, an operator sets the Display Logic switch to the Read Out position. He then moves the waveform and the two dots which appear with it to a convenient position on the screen with the Pattern Positioning joystick.

Using the Index Positioning joystick, he moves both dots till the indexing dot coincides with the most negative level of the waveform. He then maneuvers the voltage and time-scale thumbswitches till the scaling dot coincides with the most positive level of the waveform. Then the upper left readout area provides a three-digit voltage reading.

He can use a similar technique to measure the period of a waveform or time between points on the waveform. In this case, the upper right readout area gives a three-digit time readout while a vernier can supply a fourth digit.

For accurate rise-time measurements a push button under the voltage readout can automatically move the dots from the peaks of the waveform to the 10- and 90-per cent voltage levels.

Switches for Three Axes

Electronic switches in the X, Y and Z axes can provide unusual effects. For example, one can view the main sweep and the delaying sweep simultaneously, with one positioned over the other. This pr vides a complete magnifier since one can see the entire signal time sequence. It can provide a sweep magnification of up to 10^9.

When the Dual Trace plug-in is used with the Delaying Sweep the scope can display two completely independent voltages against two completely independent sweeps.

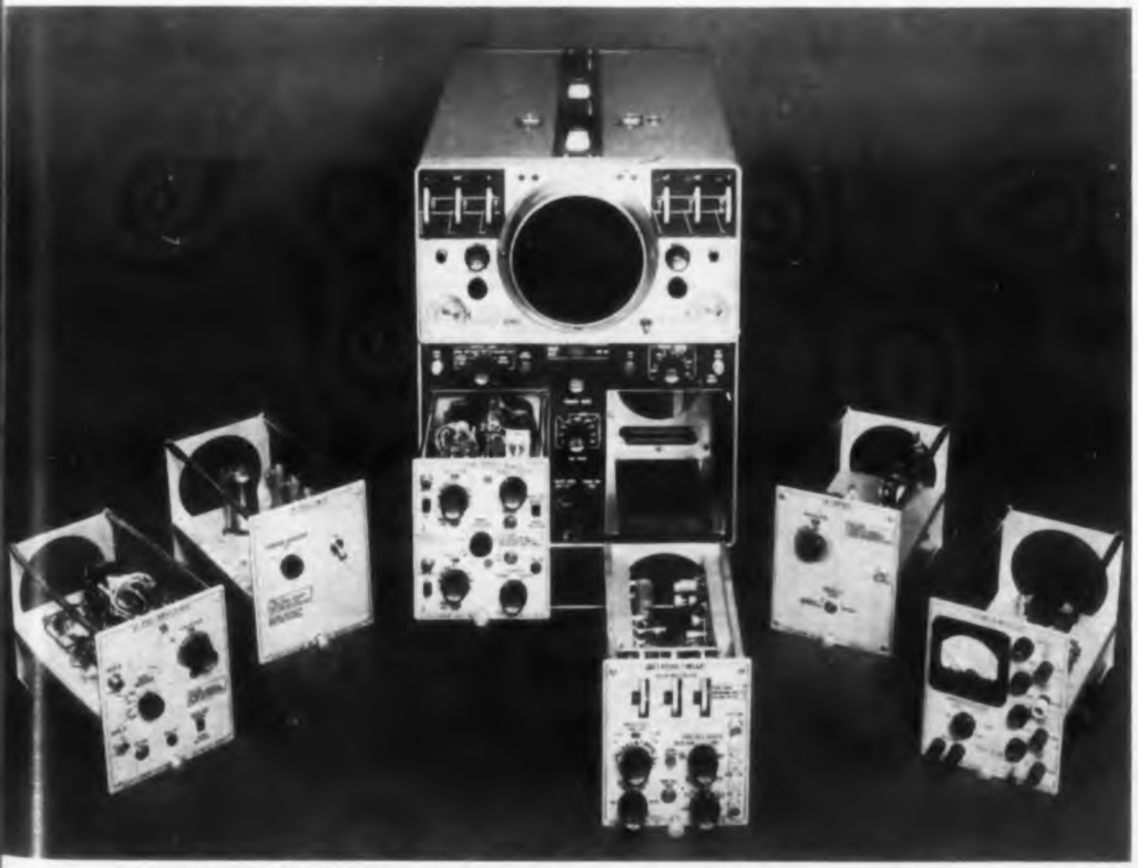
The bootstrap sweep circuits in the main frame of the 425, with a range from 10 mμsec/cm to 6 sec/cm provide sweep accuracy which is normally better than 3 per cent—always better than 5 per cent. The Delaying Sweep can provide delays from 0.5 μsec to 10 sec.

Outputs from two 40-pin connectors on top of the 425 can be used to print out each voltage and time digit, decimal point, and multiplier. Also available at these connectors are analog voltages, proportional to the three-digit voltage and time readings. These may be used to drive a pen-recorder-type XY plotter or to feed an analog computer.

There is not a single selected tube or non-standard part in the 425 or any of its plug-ins.

Available from stock, the main frame of the 425 costs $2750. The most common plug-in units range from $100 to $300.

For more information, turn to the Reader-Service Card and circle **100**.

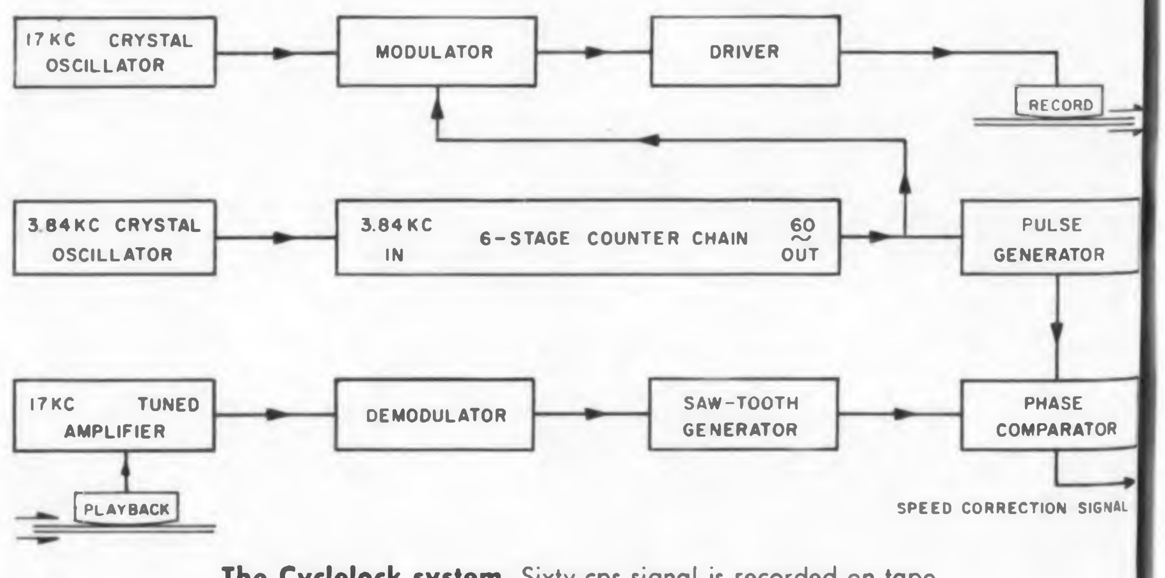


Main frame of the 425 and those plug-ins which are already available. Others will follow.

Worried About Tape Stretching? Capstan-Speed Servo Offsets Distortions

TO CANCEL the effect of temperature and humidity distortions in magnetic tape length, a speed servo system was developed to hold timing accuracy of the playback unit to ±0.005 per cent. A 60-cps signal is recorded on one of the tape's channels and compared with the original signal during playback. If the recorded signal is low in frequency, capstan speed is increased.

Designed by engineers of the Mincom Division of the Minnesota Mining and Manufacturing Co., 2049 S. Barrington Ave., Los Angeles, the Cyclelock system



The Cyclelock system. Sixty-cps signal is recorded on tape along with data. During playback, recorded signal is compared with reference. Any difference in signal is applied to capstan-motor-speed control.

Cyclelock tape speed-control system holds timing accuracy to ± 0.005 per cent, according to designers, Mincom Div. of Minnesota Mining and Manufacturing Co.

compensates for very small variations in tape length. These variations, which can be as small as 10^{-5} inches per inch for each degree F and 10^{-4} inches per inch for each percentage of change in relative humidity, can cause considerable inaccuracy of data reproduction.

With the speed control system, a 3.84-kc signal is generated by an oven-controlled crystal oscillator. It is counted down by a binary counter chain to produce a 60-cps reference, which in turn amplitude-modulates a 17-kc carrier. The modulated carrier is recorded on the tape together with the data.

During reproduction the carrier is demodulated, the 60 cps recovered and compared with the original reference signal. If there is a difference in frequency, a dc correction voltage is sent to the capstan-speed control. Since the capstan motor is a dc shunt one, the correction signal controls the speed through a simple amplifier.

On some of the Mincom Division CV-100 Video Band Recorder-Reproducers the Cyclelock system is provided for the recording mode, too. The signal is taken from the flywheel on the back of the capstan and fed to the correction system to control speed variations during recording.

For further information on this tape speed servo system, turn to the Reader-Service Card and circle **101**.

Miniaturized Control Regulates DC Motor's Speed To Accuracy of 0.1%

THE SPEED of dc motors can now be regulated to a reported accuracy of 0.1 per cent by a new control unit that uses, in effect, pulse-width modulation. Previous methods of control, which varied either the voltage or current, achieved regulation accuracies of only 1 or 2 per cent. No change in speed is required to initiate correction by the new control unit.

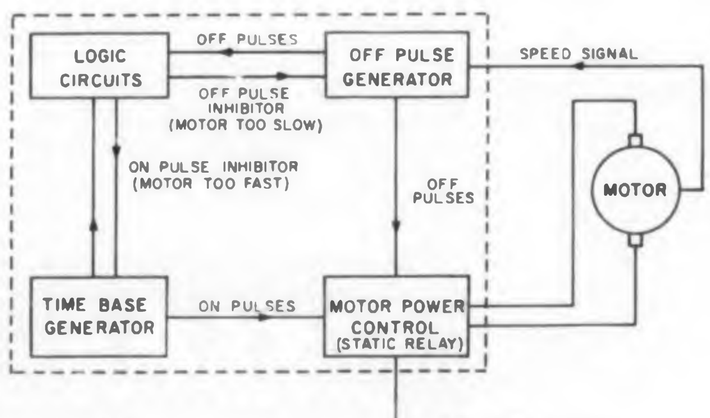
Unaffected by ambient temperature changes, vibration, shock, voltage and load fluctuations, the speed-control unit operates from the same power source that drives the motor. The device was designed by and is being manufactured by Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio

One version of the control is housed in a 2-cu-in. enclosure that includes a resistor-capacitor time base and a transistorized regulating circuit. Motor speed is sensed by an electrical transducer (such as a coil) in the motor. This pick-off transmits pulses having a frequency function exactly equal to armature speed. In a logic circuit these pulses are compared with the pulses generated by the time-base generator, and appropriate "off" or "on" signals are applied to the motor control. These integrated pulsed command signals are delivered at a high rate, on the order of 1000 per sec.

The motor remains in exact synchronism with the time base, and the only speed error is that introduced by the time base, according to the maker. The amplitude, duration or wave shape of the command pulses caused by various conditions are said to introduce no error into this system.

Since with this off-pulse-on-pulse technique the motor's speed is, in effect, locked onto the time base, the frequency generator is the main cost and accuracy variable.

When power is applied to the motor, it develops its full starting and running torque characteristics until the precise instant that the specified speed is reached. Dc motors characteristically develop about five times more starting torque than similarly rated ac synchronous motors, and this extra torque is available for both starting and running overloads. The designer is thus offered a



Functional diagram of the dc motor speed control.

choice of improving torque for a given size of motor or of reducing the motor size while retaining the desired torque. And higher operating efficiencies are possible with the dc system, which is important in satellite and space vehicle applications.

Applications of this control unit include programing controls for missiles, satellites and space vehicles; controlling the memory drums of a computer in exact synchronism with one another and a time base; and controlling the driving motors on high-speed tape recorders, which would eliminate inaccuracies caused by ac motor slip.

The control permits synchronization of any number of dc motors from one time base. It also permits synchronizing any number of slave motors to a master dc motor without the use of a time base.

Development is under way on a compact crystal-controlled oscillator that will have accuracies measurable in parts per million. This unit is presently housed separately from the control circuit in a 5-cu-in. enclosure.

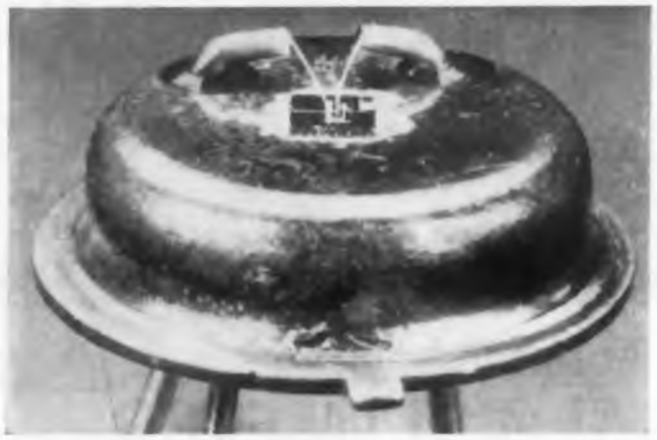
A number of the control units are being released on an experimental basis, while development of the principle continues. Each new application is engineered specifically for the job and necessitates several months of lead time. The techniques at present are not a substitute for applications adequately handled by other controls, primarily for economic reasons.

For more information on this control unit, turn to the Reader-Service card and circle number **102**.

A 1.25-in. diam. permanent magnet motor fitted with a resistor-capacitor time base and motor control.

NEW PRODUCTS

Covering all new products that might generally be specified by an electronics engineer engaged in the design of original equipment.



Silicon Transistors Have Gain Of 6 At 20 Mc 629

Types 2N696 and 2N697 diffused-junction, drift-field, npn mesa transistors have a minimum gain of 6 or more at 20 mc and high currents. Both units are designed for use in high-speed switching applications. The 2N697 has a dc pulse current gain that is a minimum of 40 and a maximum of 120; minimum and maximum gains for the 2N696 are 20 and 60. Total power dissipation of the units is 2 w at 25 C. They have a maximum collector-base voltage of 60 v, collector-emitter voltage of 40 v, and an emitter-base voltage of 5 v.

Hoffman Electronics Corp., Dept. ED, 3761 S. Hill St., Los Angeles 7, Calif.

Price & Availability: *Both units cost $28.50 each in quantities of from 1 to 99 units, $19 each in quantities of 100 to 999 units. Availability data on request.*

Price and Availability

PRICE AND AVAILABILITY data is now being added, whenever possible, to the New Product descriptions that appear in *ELECTRONIC DESIGN*. This data will help you to:

—Evaluate the products more intelligently.

—Decide which products to buy now and which to wait for.

—Schedule your orders wisely.

—Get an insight into prices and savings for similar products.

Most manufacturers have been very cooperative in providing us with *Price* and *Availability* data. Since some of the data arrived after our deadlines, it was impossible to add it to all of the products. The data represents the latest information at the time of publication.

Weight And Size Of Transistor Reduced 630

These power transistors are said to be half the size and weight of present standard components. Called Spacesavers, they are adaptable to a wide variety of mounting requirements. The units come in eight 3-amp switching types with breakdown voltages of 40, 60, 80 and 100. Direct current gain ranges from 30 to 75 and 60 to 150, and frequency responses are up to 10 and 15 kc. Leakage current at 90 C is 10 ma.

Clevite Transistor Products, Dept. ED, Waltham 54, Mass.

Price & Availability: *Price on request. Most units are readily available.*

Miniature Drum Counter 631 Is Reversible

Model 3523 four-digit reversible counter has 1/8-in. high numbers and drums that measure 0.46 in. The gears are molded of impact-resistant thermoplastic. Although furnished with a mounting bracket, the lugs may be clipped off and two screws used in the base for mounting. The dimensions of this package would be 1/2 in. wide and 5/8 in. long, not including the length of the drive shaft. Height is 11/16 in.

Haydon Instrument Co., Dept. ED, 165 West Liberty St., Waterbury 20, Conn.

Price & Availability: *List price is $4.80 with quantity discounts up to 50%. Availability data on request.*

Tunnel Diode Samples 632 Made Available

These tunnel diodes have peak-to-valley ratios ranging from 3 to 1 to 10 to 1. Peak currents range from 2 to 4 ma, average. They are packaged in JETEC 30 envelopes. Typical negative resistance is 35 ohms. At peak current, typical voltage is 50 mv; typical voltage at valley current is 200 mv. The maximum power dissipation is 20 mw. Three or four types will be made available.

General Transistor Corp., Dept. ED, Jamaica, L.I., N.Y.

Price & Availability: *Only engineering samples are available. Price on request.*

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 1, No. 9

NEW RAYTHEON MAGNETRONS FOR A WIDE RANGE OF APPLICATIONS

Designed for C-band systems requiring tunability, the RK-7156 magnetron has a minimum peak power output rating of 250 kilowatts over a frequency range of 5,450 to 5,825 megacycles. Applications include a flight-tested, revolutionary airborne weather radar system. The RK-7156 is in quantity production.

CIRCLE 832 Reader Service Card

RK-7156

* * *

X-band magnetron for airborne search radar provides one megawatt minimum peak power and 875 watts average power within a frequency range of 9,340 to 9,440 Mc. Designated QK-624, this pulsed-type tube is liquid cooled and should give at least 1,000 hours of reliable service.

CIRCLE 833 Reader Service Card

QK-624

* * *

For ground-based and airborne radar systems, the RK-7529 magnetron provides a 2.0 microsecond pulse of 3.5 megawatts minimum peak power over 2,700 to 2,850 Mc. This liquid-cooled tube is interchangeable with other fixed-frequency S-band tubes operating at similar power levels.

CIRCLE 834 Reader Service Card

RK-7529

* * *

A one kilowatt beacon magnetron, the RK-7578 weighs only 14 ozs., yet will withstand vibrations of 15 G's at 20 to 2,000 cycles and shock up to 100 G's. It is mechanically tunable and covers the 5,400 to 5,900 Mc range.

RK-7578

CIRCLE 835 Reader Service Card

* * *

Developed to withstand extreme environmental conditions, the RK-7449 magnetron is a lightweight, compact tube with a minimum peak power output of 45 kilowatts at the operating frequency of 24 kmc. The RK-7449 is required to withstand repeated shocks of 50G. Stable operation is guaranteed at vibration frequencies up to 2,000 c.p.s. with 30G applied.

RK-7449

CIRCLE 836 Reader Service Card

A Leader in Creative Microwave Technology RAYTHEON

NEW PRODUCTS

Precious Metal Paints 603

For electronic components

The Degussa line of precious metal paints and pastes, using silver, gold, and platinum, is for use in the manufacture of condensers, coils, capacitors, oscillators, and other electronic parts. They can also be used in high frequency applications. The coatings are solderable and can be electroplated.

Materials for Electronics, Inc., Dept. ED, 152-25 138th Ave., Jamaica 34, N.Y.

Transducer 619

Operates analog-to-digital encoders

This Dyna-Servo transducer converts various measurements into a shaft position for operating analog-to-digital encoders, transmitting slidewires, alarm switches, and other devices. A pointer positioned by the shaft indicates the measured variable on a 3.75-in. dial. Readout is any function of the measured variable, as determined by the type of cam used in the rebalancing system. Standard accuracy of the unit is ±0.25% of span.

The Bristol Co., Dept. ED, Waterbury 20, Conn.

Price & Availability: *Information stated on request.*

Ultrasonic Degreaser 616

Measures 44 x 18 x 36 in.

Model AC-25 ultrasonic degreaser is self-contained in a stainless-steel cabinet and measures 44 x 18 x 36 in. Using only water and a 110-v, 60-cps connection, the unit removes metal chips, grease, and certain insoluble soils from intricate parts. Components such as small motors, electronic subassemblies, and bearings can be cleaned without dismantling.

Branson Ultrasonic Corp., Dept. ED, 40 Brown House Road, Stamford, Conn.

Price & Availability: *Delivery within 30 to 45 days after receipt of order. Price is $1980 per unit.*

Transistors 604

Silicon-alloy types

Types 2N327A, 2N328A, and 2N329A transistors are general-purpose silicon-alloy units. Series 2N1034 to 2N1037 and 2N1219 to 2N1223 are also silicon units. High-voltage transistors, type 2N1275 and several 60 and 100-v devices, have been added to the line. All transistors are baked at 200 C for 200 hr for thermal stability.

Sperry Rand Corp., Sperry Semiconductor Div., Dept. ED, South Norwalk, Conn.

Capacitors 615

Flat and round paper-dielectric type

Designated MF for flats, and MR for rounds, these paper-dielectric capacitors come in values from 0.00005 to 10 μf. The flats include units from 3/8 x 1/16 x 1/8 in. to larger sizes. Dimensions for the rounds include units from 3/8 in. in length and 1/8 in. in diam. Operating temperatures range from −55 to +100 C, without derating. Working voltages are from 75 to 1000 v.

Capcon, Inc., Dept. ED, 61 Stanton St., New York 2, N.Y.

Price & Availability: *Sample and small quantities available from stock; larger quantities made to order and delivered within 2 to 3 weeks. Prices vary from $34 to $125 when ordered in quantities of 1000.*

Motor Generator 612

For remote control servo systems

Engineered to operate as a damping tachometer, a rate generator, or an integrator, this 60-cps motor generator, type V842-001, has applications in servo systems used for remote control. Generator excitation current measured at stall is 0.025 amp. No-load speed is 2800 rpm, and stall torque is 3.4 oz-in.

Kearfott Co., Inc., Dept. ED, 1500 Main Ave., Clifton, N.J.

Price & Availability: *Delivery and price data furnished on request.*

Transistor Chopper Kit 591

Plug-in type

This transistor chopper kit contains models 50P, 60P, and 70P plug-in choppers. These choppers can be inserted into a standard 7-pin miniature socket or can be soldered into a printed circuit board. They are made to alternately connect and disconnect a load to a signal source; they can also be used as demodulators to convert an ac signal to dc. Models 50P and 60P are germanium units for operation from —55 to +90 C; model 70P uses silicon transistors for high temperature applications to 150 C. Able to stand shock and vibration, the unit is suitable for military use.

Solid State Electronics Co., Dept. ED, 15321 Rayen Street, Sepulveda, Calif.

Price & Availability: *As an introductory offer, the price is $199; regular price is $232. Units are available from stock and can be delivered three days after receipt of order.*

Multiplier-Divider 586

For use with an analog computer

Model MU-500E 350-kc multiplier-divider is for use with a compressed-time-scale analog computer. Solution time is less than 2 μsec and phase shift is 1 deg at 12 kc. Time lag, phase shift, and amplitude attenuation are zero for nearly all control and process simulation. Accuracy is 0.25% full scale and the output range is ±50 v at ±10 ma.

GPS Instrument Co., Inc., Dept. ED, 180 Needham St., Newton 64, Mass.

Price & Availability: *Information will be furnished on request.*

Remote Tuned Signal Source 592

Frequency range is 50 to 2000 mc

Made to provide a source of remotely tunable rf power for antenna pattern ranges, model SS 305 signal source covers the frequency range of 50 to 2000 mc, calibrated to an accuracy of ±2%. It is designed for remote tuning, control, and band switching at distances of more than a mile. The minimum rf output is 80 mw across an impedance of 50 ohms; the output can be sine or square-wave modulated. The instrument weighs 105 lb and can be mounted on standard 19-in. rack panels.

Scientific-Atlanta, Inc., Dept. ED, 2162 Piedmont Rd., N.E., Atlanta 9, Ga.

Price & Availability: *Price is $3850. The unit will be available from stock by February 15. Delivery time is 30 days.*

Servo Control Valve 623

For go/no-go check-out systems

This servo control valve is a component for go/no-go check out systems. Designed for field use, the unit is readily adaptable to applications requiring constant control of pressure at predetermined check points. The servo valve, used with a transducer for the necessary pressure ranges, plus an amplifier can be used for check-out of pressure sensitive devices on missile or airframes automatically.

Ideal-Aerosmith, Inc., Dept. ED, 3913 Evans Ave., Cheyenne, Wyo.

Low-Pass Filter 628

Handles up to 2 kw

Model FS-23L, 13-element, low-pass filter has a 1-db down frequency of 2300 mc and a power handling capacity of up to 2 kw peak. The maximum insertion loss is 0.5 db in the pass-band; the input vswr is 1.5:1 below 0.1 db. The design is compact.

Frequency Standards, Div. of Harvard Industries, Inc., Dept. ED, P.O. Box 190, Red Bank, N.J.

592

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NEW PRODUCTS

Ceramic Components 620

Three types available

Among the ceramic components available are: ceramic-to-metal seals for use in connectors, headers and other electronic components; piezoelectric transducers for converting mechanical energy to electrical energy, or vice versa, in a wide variety of applications; and small parts that serve as insulators for high-temperature applications, in tubes or flame watcher, or as rigid mountings and spacers.

Minneapolis-Honeywell Ceramics Laboratory, Dept. ED, 1885 Douglas Drive, Minneapolis 22, Minn.

Price & Availability: *Made on order only. Sample lots delivered in 30 days after order received. Price varies depending upon individual specifications.*

Electronic Commutator 609

500 times faster than mechanical switches

This miniaturized switching device consists entirely of electronic circuits and is capable of operating more than 500 times faster than mechanical switches. For space exploration, the static commutator will consecutively open and close 60 different channels between sensing devices in a missile and the missile's radio transmitter.

Electronic Systems Development Corp., Dept. ED, 2200 Pacific Highway, San Diego 12, Calif.

Rotary Switch 614

For low-power selector use

Type 212 rotary switch has a body diameter of 1-1/8 in. and is designed for low-power selector applications. Terminals are firmly molded into the housing and cannot turn or twist out of place. Laminated coin silver contacts provide reliable contact life for a minimum of 100,000 cycles through 12 positions without appreciable increase in contact resistance.

Trolex Corp., Dept. ED, McHenry, Ill.

Price & Availability: *Delivery is about 3 to 4 weeks from receipt of order. Price based upon quantity and design requirements.*

Magnetic Shields 618

Are slotted, overlapping cylinders

These cylindrical enclosures provide low-level shielding for magnetically sensitive devices in electronic circuits. Slots in the cylinder walls permit simple assembly and facilitate bringing out leads. Maximum shielding from a minimum number of layers is obtained by the overlapping of the cylinder walls and butting joint covers. The Netic Co-Netic alloys are insensitive to shock and vibration and need no periodic annealing to maintain effectiveness.

Perfection Mica Co., Magnetic Shield Div., Dept. ED, 1322 N. Elston Ave., Chicago 22, Ill.

Price & Availability: *Many items available from stock. Others delivered 5 to 7 weeks after receipt of order. Price varies from $9 to $50 per unit. Discounts given for large quantity orders.*

Vertical Gyro 613

Has 360-deg freedom about outer gimbal axis

This B2115 vertical gyro is a 2-deg of freedom instrument with 360 deg of freedom about the outer gimbal axis and ±85 deg freedom about the inner axis. Normal erection rate is between 2 and 4 deg per min. The Scorsby drift rate in 5 min is 0.3 deg per min avg. Designed for missile environments, the gyro can withstand 5 g at 20 to 1000 cps, and 10 g at 1000 to 2000 cps.

Kearfott Co., Inc., Dept. ED, 1500 Main Ave., Clifton, N.J.

Price & Availability: *Delivery and price data furnished on request.*

Disc Thermistor 617

Has matched resistance within ±5%

Previously made only to order, type 34D4 disc thermistor is now available as a stock item. Its resistance is matched to a nominal resistance versus temperature curve within ±5%. Resistance ranges from 13,096 ohms ±5% at 0 C to 270 ohms ±5% at 100 C. The unit is suitable for applications in temperature compensation or temperature measurement.

Victory Engineering Corp., Dept. ED, 519 Springfield Road, Union, N.J.

Price & Availability: Delivery is 4 weeks after order received. Price is $4.20 per unit.

Receiving Tubes 611

5 types for TV available

Five receiving tubes for TV use include: type 10DR7, a T6-1/2 double triode; type 10EG7, a T9 double triode; types 6GN8 and 8GN8, each of which incorporates a high-mu triode and a sharp cutoff pentode in a T6-1/2 envelope; and type 12BZ6, a T5-1/2 semi-remote cut-off pentode.

Sylvania Electronic Tube Div. of Sylvania Electric Products Inc., Dept. ED, 730 Third Ave., New York 17, N.Y.

Silicon Transistor 621

For industrial control applications

Suitable for industrial controls, type CK942 pnp fusion alloy silicon transistor offers 1-μa collector cutoff current, 250-mw power dissipation, and close parameter control over the temperature range of −65 to +160 C. Intended primarily for use in high-temperature audio, switching and dc-amplifier circuits, the unit features a low saturation voltage and good current gain at collector current levels at 50 ma.

Raytheon Co., Semiconductor Div., Dept. ED, 215 First Ave., Needham Heights, Mass.

CIRCLE 818 TO 826 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Transistor Tester 593

Covers a beta range of 0 to 200

Model 902 transistor tester covers a beta range of 0 to 200; I_{CBO} is from 0 to 50 μa, and I_{CEO} is from 0 to 5 ma. Battery operated, the instrument performs tests at a constant collector voltage of 6 v. Designed to meet laboratory as well as production requirements, it is completely self-contained and incorporates a 50-μa meter for direct reading of current. All functions are controlled by two switches.

Transistor Specialties, Inc., Dept. ED, Terminal Drive, Plainview, L.I., N.Y.

Price & Availability: *Price is $49.75. Delivery is in 15 days.*

Silver-Zinc Battery 589

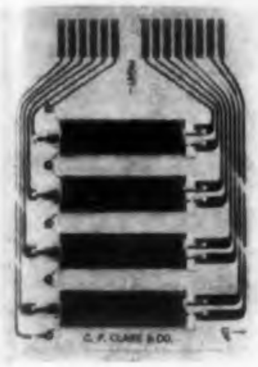
For telemetering use in missiles

Suitable for telemetering use in missiles, model 6173 silver-zinc battery has 19 15-amp-hr cells for high voltage and 5 10-amp-hr cells for filament power. When discharged at the 7-min rate, the sections yield 90 and 60 amp, respectively. At 30 min, the sections offer 30 and 20 amp respectively. Normal discharge voltages are 28.5 and 7.5 v. Operating temperature range is 0 to 100 F, shelf life is 2 yr, and the battery can be recharged 20 times. It weighs 23 lb and measures 5.5 x 7.5 x 8 in.

Yardney Electric Corp., Dept. ED, 40-50 Leonard St., New York, N.Y.

Price & Availability: *Price is furnished on request; delivery is within 30 days.*

Mercury-Wetted Relays 595



For printed circuits

The design of this assembly permits single or multiple installation of mercury-wetted contact relays in a printed circuit board. It plugs into a console in the same manner as the logic circuit it serves. Individual switch capsules and coils are affixed to the printed circuit board and sealed by the application of a vinyl coating.

C. P. Clare & Co., Dept. ED, 3101 Pratt Blvd., Chicago 45, Ill.

Price & Availability: *Units are made on order; price will be quoted on request.*

Fan 625

Delivers 550 cfm

Model 1PB95W propeller fan delivers 550 cfm at a low db rating. It is powered by a continuous duty 115 v, 60 cps, single-phase, shaded pole motor. The motor has a stainless-steel shaft, is corrosive resistant and fungus protected, and is finned to give adequate cooling surface under operation at 50 cps. The propeller is a deep pitch blade protected by a heavy nickel-chrome guard. All hardware is stainless-steel or cadmium-plated. The fan can be used in electronic racks, mobile or stationary generators, military vans, and field vehicles.

McLean Engineering Laboratories, Dept. ED, Princeton, N.J.

Price & Availability: *Units are immediately available from stock at the price of $33.50 ea in quantities of 1 to 49. There are lower prices for larger quantities.*

Pot Cores 626

For pulse transformers

Type 332P pot cores, for pulse transformers and similar applications, meet most assembly and mounting requirements. Having a 3/8-in. diameter, they are available in several varieties. One type accepts a No. 1 screw.

Ferroxcube Corp. of America, Dept. ED, Saugerties, N.Y.

Price & Availability: *The product is immediately available from stock. Price is $0.40 ea for up to 50 pieces.*

NEW PRODUCTS

Pressure Transducer 601

Diaphragm is flush-mounted

Available in pressure ranges from 0-100 to 5000 psi, gage and absolute, type 4-327 transducer has the pressure-sensitive diaphragm flush-mounted. Provision is made for adjustment of bridge balance, temperature compensation, and sensitivity external to the unbonded strain gage sensing element. It may be used in missile test stands, aircraft and missile engine test cells, and nuclear reactors.

Consolidated Electrodynamics Corp., Transducer Div., Dept. ED, 360 Sierra Madre Villa, Pasadena, Calif.

Price & Availability: Available from stock. Price quoted on request.

Miniature Telescoping Universal Joint 624

Backlash is zero

The design of this miniature telescoping universal joint, called Mini-Joint, assures no backlash for the entire assembly. Its applications are in magnetron and klystron drives, servo drives, and wherever precise transmission of information is necessary. Standard assemblies have 0.25 in. lateral travel. Torque ratings of 16, 64, and 256 oz-in. are available.

Falcon Machine & Tool Co., Dept. ED, 209 Concord Turnpike, Cambridge, Mass.

Microwave Diode 627

Crystal noise figure is 13 db max

Type 1N2792 millimeter wave diode gives low noise mixer performance at 70,000 mc. The crystal noise figure is a maximum of 13 db. Primarily developed for radar and space communications applications, it is also suitable for video detector uses.

Philco Corp., Dept. ED, 4700 Wissahickon, Philadelphia, Pa.

Price & Availability: *Price is $250 ea for orders of 1 to 99 and $166.66 ea for orders of 100 and over. There is currently a delivery time of 35 to 40 days. Units will be available from stock after March 1, 1960.*

Silicon Solar Cells 427

Come in single units and shingle arrays

These silicon solar cells are available in a rectangular configuration, measuring 1 x 2 x 0.05 cm, both in single units and shingle arrays. Series N2009 provides a typical efficiency of 9% and a spectral emissivity of 0.7 at 4 microns wavelength illumination, 0.4 at 11 microns. They are capable of 22.5 mw output at 56.5 and 0.4 v per cell when operated under sunlight levels as found in near space. Series N2000 includes units of several other efficiency levels.

Texas Instruments Inc., Dept. ED, Box 312, Dallas, Tex.

Relay 426

Measures 2-7/32 x 1-3/32 in.

Engineered to operate on as little as 2 ma, the type 8 telephone relay is 2-7/32 in. long and 1-3/32 in. wide. The long coil construction of the relay permits the use of high resistance coils. It may be used in communication and military applications, as well as in a variety of data processing machines.

Phillips Control Corp., Dept. ED, 59-T W. Washington, Joliet, Ill.

Mechanical Integrator 431

Output torque is 1 oz-in. max

Model 031-2000 mechanical integrator has an output torque of 1 oz-in. max with a disc input torque (no load) of 0.33 oz-in. The unit weighs 6.5 oz and has a ball displacement of ±0.750 in. It may be used as a breadboard item, or as a component in computing systems.

M. Ten Bosch Inc., Dept. ED, Pleasantville, N.Y.

Price & Availability: Available about 6 weeks after order received. Price on request.

A UNIQUE FABRICATION PROCESS FOR THE HOFFMAN MESA TRANSISTOR

BY NORMAN GOLDEN
Vice-President,
Research and Development
Hoffman Electronics Corporation
Semiconductor Division

The Hoffman mesa transistor is a high-frequency, diffused-junction silicon semiconductor device, usable at temperatures well above the boiling point of water. The manufacturing method of this device is unique in that it uses exclusively photographic techniques for the precise registration of the contacts and mesa area.

Low-resistivity, n-type (negative electrons) silicon slices are carefully lapped and polished to a mirror finish, flat and parallel to four millionths of an inch. Then an extremely complex cleaning procedure is performed, involving the use of high-turbulence ultrasonic agitation with relatively low average power, but peaks of 500 watts. This removes all trace of contamination, yet does not mar the transistor finish. A total of 13 cleaning solutions is used in conjunction with the agitation to attain the required degree of micro-cleanliness and meet the specified Hoffman standard.

An oxide film only two millionths of an inch thick is grown on both surfaces by heating the silicon in wet oxygen at 2200° Fahrenheit. Then gallium is diffused through the oxide layer so that the material is converted from n-type to p-type (positive electrons) conductivity within 130 millionths of an inch.

A photo-sensitive coating is deposited on the silicon slice, and an image of the 260 emitters is photographically printed on the wafer. By means of acid treatment, the oxide film is removed from the strips where the emitters are to be, the photographic emulsion serving as a protection for the remainder of the slice.

A phosphorus diffusion follows, converting the un-oxidized portions of the silicon to n-type conductivity with an approximate depth of 100 millionths of an inch.

At this stage of the Hoffman process, we have made 260 tiny transistors on each slice. However, some of the most difficult problems still remain to be solved.

PHOTOGRAPHIC REGISTRATION

For example, aluminum emitter strips must be registered into each of the 260 diffused phosphorous regions. Here each of the emitter contacts on the evaporation mask is registered with a .001" tolerance to the emitter region. In addition, none of the base contacts may short into any of the emitter regions. Here again, the tolerance is a maximum of .001". The registration itself is done under demanding optical conditions since the process is photographic. The aluminum is evaporated through photographically developed holes. Illumination must be restricted in wavelength, short in duration, and low in intensity. However, the highest accuracy of registration is still required, despite the fact that the emitter diffused regions show up as having only slightly different reflectivity than the base silicon. The registration is done on an optical comparator under conditions of essentially monochromatic illumination. A special fixture is provided so that the operator may precisely register the slice to the mask and then lock the slice into position. This operation takes two to three minutes. The fixture is designed so that the locking procedure itself does not cause any motion of the slice with respect to the mask.

After the photographic image is imprinted on the emulsion, it is developed. Care must be taken at this stage so that no shrinkage of the emulsion occurs. The aluminum is now evaporated through the emulsion holes and thoroughly bonded to the silicon by means of a high-temperature process. When the slice is cooled, a single silicon crystal re-forms, with about one part per million aluminum held in solid solution. For the p-type base connection, this serves to make a sound, non-rectifying contact. In the case of the emitter region, there is much more phosphorus than aluminum in the silicon. Therefore, the recrystallized material remains strongly n-type after the alloying process despite the presence of the aluminum.

The mesa structures are now precisely registered to the base and emitter, and photographically printed onto each slice. This photographic emulsion protects the rectangular-shaped silicon mesa region from an acid solution attack, so that only one to two ten thousandths of an inch of silicon is removed around the entire periphery of the slice except in the vicinity of the emitter and base. Thus, a raised mesa structure has been produced.

FINAL ASSEMBLY

A scribing machine, designed by Hoffman, with essentially zero backlash, accurately positions the slices, and a series of scratches is made by a diamond point. The scratches divide the slices into small (.050" x .050") squares which have the actual transistor structures on them.

The individual units must now be alloyed onto the gold-plated bases which have the necessary seals for bringing the emitter, base and collector wires through glass insulators into the package. The reliable operation of these devices requires that the glass and the metal base form a perfect seal.

Fastening of wires onto the extremely tiny emitter and base aluminum strips is now performed. Because of the minuteness of the units, this operation is conducted under a special microscope. In order to locate initially the approximate positions of the bonding chisel, transistor structure and gold wire, it is necessary to work at low magnification. However, the bonding operation itself requires high magnification. To avoid the necessity of refocusing, a stereoscopic zoom microscope is used. The base and transistor are heated to approximately 750°F and a tiny, chisel-pointed tool squeezes a fine (.0007") pure gold wire into the aluminum. This process produces an exceptionally strong bond. In fact, tests have suggested that the bond will stand acceleration in excess of 20,000 g.

Once the gold wires are fastened to the terminal posts on the base, a short acid treatment and a thorough wash are required as a final cleaning operation.

Hoffman then "pre-ages" the transistors by baking them in a high vacuum at about 300°C. The units are never again exposed to room air. They are next transferred into a chamber filled with extremely pure nitrogen. Caps are welded onto the bases, so that the units are completely sealed against contamination.

Circle 57 on Reader-Service Card

NEW PRODUCTS

Variable High Pass Filter 415

Works with impedances from 4 to 16 ohms

Model VC-213 variable high-pass filter is designed to allow accurate balance of volume between the woofer and tweeter with only one control. A combination cross-over and level control, it works with any impedance from 4 to 16 ohms. It measures 4 x 2-5/6 x 1-5/8 in. No soldering is needed.

Olson Radio Corp., Dept. ED, 260 S. Forge St., Akron, Ohio.

Transducer 423

7 pressure ranges available

Type 4-332 transducer is available in 7 pressure ranges from 0-1-1/2 to 0-150 psi differential. Output is ±100 v full scale, and the combined effects of linearity and hysteresis are less than 0.05%. The transducer can be downranged to 10% of its rated pressure without loss of accuracy and still provide ±10 v at this range. Dimensions are 4 x 3 x 2-1/2 in., and the weight is 2.6 lb.

Consolidated Electrodynamics, Dept. ED, 360 Sierra Madre Villa, Pasadena, Calif.

Price & Availability: Quoted on request.

Switches 424

Produce a single, square-wave pulse

Available in 6 pre-engineered, potted circuit packages, these switches have a circuit that produces a single, square-wave pulse with widths of 0.1 to 10 μsec. They can drive loads as low as 5 ohms and can deliver output voltages up to 180 v. Uses include computer and radar consoles, data link, setting and resetting flip-flops, and reflected pulse systems.

Micro Switch, Dept. ED, Freeport, Ill.

Price & Availability: Standard assemblies are available immediately. Prices range from $9.50 to $13.6? for ED series.

◀ CIRCLE 58 ON READER-SERVICE CARD

CIRCLE 300 ON READER-SERVICE CARD ▶

Ceramic Disc Capacitors 561

Low voltage type

Type H miniature ceramic disc capacitors are designed to meet the low voltage requirements of transistorized radios, portable wire and tape recorders, electronic timing devices, and other miniature battery-powered or line-powered equipment. Excellent for bypass and coupling, they are offered in these sizes: 0.35 in. in diam x 1/8 in. thick, 0.5 x 1/8 in., and 0.625 x 1/8 or 3/16 in. Phenolic coating and high-temperature wax vacuum impregnation are used. Operating range is +10 to +85 C; working voltage is 50 v dc.

Cornell-Dubilier Electric Corp., Dept. ED, S. Plainfield, N.J.

Price & Availability: *Units can be immediately furnished in production quantities; price is quoted on request.*

Ultrasonic Delay Line 553

Delay time is 5 to 12,000 µsec

Made to launch and propagate acoustic waves along a wire transmission media, the U.D. series of ultrasonic delay lines offer a range of delay times from 5 to 12,000 µsec. The temperature coefficient is 5 ppm per deg C over the range of —55 to +100 C. The center frequency ranges from 100 kc to 1.2 mc with a maximum bandwidth of 1 mc. The unit can be used with a carrier frequency or without, for pulsed operation. It has a wide range of input and output impedances to allow for optimum impedance matching. It meets military requirements for vibration and shock; both standard and custom designs can be furnished for such applications as computer bit storage, coders, decoders, telemetering systems, radar simulators, missiles, and aircraft.

Curtiss-Wright Corp., Electronics Div., Dept. ED, 620 Passaic Ave., W. Caldwell, N.J.

Price & Availability: *The price range is $99 to $1500 for one unit. Made on order only, it can be delivered 4 to 8 weeks after receipt of order.*

◀ CIRCLE 300 ON READER-SERVICE CARD

CIRCLE 59 ON READER-SERVICE CARD ▶

NEW PRODUCTS

Time Delay Relay 551

Preset delays are 10 to 180 sec

Developed to meet the reliability requirements of airborne, missile, and space vehicle applications, the STR series time delay relay has a preset time delay of 10 to 180 sec. It offers ambient temperature and voltage compensation. Contacts are instantaneous resetting, isolated load, spdt type. The uses include automatic reset on digital read-out equipment, computer sequencing as well as sequential timing and overload protection.

Curtiss-Wright Corp., Electronics Div., 620 Passaic Ave., W. Caldwell, N.J.

Price & Availability: *The price is $52.50 ea for a single order; in quantities of 1 to 9, $50. Reductions are made for larger orders. Delivery time is 4 to 6 weeks.*

Spray Gun 571

For cathode coating

Coatings of any material which can be melted without decomposing can be applied with this plasma flame spray gun. In electronic applications, cathodes have been successfully coated. The control unit provides all necessary adjustments with complete push button operation and control.

Metallizing Engineering Co., Inc., Dept. ED, 1101 Prospect Ave., Westbury, Long Island, N.Y.

Price & Availability: *Available by April. Price of complete assembly is $10,500.*

Terminals and Clips 575

Many types available

A wide variety of spring and fuse clips and lock washer terminals are offered. The lock washer terminals are manufactured with No. 4, 6, and 8 holes with 0.018 brass or phosphor bronze, hot tinned.

Zieric Manufacturing Corp., Dept. ED, 110 Beechwood Ave., New Rochelle, N.Y.

◄ CIRCLE 60 ON READER-SERVICE CARD

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CARD

FM Basic Tuner Assembly 573

For use in original equipment

For use in original equipment, type 579 fm basic tuner assembly has a tuned rf stage for good image rejection, stable permeability tuning, and dual limiters providing maximum noise control. The oscillator stage is completely shielded to maintain radiation well below FCC requirements. A six-tube unit, it has a tuning range of 86 to 110 mc. Typical sensitivity is 1 μv for 20-db quieting and 2.1 μv for 30-db quieting. The typical selectivity is 200 kc at 6 db, the frequency response is 15 to 25,000 cps, and the distortion is less than 0.5% at the 2-v output. The oscillator stage is shielded, maintaining radiation well below FCC requirements. Completely fabricated, the unit is furnished with all critical circuits assembled and aligned.

J. W. Miller Co., Dept. ED, 5917 S. Main St., Los Angeles 3, Calif.

Shock Machine 565

For production and lab testing

Type 16750 shock machine is designed for production and laboratory testing of small electronic, electromechanical, and mechanical components. It accommodates test specimens weighing up to 20 lb and occupying an 8-in. cube. The unit, called Varipulse, stands 7 ft 3 in. high, and occupies a floor space 12 x 16 in.

Barry Controls Inc., Dept. ED, 700 Pleasant St., Watertown, Mass.

Transistor Pads 567

Tensile strength is 5500 psi

Molded of mineral filled diallylphthalate, which conforms to MIL-P-14 D (MDG type) and MIL-P-4389, these transistor pads have a nominal tensile strength of 5500 psi. They resist continuous exposure to 400 F, and offer high dielectric strength.

Delbert Blinn Co., Dept. ED, Box 757, Pomona, Calif.

CIRCLE 61 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Digital Voltmeter 455

Resolution is 0.01%

Designed for a wide range of dc measurement applications, model V64 voltmeter has 0.01% resolution, high input impedance, and an average measuring time of 0.75 sec per reading. Used with accessories, it can make ac and low-level dc measurements. Its range without accessories is in three steps: ±9.999, 99.99, and 500 v dc.

Non-Linear Systems, Inc., Dept. ED, Del Mar, Calif.

Price & Availability: *After February 15, units will be available from stock at the price of $825.*

Temperature Transducers 449

Stand 5000 psi

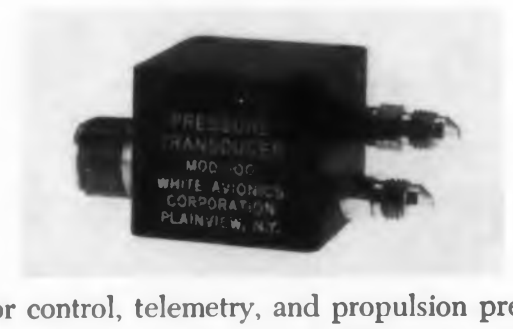
Able to stand an operating pressure of 5000 psi, type BA-9 temperature transducers have a resistance range of 50 to 5000 ohms at 77 F ±4%. Response is 0.25 sec in fluid and repeatability is 0.5%. They can be supplied with a Balco element, or with platinum or tungsten.

Transducer Labs., Dept. ED, Glenwood Springs, Colo.

Price & Availability: *$102; delivery is in 10 days.*

Pressure Transducers 465

Stands 50 g at 3 kc



For control, telemetry, and propulsion pressure measurement systems, model 100 pressure transducer stands 50 g at 3 kc. A potentiometric output type transducer, it yields infinite resolution. It is available for pressure ranges of between 0 and 15 psi and between 0 and 300 psi for corrosive and non-corrosive liquids and gases. It measures 1-1/2 x 1-1/2 x 1-1/4 in. and weighs 6 oz or less.

White Avionics Corp., Dept. ED, Terminal Rd., Plainview, L.I., N.Y.

Position Encoder 359

Gives data in 17-digit cyclic binary code

Type RD-17 photoelectric shaft-position encoder gives angular position data in 17-digit cyclic binary code with ±1 digit accuracy. The 17-digit accuracy for 1 shaft revolution is obtained in unambiguous form without the use of gears. Designed to meet applicable portions of MIL-E-4158B, the 26-lb, 10-in. diam unit includes power supplies, amplifiers and control electronics. Solid or hollow shaft models are available.

Wayne-George Corp., Dept. ED, 588 Commonwealth Ave., Boston 15, Mass.

Precision Brake 370

For fhp motors

Designed for fhp motors, this precision brake is useful in computer mechanisms, tape transports, and other mechanisms where positive stop is necessary. Braking torque is 2 to 4 lb/in. for shafts to 3/8 in. All parts, including the brake band, are made with special dies to eliminate variations in braking power. A constant duty solenoid is furnished for connection in parallel with the motor. Without load the motor is stopped in less than 1/4 revolution.

Midwest Automatic Control Co., Dept. ED, 510 Third St., Des Moines 9, Iowa.

NEW PRODUCTS

Decade Transformer 461

Has an accuracy of better than 0.001%

Developed to certify differential transformer displacement, model DRT-5 ratio transformer has a ratio accuracy of better than 0.001%. The resolution is 0.00001, the output impedance is less than 8 ohms and the input impedance is 15,000 ohms at 400 cps. The frequency range is 50 to 10,000 cps and the phase shift is negligible. The instrument is suitable for the calibration of ac meters, ratio boxes, attenuators, amplifiers, and transformers. It can also be used as a bridge circuit ratio arm or a variable ac voltage supply.

G. L. Collins Corp., Dept. ED, 2820 E. Hullett St., Long Beach 5, Calif.

Time Delay Switch 459

Handles up to 50 amp

This time delay switch handles up to 50 amp without arcing, contact damage, radio interference, audible noise, or vibration. Completely solid state, it has no moving parts and weighs 3 oz. Three types are offered: the light duty series with ratings up to 10 amp, the medium duty series with ratings to 16 amp, and the heavy duty series, with ratings to 32 and 50 amp. The maximum current required is 50 ma and the standard operating voltages are 24 and 31 v dc. The switch contains all hermetically sealed components and the entire unit is hermetically sealed in epoxy resin in an anodized aluminum case. Case dimensions are 1.25 in. in diam and 2 in. in length. The switch meets applicable parts of MIL-R-5757C, MIL-R-6106A, and MIL-R-25018.

George Harmon Co., Dept. ED, 18232 Parthenia, Northridge, Calif.

for

IMMEDIATE DELIVERY

of

ELMENCO

capacitors

IN QUANTITIES UP TO 500 PER ITEM
CONTACT THESE AUTHORIZED ELMENCO DISTRIBUTORS

The authorized distributors listed below carry a full stock of all Elmenco Capacitors and can give you Immediate Delivery from stock.

ARIZONA: Radio Specialties & Appl. Corp., 917 N. 7th St., Phoenix; **Standard Radio Parts Inc.**, 218 N. First Ave.. Tucson.

CALIFORNIA: Brill Electronics, 610 East 10th St., Oakland 6; **Electronic Supply Corp.**, 2085 E. Foothill Blvd., Pasadena; **Federated Purchaser Inc.**, 11275 W. Olympic Blvd., L. A. 64; **Hollywood Radio Supply Inc.**, 5606 Hollywood Blvd, Hollywood 28; **Pacific Wholesale Co.**, 1850 Mission St., San Francisco 3; **Peninsula Electronics**, 656 South 1st Street, San Jose; **Shelley Radio Co. Inc.**, 2008 Westwood Blvd., L. A. 25; **R. V Weatherford Co.**, 6921 San Fernando Rd., Glendale 1; **Zack Electronics**, 654 High St., Palo Alto.

COLORADO: Denver Electronics Supply Co., 1254 Arapahoe St., Denver 4.

DISTRICT OF COLUMBIA: Capitol Radio Wholesalers Inc., 2120 14 St., N.W., Wash., D. C.

ILLINOIS: Newark Electric Co., 223 W. Madison St., Chicago 6.

MARYLAND: Kann-Ellert Electronics Inc., Howard & Redwood Sts., Balt. 1.

MASSACHUSETTS: Cramer Electronics Inc., 811 Boylston St., Boston 16; **Radio Shack Corp.**, 730 Commonwealth Ave., Boston 17.

NEW JERSEY: Federated Purchaser Inc., 1021 U. S. Rte. 22, Mountainside; **Radio Elec. Service Co., Inc.**, 513 Cooper St., Camden 2.

NEW MEXICO: Midland Specialty Co., 1712 Lomas Bl. N.E., Albuquerque; **Radio Specialties Co., Inc.**, 209 Penn Ave., Alamagordo.

NEW YORK: Arrow Electronics Inc., 525 Jericho Turnpike, Mineola, L. I.; **Terminal Radio Inc.**, 85 Cortlandt St., New York 7.

PENNSYLVANIA: Almo Radio Co., 412 N. 6th St., Phila. 23; **Phila. Electronics Inc.**, 1225 Vine St., Phila. 7; **Radio Elec. Service Co., Inc.**, 701 Arch St., Phila. 6

TEXAS: All-State Distributing Co., 2411 Ross Ave., Dallas 1; **Busacker Elect. Equip. Co. Inc.**, 1216 West Clay, Houston 19; **Engineering Supply Co.**, 6000 Denton Drive, Dallas 35; **Midland Specialty Co.**, 500 W. Paisano Drive, El Paso.

WASHINGTON: C & G Radio Supply Co., 2221 Third Ave., Seattle.

CIRCLE 66 ON READER-SERVICE CARD

It could happen... with El-Menco CAPACITORS!

NEW *Mylar-Paper Dipped

CAPACITORS TYPE MPD

INSURE FAILURE-PROOF PERFORMANCE!

Only 1 Failure in 7,168,000 Unit-Hours for 0.1 MFD Capacitors

Setting a new standard of reliability!

*Life tests have proved that El-Menco Mylar-Paper Dipped Capacitors — tested at 100°C with rated voltage applied — have yielded a failure rate of only 1 per 716,800 unit-hours for 1 MFD. Since the number of unit-hours of these capacitors is inversely proportional to the capacitance, 0.1 MFD El-Menco Mylar-Paper Dipped Capacitors will yield ONLY 1 FAILURE IN 7,168,000 UNIT-HOURS.

SUPERIOR FEATURES!

- *Five case sizes in working voltages and ranges:*

200 WVDC —	.018 to .5 MFD
400 WVDC —	.0082 to .33 MFD
600 WVDC —	.0018 to .25 MFD
1000 WVDC —	.001 to .1 MMF
1600 WVDC —	.001 to .05 MFD

SPECIFICATIONS

- TOLERANCES: ±10% and ±20%. Closer tolerances available on request.
- INSULATION: Durez phenolic resin impregnated.
- LEADS: No. 20 B & S (.032") annealed copperweld crimped leads for printed circuit application.
- DIELECTRIC STRENGTH: 2 or 2½ times rated voltage, depending upon working voltage.
- INSULATION RESISTANCE AT 25°C: For .05MFD or less, 100,000 megohms minimum. Greater than .05 MFD, 5000 megohm-microfarads.
- INSULATION RESISTANCE AT 100°C: For .05MFD or less, 1400 megohms minimum. Greater than .05MFD, 70 megohm-microfarads.
- POWER FACTOR AT 25°C: 1.0% maximum at 1 KC.

Write for Technical Brochure Giving Complete Information on the El-Menco Tubular Dur-Paper Line.

THESE CAPACITORS WILL EXCEED ALL THE ELECTRICAL REQUIREMENTS OF E.I.A. SPECIFICATION RS-164 AND MILITARY SPECIFICATIONS #MIL-C-91A AND MIL-C-25A.

FOR FAILURE-PROOF PERFORMANCE . . . COUNT ON EL-MENCO MYLAR-PAPER DIPPED CAPACITORS . . . FROM MISSILE GUIDANCE SYSTEMS TO DATA PROCESSING EQUIPMENT!

*Registered Trade Mark of DuPont Co.

El-Menco *Capacitors*

THE ELECTRO MOTIVE MFG. CO., INC.

WILLIMANTIC CONNECTICUT

Manufacturers of El-Menco Capacitors

● molded mica ● dipped mica ● mica trimmer ● dipped paper ● tubular paper ● ceramic ● silvered mica films ● ceramic discs

Exclusive Supplier To Jobbers and Distributors in the U.S. and Canada
Arco Electronics, Inc., 64 White St., New York 13, N. Y.

CIRCLE 67 ON READER-SERVICE CARD

NEW PRODUCTS

Maser Amplifiers 572

For systems uses

These microwave maser amplifiers, for advanced systems applications, are particularly suitable for space vehicle communications and tracking, radio astronomy, and ground-to-ground communications. An amplifier noise temperature of less than 10 K is possible in the 1 to 15 kmc band with a gain of 20 to 30 db and a bandwidth of 5 to 30 mc. The large electromagnet of most previous masers has been replaced in this unit by a small permanent magnet. The addition of a second cavity to a conventional single-cavity maser increases the bandwidth to 18 mc when the over-all gain is 26 db.

Hughes Aircraft Co., Dept. ED, Florence Ave. and Teale St., Culver City, Calif.

DC Bridge 574

Sorts 5000 pieces per hr

Model AB-4-5 dc bridge can sort resistors into three groups automatically at the rate of 5000 pieces per hr. It operates with the following accuracies: from 10 to 100 ohms, ±0.3%; from 100 ohms to 2 meg, ±0.1%; from 2 to 10 meg, ±0.2%; and from 10 to 100 meg, ±0.3%. A built-in seven-dial resistance decade is set to the nominal value of resistance being checked. Tolerance limits for the three bins are set by plug-in units. Electromechanical counters show the number of pieces in each bin.

Industrial Instruments Automation Corp., Dept. ED, 89 Commerce Rd., Cedar Grove, Essex County, N.J.

Harness Board Posts 569

Made of nickel plated carbon steel

These nickel plated carbon steel posts are driven into the harness board as guides to permit rapid preassembly of wiring circuits. Stock sizes include 1/2, 3/4 and a heavier thickness in the 1-1/2 in. length.

Extra heavy duty sizes are also available.

John Hassall, Inc., Dept. ED, Cantiague Road, Westbury, Long Island, N.Y.

Price & Availability: *Available from stock. Special sizes quoted upon request. Typical price per 100 of 3/4 x 0.072 in. in quantities of 1000 is $2.75.*

Temperature Sensors 568

For temperatures to 500 F

Models S8A and S8B sensors provide sensing of temperatures to 500 F. Resistance is 676 ohms at 25 C and varies at a rate of 3.06 ohms per deg C at 25 C. Model S8B is self adhering. Model S8A is furnished with pressure sensitive installation tape, or can be cemented in place or held by mechanical means. Both type weigh less than 4 g and are calibrated within an accuracy of $\pm 1\%$.

Minco Products, Inc., Dept. ED, 740 Washington Ave. North, Minneapolis 1, Minn.

Price & Availability: *Immediate shipment from stock in quantities to 25. Prices range from $19.80 ea for 1 or 2 units, down to $11.90 ea in quantities from 51 to 100.*

Trimming Potentiometer 562

Withstands 100 g acceleration

Model 1W-STK trimming potentiometer withstands acceleration to 100 g, exceeding MIL-R-19, and shock to 50 g, exceeding NAS 710, Procedure III. Two to ten of these potentiometers can be stacked in a row, held together by a steel bolt and nut. They are furnished with longer than average leads. They operate over the temperature range of -55 to $+140$ C and are rated at 1.3 w at 40 C. A 360-deg wiper maintains its setting. The inductive reactance is not measurable at 100 kc. They exceed NAS 710 for impedance and can be sealed to meet MIL-E-5272A.

Handley, Inc., Dept. ED, 2030 Colorado Ave., Santa Monica, Calif.

NEW PRODUCTS

Communication Filters — 436

With 21 channels

For use with multiplex systems, this line of standard-tone filters has 21 channels. The filters have high interchannel attenuation and flat pass band characteristics. They conform to Mil specs. Telemetering filters, from 400 to 70,000 cps, can also be furnished.

Torotel, Inc., Dept. ED, 5512 E. 110th St., Kansas City, Mo.

Price & Availability: *In quantities of 1 to 10, the standard-tone filters are priced at $45 ea and can be delivered in 10 days. For larger orders, price and delivery time will be quoted. Price and availability of the telemetering filters, made to customer specifications are also quoted on request.*

Transistorized Choppers — 463

Are plug-in type

Models 50P, 60P, and 70P plug-in transistorized choppers can be immediately inserted into a standard seven-pin miniature socket or can be soldered to a printed circuit board. They are designed to alternately connect and disconnect a load from a signal source, are capable of linearly switching or chopping voltages over a dynamic range from a fraction of a millivolt to 10 v, and may be used as demodulators to convert an ac signal to dc. They can be driven from dc to hundreds of kilocycles. Able to stand shock and vibration, they are suited to military, missile, and portable applications. Model 70P is recommended for high temperature uses.

Solid State Electronics Co., Dept. ED, 15321 Rayen St., Sepulveda, Calif,

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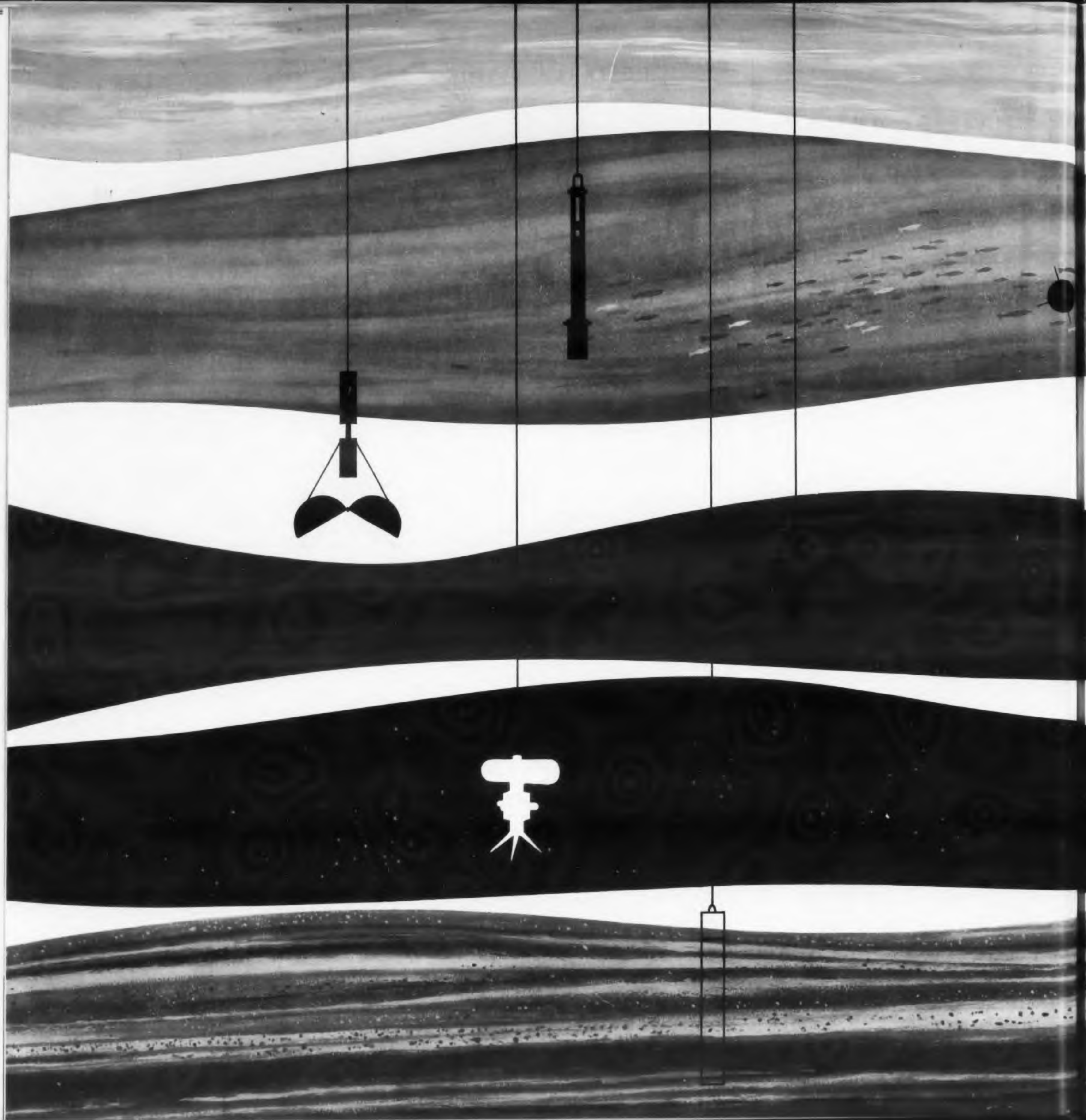
◀ CIRCLE 71 ON READER-SERVICE CARD

CIRCLE 72 ON READER-SERVICE CARD



◄ CIRCLE 920 ON CAREER INQUIRY FORM, PAGE 141

NEW PRODUCTS

Field Strength Meter 464

Measures pulse, cw, or modulated carriers

Intended for Loran and similar services, this hf-vhf field strength meter measures pulse, cw, or modulated carriers. Having the military designation of AN/PRM-21, the instrument operates from a 12-v battery or 115 v ac. A self-contained comparison pulse generator permits measurements of peak pulse field strength on the cathode-ray indicator. Identification of pulse rates is by means of an internally calibrated timing generator.

ITI Electronics, Inc., Dept. ED, 369 Lexington Ave., Clifton, N.J.

Price & Availability: *Both price and delivery time required are by quotation only.*

Free Gyros 448

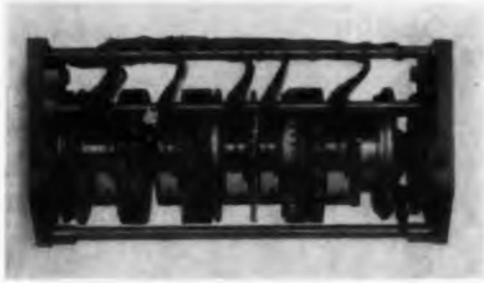
Operate in extreme environmental conditions

Models A2322-01 and A2311-04 free gyros are hermetically sealed and ruggedly constructed to operate in extreme environments. They stand 60 g of shock for 0.11 sec and 60 g vibration along any axis. Containing remotely operable caging and uncaging mechanisms, these units have 260-deg of gimbal freedom at the outer axes and ±85 deg of freedom at the inner axes. They can provide output signals of pitch, roll, or yaw. The operating temperature range is —65 to +185 F; the excitation is 115 v, 400 cps, three-phase; and the run-up time is within 1 min. Applications are in missiles and other vehicles requiring guidance or stabilization.

Kearfott Co., Inc., Dept. ED, 1500 Main Ave., Clifton, N.J.

Analog-to-Digital Converter 457

Direct reading type



This direct reading analog-to-digital converter displays time values in hours, minutes, and seconds. It transmits this information simultaneously as a coded electrical signal by means of coded drum assemblies and pick-off brushes. Step time is 40 msec max and 10 msec min. The brush load is 50 ma at 40 v dc. The operating pressure range is 14.7 to 0.55 psi. The unit has an operation life of 1000 hr and weighs 1.75 lb. It can be used for recording and simultaneous readout of continuous or interrupted industrial or aircraft procedures and processes, and generation of coded digital signals with equivalent visual numerical presentation.

Kearfott Co., Inc., Dept. ED, 1500 Main Ave., Clifton, N.J.

Price & Availability: *Price is furnished on request. Delivery time is from 60 to 90 days.*

Accelerometer Calibrator 451

Frequency range is 50 to 30,000 cps

Model 4290 calibration exciter vibrates accelerometers or other small vibration pick-ups at a constant test level over the frequency range of 50 to 30,000 cps. A small accelerometer acts as a monitor for servo regulations of the driving signal generator to obtain the constant level of vibration. Used with model 3301 response recorder, it automatically measures and plots an accelerometer frequency response calibration from 200 to 20,000 cps and indicates mounted resonance up to 50,000 cps.

B & K Instruments, Inc., Dept. ED, 3044 W. 106th St., Cleveland, Ohio.

Power Supplies 454

Come in recessed and table models

For industrial and laboratory applications where 115 v ac line voltage is available for input, these power supplies are for portable, recessed, or table top use. Models 187 and 189 provide 0 to 120 v ac at 1 amp, 0 to 12 v ac at 2 amp, and 0 to 12 v dc at 2 amp. Models 190 and 191 have the following outputs: 0 to 120 v ac at 3.5 amp, 0 to 10 v ac at 10 amp, 0 to 20 v ac at 5 amp, 0 to 6 v dc at 10 amp, and 0 to 15 v dc at 5 amp. All units also supply line voltage at 10 amp. Accessories can be furnished to increase the dc output to 0 to 300 v at 100 ma and reduce ripple to less than 1%.

Buck Engineering Co., Dept. ED, Marcy St., Freehold, N.J.

Price & Availability: *Models 187 and 189 are $79; models 190 and 191 are $139. They are available from stock.*

Germanium PNP Power Transistor 450

Maximum current rating is 5 amp

Germanium pnp power transistor type 2N1011 has a maximum current rating of 5 amp, a current gain range of 30 to 75 when I_c is 3 amp dc, and a maximum collector-base voltage rating of 80 v. It dissipates 35 w at 25 C, mounting base temperature. It meets environmental testing requirements. Suited for power switching and power control circuits, it can be used in aircraft power supplies, missiles, and communications power supplies. Other uses are high current switching and audio amplification. It meets the requirements of MIL-T-19500/67.

Bendix Aviation Corp., Red Bank Div., Dept. ED, Long Branch, N.J.

Price & Availability: *In quantities of 1 to 99, the price is $10.50 ea; 100 and up, $7. Delivery time is two weeks on commercial items. When military testing is required, delivery time will be quoted.*

TV Image Storage System 439

Provides instant recall

This TV image storage system, called Electrostore, stores a single frame of television at the touch of a button and makes the stored picture available for prolonged examination on a conventional monitor. The system records the signal in an electrostatic storage tube. The readout of the stored image, as well as the input, is a composite video having standard amplitude and polarity. The system has input and output video bandwidths of 8 mc. The over-all resolution exceeds that of conventional TV systems.

Image Instruments, Inc., Dept. ED, 2300 Washington St., Newton Lower Falls 62, Mass.

Voltage to Digital Converter 442

Linearity and accuracy are 0.01%

Model MTD-704 voltage-to-digital converter translates input analog voltages into four binary-coded decimal digits, plus sign and overflow digits. The input full scale range is ± 10 v dc with provision for an extended range of ± 12 v dc. Linearity and accuracy are rated at 0.01%. The maximum conversion rate is 5000 independent conversions per sec. A completely solid state unit, it meets the environmental requirements of MIL-E-4158B. Modular design is used. Applications are in automatic checkout systems, ground support equipment, and mobile data acquisition systems.

Epsco, Inc., Equipment Div., Dept. ED, 275 Massachusetts Ave., Cambridge, Mass.

Price & Availability: The price can be furnished on quotation only. Delivery time is about 60 days.

NEW PRODUCTS

Floated Rate Integrating Gyro 458

Linearity is 0.02%

Designed to be mounted directly on the frame of missiles or aircraft, model M2514-02 floated rate integrating gyro provides a linearity of 0.02% and an angular momentum of 250,000 gm cm^2 per sec. It can be used in place of a stable platform in some systems. It can be used in high speed aircraft or missile flights where severe environmental conditions are encountered.

Kearfott Co., Dept. ED, 1500 Main Ave., Clifton, N.J.

Price & Availability: *Prices will be furnished on request. Units are delivered in 60 to 90 days.*

Phase Detector 446

Measures from 200 to 1000 mc

Type 205B2 precision phase detector has an accuracy of ± 0.05 deg or $\pm 1\%$ from 200 to 1000 mc. Resolution is less than 0.01 μμsec. A phase angle of less than $10^{-14} \times 360 \times$ frequency can be read on the dial. The maximum input signal depends on the sensitivity of the receiver; it is about 20 μv for a receiver with a 5-μv sensitivity, and about 3 v min when the panel meter is used as an indicator. The impedance is a nominal 50 ohms for input and output. In addition to measuring phase angle between two sine waves, this instrument can be used to measure phase angle of a pulse-modulated or a continuous sine wave, or two pulse-modulated coincident sine waves.

Ad-Yu Electronics Lab., Inc., Dept. ED, 249-259 Terhune Ave., Passaic, N.J.

Price & Availability: *Price is $2235 fob Passaic. Delivery time is two weeks.*

NEW PRODUCTS

Cathode Ray Tube 443

For oscilloscope applications

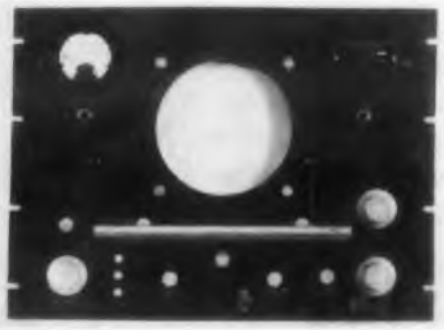
Having a 3-in. rectangular face-plate, type 3BDP cathode ray tube is for oscilloscope applications. An improved replacement for type 3SP, it has a pressed face-plate to minimize parallax errors and a gun structure which provides greater rigidity and improved electrical stability. Focus and deflection are electrostatic. Over-all length is 9 1/8 in.

Allen B. Du Mont Labs., Inc., Dept. ED, 750 Bloomfield Ave., Clifton, N.J.

Price & Availability: *Prices are furnished on request. Except for very large quantity orders, delivery is from stock.*

Test Set 435

Checks transmission on audio circuits



Model TMS-0100 test set is for checking the characteristics of transmission lines and other voice-band equipment. Using swept-band techniques, it reduces the time needed to check-out a transmission network. A swept-frequency generator provides a sinusoidal wave of adjustable constant amplitude at all frequencies in the voice-band. A measuring system compares the network input and output regardless of the absolute power level. The information is displayed with a cathode ray tube. The unit is housed in a 19-in chassis for rack-mounting or a portable cabinet. A typical use is to check the insertion gain or loss of transmission circuits in service.

Hallamore Electronics Co., Div. of Siegler Corp., Dept. ED, 714 N. Brookhurst St., Anaheim, Calif.

Waterproof Markers — 576

The Speedy-Marx line of pressure sensitive electrical markers now come on quickly released cards. These markers, which are unaffected by grease, dirt, and abrasion, are available in constructive and solid numbers, letters, and symbols. Special markers can be ordered.

North Shore Nameplate Inc., Dept. ED, 214-27 Northern Blvd., Bayside 61, N.Y.

Price & Availability: Minimum order is 25 identical or assorted stock items or 50 identical special items. Stock items, in quantities of 25 to 99, are $0.195 per card. Special items, in quantities of 25 to 99, are $0.30 per card. Delivery from stock is immediate; on special orders, one week. Prices are reduced for large quantity orders.

Alligator Clips — 577

For heavy terminal use, these clips have matched jaws opening to 5/8 in. Both solder and solderless connections are available. They are made of cadmium-plated steel or solid copper.

Herman S. Smith, Inc., Dept. ED, 2326 Nostrand Ave., Brooklyn 10, N.Y.

High Fidelity Speakers — 578

Model K-12-HFC 12 in. coaxial speaker is a two-way extended range system with flat response from 30 to 18,000 cps. Impedance is 8 ohms. Power handling is 15 w program, 30 w peak.

Minneapolis Speaker Co., Dept ED, 3806 Grand Ave. S., Minneapolis 9, Minn.

Cable Clamps — 579

Are made of cadmium-plated carbon steel, heat treated, for performance at temperatures up to 550 F. Presently designed in the 10-32 thread size in 3 bracket lengths of 0.45, 0.65, and 0.85 in. Mounting holes 0.13 in. in diameter permit the use of 1/8-in. aluminum alloy rivets.

Elastic Stop Nut Corp. of America, Dept. ED, 2330 Vauxhall Road, Union, N.J.

Metal Stampings — 580

Strips of base metals such as nickel, kovar, molybdenum steel, and others are clad with tin-lead solders, silver, gold, and related alloys. The clad strip is stamped into discs, washers, and special shapes for automatic joining operations. Other uses are heat sinks, base rings or tabs, diaphragms, and contacts for special electronic applications.

Alloys Unlimited, Dept. ED, 21-01 43rd Ave., Long Island City, N.Y.

Correction Notice

Type XR-5019 epoxy resin, (*ED*, Nov. 11, 1959, p 148), has an initial viscosity of 1000 cps at 76 C, and not 100 cps as stated. The product is made by Minnesota Mining and Manufacturing Co., 900 Bush Ave., St. Paul 6, Minn.

NEW PRODUCTS

Directional Gyro 473

Provides attitude information in aircraft and missiles

Type A2215 directional gyro provides accurate attitude information in aircraft and missile applications. A liquid bubble-type vertical sensing element generates error signals proportional to spin axis displacement from horizontal; wiring modifications enable the sensor to be connected to the leveling torquer to complete the inner axis leveling loop. Drift is 4 deg per hr max. The unit stands vibration of 5 g from 20 to 1000 cps, or 10 g from 1000 to 2000 cps. The operative temperature range is −54 to +71 C.

Kearfott Co., Inc., Dept. ED, 1500 Main Ave., Clifton, N.J.

Dust Hood 373

Working area measures 34 x 24 x 19-1/4 in.

With a 34- x 24 x 19-1/4 in. working area, this dust hood, called Microvoid, removes airborne dust particles down to 0.5 micron in diam. An internal positive pressure prevents unfiltered room air from entering the open front. The unit is constructed of optically clear, 1/4 in. Plexiglas with all edges fused and flame polished to eliminate shadows, rough surfaces, and leakage. The hood weighs 35 lb.

Air-Shields, Inc., Dept. ED, Industrial Div., Hatboro, Pa.

Shielded Air Vent 421

Attenuates rf 100 db min

This shielded air vent provides 100 db min attenuation of rf up to 10,000 mc and beyond. Applications of the unit include: shielded enclosures, test equipment, computers, microwave cabinets, telemetry equipment, scintillation counters, and radiation measuring devices.

Shieldair, Dept. ED, Box 28H, Riverton, N.J.

Price & Availability: *Delivery varies according to special features required. Price on request.*

◄ CIRCLE 86 ON READER-SERVICE CARD

Motorized Rheostats 563

For remote control use

These motorized rheostats are used in remote control applications or where a predetermined rate of resistance or voltage change must be smoothly achieved. Standard drives consist of a motor with integral gear reducer, and cam-operated limit switches to accomplish reversal of the control. Assemblies for horizontal and vertical mounting are available.

Ohmite Manufacturing Co., Dept. ED, 3677 Howard St., Skokie, Ill.

Environmental Chamber 557

Measures 12 x 7 x 10 ft

Measuring 12 x 7 x 10 ft, this walk-in environmental chamber handles all standard tests except altitude. Tests include temperatures as high as +185 F and as low as —90 F soak and —65 F operational as well as fungus, salt spray, sand, dust, sunshine, rain, and humidity. The chamber has a mechanical refrigeration system and a 25-ton CO_2 cooling system. It is suitable for testing all types of mobile ground support equipment, test stands, load banks, and many other items.

American Electronics, American Labs Div., Dept. ED, 1536 E. Ross Ave., Fullerton, Calif.

Single Crystal Metal Specimens 413

Usual tolerance is ±2 deg

Single crystal specimens in aluminum, cadmium, copper, lead, nickel, silver, tin, and zinc are offered in many sizes and shapes. Almost any crystal orientation may be specified; the usual tolerance is ±2 deg. Unusual shapes such as hollow cylinders and tensile test specimens with enlarged ends can be furnished. Electrical, magnetic, and physical properties are excellent. Typical applications are in ferrites, semiconductors, and platinum cobalt crystals.

Flow Corp., Dept. ED, 85 Mystic St., Arlington 74, Mass.

Oscillator Control 564

Provides stable audio sources

Employing a zero temperature coefficient reed and ceramic ferromagnetic structural material, model J-610 oscillator control unit provides stable audio sources when used in recommended tube or transistor circuits. Stability is within 0.01% or 0.1 cycle, whichever is greater. Output voltage is essentially sinusoidal with distortions as low as 0.5% obtainable.

Security Devices Lab., Div. of Sargent & Greenleaf, Inc., Dept. ED, Rochester 21, N.Y.

Oven 570

For testing and conditioning

Designed for temperature testing and conditioning processes, this forced air circulation oven has a temperature range from 35 to 350 C. The unit has through wall portholes for insertion of thermocouples or electrical test leads, indicating-controlling thermostat, and an automatic overtemperature controller.

Electric Hotpack Co., Inc., Dept. ED, Cottman & Melrose St., Philadelphia 35, Pa.

Price & Availability: *Delivery 30 days after order received. Prices vary with unit size. Quotation on request.*

Pressure Switch 552

Stands to 200 psi

This miniature, adjustable pressure switch exceeds the requirements of MIL-E-005272B for performance up to 200 psi under vibration, shock, and acceleration test conditions. A pressure capsule and a snap-action switch are contained in a stainless steel housing. The volume of the switch is less than 1 cu in. and the weight is slightly more than 1 oz.

The Bristol Co., Dept. ED, Waterbury 20, Conn.

Price & Availability: *The price is on quotation only; units are from stock after February 1st.*

◄ CIRCLE 88 ON READER-SERVICE CARD

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Torquemeter 419

Provides adjustable full-scale torque

This torquemeter provides linear deflection to any full scale torque within 50% to 100% of the sensor maximum torque. The sensor detects dynamic torque transmitted by shafts at speeds to 24,000 rpm without brush contact with the rotating element. Accuracy is within 2% of full scale. Interchangeable sensors have maximum torque ratings of 0 to 1 oz-in. up to 0 to 500 lb-in.

Rotiform Co., Dept. ED, 1509 Colorado Ave., Santa Monica, Calif.

Pilot Lights 416

Are water-tight

Type 101-8430W water-tight pilot lights measure 1-7/64 in. in length and mount in a single 15/32-in. clearance hole They have a flat neoprene gasket on the shank of the lens holder and a retained O-ring seal behind the flange of the mounting bushing. No special insulating washers are required. Able to accommodate a T-1-3/4 midget-flange-base incandescent lamp of 1.3 to 28 v, units meet all applicable Mil specs.

Dialight Corp., Dept. ED, 60 Stewart Ave., Brooklyn 37, N.Y.

Price & Availability: The price is quoted on request. Units are immediately available from stock.

Cleaning Equipment 422

Comes in 3 sizes

This cleaning system is available with up to four or more cleaning stages: a Freon distillate flush, sonic energy clean, sonic energy rinse, and Freon vapor rinse. It may be used for cleaning parts or assemblies which are incompatible with hydrous solution. The complete system has a stainless steel cabinet, and comes in 3 cleaning chamber sizes of 9 x 14, 14 x 20, and 18 x 25 in.

Sonic Energy Products, Dept. ED, Bendix Aviation Corp., Davenport, Iowa.

Price & Availability: Delivery 90 days after order is received. Prices quoted on special order.

CIRCLE 89 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Potentiometer 433

Available with 0.05% linearity

Designed to meet the environmental requirements of MIL-E-5272B and NAS 710, model 0610M multiturn potentiometer measures 1/2 in. in diam. It has a stop torque-limit of 25 oz-in. Operating temperature range is from −55 to +125 C. It is available with a linearity to 0.05%.

Analogue Controls, Inc., Dept. ED, 200 Frank Road, Hicksville, N.Y.

Price & Availability: *Standard catalog models available in 2 to 4 weeks. Prices on quote.*

Wattmeter 512

Resolution to 0.01% of rated input

For measurements at sustained accuracy and resolution down to 0.01% of rated input, model 1483 electronic wattmeter provides a low impedance dc output. It can be used to actuate digital meters and to drive strip-chart recorders. Ranges are 250, 500 and 1000 w. Input is 5 amp normal and 10 amp max. The unit measures about 20 x 14 x 10 in., and approximate weight is 27 lb.

Weston Instruments Div. of Daystrom, Inc., Dept. ED, 614 Frelinghuysen Ave., Newark 2, N.J.

Bandpass Amplifier 429

Has a 30 to 300 mc range

Bandpass amplifier model 330-M4 has an rf gain of 6 db, noise figure of 8 db avg, and a 30 to 300 mc range. The unit is basically a distributed bandpass amplifier coupled to parallel grounded grid amplifier stages having individual outputs. It measures 5-1/4 x 5-1/4 in. with a standard 19 in. relay rack panel.

HRB-Singer, Inc., Dept. ED, Science Park, State College, Pa.

Silicon Zener Diodes 441

Are rated at 10 w

These 10-w silicon Zener diodes have three-layer seals providing high resistance to temperature extremes, humidity and shock. Designed specifically for commercial equipment applications, they have low Zener impedance and sharp Zener knees. They are furnished in the standard RETMA 10% voltage steps from 5.6 to 27 v.

International Rectifier Corp., Dept. ED, 1521 E. Grand Ave., El Segundo, Calif.

Price & Availability: *Priced at approximately $5.40 ea, units are available from stock.*

Digital Module 430

Has 2 independent circuits

Containing 2 independent circuits, this transistorized module, model ST-102, is designed to drive the firm's line of M-Pac circuits. The output signal switches between 0.7 and 20 v as the input signal crosses the triggering level. Power requirements are 20 v at 7 ma, and —90 v at 0.1 ma.

Computer Control Co., Inc., Dept. ED, 983 Concord St., Framingham, Mass.

Price & Availability: *Available from stock. Price is $59.*

CIRCLE 93 ON READER-SERVICE CARD ➤

SERVICES FOR DESIGNERS

Technical Bibliographies 97

World Electronics makes it possible to receive specialized bibliographies in variety of subject areas, eliminating cross references and other time-consuming activities.

You can subscribe to one or many areas of interest. Among the list of titles available for subscription are: semiconductors; transistors and diode circuits; transistor and diode sine and analog circuits; transistor and diode pulse and digital circuits. Each title is broken down into more specific areas of concentration.

Every month, except August, the company sends a list of articles and books covering the selected subject (s). The subscriber files the material in a folder furnished in the first mailing. Such an arrangement provides convenience and a bibliography that is automatically cumulative. All articles and books received during the previous calendar month are included in the list mailed to the subscriber. The lists are not only complete, but also up to date, being only 10 days behind the original published material. All major publications are scanned regularly, foreign as well as American.

World Electronics, Dept. ED., 1805 68th St., Philadelphia 26, Pa.

Bondable, Dyeable, and Printable Fluorocarbons Available 98

Raibond represents a class of fluorocarbons which have been treated by RAI to impart colorless bondable, printable and dyeable surfaces. It is an application of radiation-induced graft-copolymerization. By combining the effects of atomic radiation with specific chemical systems, it is possible to modify plastic surfaces to obtain specific and desirable surface properties without significantly altering the other characteristics of the plastic. Raibond can be supplied in many fluorocarbon shapes, and the process can be applied to many different configurations. Items such as large Teflon tubes for electrical tube cores, Teflon rods and plugs for waveguides, gaskets, molded blocks, and thin-wall molded shapes (such as radome covers) can be treated to impart clear, colorless, bondable, and dyeable surfaces on one, some or all surfaces. The firm can apply the Raibond process to the desired material, or supply Teflon and Kel-F sheets, film and rods which have been converted to Raibond.

Radiation Applications Inc., Dept. ED, 370 Lexington Ave., New York 17, N.Y.

Metal Fabrication 105

Manufacturers can now take advantage of a specialized service process that offers efficient fabrication of parabolic reflectors, and the Mecaform spinning of Nu metal shields, chassis, high voltage heads, and electronic circular containers of all types.

C. W. Torngren Co., Dept. ED, 236 Pearl St., Somerville, Mass.

Test Instrument Information 106

Any question a purchaser may have pertaining to locating, comparing, evaluating, specifying, or procuring any one of the 5300 electronic test instruments made by 400 manufacturers on the market today will be answered promptly without cost or obligation through use of a new question outline form offered by Technical Information Corp., New York.

The full page outline, giving adequate room for posing problems in detail, is in the form of a postage paid reply letter which can be sent back to the company for answers. Questions on the firm's technical information service, a centralized source of authoritative instrument data, are also invited.

Technical Information Corp., Dept. ED, 41 Union Square, New York 3, N. Y.

Patent Digests 107

Industrial Patent Research Co., Columbus, Ohio, is offering a patent digest service for management and research and development staffs. These short summaries of patents, free of legal terminology and redundant detail, can be more easily understood by scientific personnel.

Patents to be analyzed are provided by the client to IPR which prepares the analyses in extract-abstract form, and then distributes them to designated personnel of the client company. Examples of patent analyses in typical fields of interest are available.

Industrial Patent Research Co., Dept. ED, 2266 E. Main St., Columbus 9, Ohio.

Tape Recording 108

Sigma Electric Co., New York N. Y., offers development experience in tape recorder applications involving: pulse operated switching; voice actuated relays; automatic telephone dialing; multiple point remote control, and continuous play or record systems with actuation for start and stop at the end of each cycle.

Sigma Electric Co., Dept. ED, 11 E. 16th St., New York 3, N. Y.

NEW LITERATURE

Switches 113

Catalog 77b, 16 pages, contains data on a variety of sealed, environmentproof, and hermetically sealed switches. Applications of the switches include aircraft, spacecraft, rockets, missiles, launching and ground support, ordnance, and mobile use. Information is given on mounting, electrical ratings, operating characteristics, and contact arrangements. Micro Switch, Freeport, Ill.

Pressure Monitor System 114

This technical manual, five-pages, contains data on the model 203A digital pressure measurement and control system. A block diagram showing interconnection of the pressure transducer, power supply, preamplifier, and amplifier is included in the manual. Technical Industries Corp., 389 N. Fair Oaks Ave., Pasadena, Calif.

Vinyl Tubing 115

The firm offers samples of extruded tubing made from polyvinyl chloride resins. These samples are 2-1/2 to 6 in. long, and cover 5 grades of tubing, three of which meet various MIL specifications. They come in a folder that is imprinted with charts giving information on the five grades. Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill.

Frame Grid Tubes 116

Production techniques used in the manufacture of frame grid tubes are illustrated and described in this 13-page booklet. Technical data include typical characteristics, limiting values, and base connections for a variety of amplifiers and mixers. Amperex Electronic Corp., 230 Duffy Ave., Hicksville, N.Y.

Selenium Rectifiers 117

The firm's line of selenium rectifiers is described in bulletin No. 295, an eight-page brochure. Basic rectifier information, product description, and methods of selecting rectifiers are covered in the bulletin. Outline drawings and terminal arrangement tables are included. Radio Receptor Co., Inc., 240 Wythe Ave., Brooklyn 11, N.Y.

Zener Diodes 118

This eight-page brochure contains articles on referencing and instrumentation with Zener diodes, and output regulation utilizing the switching action of Zener diodes. Detailed circuits, performance curves, and photographs appear in the booklet. International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif.

Connectors and Cables 121

Rack-and-panel connectors made by Ampenol and type RG/U coaxial cables are described in this illustrated four-page brochure. Among the connectors listed are: cable clamps; barrier polarization types with and without shells; printed circuit connectors, and a series of plugs and adapters. Coaxial cables are listed in table form. Schweber Electronics, 60 Herricks Rd., Mineola, L.I., N.Y.

Power Stacks 122

Bulletin No. 308, four-pages, contains a list of selected power stack assemblies ranging in output from 3 to 30 kw dc. Design data are shown for 125 and 250 v dc units, convection and forced air cooling. The required ac input voltage and the rated output are given for each unit. Radio Receptor Co., Inc., 240 Wythe Ave., Brooklyn 11, N.Y.

Motor Generator 123

Two-page bulletin No. MO-3.14 provides performance data and design specifications on the RBG-2407 miniature motor-generator. The unit consists of a low inertia control motor and an ac drag-cup rate generator. Motor speed-torque and speed-voltage curves are included in the bulletin. National Pneumatic Co., Inc., 125 Amory St., Boston 19, Mass.

Gears and Pinions 124

Data on die cast gear and pinion combinations appear in this 10-page catalog. Combinations include: gear and pinion, flanged pinion, cup gear and pinion, plus special units. All are available with hole or shaft. Mechanical specifications and outline drawings are contained in the catalog. Gries Reproducer Corp., 125 Beechwood Ave., New Rochelle, N.Y.

Welding Equipment 125

Descriptions, design and performance data, and illustrations of electronic welding equipment appear in this four-page catalog. Among the units described are power supplies, welding heads, a control unit, a bench welder, and handpieces. Weldmatic Div. of Unitek Corp., 380 N. Halstead Ave., Pasadena, Calif.

Thermocouple Wire 126

Pure platinum, platinum-10% rhodium, and platinum-13% rhodium thermocouple wires are described in this four-page bulletin, No. TC-2. Physical and electrical properties for standard and premium grades of the 3 wire types are listed. J. Bishop & Co., Platinum Works, Malvern, Pa.

NEW LITERATURE

Sealing Alloys 129

Alloys developed for sealing metal to glass are described in this four-page booklet. Called Rodar, Niromet 46, and Niron 52, the alloys have a tensile strength of 150,000 psi. Minimum tensile strength for Niromet 46 and Niron 52 is 70,000 psi; for Rodar it is 65,000 psi. Wilbur B. Driver Co., 1875 McCarter Highway, Newark 4, N.J.

Threaded Fasteners 130

Catalog 5918 is a guide to the selection of threaded fasteners for high temperature use. The 80-page book contains a complete listing of fastener types, material and configuration for use in temperatures up to 900, 1200, and over 1200 F. Detailed standard drawings of the firm's nuts are included as a further guide to the selection of the correct fastener for the job. Elastic Stop Nut Corp. of America, 2330 Vauxhall Road, Union, N.J.

Resin Cartridge 131

This one-page data sheet illustrates and describes type PPC TC-459 cartridge kit for packaging epoxy resin. Applications include potting electrical connectors and cable junctions. Data on the preparation of the kit is contained in the bulletin. Electronic Production & Development, Inc., 501 N. Prairie Ave., Hawthorne, Calif.

Electronic Chronograph 132

Data on a transistorized electronic chronograph that converts varying time intervals into digital coded electrical signals is contained in bulletin No. 104a. The instrument measures time between events to a resolution of 20 mμsec with an accuracy of 1 part in 10^7 per day. Applications for the quantizer, series LfQ, are included in this two-page data sheet. Computer Equipment Corp., 1931 Pontius Ave., Los Angeles 25, Calif.

Explosion-proof Controls 134

This two-color, four-page booklet contains information on indicating, nonindicating, and recording explosionproof controls. The controls are available in a variety of temperature ranges up to 1100 F. Photographs of control models IVS, VS, and RVS appear in the booklet. Partlow Corp., New Hartford, N.Y.

Switches and Actuators 135

Detailed information on miniature and subminiature plastic-cased snap-action switches and actuators is contained in catalog No. 12. Among the switches described are: push button and plunger switches, toggle switches, lever and roller actuated switches, and limit switches. Haydon Switch, Inc., Waterbury 20, Conn.

Terminal Blocks 136

Catalog No. 76 contains data on the firm's line of sectional terminal blocks, terminals, and cable and conduit fittings. Complete technical data, detailed engineering specifications and drawings, and photographs are included in the 12-page booklet. Buchanan Electrical Products Corp., Hillside, N.J.

Rigid Custom Extrusions 137

"A Guide to Rigid PVC Custom Extrusions" is a two-page data sheet that describes the advantages of polyvinyl chloride. The illustrated bulletin includes sections on polyvinyl chloride part design and factors in selecting the plastic material. Alpha Plastics Inc., 78 Okner Parkway, Livingston, N.J.

Electronic Buying Guide

Over 40,000 items are listed in this 312-page catalog, No. 85, devoted to industrial electronic parts and equipment. Engineering specifications, schematic diagrams, and technical articles are included. The catalog also contains a complete index of products and manufacturers. *Write on company letterhead to Radio Shack Corp., Dept. ED, 730 Commonwealth Ave., Boston 17, Mass.*

NEW LITERATURE

Industrial Controls 145

Containing charts, drawings, and diagrams, this booklet, entitled, "Industrial Temperature Measurement and Control," discusses the following topics: ways of responding to temperature; ways of putting temperature response to work; the firm's element for mercury-bulb instrumentation, and a score sheet for the mercury-bulb system. The 23-page booklet also provides basic concepts of electrical, pneumatic, and mechanical controls. The Partlow Corp., 532 Campion Road, New Hartford, N.Y.

Electron Tubes 146

Trends in the design and manufacture of electron tubes for entertainment, industrial, and military applications are discussed in this 24-page booklet, entitled, "A New Era of Sylvania Electronic Tubes." Sylvania Electric Products Inc., 1100 Main St., Buffalo, N.Y.

Crystals 147

This 12-page booklet includes an article entitled, "Induction Heating in Zone Refining, Zone Leveling and Crystal Growing." Techniques of growing germanium and silicon crystals are explained and illustrated. An article on coil design and construction also appears in the booklet. Lepel High Frequency Labs, Inc., 55th St. & 37th Ave., Woodside 77, N.Y.

Tape Transports 148

Illustrated bulletin No. 1618 describes model 5-681 digital-tape recorder/reproducer transport that operates at speeds up to 30 ips, and model 5-682, a transport that operates up to 150 ips. Both are designed for computer, industrial, military, and laboratory applications. Operating characteristics and specifications for both units are included in the brochure. Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

Gyroscope Manual

This technical manual on subminiature rate gyroscopes covers basic principles of operation, operating characteristics, standard types available, transformer pick-off, and use and design of one, two, and three axis sensors for rate and acceleration. General application and operating data are for design use in applications such as fire control systems, autopilots, missile homing, navigation, and instrumentation. The 62-page manual includes a 20-page appendix that contains a complete glossary of gyro technology. *Send $2.00 to Sanders Assoc. Inc., Dept. ED, 95 Canal St., Nashua, N.H.*

Electronic Connectors 154

Catalog No. 60, 16-pages, contains application data on electronic connector types including printed circuit, MS, rack and panel, triaxial, glass seal, BT miniature plugs, receptacles and cable assemblies. Special type connectors are also described. H. H. Buggie Div., Burndy Corp., Toledo, Ohio.

Ceramic Capacitors 155

Bulletin No. H-4 describes the firm's series of subminiature ceramic capacitors designed for 1/10-in. modular spacing in printed circuitry, and other tight packages. Mucon Corp., Dept. K, 9 St. Francis St., Newark 5, N.J.

Washers 156

This brochure contains measurements, weights, sizes, and a complete listing of flat steel, brass, finishing, and lock washers for internal and external use. Accurate Threaded Fasteners, Inc., 2901 W. Montrose, Chicago 18, Ill.

Games for Electronic Computers 157

This 12-page booklet describes 12 games for matching the machine against the human operator. Adaptation of these games to various computers, including the company's Sexiac electronic digital computer kit, is also explained. Willis G. McCormick Co., 15733 Septo St., Sepulveda, Calif.

NEW LITERATURE

Connectors **165**

Bulletin No. 115, four pages, contains data on the company's rack-and-panel or cable connectors. Series 8007 is available with 75, 100, and 130 contacts and a screw-actuating device for mating and vibration lock. Series 8008 is available with 80, 95, 110, 125, and 140 contacts, but has no screw-actuating device. The bulletin provides diagrams and photographs. Elco Corp., M St. below Erie Ave., Philadelphia 24, Pa.

Transistors **166**

Complete specifications and characteristics of the firm's line of pnp and npn transistors appear in this 16-page brochure, No. G-200. Sections are devoted to: audio transistors for audio amplifiers and low speed computers; computer transistors; high current computer transistors; bilateral transistors; drift transistors; high voltage transistors; and silicon alloy junction transistors. General Transistor Corp., 91-27 138th Place, Jamaica 35, N.Y.

Components **167**

Contained in this six-page booklet is data on the firm's line of components. Included are: filters, networks, and delay lines; rf and if coils and transformers; special coils and toroids; wirewound resistors, and subassemblies. The booklet is illustrated. Fugle-Miller Labs, Clark, N.J.

Tube Sockets **168**

This two-page data sheet describes 7 and 9 pin miniature tube sockets with shield base, saddle for top mounting, and snap-on base. Specifications and outline drawings for all types are included in the bulletin. Elco Corp., M St. below Erie Ave., Philadelphia 24, Pa.

Grommets **169**

One-piece, solid, nylon grommets are described in this four-page illustrated brochure. Specifications are given in table form. Photographs and outline drawings are included to facilitate installation. Western Sky Industries, 21301 Cloud Way, Hayward, Calif.

Connector Potting Form 174

Nylon potting forms from 1/2 to 1-1/2 in. ID are described in a one-page, illustrated bulletin. The forms mold compounds used to pot electrical connectors against the effects of moisture, oil, hydraulic fluid, salt spray, and fungus. Electronic Production & Development, Inc., 501 N. Prairie Ave., Hawthorne, Calif.

Power Inverter 175

Transistorized power inverter, model TPI-3, designed for operation in any airborne environment, is described and illustrated in this two-page data sheet that outlines its specifications. A simplified circuit diagram is included. Southwestern Industrial Electronics Co., 10201 Westheimer Rd., Box 22187, Houston 27, Tex.

Switches and Relays 176

The firm's line of electrical switches and relays is described in this four-page brochure. Switches described and pictured include miniature, subminiature, appliance, open blade, general purpose, metal clad, machine tool, and others. Several types of relays are listed in the brochure. Acro Div., Robertshaw-Fulton Controls Co., Box 449, Columbus 16, Ohio.

Optical Systems 177

Technical descriptions and photographs of a radar recording camera test set, fire control simulator, radar target folder viewer, and radar film assessor appear in this 16-page booklet. Other systems described in the folder include data display equipment, photogrammetric devices, and visual simulators and trainers. Mast Development Co., Inc., 2212 E. 12th St., Davenport, Iowa.

PC Connector 178

Series 6003, card-edge type printed circuit connector, is described in a two-page bulletin, No. 116. The connector is available with 14, 21, 31, and 37 contacts at 0.078-in. centers. Specifications and outline drawings are contained in the bulletin. Elco Corp., M St. below Erie Ave., Philadelphia 24, Pa.

NEW LITERATURE

Power Nomographs 185

The nomographs in this eight-page bulletin, No. 5000E, aid in predicting the long term performance of the firm's composition fixed resistors. The information shows how power input, temperature rise, ambient temperature, life, and permanent resistance changes are interrelated. Examples are included to illustrate the use of the nomographs. Allen-Bradley Co., 136 W. Greenfield Ave., Milwaukee 4, Wis.

Switches and Terminals 186

This 24-page catalog contains data on multi-circuit push button and stack switches in addition to range heater, motor-reversing, toggle, and slide switches. Details of handles, hardware, shaft styles, and terminals are included. Dimension drawings, wiring diagrams, circuit sequences, and electrical ratings appear in the catalog. Ark-Les Switch Corp., 51 Water St., Watertown 72, Mass.

Magnetic Triggers 187

Information on magnetic triggers for silicon controlled rectifiers is contained in this four-page brochure. A selection chart showing specifications of full-wave, half-wave and small-size 400-cps models, dimensional diagrams, and charts showing transfer characteristics and output and control signals are included. Avion Div. of ACF Industries, Inc., 11 Park Place, Paramus, N.J.

Environmental Testing 188

This 10-page brochure contains descriptions and capacities of apparatus required for military and commercial testing of electronic equipment. Tests include shock and vibration, temperature, altitude, humidity, salt spray, sand and dust, pressure, and electronic radiation. Equipment is capable of meeting requirements for most current military specifications. Stavid Engineering, Inc., Plainfield, N.J.

Zipper Tubing 194

Catalog Z-2 discusses the characteristics, construction, applications and specifications of zipper tubing. How-to-use instructions, permanent sealing directions, accessories listing, and ordering information are also included. In addition, the forming, closing and sealing equipment are illustrated and discussed. Alpha Wire Corp., 200 Varick St., New York 14, N.Y.

Audio Line Amplifier 195

Model CA-5A audio line amplifier is described in this two-page bulletin. The amplifier powers up to 50 headsets in parallel so that audio impulses applied to any of the microphones are transmitted to all connected headsets. The bulletin covers application, specifications and technical description of the unit. Photographs are included. Flite-Tronics, Inc., 3312 Burton Ave., Burbank, Calif.

Differential Amplifier 196

Complete specifications and operating data of a differential amplifier appear in this six-page brochure, No. 3015-B. Power supplies, mounting modules, filters, and other accessories are described. The brochure contains photographs and a block drawing of the amplifier. Beckman Systems Div., 325 N. Muller Ave., Anaheim, Calif.

Word Indicator Lights 197

Catalog No. 159C, 16-pages, describes the Roto-Tellite line of word indicator lights. They have a visible legend area of 15/32 x 1-1/4 in. that will accommodate up to 3 rows of 0.125 in. high characters, 14 per row. Circuit outlines and mounting dimensions are included in the catalog. Master Specialties Co., 956 E. 108th St., Los Angeles 59, Calif.

Miniature Pulse Transformers 198

Detailed description of miniature pulse transformers for blocking-oscillator pulse coupling, inverting and impedance matching is outlined in bulletin No. PT 160, two-pages. Grain oriented, thin metal core material is used in the transformers. Characteristics are presented in table form. Valor Instruments, Inc., 13214 Crenshaw Blvd., Gardena, Calif.

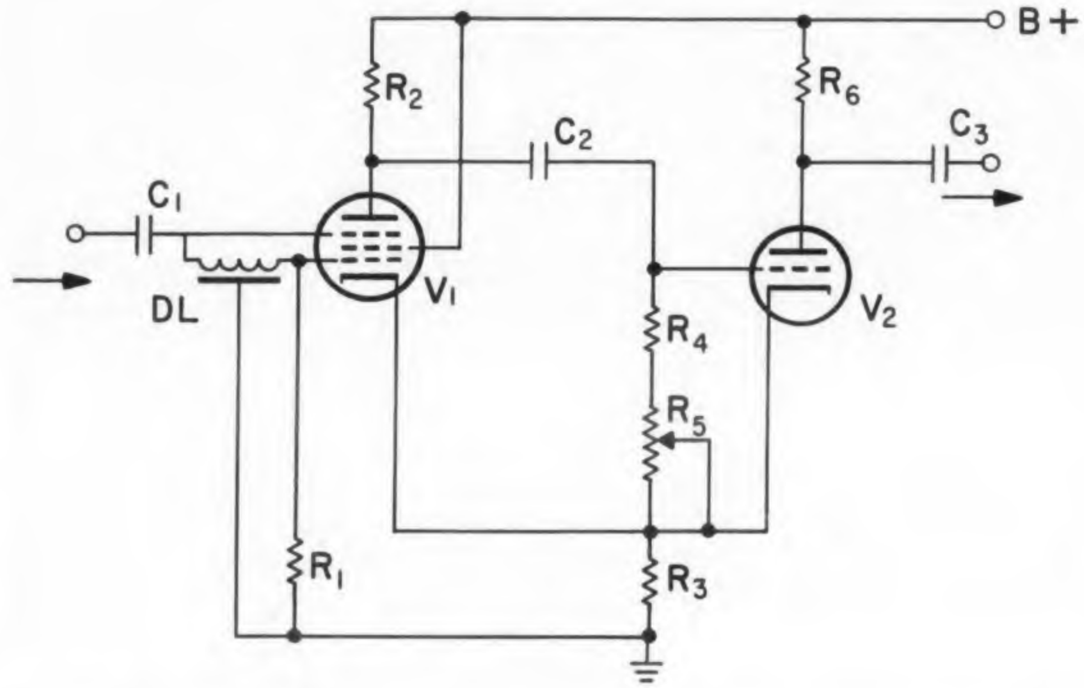
Modified One-Shot Multi Acts As Pulse Decoder

A SIMPLE method for pulse decoding and producing squared output pulses of predetermined duration is illustrated by the circuit shown. The functions of a coincidence circuit and a separate one-shot multivibrator are here combined in a modified multivibrator circuit.

The pulse decoder, pentode tube V_1, is connected in a gating circuit to produce single pulses from pairs of pulses spaced p microseconds apart. The design is such that V_1 is cut off by the positive voltage on its cathode. This bias is established by the drop across R_3 as a result of the current drawn by the normally conducting triode V_2.

Positive pulses are fed through coupling capacitor C_1 to both the p microsecond delay line, DL, and the suppressor grid of V_1. The delayed pulse output from DL is applied to the control grid. Conduction of V_1 will not occur until positive signals of proper amplitude and phase are applied to both the control and suppressor grids. This takes place only when pulse input is spaced p microseconds apart. When V_1 conducts, a negative output pulse is produced at the plate.

This negative pulse is applied, through C_2, to the grid of triode V_2, cutting the tube off. It remains cut-off while C_2 discharges. When the cut-off point is reached, plate current in V_2 again begins to flow. The turn-off time is determined by the time constant of the RC combination $C_2(R_4 + R_5)$. This also establishes the output pulse width. As soon as plate current starts to flow in V_2, a second switching process occurs, and the normal condition (V_2 on, V_1 off) is re-established.



The modified multivibrator circuit acts as a pulse decoder and produces output pulses with a width determined by the time constant $(R_4+R_5)C_2$.

A. N. Clay, Senior Engineer, ITT Laboratories, Nutley, N. J.

Square-Loop Core for Short-Circuit Protection

A TRANSFORMER with a square-loop core was used to protect the regulating transistor in a regulated power supply. Basically, transistor regulated power supplies use a transistor in series with the load whose collector-to-emitter impedance is changed to compensate for load variations. If the regulated output is shorted, the entire unregulated output appears across this transistor. Where the unregulated output is greater than the transistor breakdown voltage, the transistor can be permanently damaged. A fuse in the output circuit will not help since the transistor breakdown will occur faster than any fuse will blow.

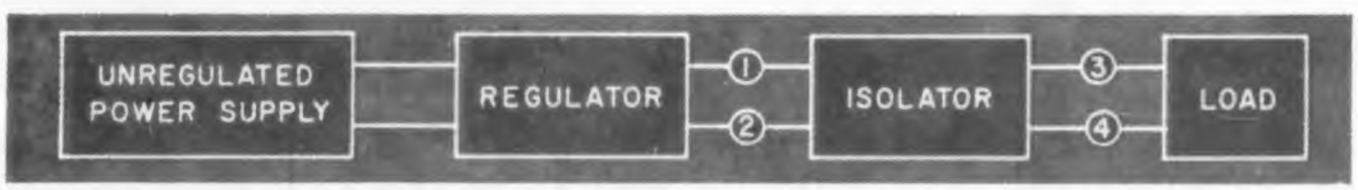


Fig. 1. Isolator is placed between regulating transistor and load.

The position of the regulator "isolator" is indicated in Fig. 1; its circuit in Fig. 2. While this basic circuit has previously appeared in the literature (Shea, R. F. "Transistor Circuit Engineering", John Wiley & Sons, p 422), the particular application described here is new.

If a short is placed across the output terminals *3-4* (assume *T1* is conducting), the square-loop core material will immediately be saturated by the increased collector current. This current is limited by the base drive provided by windings

A HERITAGE IN ELECTRONICS

Of Interest to the Electrical Industry

SINCE the establishment of our business in 1919 it has been our sincere desire to secure and maintain the good will of every customer using our equipment, by supplying relays of the finest quality—properly designed, accurately fabricated and carefully assembled. . . . We are constantly designing, developing and testing, with two objectives in view: *First*, to make our relays superior in every respect, and *Second*, to have new types and designs ready for each new requirement as the electrical industry progresses. . . . Realizing that an electrical control scheme is no better than any one relay used in it, we consider the design and materials first, and the cost last. Although we have many varieties of relays, we never sacrifice the quality of any type in meeting competition. . . . We solicit your relay business and feel justified in saying that, *"The more you use Leach Relays, the more you will be convinced that they have created new high standards in accuracy and dependable performance."*

LEACH RELAY COMPANY
860 South Los Angeles Street
LOS ANGELES . . . . CALIFORNIA

LR

(from original Leach catalog)

Val Leach, founder of Leach Corporation, wrote the advertisement, left, 27 years ago. In it Mr. Leach laid down a business philosophy that is as valid today as it was in 1933. He knew there would be no room for "yesterday's heroes" among the companies supplying the vital, growing electronics industry. He knew that success would be in direct ratio to uncompromising product reliability. And he also knew that technological progress could only be based on the solving of tomorrow's problems.

Today, Leach continues to provide the industry of flight with reliable, high performance relays and contactors in the tradition of the original Leach Relay Company. Over the years, Leach has also pioneered and developed many other advanced technical products and services. Today, their scope greatly enlarged, Leach designs, engineers and manufactures:

ELECTRO-MECHANICAL AND ELECTRONIC COMPONENTS—relays, contactors, solid state devices

INSTRUMENTS—tape recorders, accessory equipment, recording accelerometers

POWER CONVERSION EQUIPMENT—motor generator sets, DC and special purpose power supplies

CONTROL AND DISTRIBUTION EQUIPMENT—control and distribution centers, load banks, bench panels, test benches

..... with the know-how to incorporate them into **ELECTRONIC SUB-SYSTEMS AND SYSTEMS.**

This year Leach Corporation celebrates its 40th anniversary in electronics with a reaffirmation of Val Leach's time honored principles:

Solving problems is the core of the Leach philosophy of doing business. Leach will continue to base its success on anticipating customer needs and meeting them with advancements tailored to specific requirements.

For electronic sub-systems and electro-mechanical components to meet the requirements of the space age... **LOOK TO LEACH**

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CIRCLE 204 ON READER-SERVICE CARD

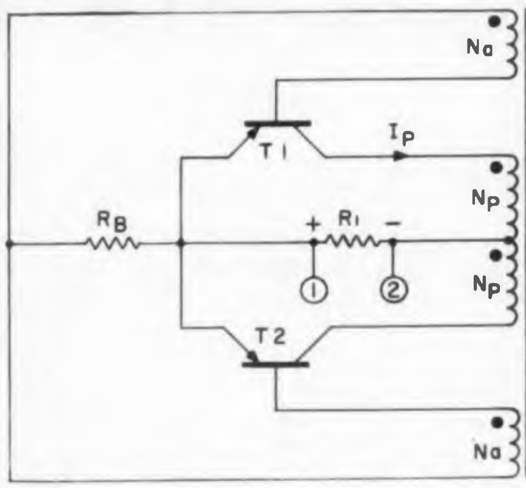


Fig. 2. Square-loop cored transformer causes short circuit at load to appear as a high impedance in series with regulating transistor.

Na. Since E_s is constrained to be zero by the short, and since $E_s = -N_s d\phi/dt$, $d\phi/dt = 0$. The voltage induced in N_a will go to zero since it also is a function of $d\phi/dt$. Since the base drive is now zero, ideally the transistor's input impedance should be infinite. Actually, since the collector to emitter voltage becomes large (equal to the regulated voltage) some current will be drawn. However, the previously troublesome load short has been converted to a high impedance. The regulating transistor is in no danger of having an overload voltage placed on it.

Resistor R_1 across the regulator output is usually needed since the near no-load condition during shorting is too stringent a design requirement on the regulator. The base resistor (R_b) is selected for the desired bias point during normal operation. A value of 40 turns for N_p and 6-8 turns for N_a has been successful; with N_s determined by the output level desired. The transistors are determined by the power to be handled and the fact that the breakdown voltage should be about 240 per cent of the regulator output (twice the regulator output plus switching spikes).

Stanley Sokol, Design Engineer, Ford Instrument Co. Bldg., 4722, Rm. S9, Redstone Arsenal, Ala.

Meter Relays Protect TWT's

We have used meter-relays in two applications to prevent electrical damage to traveling wave tubes. The circuit in Fig. 1 is used to prevent helix burn-out due to excessive helix current. Fig. 2 prevents electron gun damage due to electron beam de-focusing caused by improper solenoid magnetizing current.

Fig. 1 uses a high-limit meter-relay. The meter movement is placed in series with the helix and ground. Excessive helix current (maximum helix

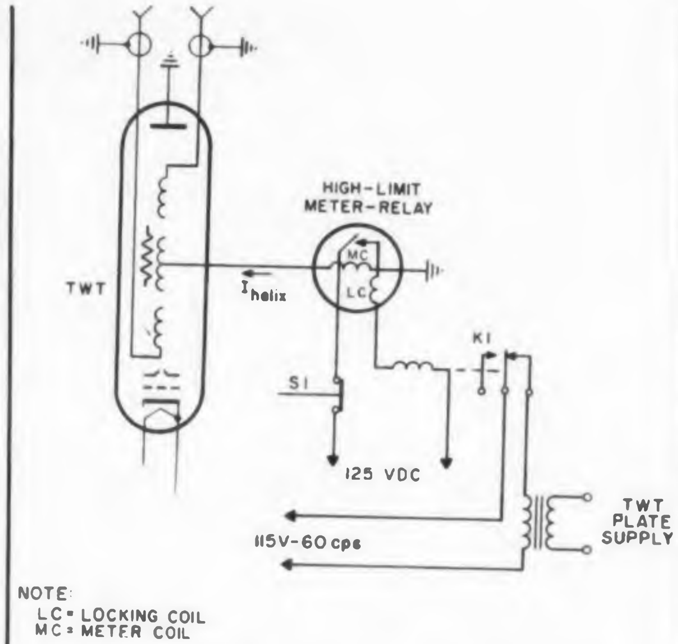


Fig. 1. A high-limit meter-relay protects a TWT from helix burn-out due to excessive helix current.

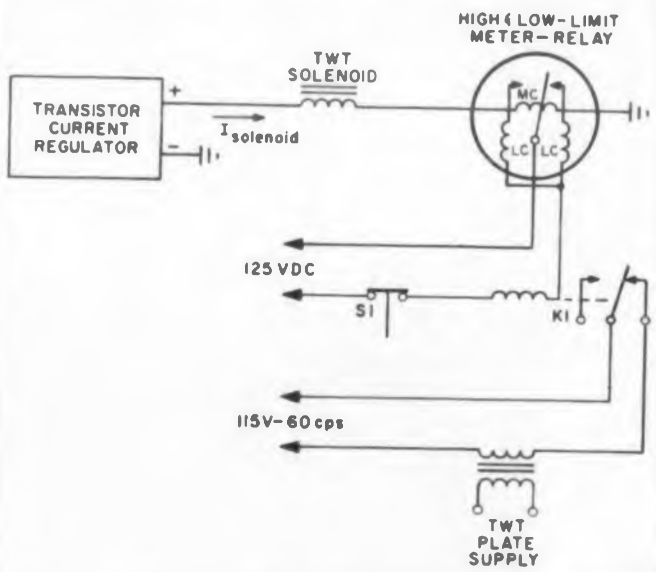


Fig. 2. A high-low limit meter-relay prevents electron gun damage caused by improper solenoid magnetizing current.

current for the tube type) will cause the meter-relay to lock closed, energizing the load relay *K*1. Energizing *K*1 removes the primary power from the high voltage TWT supply. Switch S1 in series with the locking circuit is used to clear the meter-relay circuit when the fault has been corrected.

Fig. 2 uses a high-low limit meter-relay. The meter movement is in series with the current regulated solenoid supply and the TWT solenoid. The limits are set to within 15% of the recommended solenoid currents. Should the current exceed the specified limits, the meter-relay will lock closed, energizing *K*1. This removes the high voltage TWT supply.

In both circuits high voltage is kept off the TWT's until the circuit is manually cleared by pushing push-button switch S1.

Walter W. Frey, Radar Systems, Airborne Instruments Laboratory, a Division of Cutler-Hammer, Inc., Huntington, N. Y.

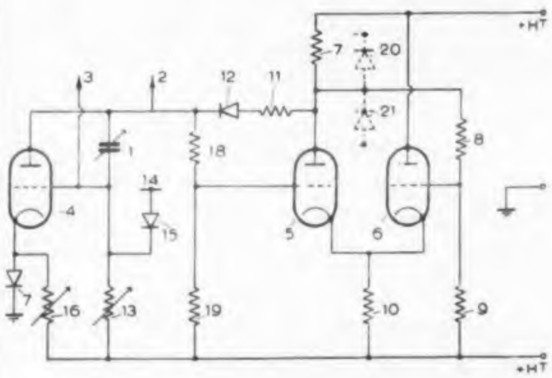
PATENTS

Sawtooth Waveform Generator

Patent No. 2,897,453. Hugh Lyon Mansford. (Assigned to EMI Ltd.)

A capacitor is switched from charge to discharge in a manner which facilitates adjustment of the forward and reverse strokes of a sweep circuit.

Capacitor *1* charges through diode *12* in a Miller fashion as set by resistor *13;* triode *5* is cut off during the charging period. The voltage across resistor *18* and *19* rises until triode *5* conducts to switch triode *6* off and, as a result, diode *12* cuts off. Capacitor *1* discharges through tube *14* and resistor *16* in series until triode *5* cuts off to reset the sweep cycle.

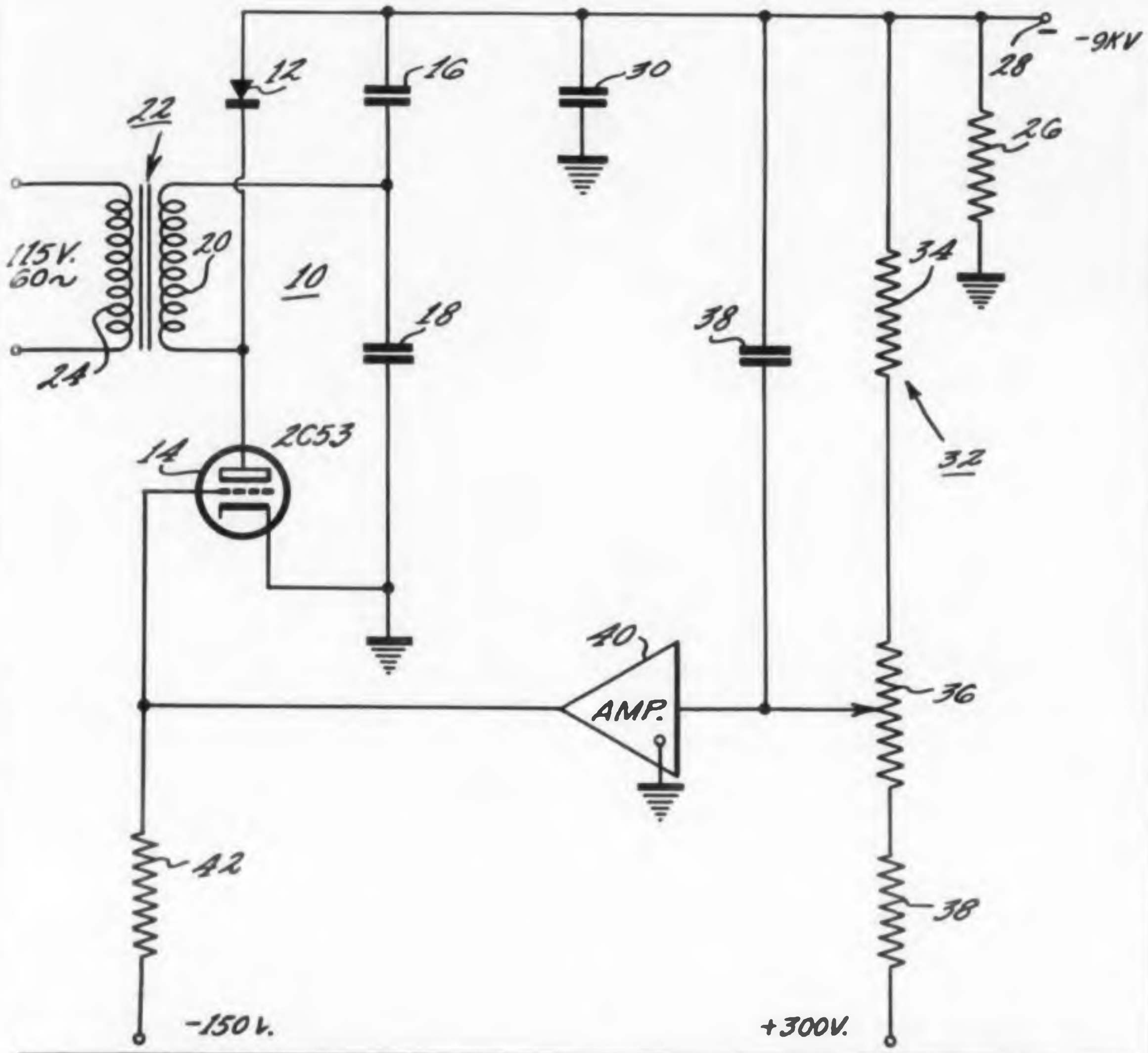


Power Supply

Patent No. 2,905,881. Samuel Aron (Assigned to RCA.)

A regulated, negative, voltage-doubler power is supplied by making one rectifier an adjustable impedance sensitive to changes in the voltage across the load.

The circuit analysis is simplified by considering tube *14* essentially as a diode. Capacitors *16* and *18* will charge to the voltage across secondary winding *20* of transformer *22*. Amplifier 40, however, meters any change in the output voltage and adjusts the bias on tube *14* modifying the voltage across capacitor *18* to stabilize the output voltage.


22
12
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2C53
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AMP.
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-150v.
+300V.

BOOKS

A Technical Writer's Handbook

Margaret Norgaard, Harper & Brothers, 49 E. 33rd St., New York 16, N.Y., 241 pp, $3.75.

"The prime requisites of technical writing are clarity, logic, and accuracy, embodied in a vigorous prose that awakens imagery and carries life, action, and conviction," says the author, who then goes on to show how these requisites can be achieved.

This book offers concrete help to engineers, scientists, businessmen, and government workers in writing a variety of clear and colorful reports planning effective visual presentations, and preparing speeches.

The Handbook covers all aspects of technical writing and answers such practical questions as: What is good technical writing? Who reads technical literature and what are the emotional factors that color understanding of technical fact? What are the basic methods of research? What are the modern practices in grammar and punctuation, and the logical reasoning behind them? What is the application of logic to technical writing? What constitutes good writing style?

Included are a complete grammar section, stressing modern usage, a punctuation guide, and an analysis of the emotional factors that sway readers. An appendix includes examples of different types of good technical writing.

Economic Control of Interconnected Systems

Leon K. Kirchmayer, John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y., 207 pp, $12.50.

Mathematical methods, computers and controllers are applied in this text to obtain the most economic operating conditions for interconnected electric utility systems. A number of important tools for the development of optimalizing computer controllers are discussed. Specifically, these tools include: the use of theoretical and differential analyzer methods for predicting the dynamic performance of interconnected systems and associated controllers; the development of mathematical models of the process whose operation is to be optimalized; the use of mathematical methods to determine equations whose solutions result in optimal economic performance and the integration of computer and controllers to obtain computer-control systems.

The information given is based primarily on a course given by the author to participants in the General Electric Power Systems Engineering Course. The book is suitable for a senior or graduate level course in systems engineering.

Chapter 1 presents descriptive material concerning governing-system and control characteristics necessary for an analysis of the dynamic performance of interconnected systems. Chapter 2 describes various schemes for maintaining frequency, interchange, and economic allocation of generation within a given operating area by automatic computer-controller means.

Linear Circuit Analysis

B. James Ley, Samuel G. Lutz and Charles G. Rehberg, McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 36, N.Y., 567 pp, $12.50.

The fundamental theory of linear lumped circuits is presented here for either the advanced undergraduate or beginning graduate student. One of the authors' main objectives is to present electric circuit theory as a general method of analysis for all physical problems specified by simultaneous linear integrodifferential equations. In order to accomplish this, electrical and mechanical analogues are treated, and mechanical problems appear throughout the book. In addition to the numerous examples worked out in the text, problems are found at the end of each chapter.

Those aspects of circuit theory that are a common basis for advanced courses are emphasized. Among the topics included are the formulation of network equations and their solution in the time domain by classical methods or in the frequency domain by Fourier or Laplace transforms.

Cascaded Reflex Voltmeter Yields High Input Z, Wide Range

Yu. V. Mikhatskiy

THE REFLEX voltmeter circuit (Fig. 1) has been quite popular lately. This circuit is used for measuring dc voltages from very high resistance sources. Thanks to its heavy negative feedback, the reflex voltmeter circuit has many valuable properties: (a) large input and small output resistance, (b) possibility of measuring a wide range of voltages, (c) scale linearity, (d) high stability. These lead to permanence of calibration with variations in supply voltage and replacement of tubes.

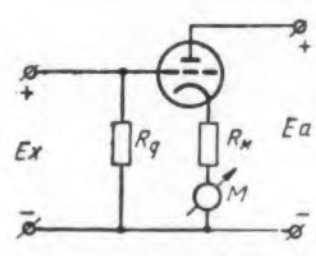

Fig. 1. Basic reflex voltmeter.

However, the input resistance of the reflex voltmeter usually does not exceed 10^8 to 10^9 ohms. Where a higher input resistance is necessary, circuits with electrometer tubes are used. However, electrometer tubes with high resistances, 10^{13} to 10^{14} ohms, do not have many advantages of reflex circuits.

Circuits with electrometer tubes make it possible to measure voltages up to only two or three volts. The use of voltage dividers, in reflex circuits, to insure an input resistance of 10^{13} to 10^{14} ohms is practically impossible, because of the instability of the division coefficient.

However, the cascaded-reflex voltmeter has all the advantages of ordinary reflex voltmeters, but has an input resistance of 10^{11} to 10^{12} ohms.

The input resistance of the reflex circuit is determined by the grid current of the input tube. The principal components of the grid current are the electronic and ionic component, the thermionic grid current, and the conduction currents. The remaining components play a secondary role. The curve of the total grid current is illustrated in Fig. 2.

A feature of the reflex circuit is in operation with large negative bias. In this case the grid current is negative. Consequently, a principal role is played, in the reflex voltmeter, by the ionic current and by the thermionic grid current. The latter can be reduced substantially by reducing the filament voltage.

The magnitude of the grid current for a given tube depends on the anode current and on the anode voltage; as they decrease, the ion current also decreases. As the anode voltage is decreased, the grid current diminishes rapidly; ionization

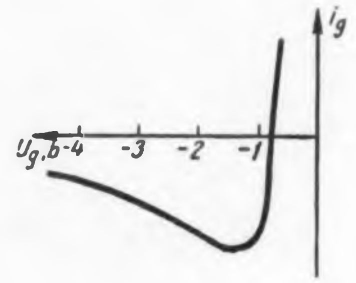

Fig. 2. Grid current vs. grid voltage for the input tube of a reflex circuit.

ceases with the anode at 6 to 9 v. Such a mode is typical of electrometer tubes.

In the cascaded-reflex voltmeter (Fig. 3), the grid current of the first tube is greatly reduced by a substantial reduction in the plate current. This is attained by connecting a very large resist-

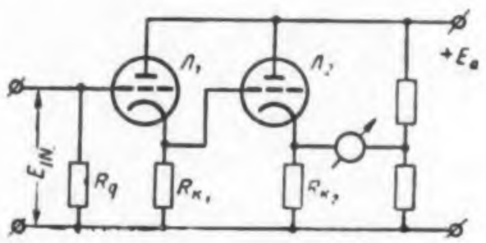

Fig. 3. The cascaded reflex voltmeter.

ance, R_{k1}, of tens or hundreds of megohms in the cathode circuit.

An experimental verification has shown that, in a type 6S1Zh tube, with $R_{k1} = 45$ megohms and with a simultaneous reduction of the filament voltage to 4 v, the grid current drops to 10^{-12} amp.

The resistance R_{k1} serves as grid resistor for the second tube, and must pass the grid-current of this tube. The resistance R_{k2} should be small but sufficient to permit inclusion of a measuring instrument in the cathode of the second tube.

The cascaded-reflex voltmeter was used for a model of a pulse voltmeter, for measuring the voltage of single and repeated pulses with a very low duty cycle. The diagram of the voltmeter is shown in Fig. 4.

Connected to the input of the circuit is a cathode follower, which makes it possible to measure pulse voltages arriving from sources with relatively large output resistance. The pulses are fed from the output of the cathode follower to a diode detector.

The dc voltage across the capacitor of the detector is measured by the cascaded-reflex voltmeter. The first tube in the reflex voltmeter is a 6S1Zh, since the grid leakage resistance of this tube can be made sufficiently large. Consequently the time constant of the discharge of the capacitor is sufficiently large even for a small value of the capacitance. This makes it possible to measure pulse voltages of relatively short duration.

The voltmeter has two ranges, 50 and 250 v. The ranges are changed by a switch at the 250-v setting in Fig. 4 which changes the plate voltage

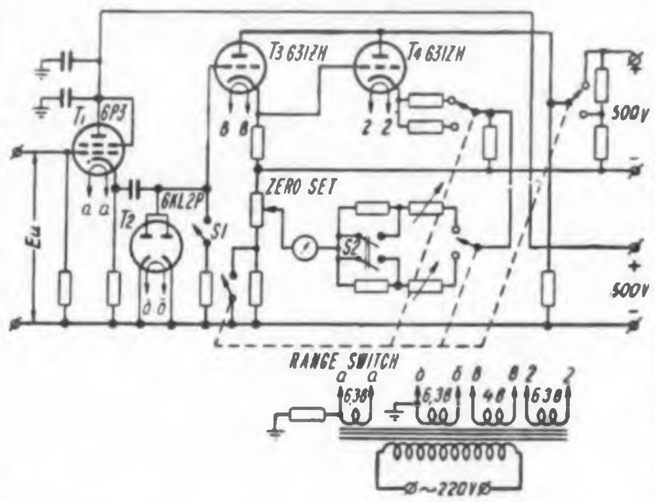

Fig. 4. A pulse voltmeter using the cascaded-reflex circuit.

and switches the resistance of a bridge circuit in the cathode circuit in tube T_4.

The switch S_2 (in the "single-pulse" position in Fig. 4) serves to retain the same voltmeter calibration during the measurement of single and repeated pulses.

Variation of the resistance in series with the milliammeter compensates for the difference in the dc voltage produced on the grid of T_3 during the charging of the capacitor. Pushbutton S_1 (shown normally open in Fig. 4) serves to drop the voltage and permits rapid discharge of the capacitor. The instrument is fed from stabilized sources.

In the tests of the model the following was noted:

- The voltmeter scale is almost linear.
- After the instrument has warmed up, no differences in readings were observed (the observations lasted for approximately 4 hr.)
- The voltmeter can be used to measure voltages

of 3- to 5-μsec video pulses.

▪ The effect of input resistance, determined by the leakage resistance and by the grid current of the first tube is 2 x 10^{11} ohms (time constant of discharge is 400 secs).

[*Translated from an article "Cascade Reflex Voltmeter" in the October 1959 issue of* Izmeritelnaya Tekhnika (Measurement Engineering).]

Simple Technique for Measuring Phase and Amplitude in Automatic Control Systems

A. S. Lifshitz and I. A. Dedok

IN THE design of automatic control systems it becomes necessary to determine experimentally the amplitude and phase vs. frequency characteristics of the individual elements and of the system as a whole.

There are several methods for determining the frequency characteristics. The most popular methods use loop oscillographs or low-frequency cathode-ray oscilloscopes to determine the frequency characteristics, or they use a phase meter to determine the phase-frequency characteristics.

Each of these methods has advantages and shortcomings. The determination of the frequency characteristics by loop oscillograph is accurate, but it requires a rather long time to record and interpret the oscillograms.

Determination of frequency characteristics with a cathode-ray oscilloscope involves measurements of the amplitude, frequency, and phase shift of the input signal of the tested element. These involve a great loss of time and reduced accuracy.

A phase meter measures the phase accurately only if the output of the tested element is free of distortion and of noise background, for the latter may cause false readings.

By introducing a phase-shift network and a voltage divider in the circuit for measuring fre-

Mikhatskii, IU. V.
CASCADED REFLEX VOLTMETER YIELDS HIGH INPUT Z, WIDE RANGE. Electronic Design, v. 8, no. 3:124-127, incl. diagrs. Feb. 3, 1960.

Translation of an article "Cascade reflex voltmeter" in Izmeritel'naia tekhnika, no. 10, Oct. 1959. 2 refs quency characteristics, it is possible to use a cathode-ray oscilloscope and at the same time to reduce the measurement time substantially.

The procedure is to read the phase shift of the phase-shift network, and to read the output-to-input-signal ratio on the voltage-divider scale.

The operating principle of this instrument is based on a comparison of the phase and the amplitude of the output signal of the tested element with the phase and amplitude of the phase-shift network signal.

The phase-shift circuit consists of standard dc amplifiers *1, 2, 3* and a dual sine-cosine potentiometer *4, 5* (Fig. 1).

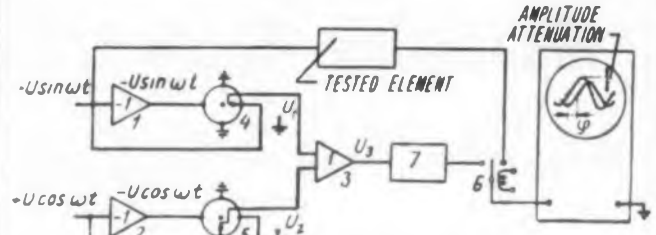

Fig. 1. Equipment for phase and amplitude measurements in automatic control systems. *1, 2,* and *3* are standard dc amplifiers; *4* and *5* are a dual sine-cosine potentiometer; *6* is a vibrator; and *7* is a voltage divider.

Potentiometers *4* and *5* receive, respectively, voltages $\pm U \sin \omega t$, $\pm U \cos \omega t$. These are applied from the low frequency generator.

The voltages picked off the sliders of potentiometers *4* and *5* respectively are $u_1 = U \sin \omega t$, $\cos \phi$ and $u_2 = U \cos \omega t \sin \phi$, which are then summed by amplifier 3.

$$U_3 = U_1 + U_2 = U \sin \omega t \cos \varphi + U \cos \omega t \sin \varphi = U \sin (\omega t + \phi)$$

The voltage from the tested link, U_{meas}, and the voltage from divider *7* are applied to the cathode-ray oscilloscope through vibrator-converter *6*.

By rotating the slider of the potentiometer, the phase shift between the voltage u_{meas} and the voltage u_3 from the phase shifter is reduced to zero, and the values of the amplitudes are equalized with the voltage divider.

If the voltage u_3 is applied to the horizontal deflection plate of a cathode-ray oscilloscope, and the voltage u_{meas} from the tested link is applied to the vertical deflection plate, an ellipse will be displayed on the cro screen in the general case when the phases and amplitudes do not coincide. (Fig. 2a.)

If the phases are equal, the ellipse degenerates into a straight line which makes an angle of 45 deg with the horizontal (Fig. 2b) if the amplitudes are equal. The accuracy of the measurement of phase and amplitude depends essentially on the precision of the sine-cosine potentiometer of the voltage divider, and on the accuracy of the read-

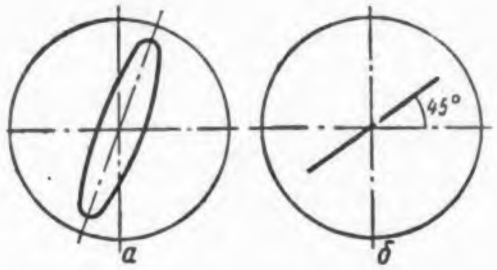

Fig. 2. When the voltage from the phase shifter is not in phase with the measured voltage, an ellipse results as shown in *(a)*. When the voltages are equal and in phase, the pattern in *(b)* results.

ings. Fig. 3 shows the calculated and experimental values (circles) of the frequency characteristics plotted with this instrument for an element having a transfer function $W(p) = 1/(1 + pT)$, with $T = 1$ sec.

As can be seen from Fig. 3, the experimental

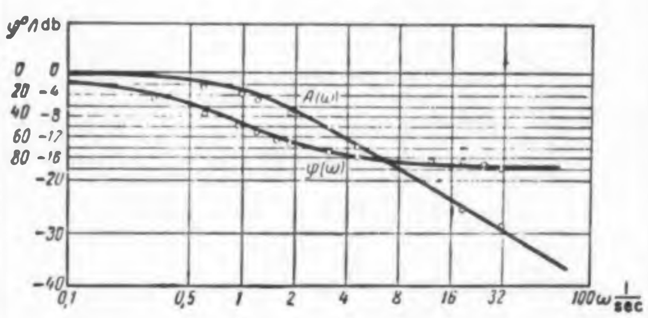

Fig. 3. Gain and phase characteristics, calculated (solid lines) and experimental (circles).

results of the phase measurements agree with the calculated ones within one degree, regardless of the value of the measured phase.

The frequency range of the measured signal is limited by the operating frequencies of the vibrator-converter, which is 400 cps, and ranges from 0 to 40 cps.

The instrument for determining the frequency characteristics is reliable in operation and can be used to investigate commercial automatic control systems.

[*Translated from an article "Determination of Frequency Characteristics in the Design of an Automatic Control System" in the October 1959 issue of* Izmeritelnaya Tekhnika (Measurement Engineering).]

E. Brenner

Tuned Transistor Amplifiers

SINGLE tuned transistor amplifier stages have finite complex input and output admittances whose resistive and reactive components depend on the operating point and the temperature. In the design of such stages one should distinguish between resistive and reactive matching. Resistive matching refers to the achievement of a desired over-all Q, with a given tank circuit Q, under optimum power transfer conditions. However, the detuning due to the variation of reactance is neglected. Reactive tuning meets a specification for maximum detuning together with a corresponding optimum power transfer.

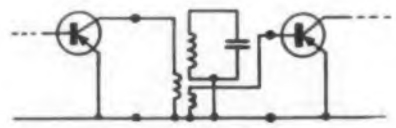

Fig. 1. Ac circuit of narrowband tuned amplifier.

Considering a common emmitter stage (Fig. 1) the equivalent circuit, Fig. 2, may be drawn. In this circuit the transistor input and output admittances are capacitive, that is,

$$Y_i = G_i + j\omega C_i;\; Y'_o = G'_o + j\omega C'_o$$

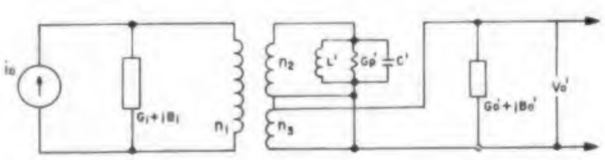

Fig. 2. Equivalent circuit of Fig. 1.

Referring all values to the primary (n_1) winding, the equivalent circuit shown in Fig. 3 is drawn.

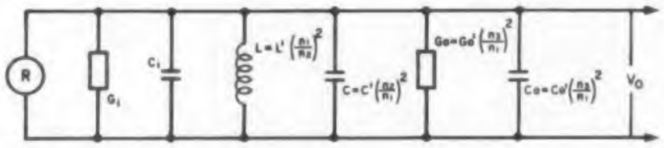

Fig. 3. Circuit equivalent of Fig. 2 at the terminals of i_o.

The resonant frequency used below refers to the resonant frequency obtained from Fig. 3.

The power delivered to the succeeding stage, P_o ($P_o = v^2_{out}\, G_o$), is related to the maximum power which the stage can deliver by

$$\eta = \frac{P_o}{P_{omax}},\; P_{omax} = |\,i_o\,|^2/4\,G_i$$

Using the normalized parameters:

$$q = \frac{G_p}{G_p + G_o + G_o} = \frac{Q \textit{ of entire circuit}}{Q \textit{ of tank}}$$

and

$$g = G_i/G_p$$

the general expression for η is:

$$\eta = 4gq[1 - q\,(1 + g)]$$

The optimum resistive match may be shown to occur when:

$$G_o = G_i,\; G_p = G_i 2Q/(Q_{tank} - Q)$$

yielding the value:

$$\eta_{opt} = (1 - q)^2$$

In the left half of Fig. 4, η_{opt} and 1/g are shown as functions of q. The detuning due to variation of transistor input and output capacitance is shown, normalized with respect to bandwidth, for 100 per cent of C_o and C_i in the right half of Fig.

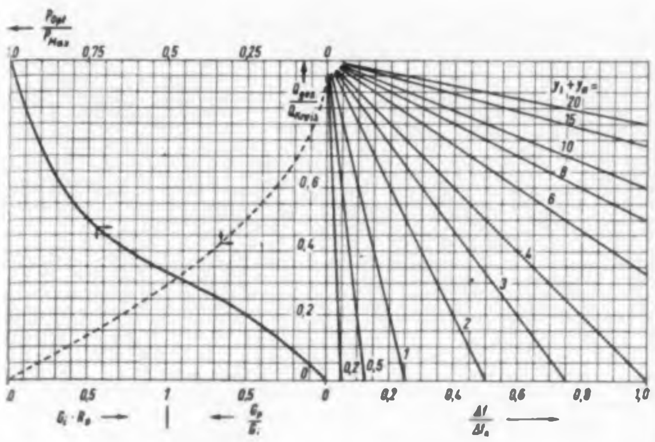

Fig. 4. Chart for resistive matching.

4. Normalized susceptance is used, that is, $b = \omega C/G$.

Denoting by Δf the detuning due to 100 per cent change in C_o and C_i,

$$\frac{\Delta f}{\Delta f_B} = \frac{1}{4}(1 - q)(b_o + b_i)$$

In many transistors C_i/G_i is negligible compared to C_o/G_o and if base resistance is also neglected, one may write:

$$\frac{\Delta f}{\Delta f_B} \approx \frac{1}{4}(1 - q)\,\omega_o/\omega_c$$

where ω_c is the cut-off frequency of the short-circuit current gain.

When the maximum detuning is prescribed, then Fig. 5 may be used to obtain the circuit

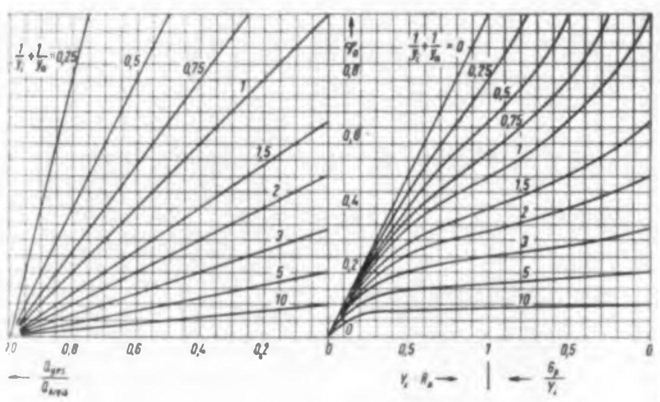

Fig. 5. Chart for reactive matching.

parameters for optimum design. In this chart

$$\psi_o = \Delta f/\Delta f_B$$

For a given value ψ_o, the optimum q and susceptance values are found in the left portion of the chart. The family of curves at the right gives the value G_p. The optimum power transfer is

$$\eta_{opt} = 4\,\psi_o^2/b_i\,b_o$$

Abstracted from an article by H. Beneking Nachrichtentechnische Zeitschrift, Vol. 12, No. 11, Nov. 1959, pp 543-546.

ELECTRONIC DESIGN

DIGEST of recent papers and literature of interest to design engineers

Spurious RF Emissions Predicted From Output Stage Analysis

SPURIOUS rf energy emanating from a high-frequency transmitter can present great difficulties for the design engineer. He would be considerably aided if he could predict from his circuit parameters, what the frequencies and power levels of the spurious emissions would be. The following method of analyzing the transmitter's radiated spectrum seems to show promise of accuracy when applied to transmitters which:

1. Operate in the high-frequency range
2. Have a tuned single-ended output
3. Can be represented by lumped, constant parameters.

In analyzing the spectrum, only harmonics of the oscillator frequency are considered. Output frequencies caused by modulation splatter or carrier noise are not.

Equivalent Transmitter Circuit

This prediction method considers only the transmitter's final output stage. A stage-by-stage analysis, it is felt, does not produce results accurate enough to warrant its cumbersome and tedious calculations. This is because of the numerous random variables, such as lead length, lead placement, and normal component tolerances which are involved.

Fig. 1 is a constant-current equivalent circuit for a transmitter which meets the conditions given above. In this circuit Z_L represents the impedance of the transmission line and the antenna network. The output circuit block consists of the final tuned circuit and the antenna coupling circuitry. It is assumed that the output impedance of the transmitter is large compared with the output circuit and is ignored.

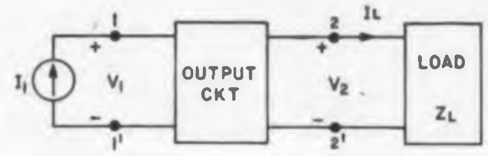

Fig. 1. Constant current equivalent circuit of the transmitter's output stage.

From the network loop equations, the load current can be written as:

$$I_L = I_1 \frac{|Z_T|}{Z_L + Z_{22}}$$

where

Z_T = transfer impedance $Z_{12} = Z_{21}$
Z_{22} = self impedance of loop 2
Z_L = load impedance

Thus, to predict the output power spectrum, it is necessary to determine:

1. The harmonic currents generated by the tube ($I_1, I_2, I_3, \ldots . I_N$)
2. The absolute value of the transfer impedance (Z_T). Note that only its absolute value is necessary since it alone appears in the numerator.
3. The real and imaginary components of the output impedance Z_{22}.
4. The real and imaginary components of the load impedance Z_L.

Determining the Harmonic Currents

General methods for obtaining the harmonic currents in tubes operating with various angles of plate current flow have been devised. One of these expresses the instantaneous plate current as:

$$i_L = k\left[\cos b - \cos\frac{\theta}{2}\right]^{\frac{3}{2}} \qquad (1)$$

The Fourier current integral is:

$$I_N = \frac{2k}{\pi}\int_0^{\frac{\theta}{2}}\left[\cos b - \cos\frac{\theta}{2}\right]^{\frac{3}{2}} \cos nb \; db. \qquad (2)$$

where: I_N is the current amplitude for each harmonic being considered
b = carrier time angle
θ = angle of plate current flow with respect to each cycle of the operating frequency.

The maximum value of plate current is:

DIGEST

$$I_M = k\left[1 - \cos\frac{\theta}{2}\right]^{\frac{3}{2}} \qquad (3)$$

Peak plate current can also be determined by plotting the load line on the tube characteristic curves.

In a problem involving a given transmitter, I_{max} and θ can be specifically determined from the transmitter's operating characteristics. The absolute values of the harmonic currents can be obtained from Eq. 2.

If it is desired to determine the spurious spectrum for various values of θ and I_{max}, a normalized plot of the ratio of I_N and I_{max} is helpful. In Fig. 2, the ratio I_N/I_M is plotted for the various angles of plate current flow. Thus, the absolute harmonic current values can be found by multiplying the current ratio corresponding to a certain θ, by the output tube's peak current.

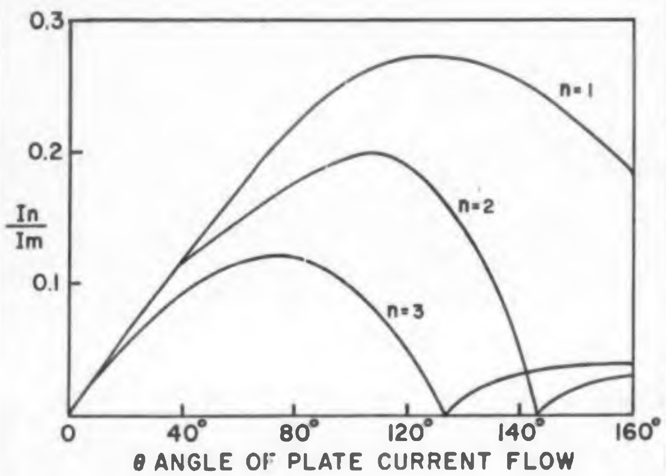

Fig. 2. Illustrative plots of general harmonic current ratio curves.

This analysis indicates levels of currents associated with frequencies which are harmonically related only to the carrier frequency. If frequency multiplication occurs in a transmitter, frequencies which are harmonically related to the oscillator fundamental frequency must be separately inserted. These additional harmonic currents must be considered at all multiples of the oscillator frequency which are not multiples of the transmitter output frequency. They can be inserted in the equation at the appropriate frequencies, with magnitudes of 0.5 times the value of the envelope described by the carrier harmonics. The number 0.5 was empirically evolved as a correction factor after evaluation of several theoretical and actual test data. This is a rough approximation which presently appears to provide adequate accuracy for most prediction purposes. If the worst case is desired, the magnitude of the oscillator harmonics can be made equal to the envelope of the carrier harmonics. The process of inserting these plate currents at the oscillator harmonic frequencies will be shown in the sample problem.

Sample Problem

To illustrate the technique just described, the power output spectrum of a high-frequency, 2 to 30 mc, three-stage, 100-w cw transmitter was predicted and compared to measured data for the same transmitter. In the transmitter the 3-mc oscillator frequency was multiplied to obtain a 6-mc carrier frequency.

The transmitter's output tube was designed to operate with an angle of plate current flow slightly less than 180 deg. The output current was expressed as the 3/2 power of the grid voltage, and the Fourier components were found as ratios of harmonic currents to the peak plate current. Peak plate current was determined by plotting the operating load line on the tube characteristic curves.

This peak current value was then multiplied by each Fourier harmonic current ratio to yield absolute values of harmonic current at frequencies which are multiples of 6 mc. Since it is known that the transmitter oscillator is operating at 3 mc, harmonic currents are to be expected at all multiple frequencies of 3 mc.

As an approximation, these harmonic currents were inserted in Fig. 3 with magnitudes empirically chosen to be half the magnitude of the

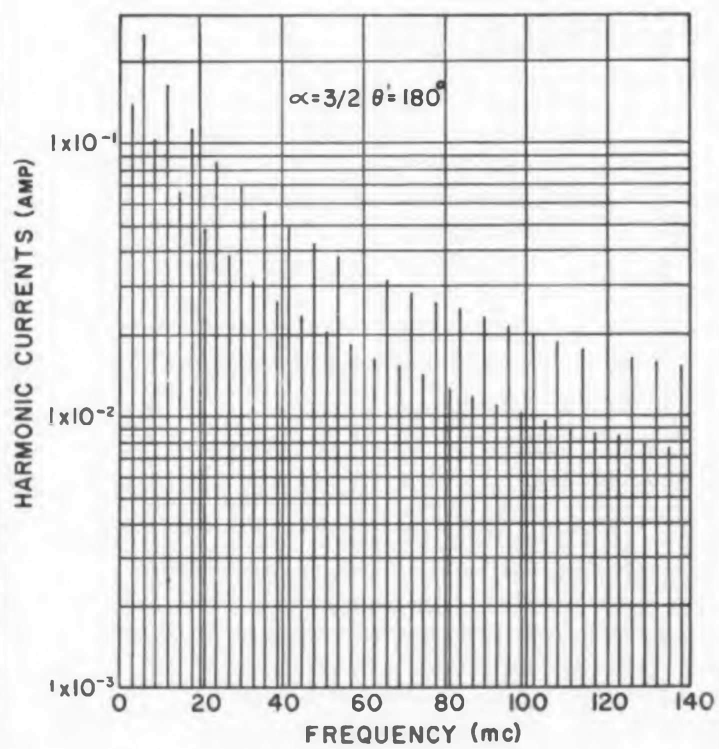

Fig. 3. Theoretical harmonic current content of a power amplifier tube plate current pulse.

envelope described by the mathematically predicted currents. Fig. 3 represents the theoretical harmonic current content of the power amplifier tube-plate current pulse.

The output circuit of this transmitter consisted of a tuned LC circuit and a fixed coupling link as shown in Fig. 4. Z_{22}, the output impedance of this circuit, was determined by averaging a series of bridge measurements taken across the antenna terminals of the transmitter, with the plate lead of the power amplifier tube removed.

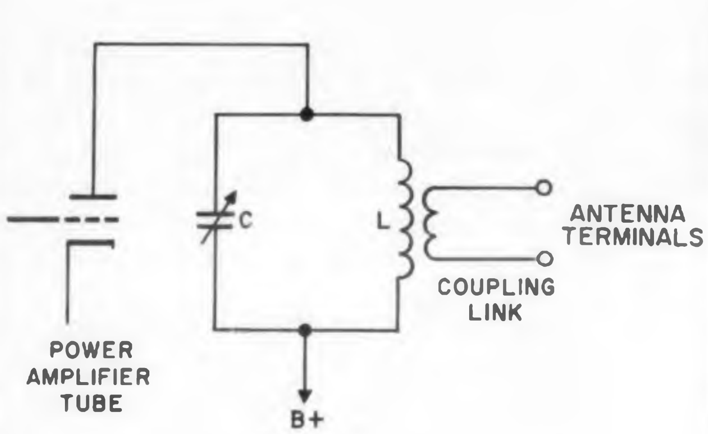

Fig. 4. Output circuit for the sample transmitter.

Much difficulty was encountered in measuring the transfer impedance (Z_T). The measuring technique is shown in Fig. 5. The tube-plate lead was connected to a signal generator and the output circuit was driven with a known current. The effective open-circuit voltage developed across

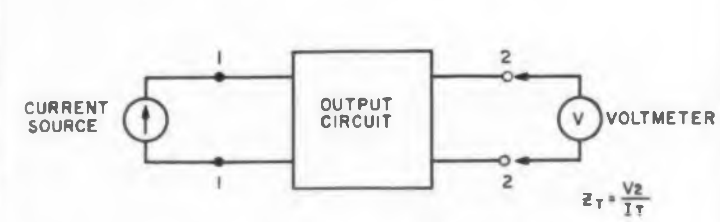

Fig. 5. Circuit for the measurement of the output circuit transfer impedance Z_T.

the antenna terminals (2) was measured with a high-impedance rf voltmeter. Z_t was determined by dividing this voltage by the current.

A calibrated dummy load having real and reactive components, provided a known load impedance (Z_L).

The portion of the harmonic current reaching the load was calculated from Eq. 1, previously given.

Harmonic power dissipated in the load was calculated from:

$$P_N = \frac{I_N Z_T}{Z_{22} + Z_L} R_L \qquad (4)$$

where

R_L = the real component of the load impedance.

The resulting predicted power spectra are compared with the actual measured spectrum in Fig. 6. It was suspected that the impedance measuring technique yielded transfer impedance values which were too high at frequencies above 120 mc. The power spectrum calculated from the measured transfer impedance seems to uphold this view since Fig. 6 shows the calculated spectra to

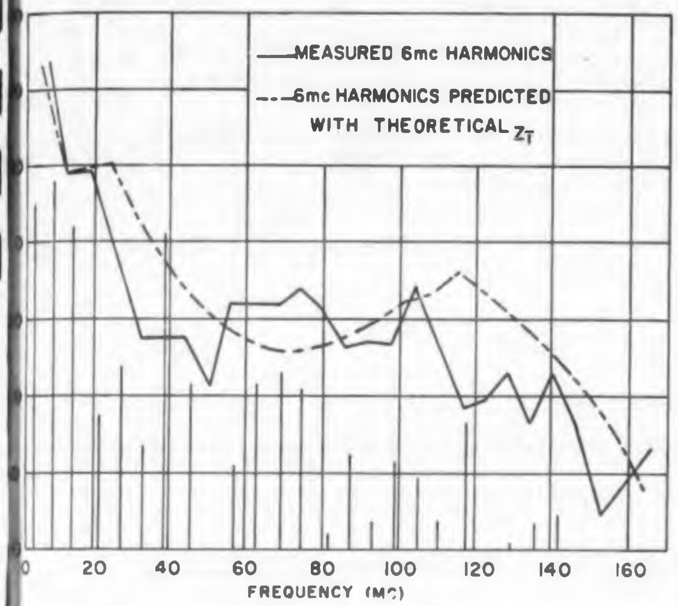

Fig. 6. Measured and theoretical plots of transmitter harmonic output.

be much higher than the measured spectra in the upper range. The vertical lines on Fig. 6 represent the power levels for the oscillator frequency harmonics. These were plotted separately to show their level relative to the carrier harmonics. It was found that the oscillator harmonic currents as estimated were too large in this case to accurately predict the measured values.

Conclusions

From the results, it is realized that more measurements must be made before a completely accurate method for estimating these harmonics can be applied to any transmitter. However, the prediction technique described appears to have great promise.

Digester from a paper, "Prediction Factors Influencing Transmitter Power Spectrum," by James J. Crenca and Donald Berilla, Jansky & Bailey, Inc., and Charles R. Miller, Rome Air Development Center, presented at the Fifth Conference on Radio Frequency Reduction and Compatibility, October 1959, Chicago, Ill.

REPORT BRIEFS

Phase-Modulated Antennas

The resolution of a passive antenna system can be improved through phase-modulation, cross correlation, and synchronous detection. Possible methods for constructing radiation patterns of the form (NKx sin NKx) by means of these techniques are presented. The relationship between the coefficients of a linear additive array and those of an equivalent product array is also stated. *Phase-Modulated Antennas, Charles J. Drane, Jr., Air Force Cambridge Research Center, Bedford, Mass., Apr. 1959, 19 pp, Micro-film $2.40, Photocopy $3.30. Order PB 142962 from Library of Congress, Washington 25, D. C.*

Intermediate Frequency Amplifiers

Small-size, very high-gain, high-level-output intermediate frequency amplifiers for use in radio interference measuring sets were designed and constructed. Results of the study and design phase are given. Recommendations for electronic and constructural modifications which will result in better production results are made. The factual data section includes a description of the study program, a detailed description of the two types of amplifiers which were investigated. *Intermediate Frequency Amplifiers, A. W. Pearson, General Electronic Laboratories, Inc., Cambridge, Mass., July 1, 1954-July 1, 1957, 171 pp, Mircofilm $8.10, Photocopy $27.30. Order PB 143358 from Library of Congress, Washington 25, D. C.*

Coupling Network Design

The problem of broadband coupling-network design is one of primary practical importance in electrical engineering. This report is concerned with the derivation of a method for such network design. The design problem may be stated as follows: "To design a two-port coupling network that presents some prescribed input impedance, Z_{in}, when terminated in a prescribed load impedance, Z_L, both input and load impedances being described over a certain band of frequencies." A method for the design of practical lossless ladder networks, based on a point-by-point matching in the frequency domain, is described. *Coupling Network Design Using Discrete-Frequency Data, P. A. Ligomenides, Stanford Electronics Laboratories, Stanford University, Calif., Oct. 22, 1958, 195 pp, Microfilm $8.70, Photocopy $30.30. Order PB 143066 from Library of Congress, Washington 25, D. C.*

Broadband Components

Results are summarized for the development of ridged guide components in the 3.75 to 15 kmc range. The first objective was concerned with obtaining complete design information on the transmission line properties of the single ridged guide system, and the second objective was concerned with the building of a number of ridged guide components. General design information of single and double ridged guides is presented in graphical form and allows the determination of all the electrical properties of ridged guide transmission lines. The following components are discussed: ridged to rectangular guide adapters, coax to ridged guide adapter, H-bend, termination, crystal mount, tuner, variable attenuator, and slotted section. Performance of these components is in some respects below that of the conventional narrow-band devices. With additional engineering effort, these components are expected to be comparable in performance to the conventional items. *Extremely Broadband Components Development, Samuel Hopfer, Polytechnic Research and Development Co., Inc., Brooklyn, N. Y., Aug. 1954, 80 pp, Microfilm $4.50, Photocopy $12.30. Order PB 143102 from Library of Congress, Washington 25, D. C.*

Thermoelectricity Abstracts

This bibliography represents the accumulation of unclassified references to the literature on thermoelectric research, development, and application resulting from a search of abstract journals, indexes and bibliographies immediately accessible. Some early, as well as current, material are included. Additional bibliographies will be issued at intervals, the objective being to attain as complete coverage of the literature as possible. Arrangement for periodical entries is alphabetical—by author, or by title if author is lacking; and for research reports by issuing agency. Each entry is numbered in preparation for an anticipated index. Abbreviations for journal titles are based on those used by the U.S. Naval Research Laboratory Library. A list of these abbreviations together with the journals which they represent appear on the pages following the introduction. The majority of the journals and books referred to should be available for consultation or borrowing at the larger public or research libraries. Research reports can usually be obtained through established borrowing procedures from the Armed Services Technical Information Agency and the Office of Technical Services. AD and PB numbers are included when known. *Thermoelectricity Abstracts, Naval Research Laboratory, Washington, D. C., May 1959, 104 pp, $2.50. Order from OTS, Washington 25, D. C.*

YOUR CAREER

NEWS AND NOTES

Demand for engineers rose appreciably last year in the U.S., resulting in spirited recruiting by industry. But a measure of stability was also evident in the employment picture: numerical shortages dropped and engineering turnover headed for a new decline.

These and other facts on the supply and demand of engineers were disclosed by the Engineering Manpower Commission of the Engineers Joint Council in its ninth annual report.

The commission noted that numerical shortages of engineers "were not widespread because of the large number of engineering graduates available for immediate employment." Last year's B.S. graduates were put at 38,162, "the largest class since 1951; 36 per cent greater than in 1956, and 41 per cent over 1955, the period in which the shortage was most acute."

But the report warned that as the economy expanded, shortages might once more be pronounced, inasmuch as enrollments in engineering schools declined in 1958 and 1959.

"The demand for engineering graduates will increase," the commission said, "and by 1966 there will be 15 graduates recruited for every 10 hired in 1959."

As for engineering turnover, the report said it averaged 9.5 per cent in 1958, a drop from the 11 per cent of 1957, and when the final figures were in, would likely show a further dip to 8.6 per cent for 1959. The main causes of engineer losses were given as resignation, 55 per cent; death and retirement, 9 per cent, and military leave, 6.5 per cent.

Starting salaries last year were reported at new average highs: $510 a month for B.S. graduates, $600 for M.S. and $825 for Ph.D.'s.

What can an electronics company do when it's (1) small; (2) situated in a farming area, and (3) desperately short of engineers? New Hampshire Ball Bearings, Inc., of Peterborough, N.H., like many rural electronics plants, has an answer.

As Arthur N. Daniels, president of the concern, explains it, the solution is to spread thin what engineering talent is available and open a school to train engineering assistants.

New Hampshire Ball Bearings operates the school. A graduate of the Massachusetts Institute of Technology and former War Production Board aide, Sid Doyle, is director of education. The course runs for a year, with work divided equally between the classroom and the laboratory.

The first class was recruited by visiting high schools in the area and explaining the program to seniors. Fifty students applied for training. Twelve were selected. Eight earned diplomas and went to work at New Hampshire Ball Bearings.

The word spread among high school students after that, and they have competed to enroll. Trainees get paid for class work as well as duties in the plant. They can take a job anywhere after they graduate, but most stay and help the company turn out miniature and instrument ball bearings.

Mr. Daniels is pleased with the arrangement. "From cows to calculus," is the way he describes the students' progress.

* * *

Pass the word along to service technicians: free training in several aspects of transistor theory and trouble shooting is being offered by the Delco Radio Division of General Motors. Classes, which run a week, are conducted at 30 centers in the country. To apply, fill out an application blank, available from Delco distributors, or write for further information to Ted R. Hayes, Service Manager, Delco Radio Division, Kokomo, Ind.

For each of you lads with E.E.,
Now's the time to flog that degree!
Never stay in one town
But keep shifting around—
Transporting the family is free.

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Advancement Your Goal?

Use New Form To Speed Action

ELECTRONIC DESIGN's new Career Inquiry Service form is designed to help engineers advertise themselves. This new service speeds applicants to the jobs they seek. It is the first such service offered in the electronics field and is receiving high praise from personnel managers.

To present your qualifications immediately to the personnel managers of companies that interest you, simply fill in the attached standardized short resume.

Study the employment opportunity ads in this section, and circle the numbers at the bottom of the form that correspond to the numbers of the ads that interest you.

ELECTRONIC DESIGN's Reader Service Department will act as your private secretary and type neat, duplicate copies of your standardized resume and send them to all companies you may select . . . *the same day the resume is received.* (ELECTRONIC DESIGN will detach the circle number portion of the form so that no company will know how many numbers you circled.)

The standardized resume will permit personnel managers to inspect your qualifications rapidly. If they are interested, they will get in touch with you directly. In the past much time has been lost through personnel-manager requests for resumes from applicants who proved ineligible.

MAIL CAREER INQUIRY SERVICE FORM TO READER SERVICE, ELECTRONIC DESIGN, 830 THIRD AVE., NEW YORK 22, N. Y.

ELECTRONIC DESIGN **CAREER INQUIRY SERVICE** USE BEFORE MAR. 16, 1960

After completing, mail career form to *ELECTRONIC DESIGN*, 830 Third Avenue, New York, N. Y. Our Reader Service Department will forward copies to the companies you select below. (3)

(Please print with a soft pencil or type.)

Name ______________________ *Telephone* ______________

Home Address ______________ *City* ______________ *Zone* ______ *State* ______________

Date of Birth ______________ *Place of Birth* ______________ *Citizenship* ______________

Position Desired ______________________________

Educational History

College	*Dates*	*Degree*	*Major*	*Honors*

Recent Special Training ______________________________

Employment History

Company	*City and State*	*Dates*	*Title*	*Engineering Specialty*

Outstanding Engineering and Administrative Experience ______________________________

Professional Societies ______________________________

Published Articles ______________________________

Minimum Salary Requirements (Optional) ______________________________

Use section below instead of Reader Service Card. Do not write personal data below this line. This section will be detached before processing.

Circle Career Inquiry numbers of companies that interest you

900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924
925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949

CAREER COURSES

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 consecutive days and intended to draw attendees from all geographic 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.

National Courses

Course in X-Ray Spectrography, New York

The thirty-fifth Norelco X-Ray School will be devoted entirely to the subject of X-Ray Spectrography. Registration is open to chemists, metallurgists, physicists, production supervisors, quality control engineers and others interested in the application of X-ray Spectrography. Monday through Thursday meetings involve classroom and laboratory work. On Friday, guest speakers discuss interesting problems and how they are handled by specific industries. There is no registration fee. Sessions will be held at the Henry Hudson Hotel, 353 West 57th St., New York, N. Y., during the week of February 15-19.

Regional Lectures

Managing the Development Engineering Function, AMA, Feb. 10-12, Dallas

In most industries other than chemical, research and development and development engineering are closely allied. In this seminar, the development engineering function will be analyzed and its relationship to research and development will be discussed. This seminar is of interest to all key personnel of both corporate departments and divisions. For further information for this seminar and the following one write to: American Management Association, Hotel Astor, Times Square, New York, N.Y.

Evaluation and Measurement of R&D, AMA, Feb. 15-17, New York

The evaluation and measurement of research and development and the various aspects of this broad subject will be discussed at this seminar, as well as the techniques that have been developed for evaluation and measurement. The seminar has been developed for those in the finance area charged with these responsibilities, and for key members of the research and development group.

professional opportunities at Honeywell Aero

FLIGHT CONTROL SYSTEMS: Analytical, systems, and component engineers to work in areas such as advanced flight reference and guidance systems. Positions range from analyzing stability and control problems, systems engineering through design, testing and proof of electrical and mechanical equipment—including flight test and production test.

GROUND SUPPORT: Electrical Engineers to design equipment for testing complex electronic systems, preferably with experience in digital techniques, solid state circuitry, and logic circuit design as applied to automatic checkout systems.

EVALUATION: Graduate engineers with electronic background desiring opportunity in development, qualification and reliability testing. Must have ability to design and develop specialized equipment which can duplicate environmental conditions encountered by advanced projects. Assignment in this work leads directly to a career in design, research or advanced system development.

ADVANCED GYRO DESIGN: Engineers with two and up to twenty years' experience in precision gyro and accelerometer development, servo techniques, digital techniques, solid state electronic development, advanced instrumentation and magnetic component design.

PRODUCTION: Electrical engineers to assume responsibility for placing complex devices such as platforms, floated gyros, accelerometers, vertical and rate gyros, calibrators and computers into production. Work with design engineers to introduce production know-how and techniques into original design. Responsible for estimating, processing, and tooling during the pre-production phase; directing assembly, calibration, and inspection efforts during initial production phases.

INSTRUMENTATION: Development and design in the critical areas of test instrumentation for Aero products. Two years' experience in test instrumentation desired.

To investigate any of the above professional opportunities at the Aeronautical Division, please write in confidence to Bruce Wood, Dept. **369.**

Honeywell

AERONAUTICAL DIVISION

1433 Stinson Blvd. N.E., Minneapolis 13, Minnesota

To explore professional opportunities in other Honeywell operations coast to coast, send your application in confidence to H. K. Eckstrom, Honeywell, Minneapolis 8, Minnesota.

CIRCLE 904 ON CAREER INQUIRY FORM

Engineers...

RCA and DEFENSE

WEST COAST

No longer does the width of the oceans shield America.

Today an entirely new concept of defensive tools must link arms to guard us. Missiles protect cities and military installations. ASW units scour the seas. BMEWS alerts us to attack. Mach 3 interceptors, anti-missile missiles, listening posts on the floor of the oceans, atomic rockets—they all play a part in the defensive scheme of things, if not now, tomorrow.

A continuous flow of new and better defensive weapons must be developed, designed, and delivered to the armed forces by engineers—this is a *must* for survival. Never in our history have engineers been such a vital cog in this country's security. And this role grows daily.

RCA's own West Coast expansion program has created a number of exceptional career opportunities for creative electronic and mechanical engineers versed in systems, projects, and development and design engineering in these areas: information handling, data processing, electronic countermeasures and missile launch control and checkout systems. Our new, modern electronic center in the San Fernando Valley will be where you'll work and grow *with* RCA on the West Coast.

If you're interested in building your future on solid ground, RCA—the world leader in electronics—is the place to start. Let us hear from you very soon, in all confidence of course.

Call collect or write:
Mr. O. S. Knox
EMpire 4-6485
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Dept. 360-B
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CIRCLE 921 ON CAREER INQUIRY FORM

CAREER COURSES

PAPER DEADLINES

Convention Program Chairmen have issued the following deadlines to authors wishing to have their papers considered for presentation.

Those interested in presenting papers or in suggesting symposia for the 1st Annual Symposium on Human Factors in Electronics, scheduled for Mar. 24-25 in New York, should correspond as soon as possible with Mr. R. R. Riesz, Chairman, Papers Procurement Committee, C/O Bell Telephone Laboratories, Meetings Committee, C/O Bell Telephone Laboratories.

February 15: Deadline date for papers of 300-2500 words for the **3rd International Conference on Medical Electronics** to be held **July 21-27** in London. Papers should deal with problems encountered in the operation of equipment or with limited aspects of a wide subject. The committee has listed the following sessions in which they are particularly interested: instrumentation for biological needs; medical electronics in space research; ultrasonics; the respiratory system; the digestive system; the circulatory system; electronics aids to sight, hearing, and locomotion; the nervous system; and electronic aspects of human engineering. Papers must be double spaced and submitted in triplicate. Send to: *Lee B. Lusted, M. D., Dept. of Radiology, University of Rochester, School of Medicine, Rochester 20, N. Y.*

March 1: Deadline for rough draft manuscripts for the **Joint Automatic Control Conference,** scheduled for **September 7-9** in Boston, Mass. Papers may be on any significant aspect of automatic control. Possible topics might include: sampled data, theoretical aspects of computer control, operating results in computer control, nonlinear control, adaptive control, statistical control, cybernetics, super-slow control systems components, actuators, criteria objectives for control, maintenance in complex systems, component dynamics and techniques for testing dynamic system. Final copy deadline is May 1. Papers may be submitted to: *Harvey A. Miller, JACC Program Committee-IRE, Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.*

A call for technical papers for the **1960 West Coast Audio Engineering Society Convention** scheduled for **March 8-11** at the Alexandria Hotel, Los Angeles, Calif., has been issued. Authors are urged to send titles and 25-50 word abstracts immediately to *Walter T. Selsted, Ampex Corp., 934 Charter St., Redwood City, Calif.*

TYPICAL PROGRAMS:

Study of the fundamental photo processes in the wider gap III-V compound semiconductors. Ability to take primary responsibility, functioning with minimum of supervision.

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Analytical and experimental investigations in **Avalanche Mode Switching Transistors** for very high-speed applications in computers.

Analysis and synthesis of circuitry applications for new semiconductor devices. Knowledge required in electronic circuits; familiarity with computer problems and ultra-high-frequency techniques. Experience desirable in microwave applications of solid state devices.

Laboratory facilities are located in Endicott, Poughkeepsie, Kingston, Owego, and Yorktown Heights, N. Y.; Lexington, Ky.; and San Jose, California.

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To learn more about opportunities for you at Sanders—and the advantages of our location in the progressive New England community of Nashua, New Hampshire (less than an hour from downtown Boston), send a resume to Lloyd Ware, Staff Engineer, Dept. 920.

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CIRCLE 906 ON CAREER INQURY FORM

CAREER OPPORTUNITIES BROCHURES

Missile and Space Systems

"For Careers In Motion . . ." is an 11-page illustrated brochure describing Missile and Space Systems, a division of the United Aircraft Corp. The division was established to develop concepts and to engineer complete weapon and space systems including missile, orbital, lunar and space projects.

Weapon systems engineering and the complementary skills required for systems engineering are briefly outlined under the following headings: technical military planning, electronic engineering and aeronautical engineering. Advancement prospects, company facilities and benefits are listed.

John W. North, Engineering Dept., Missile & Space Systems, Dept. ED, East Hartford 8, Conn.

CIRCLE 870 ON READER-SERVICE CARD

Mountain View Operations

The Mountain View Operations, a part of Sylvania Electronic Systems, are briefly reviewed in this folder. Work on all aspects of electronic systems from basic research in microwave physics—to development of advanced tube and components—to creation of complete countermeasures and reconnaissance systems is offered. An organization chart, company benefits and community benefits are listed.

Wayne L. Pearson, Sylvania, Dept. ED, P.O. Box 188, Mountain View, Calif.

CIRCLE 871 ON READER-SERVICE CARD

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