Electronics World

APRIL, 1965
50 CENTS

THE ELECTRONICS INDUSTRY—

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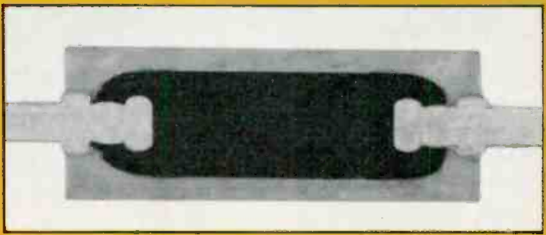
MARINE RADIOTELEPHONE ANTENNA
DESIGNING THE HI-FI SPEAKER

SPECIAL ISSUE: FIXED RESISTORS



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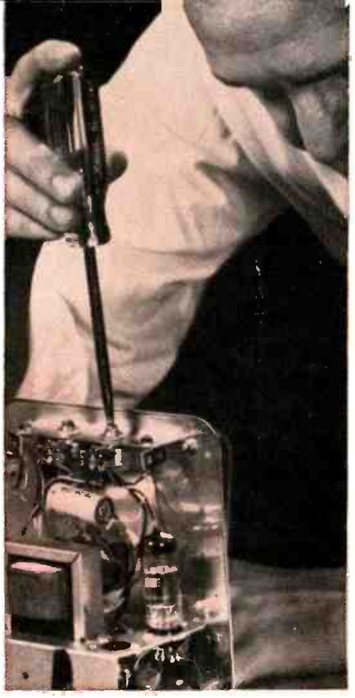

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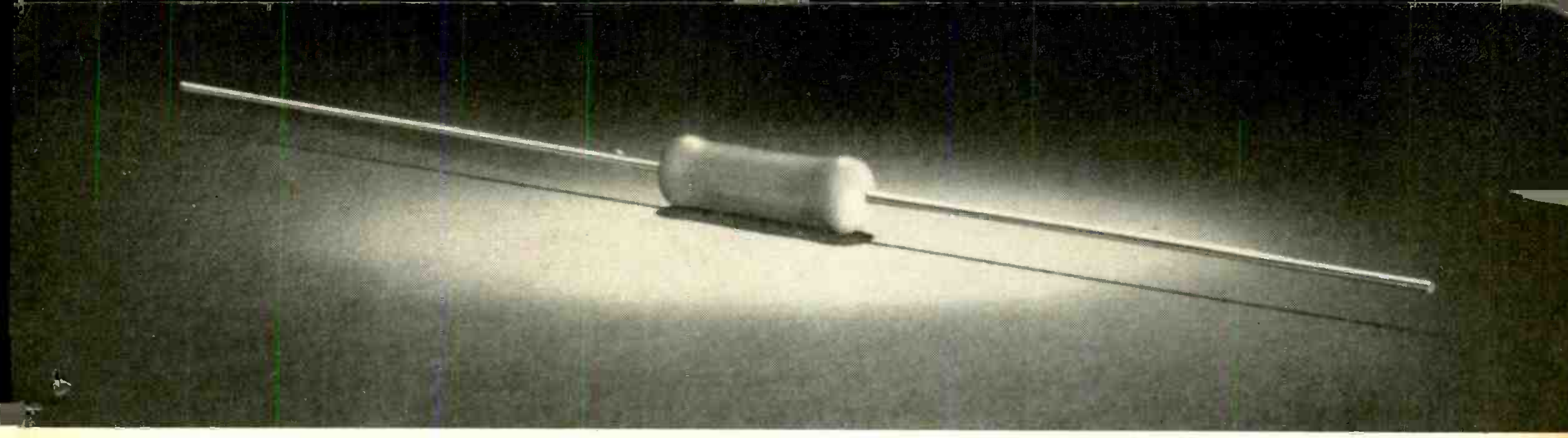

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Electronics World

CONTENTS

APRIL 1965
VOL. 73, No. 4

THIS MONTH'S COVER includes a belt of fixed resistors for use by an automatic processing machine. In this configuration, the resistor lead wire can be cut to any desired length, bent to any desired shape, and then automatically inserted and soldered into a printed-circuit board. The top insert is an interior view of an Allen-Bradley carbon resistor. The center insert shows the inside arrangement of a typical Ohmite wirewound type, while the lower insert shows the manner of film slitting used by IRC to increase the resistance values of their film resistors . . . (Photo: Jay Seymour, Burns Bros., N.Y.)

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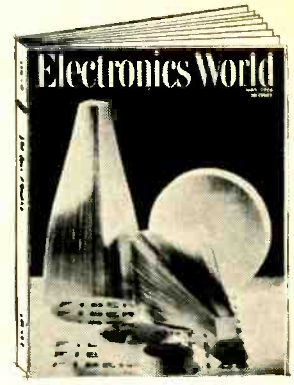

FIBER OPTICS IN ELECTRONICS

Fritz O. Kahl, Senior Product Specialist at Corning Glass Works, surveys the present state-of-the-art in this comprehensive article. Not only does he cover operating principles and characteristics, but he discusses in detail such applications of fiber optics in inspection tools, special CR tubes, image intensifiers, and vidicons.

SOLID-STATE DIMMERS & POWER CONTROLS

This is the first of two articles covering new types of power controls. This part deals with the new dimmers and power-control circuits now available, their capabilities and limitations. Basic operating principles and the types of loads they are capable of handling are also covered.

TUNING FORK AS AN ELECTRONIC COMPONENT

Most people associate tuning forks with choral groups, but because of its inherent high-"Q" and long-term stability, it is finding wide application in the electronics field. Some of the most important of such applications are included along with future possible uses for such devices.

RELIABILITY OF ELECTRONIC COMPONENTS

This article explains how reliability is estimated and how equipment can be designed for reliability improvement. A chart of typical failure rates for various types of electronic components is a valuable addition to the text.

SPECTRUM ANALYZERS

Operating principles and important applications of instruments that produce CRT display of input signal strength vs frequency. Uses for such analyzers include communications-band monitoring, checkout of radar and other pulse-modulated equipment, and general transmitter testing.

SSB COMES TO MARINE RADIO

As marine frequencies move toward v.h.f., more and more marine operators are shifting to SSB. Here are the details.

All these and many more interesting and informative articles will be yours in the MAY issue of ELECTRONICS WORLD . . . ***on sale April 20th.***

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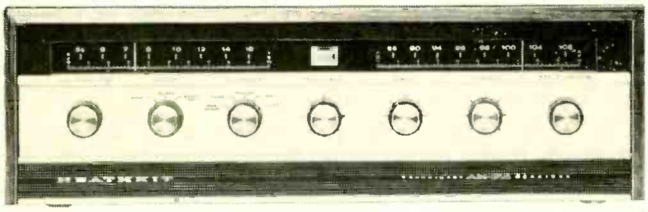

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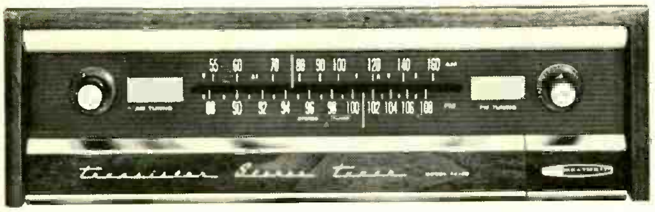

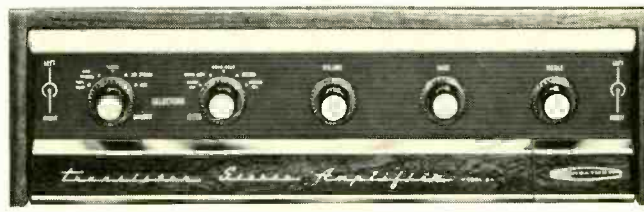

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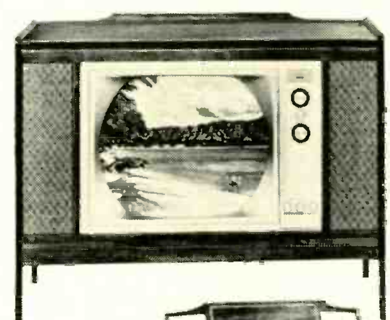

GR-53A
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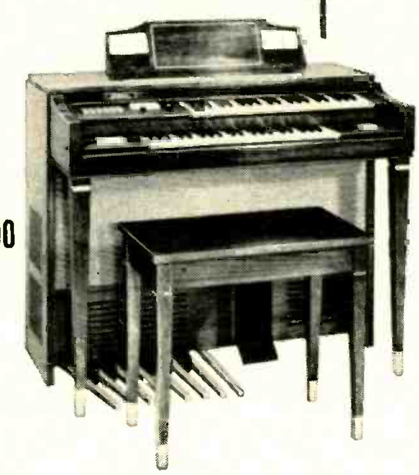

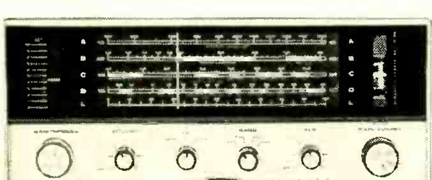

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Assembled IMW-11 . . . . $39.95

IM-13
$32^{95}

Deluxe "Service Bench" Vacuum Tube Voltmeter, IM-13 . . . . . $32.95
Measures AC volts (RMS), DC volts, resistance & db. Separate 1.5 & 5 volt AC scales for high accuracy; "gimbal" mounting bracket for easy bench, shelf or wall mounting; meter tilts to any angle for best viewing; smoother vernier action zero & ohms adjust controls; large, easy-to-read 6" 200 UA meter; and single AC/Ohms/DC test probe. 7 lbs.
Assembled IMW-13 . . . . $49.95

IG-112
$99^{00}

New! Heathkit FM Stereo Generator, IG-112 . . . $99.00
Produces all signals required for trouble-shooting & alignment of multiplex adapters, FM tuners & receivers. Generates mono FM or composite stereo FM signals. Switch selection of 400 cps, 1000 cps, 5000 cps, 19 kc, 38 kc, plus 65 kc or 67 kc SCA test signals for complete alignment capability. Simple to assemble & use. 10 lbs.

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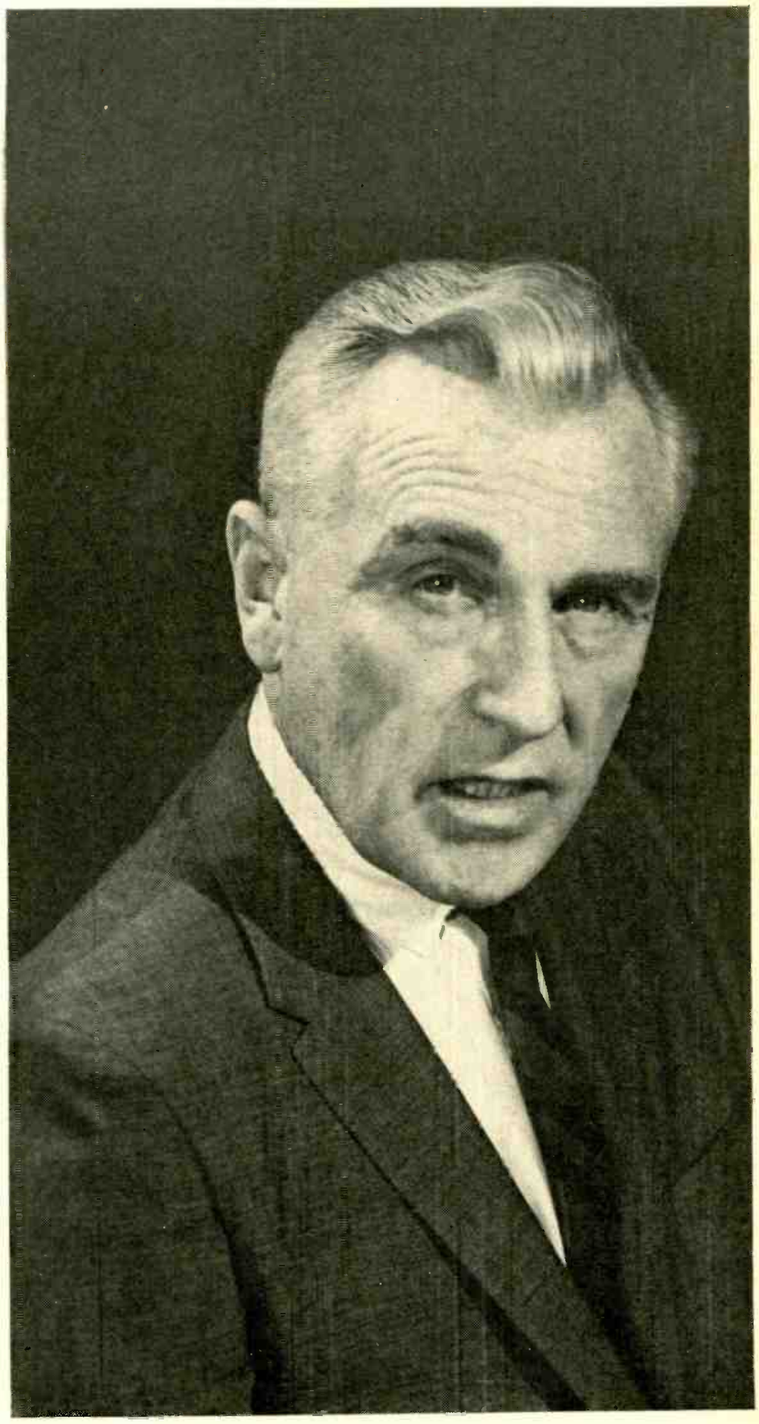

who holds a full time job and has family obligations. And few residence schools offer educational programs directly related to current employment requirements in the electronics industry.

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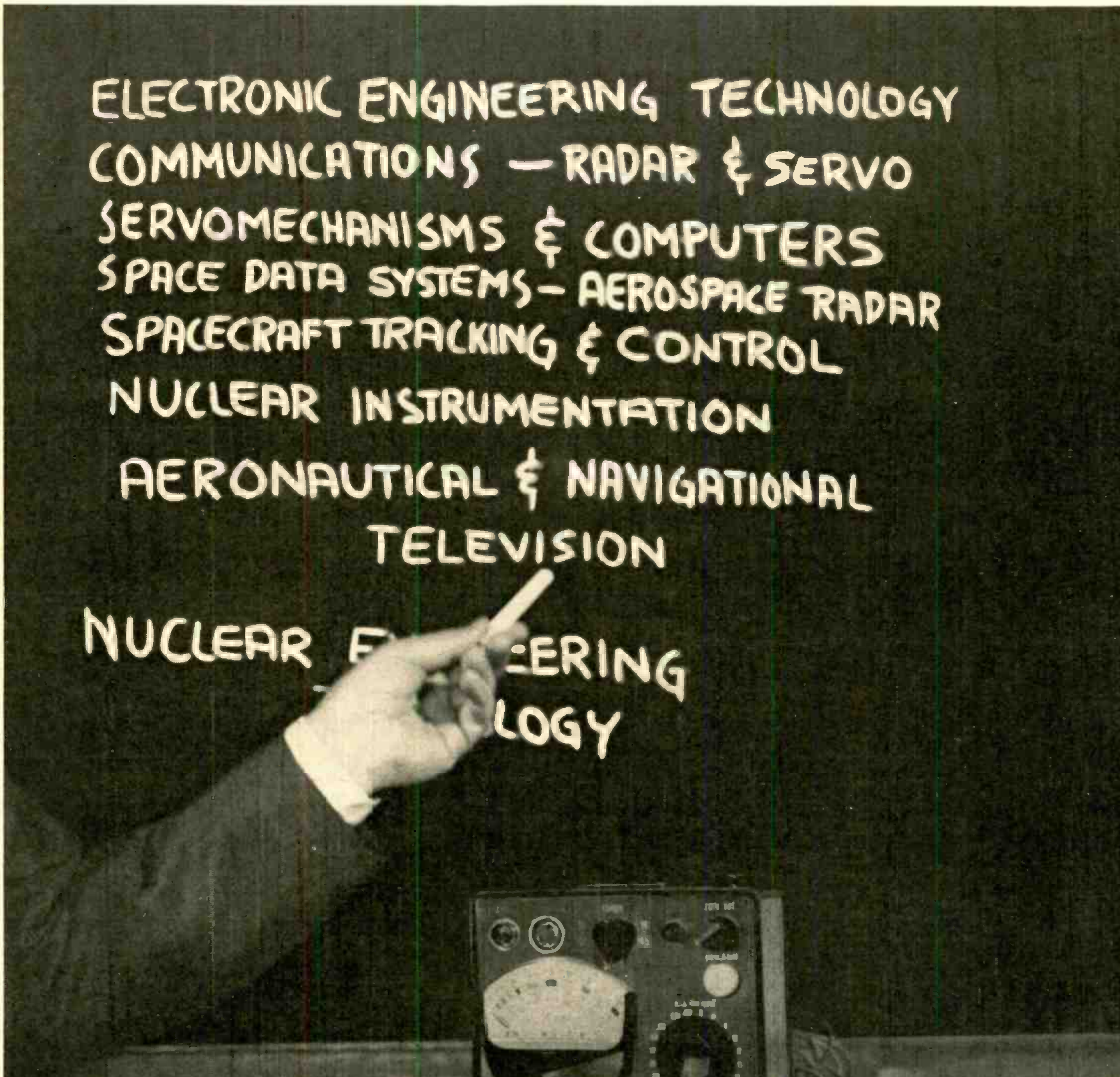

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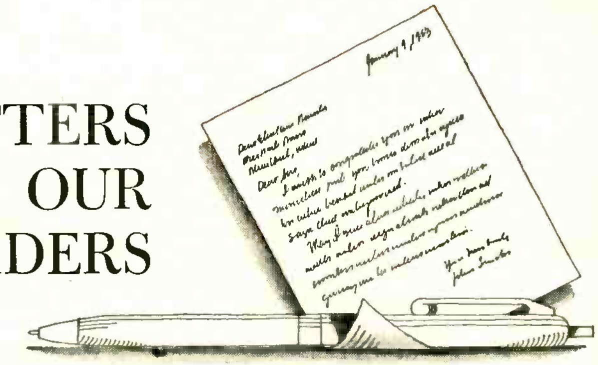


SCA MUSIC MULTIPLEXER

To the Editors:

In reference to a recent article on the construction of an SCA background-music multiplexer, here is some information which may prove of value to would-be users of the service.

Several years ago, I was employed by a local radio station whose main source of income was derived by supplying background music. From time to time, the station would hire extra personnel to canvass the area in search of "bootleggers," those business concerns using the service without paying for it.

Briefly, the action was as follows: If the employee located a bootlegger, the station would play three musical selections on which it held the copyright. The employee would log the time of day and the name of each selection. The bootlegger was then sued for violation of copyright. I was told, at the time, that the station had never lost a case and that the fine was $250 per selection.

EDWARD C. YOUNG
Alhambra, Calif.

° ° °

TRANSISTORS AND NOISE

To the Editors:

Reference Mr. W. A. Rheinfelder's article "Noise Performance of Transistors in Audio Circuits" appearing in your January, 1965 issue:

The 2N2958, 2N2538, and 2N2218 are all silicon planar epitaxial (not mesa) devices optimized for high-current service, with device parameters targeted for *beta* peaking in the region of 150 ma., and with gain roll-off maintained all the way out to ½ ampere and beyond. In addition, the 2N2538 is gold-doped to provide for high-speed switching in the area of 150-ma. collector currents. The 2N834 is likewise a silicon planar epitaxial unit, but of small geometrical construction and specifically intended for use as a saturated computer switch. It is designed to provide very fast turn-on and turn-off times in the 10-ma. region and represents a poor choice for low-level, linear-amplifier circuitry. The 2N720 is simply a package and gain variation of the old 2N699, an outmoded large-area mesa transistor once used for slow-speed switching in the 10-milliamp region and/or where high values of reverse voltages may be encountered.

From the preceding device descriptions, it can be appreciated that all of these particular silicon transistors are inappropriate for low-noise audio-input applications where the operating point is in the region of 300 to 600 ma., as in Mr. Rheinfelder's tests. In order to provide proper performance in such stages, a silicon transistor should be selected with full regard for its gain characteristics at these typically low collector currents. As with any component, a silicon transistor performs poorly if misused. After all, one would hardly choose a 6L6 for the input stage of a tube amplifier.

Germanium-alloy "signal" (dissipation capabilities less than one watt) transistors are now essentially obsolete, having been totally dropped by seven of the major U.S. manufacturers and vastly de-emphasized by the four remaining large sources of original U.S. supply. Germanium-alloy transistor prices have consequently risen, as is typically the case when a product approaches the technological end-of-life phase.

Under such circumstances, it is indeed fortunate that silicon transistors are now available that match and vastly exceed the low-noise performance of germanium-alloy units. Such transistors as the 2N930, 2N930A, 2N2484, 2N2511, etc. will deliver this performance. These silicon units are wide-band premium types, but such lower cost epoxy-cased counterparts as the 2N2925 will yield similar results. (Epoxy-cased units may require individual shielding.) From the equipment-manufacturer's standpoint, it is now entirely feasible to obtain silicon planar transistors for ultra low-noise, low-level input applications in hermetically sealed TO-5 and TO-18 metal cases at prices from 30¢ to 80¢ per unit (5000 pieces and up).

BRYAN GEYER
Hermosa Beach, Calif.

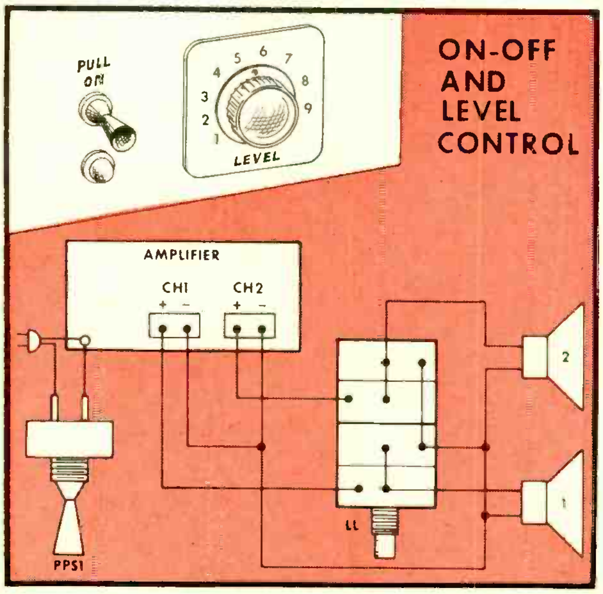
Following are some comments from Author Rheinfelder in reply to the above letter.—Editors.

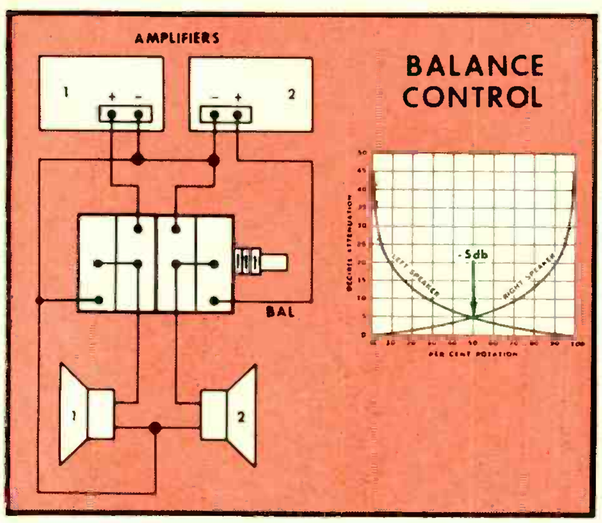
To the Editors:

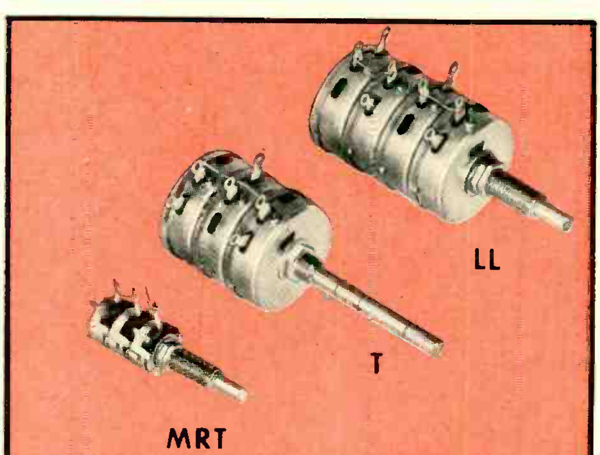
The information presented in my article was obtained by careful measure-

MALLORY Tips for Technicians

Where to use audio attenuators







Are volume control "twidgeters" upsetting the careful balance of your hi-fi rig? After you spend an hour or better setting "levels", "contour", "bass", and "treble" does your dear wife come along and goof the whole deal up because everything is too *LOUD?*

Why not maintain your balance, your temper, and your domestic tranquility by installing a simple on-off switch and an audio attenuator. In this way the dear girl can simply turn the music on at one place and control the sound with one knob. The drawing to the left shows a Mallory PPS1 push-pull switch and an LL pad controlling the whole works. It works great and looks fine. If you want to add a "Hands Off" sign on your amplifier, that's up to you.

Balance Control. We have a brand new control you'll be interested in (BAL8 and BAL16). It's a true stereo balance control. Consists of two L pads connected back to back so that when one level goes up the other goes down. Dead center loss is a tiny 5 db which you'll never miss. Saves a lot of time and gives marvelous flexibility to your stereo sound system.

Remote Speaker Control. Why not install a set of stereo speakers in your family room or other remote location? Use an LL dual pad to control the level here, too. You can install the LL in one speaker enclosure and eliminate all those extra steps back to the main controls. Or you might want to check out the RR50 control (a dual rheostat) which is the perfect low-cost way to control inexpensive speakers in the basement or on the porch.

Your Mallory Distributor can help you select an audio attenuator exactly right for the job. Choose from the new miniature MRL, MRT and MRLL pads . . . rugged Mallory RL, RT and RR . . . the 15-watt T, L, LL, and BAL pads, or the powerful 50-watt MGL and MGT series. You name it, he has it.

In case you'd like a complete list of Mallory audio controls and other precision electronic components, drop us a line. We'll send you the new 1965 Mallory Catalog. Write to MALLORY DISTRIBUTOR PRODUCTS COMPANY, a division of P. R. Mallory & Co. Inc., P.O. Box 1558, Indianapolis, Indiana 46206.

ments on several hundred transistors of various types, using the best laboratory equipment available today. Needless to say, the so-called low-noise types of the various transistor manufacturers, including the types mentioned by Mr. Geyer, were tested, as well as some of the high-power types, because it is well known for silicon transistors that some of the high-power transistors operate at a very low noise level at low currents. This has been explained by the larger geometry in higher power transistors which results in a reduced current density. Also, silicon transistors as a rule show a good *beta* hold-up at low currents. High-power units should therefore be included in a complete study, as well as switching types which, in many cases, make good amplifiers. Of necessity, the article showed only a few types of the more interesting categories.

I did not state anywhere that germanium transistors are better than silicon. I do not think that a general statement of this type can be made. Rather, my article went into detail to explain the different types of noise, as well as statistical evaluation. I thought it was made quite clear that a low-noise silicon unit could be picked. However, chances of obtaining one off the shelf would be slim as compared to germanium-alloy units. The average builder of equipment is in no position to buy a large lot of transistors to obtain a low-noise unit by selection.

As a concluding remark, I can assure the readers from my close relationship with transistor manufacturers that germanium-alloy transistors are by no means obsolete and will remain available for the applications where they show superior performance.

WILLIAM A. RHEINFELDER
Phoenix, Arizona

* * *

PHOTOCELL COLOR ORGAN

To the Editors:

When Fred Blechman's version of a photocell color organ appeared in the July, 1964 issue of ELECTRONICS WORLD, I decided to try out his design. The results were most gratifying.

I thought you would be interested in seeing a picture of the novel display lamp I used in connection with this device. I used a burned-out *G-E* CG5948 transmitter tube with an inverted aluminum baking pan as a base. After enlarging the original hole in the bottom of the tube from about 5/16" to 1 1/16" with the aid of a set of dentist carborundum tools and a few prayers, I finally succeeded in inserting nine 7½-watt bulbs, red, blue, and green, evenly distributed around the upper section of the tube. If you have had the experience of putting a small ship model in a bottle, you will get the idea of my feeling that at any moment a connection might separate.

FRANK J. ROBINSON, SR.
Harvey, La. ▲

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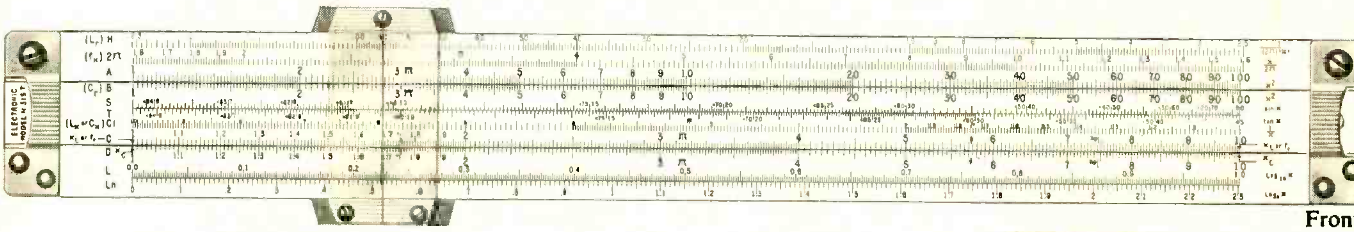

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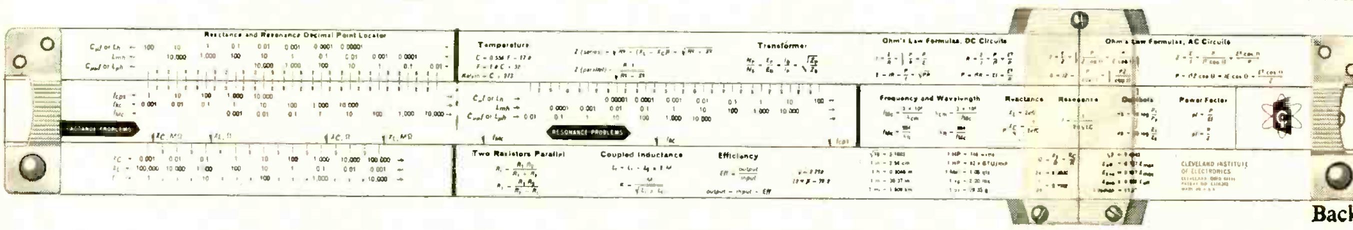

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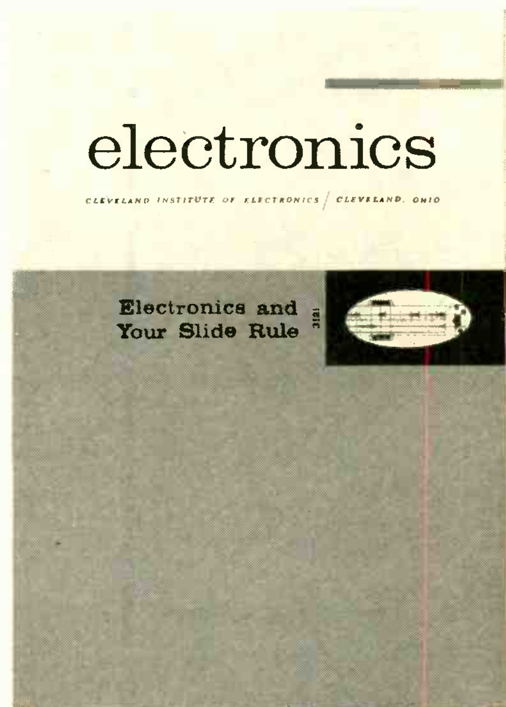

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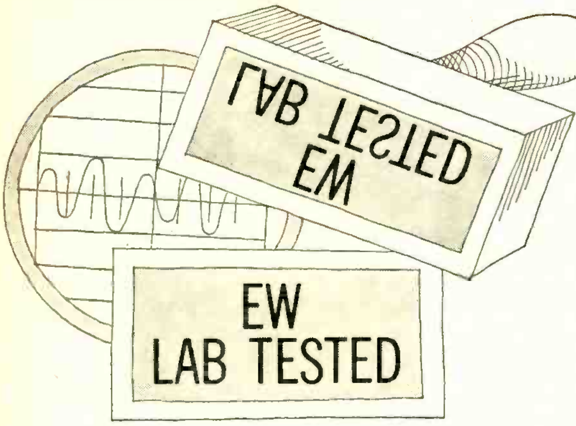


HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Sherwood S-9000 Amplifier
Weathers "Townsend" Turntable/Arm

Sherwood S-9000 Amplifier

For copy of manufacturer's brochure, circle No. 56 *on coupon (page* 17).

THE new *Sherwood* S-9000 is a compact, 100-watt (continuous power rating) solid-state integrated stereo amplifier. Unlike most transistorized high-fidelity amplifiers, it uses no germanium devices. Its semiconductor complement includes 22 silicon transistors and 4 silicon rectifier diodes. The ability of silicon semiconductors to withstand high ambient temperatures helps to assure long life for the S-9000 in almost any type of installation.

Each pair of output transistors, individually mounted on large, finned black anodized heat sinks, is driven by a complementary pair of *n-p-n* and *p-n-p* transistors, through a special three-winding transformer. The speakers, which may be from 4- to 16-ohms impedance, are isolated from the output transistors by 3000-μf. capacitors.

The low-level amplifier stages make liberal use of negative feedback for gain equalization, tone-control action, and stabilization. Over-all negative feedback is applied from the speaker outputs over three stages for low distortion. The tone controls are of the so-called Baxandall type, having a sliding inflection point instead of the more common "hinged" characteristic. This allows the response at the upper and lower limits of the audio spectrum to be adjusted with little or no effect on the mid-range response.

The amplifier has two high-level and two low-level inputs (for magnetic phono cartridge and tape head). In addition, there are tape output and tape monitor input jacks, with a front-panel switch to select tape-monitor operation. A function switch provides for normal or reversed-channel stereo operation, either input through both outputs, or both inputs mixed for mono use. Both channel tone controls are ganged for single-knob operation. The loudness control has switchable Fletcher-Munson compensation which boosts the low-frequency response at low levels. A balance control is capable of cutting off either channel completely without significantly affecting the level of the other channel.

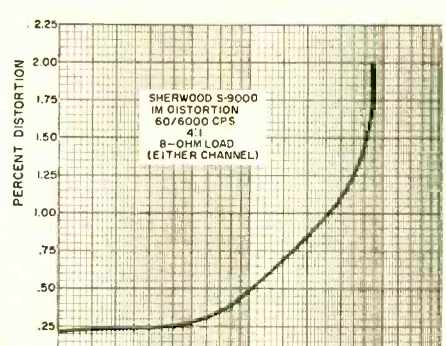
A row of slide switches under the control knobs operate the high- and low-cut filters, tape-monitor function, loudness compensation, speaker phase reversal, and speaker cut-off for headphone listening *via* a front-panel phone jack. There is a small knob on the front panel which adjusts the phone level to match that of the high-level input.

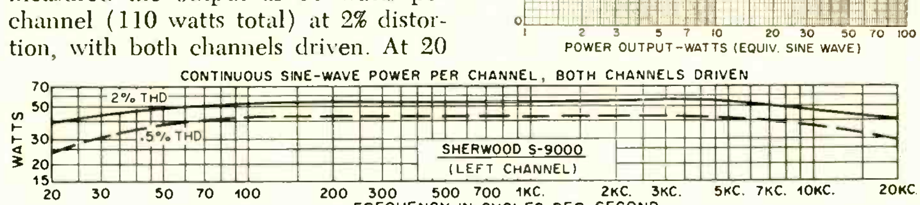
The amplifier is rated for a total of 150 watts music power output or 100 watts continuous power output. We measured the output as 55 watts per channel (110 watts total) at 2% distortion, with both channels driven. At 20 and 20,000 cps, this fell to 40 watts. At 0.5% distortion, the mid-range power was 42 watts, reducing to 24 watts at 20 cps and 30 watts at 20,000 cps. All measurements were made with 8-ohm resistive loads and a 117-volt a.c. line. The amplifier was not damaged in any way by sustained full-power operation, and remained cool after hours of use.

The frequency response was flat within ± 0.5 db from 20 to 20,000 cps. RIAA equalization was within 1 db of the ideal characteristic from 30 to 15,000 cps. The NAB tape playback equalization was within 2.5 db of the required characteristic from 90 to 15,000 cps, but fell off to -10 db at 30 cps. The filters had 12 db/octave slopes, with sharp knees, commencing at 100 cps and 5000 cps. They were very effective in removing unwanted noise with practically no effect on the program content.

The intermodulation distortion of the amplifier, unlike that of most transistor amplifiers, remained very low at low power levels. It was under 0.25% up to 2 watts output, rising to 1% at 25 watts and 2% at 44 watts, with both channels driven. The hum level was -70 db on high-level inputs, and better than -60 db on phono input, referred to 10 watts output. Crosstalk between channels was -47 db on high-level inputs, and -35

(*Continued on page* 86)





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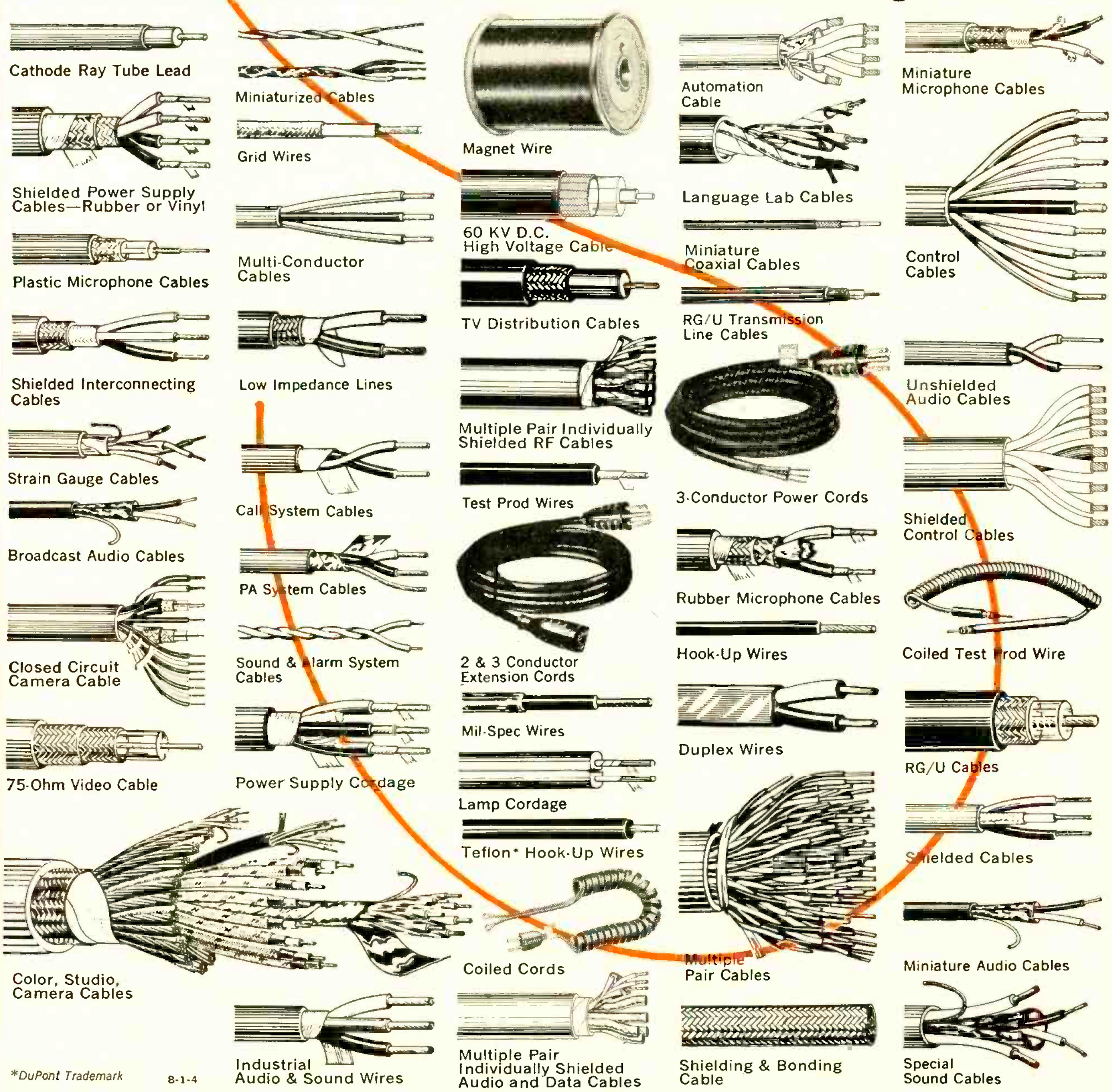

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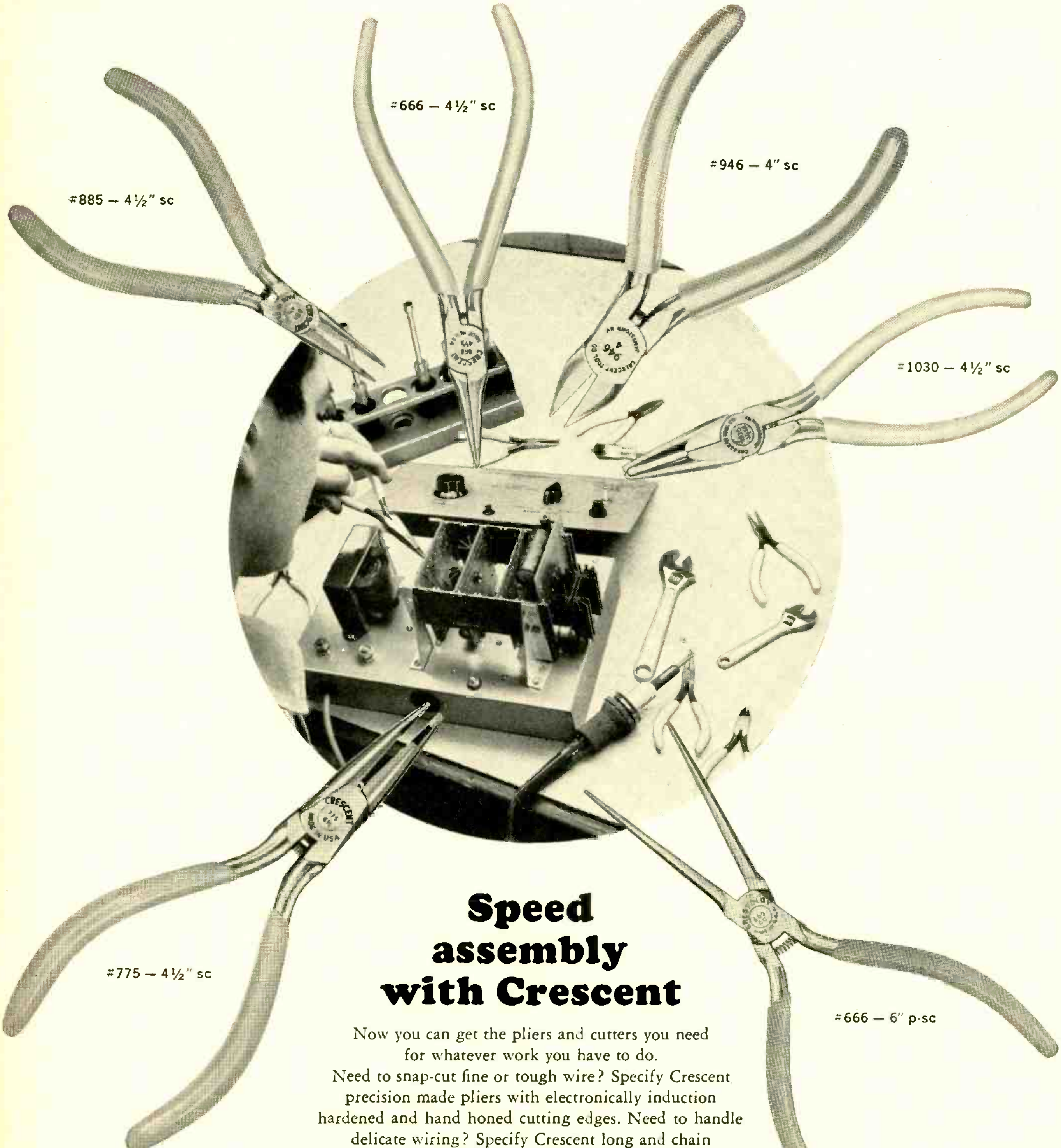

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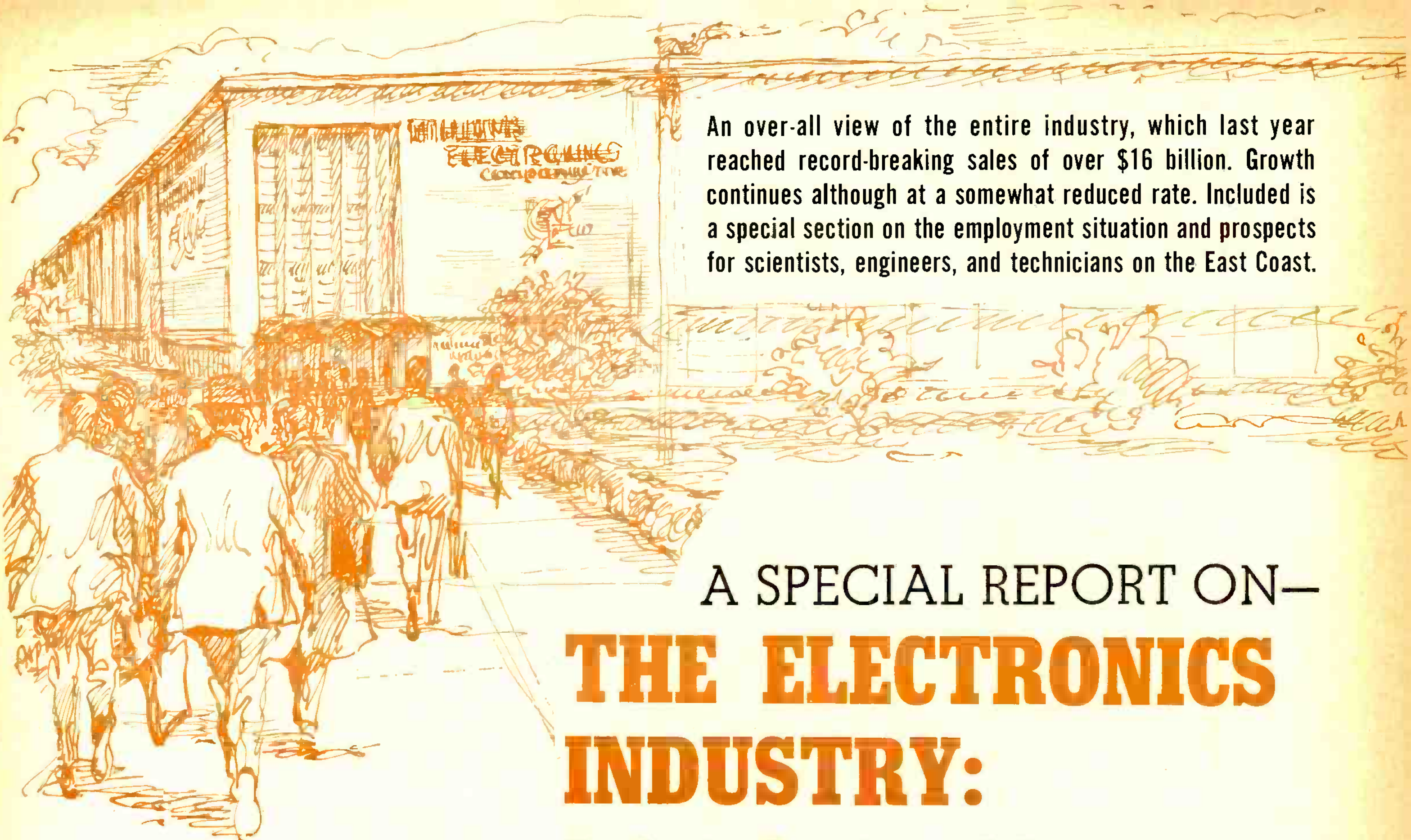


An over-all view of the entire industry, which last year reached record-breaking sales of over $16 billion. Growth continues although at a somewhat reduced rate. Included is a special section on the employment situation and prospects for scientists, engineers, and technicians on the East Coast.

A SPECIAL REPORT ON— THE ELECTRONICS INDUSTRY:

Products, People, and Prospects

THE electronics industry adds up to about 200,000 scientists and engineers, around 300,000 to 400,000 technicians, plus about 800,000 production workers in some 6000 plants, in addition to a large number of small and privately owned businesses in the United States. These owners and employees used their heads and hands to transform electron tubes, solid-state devices, and passive components into $16.3 billions worth of electronics products and systems in 1964. Such electronics gear, ranging from radios to radar, and television to computers, explores outer space and also protects, informs, educates, and entertains us.

Yet some of these products were made by companies that transformed the crystal radio and radio communications business from $1 million in sales in 1914 to a booming $5 million radio industry in 1922. By 1947 this industry made $810 million worth of consumer electronic products, chiefly in the form of radio receivers and TV sets.

Military Electronics

The biggest change was wrought by electronics companies during World War II. In 1935 about $20 million worth of defense products, mostly radios and communications gear, was sold to the U.S. Government. This sum zoomed to $680 million by 1947 with armaments for World War II. But that figure dropped to $655 million by 1950 as our armed forces continued to be demobilized.

The start of the Korean conflict in 1950 drove defense electronics sales up to $1.2 billions by 1951. By 1957, defense electronics sales to the U.S. Government had passed $4 billions—more than twice as much as the $1.5 billion worth of radio-TV and other consumer products made that year. In 1964 the electronics industry sold some $8 billion worth of military products to the Department of Defense (DOD) plus another $1 billion to the airplane and aerospace agencies. Those $9.4 billion in sales outstripped the industry's $2.9 billion of consumer products, $3.4 billion of commercial-industrial products, and $620 million of replacement components.

The Korean conflict pointed up the strong dependence of the U.S. Government on electronics companies, and *vice versa*. The U.S. Government then began rebuilding its hastily dismantled World War II arms and defenses in the face of continuing Russian opposition. Uneasy East-West tensions led the Department of Defense to realize it could no longer quickly muster an "arms industry" in war time, then let it collapse when war ended. Instead of this "feast or famine" defense industry of aircraft, ordnance, and automotive suppliers, there evolved a "permanent peacetime private defense industry." Included here were privately owned, government-supported, engineering-oriented companies, such as the new breed of electronic firms.

The original radio-TV manufacturers had small groups of engineers, backed by heavy production facilities that turned out volumes of predictably similar units. The newer types of electronic-engineering companies sprang up, often run by engineers and technicians-turned-managers.

These electronic-engineering companies had never made radios or TV sets. They had far greater numbers of engineers and technicians and far fewer production workers than radio-TV makers. Some of these companies were actually airframe manufacturers who bought or burrowed into the electronics industry. These companies, mainly on the West Coast, needed electronics capabilities to survive in a business which was rapidly becoming an airborne electronics system housed in a fuselage. They also required electronics capabilities, in the late 1950's, in order to stay alive in the missile and aerospace fields.

Now, three Federal agencies—Department of Defense, National Aeronautics and Space Administration, and the Federal Aviation Agency—buy about 60% or more of the entire electronics output. Some electronic defense-aerospace companies sell virtually all their goods and services to the

SUPPORT BY FEDERAL FUNDS

About 75% of scientists and engineers working in electronics companies are supported by Federal funds, based on a survey by Electronic Industries Association (EIA) and the Department of Defense (DOD). Some 200,000 engineers and scientists counted here held various jobs in electronics companies.

Approximately 128,000 or 83% worked on industry defense-aerospace contracts, while 8% worked directly for the Federal Government. Another 5% did research in universities and non-profit organizations, mainly for the Federal Government. The rest included consultants, engineers, and scientists between jobs, and some unidentifiables.

About 74,000 scientists and engineers, including electronics specialists, worked on NASA programs in January 1964. NASA estimated that by January of 1965 about 82,000 scientists and engineers would be working for it. Of these, only 12,000-15,000 worked directly for NASA, while the others were working under grants or contracts with industrial companies.

U.S. Government. Others sell varying percentages of their output to the Government. In effect, such firms have taken the place of the old government "arsenals" which made and stored the shot and shooters for our national defense. Business and industry purchase about 20%.

Consumers now buy only 17% of the electronics industry's output, although once they were the backbone of the radio industry. Actually, consumers pay for defense-aerospace electronics—indirectly, as taxpayers. The remaining 3% of the electronics market represents replacement parts to help maintain the other 97 percent of the gear.

Research & Development

Electronics companies broadened their lines, increased their technical manpower payrolls, and stepped up their research and development (R&D) activities. Government funds for R&D have triggered shock waves of new products and new technologies. General R&D funds, for various government agencies, have tripled from about $5 billion in 1953 to about $15 billion in 1964, and may double to about $30 billion by 1970. Some 50% of NASA's budget goes for test programs: R&D, test, and evaluation. NASA spends 45% of launch vehicle costs, 70% of spacecraft costs, and 90% of tracking and data acquisition cost—on electronics.

The first step towards any production starts with winning basic study or R&D contracts. Such contracts put and keep companies with big laboratories and top-notch scientists, engineers, and technicians into the forefront of fast-moving technologies. Electronics parts or systems today start with understanding basic materials in the quest to build reliable equipment and systems. The need for reliability runs high to keep up with the increased cost of such systems.

Since Congress controls Federal spending, Government contracts now blend politics and economics with technology. Congressmen are alert to the needs of their constituents—because contracts mean jobs in defense plants, in Federal installations, and in laboratories.

Commercial civil war now rages across the United States. The struggle often starts in ivy-covered college and university laboratories, or in public and private R&D laboratories that are the wellsprings of brains and new technologies. These institutions compete directly for R&D contracts. Their teaching staffs often serve as consultants. Next, many towns, cities, and states are in a tug-of-war with other areas to attract electronics plants and laboratories. And, once built, these plants and laboratories compete for contracts.

Every one of the top 10 prime defense-aerospace government contractors who received an award of $10,000 or more for experimental, developmental test and research (EDTR) work in Fiscal Year 1964 (ended June 30, 1964) had one or more plants in California. For example, companies with headquarters in New York City (*General Dynamics, General Electric, Radio Corporation of America, Sylvania,* and many others) also have divisions in California and other parts of the country. This is partly a geographical diversification to attract contracts, to engage technical manpower, to be near educational institutions, and/or to be in labor surplus areas that are given some consideration in Federal contract awards.

California received 21.2% of all prime award dollars in the first quarter of Fiscal 1965. Next came Texas with 9.6%, New York with 6.7%, Massachusetts with 6.1%, and Georgia with 5.8%.

Politics inevitably conflicts with proficiency in evaluating geographic distribution of Federal R&D funds. For Fiscal Year 1963, California received $3.8 billion or 38.4% of all research contracts awarded chiefly by DOD, NASA, and the National Science Foundation.

However, New York State's Congressional delegation objects to having received only $917 million, or 9.2% of all such contracts and Massachusetts' solons raise similar objections to having received only $452 million, or 4.6% of the total.

Geographical Areas

Geographically, the cradle of the original radio (and TV) industry was in the Chicago-Midwest area, home of *Motorola, Zenith, Admiral,* and many other manufacturers and component suppliers, and in the eastern Philadelphia (*Philco*)-Camden (*RCA*) area.

Even now, the Chicago/East North Central area (Ohio, Michigan, Wisconsin, Illinois, and Indiana) is slowly outgrowing its origins while trying to hold on to the graduates of its colleges and universities who fled (or were lured) to the East and West coasts. This area now has about 15% of the industry's engineers and produces 23% of the U.S. electronics output, with some 1220 plants representing 20.38% of the U.S. total. Paradoxically, while many defense-aerospace electronics firms now smart under thinning government business, the conservative Chicago-Midwest area prospers in consumer electronics, chiefly color-TV. In 1964, about $418 million worth of color-TV sets was sold, compared with about $968 million worth of monochrome sets. By 1970, color-TV may earn more dollars than black-and-white TV.

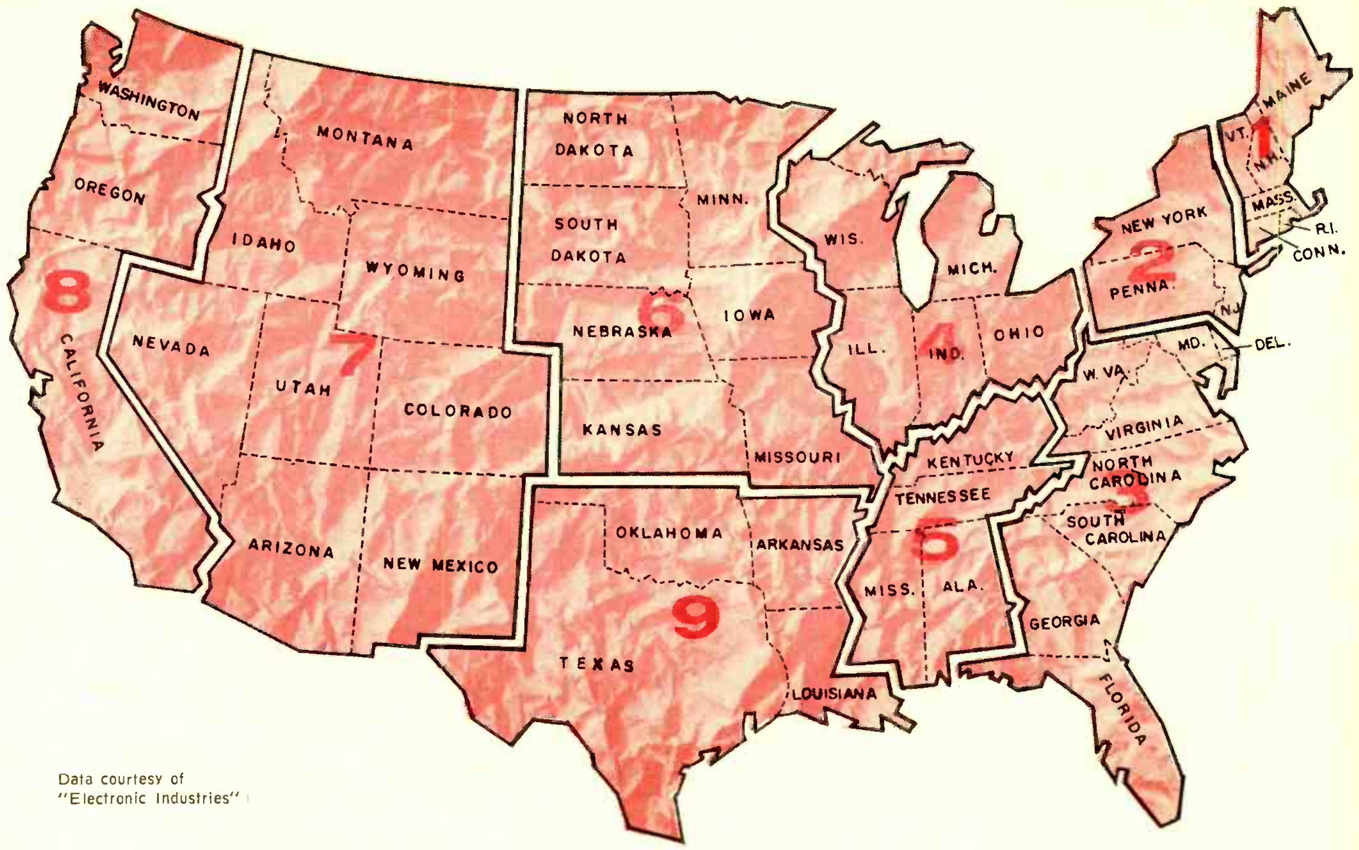
The birth of the aerospace age helped the rebirth of part of the South. NASA has built up a complex of facilities in the "Golden Crescent" of the Gulf of Mexico: the Manned Spacecraft Center at Houston, Texas; the big spacecraft plant at Michoud, Louisiana; the Mississippi Test Facility; the George C. Marshall Space Flight Center at Huntsville, Alabama; and John F. Kennedy Space Center, NASA, Cocoa Beach, Florida, which collaborates with elements of DOD including the Atlantic Missile Range in civilian-military operations. In recent years Florida has become an electronics manufacturing-R&D area, as a kind of California for New England and Middle Atlantic electronics companies and their divisions that migrated southward.

The South Atlantic States (Maryland, Delaware, Virginia,

TECHNICIAN-TO-ENGINEER RATIOS

An average of 38 technicians was employed for every 100 scientists and engineers in various categories in 1963, reported the Engineering Manpower Commission of the Engineers Joint Council. In government, the 82:100 ratio for state governments contrasts with the 29:100 ratio in Federal Government.

In industry, communications had the highest ratio of 237:100, followed by R&D with 54:100, and utilities with 44:100. Consulting services had the lowest average of 14 technicians per 100 scientists and engineers.



Data courtesy of "Electronic Industries"

REGION	1 NEW ENGLAND	2 MIDDLE ATLANTIC	3 SOUTH ATLANTIC	4 EAST NORTH CENTRAL	5 EAST SOUTH CENTRAL	6 WEST NORTH CENTRAL	7 MOUNTAIN	8 PACIFIC¹	9 WEST SOUTH CENTRAL	TOTALS
NO. ELECTRONIC PLANTS	875	1949	307	1220	56	189	109	1179	100	5984
% of PLANTS	14.64	32.57	5.13	20.38	.93	3.16	1.82	19.70	1.67	100
% of ELECTRONIC ENGINEERS	10.70	24.20	10.10	14.43	.41	4.99	2.62	27.43	5.12	100
% of ELECTRONIC PRODUCTION	10.60	36.50	5.30	23.00	.50	2.60	2.50	16.70	2.30	100
% DISTRIBUTION of FEDERAL R&D FUNDS*	6.0	16.0	14.0	7.0	4.0	3.0	9.0	36.0	5.0	100

*% Distribution of Federal R&D Obligations for all performers (intramural and extramural) by geographic divisions and states by selected agencies ($12.3 billion) for Fiscal Year 1963 (ended June 30, 1963). ¹Included with Pacific States are Alaska and Hawaii.

West Virginia, District of Columbia, North Carolina, South Carolina, Georgia, and Florida) have about 307 plants, or 5.13% of the industry total. These produce some 5.3% of industry output, with 10.10% of U.S. electronics engineers, indicating a high engineering-to-production ratio.

Chief contenders for all electronics markets are West Coast companies, leading with their brains and daring. In 1963, Western electronics companies made about $3.9 billion worth of goods (at factory prices) which represented nearly 25% of all U.S. electronics output. Companies in the sprawling Los Angeles area alone accounted for 59% of that production, and San Francisco firms accounted for 20.7%. Arizona, San Diego, and the rest of the West produced the remaining 20%.

Los Angeles companies, including a number of airframe-aerospace-electronics firms, as well as San Francisco companies were hard hit by recent slashes in government business. Companies in the San Francisco-Palo Alto area, for example, suffered reverses from reduced spending for microwave systems as the DOD changed from the world's biggest builder of such facilities to become the world's biggest user of microwave.

Out west, the fastest growing area is Arizona, with $230 millions in sales in 1963, representing 5.9% of western electronics output. Some industry observers suggest higher cost of labor discourages further expansion in California. Several California firms have expanded facilities outside the state.

The backbone of the electronics industry continues to be the heavily populated, industrialized, urbanized nine Northeastern states. These are New York, New Jersey, and Pennsylvania, plus the six New England states. The "six" comprising New England are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. They have 875 plants, representing 14.6% of the U.S. total and account for 10.60% of U.S. electronics output. The area has about 10.70% of the nation's electronics engineers with engineering on a par with production.

New England's skilled craftsmen and educational institutions were "naturals" in creating a thriving electronics business. For its role in World War II, *Raytheon*, then largest single employer in Massachusetts, was synonymous with "radar." During the 1950's electronics companies clustered around Greater Boston, the "Hub" of New England. Many of these firms moved to "Route 128—The Electronic Highway" that rings Boston.

Electronics activities in the Boston area (including Cambridge) are strengthened by such institutions as Harvard and the Massachusetts Institute of Technology (MIT) with its famed Lincoln Laboratories, plus consultants such as *Arthur D. Little, Inc.* The educational institutions, in turn, derived electronics fame from their staffs, which boasted such men as Draper, Edgerton, Zacharias, and Wiesner.

After World War II, three developments modified the electronics field. First, the consumer radio-TV business became secondary to the complex electronics industries which make sophisticated defense-aerospace equipment and systems. Second, the U.S. Government became the biggest buyer and strongest influence on electronics. Third, electronics became much more of a political-economic-technical business, with sharp competition for government contracts and technical manpower on a state and regional basis.

West Coast firms, chiefly in California, now lead in R&D contracts, but western electronics business suffers because of decreasing airplane and missile production. The Midwest thrives on consumer electronics, despite foreign competition, but complains of its low share of government business. Meanwhile, East Coast electronics companies still hold a big share of the electronics business.

EAST COAST EMPLOYMENT SITUATION

As recently as 1963, all sectors of the electronics industry were doing well, except for a slight decline in electronic part replacements. From 1960 through 1963, there had been a high demand for technical manpower, too. This period included a sharp rise in military spending by the Kennedy Administration. Yet this was counterbalanced by cancellation of the Skybolt air-to-ground missile in December, 1962 and the U.S., Soviet, British limited nuclear test ban treaty in mid-1963.

Some of the steam and growth began to go out of the defense business starting in January 1964 when a $2 billion cut was ordered in government spending—from airplanes and missiles to shoelaces. The re-appraisal of our defense posture resulted in reducing or leveling defense-aerospace budgets, a sharper trend from production of weapons systems into more R&D, and a decrease in technical manpower. Paradoxically, while Government electronics business had flattened out on a high level, the civilian-industrial electronics business was thriving with much of the rest of the economy in a boom that had started in February 1961 and was continuing in 1965.

Under these changing conditions, sales and employment of electronics companies in 1964 and early 1965 paralleled Charles Dickens' description of Europe in 1775. In "A Tale of Two Cities," he wrote, "It was the best of times, it was the worst of times." Such mixed conditions were evident among East Coast electronics companies, the six New England states through the three Middle Atlantic states, to the eight South Atlantic states.

These 17 states, plus Washington, D.C., represent 52.34% of all electronics plants, which create 52.40% of electronics output, with 45% of all electronics engineers. Profits of these companies and jobs of their employees depend heavily upon DOD, NASA, Atomic Energy Commission, and Federal Aviation Agency which spend about 60 cents out of every $1 earned by such electronics companies.

Estimates of factory sales for various electronic products.

PRODUCTS	YEARS (in millions of dollars)				
CONSUMER ELECTRONICS	1962	1963	1964	1965	1966
Television: Black & White	$ 926	$ 926	$ 968	$ 840	$ 750
Television: Color	170	283	418	700	850
Television: TOTALS	$ 1,096	$ 1,209	$ 1,386	$ 1,540	$ 1,600
Radio: Table, Clock, Portable	$ 227	$ 197	$ 166	$ 166	$ 166
Radio: Automobile	181	206	200	200	200
Radio: TOTALS	$ 408	$ 403	$ 366	$ 366	$ 366
*Other Consumer Products	$ 1,111	$ 1,168	$ 1,169	$ 1,250	$ 1,320
CONSUMER: TOTALS	$ 2,615	$ 2,780	$ 2,921	$ 3,156	$ 3,286
INDUSTRIAL & COMMERCIAL	$ 2,710	$ 3,060	$ 3,400	$ 3,600	$ 3,900
GOVERNMENT ELECTRONICS					
Defense Department	$ 7,360	$ 7,670	$ 7,924	$ 7,980	$ 8,000
NASA	560	950	1,310	1,500	1,650
Federal Aviation Agency	160	150	125	135	145
GOVERNMENT: TOTALS	$ 8,080	$ 8,770	$ 9,359	$ 9,615	$ 9,795
REPLACEMENT PARTS	$ 620	$ 590	$ 620	$ 630	$ 650
GRAND TOTALS	$14,025	$15,200	$16,300	$17,001	$17,631

*Includes: phonographs, tape recorders, records and magnetic tape, high-fidelity components, electronic organs, pleasure boating equipment, home training kits, electronic ovens, toys, etc.

Sources: Electronic Industries Association, U.S. Government, electronics companies.

Massachusetts & Connecticut

In Massachusetts, the biggest electronics-producing state in New England, the heart and hub centers around Greater Boston. Research-based and electronics industries account for about 25% of all manufacturing jobs in Greater Boston. The area has about 32,000 scientists and engineers, backed by about five times as many technicians. There are many universities and colleges in the area which attract the teachers and students who, in turn, attract government contracts. Eighteen technical schools geared to science and engineering include Franklin Institute, Wentworth Institute, and Lincoln Institute, which annually graduate about 10% of all technicians in the U.S.

Three of Massachusetts' biggest employers are *Raytheon*, *Sylvania*, and *General Electric*. Among the most representative is *Raytheon*, which has better than two-thirds of its operations in Massachusetts. In 1963, its combined electronics scientific-engineering and technical support manpower there numbered 3700. However, as government business declined, the net technical manpower employed in 1964 had eased to 3100. *Raytheon* officials estimate they may employ about the same number of technical employees during 1965.

Another diversified, yet representative, East Coast electronics company is *Sylvania Electric Products*, a subsidiary of *General Telephone & Electronics*. Unlike many East Coast electronics firms, *Sylvania*'s operations in Massachusetts, New York, and Pennsylvania have required increased employment of electronics scientists, engineers, and technicians. Such technical manpower totaled about 1800 in 1963, edged up to about 1875 in 1964, and may further increase to about 1900 to 1925 in 1965.

Behind these unusual constant increases is *Sylvania's* thriving East Coast electronics activities. These include steadily rising sales of color-TV sets and improved color cathode-ray tubes. Work in electronics systems expanded, chiefly on an improved ground electronic control system for Minuteman missiles. A *Sylvania* Multi-Phased Array Radar (MAR I, which operates and steers electronically), is being tested as part of the high-priority Nike-X anti-missile-missile system.

Microelectronics and integrated circuits operations are being broadened. *Sylvania*'s Bayside, N.Y. research laboratories specialize in commercial-industrial electronics. And a newly created Commercial Electronics Division, near Boston, concentrates on closed-circuit TV, and plans to expand into communications and information systems.

In the Stamford, Conn. area, new research facilities were recently opened by *CBS Laboratories*. The company doubled its space and increased its personnel from 60 to 450 in five years. To encourage just this particular kind of growth, the Connecticut Research Advisory Committee has been established "to explore (*Continued on page 81*)

NEW INDUSTRIAL RADIO BAND

By LEO G. SANDS

A block of 30 channels in the 72-76 mc. band has been opened for remote-control applications in Manufacturers Radio Service.

TO relieve some of the channel loading and to make it possible to operate vital industrial communications and remote-control systems on interference-free channels, a segment of the 72-76 mc. v.h.f. band has been made available to the Manufacturers Radio Service.

Heretofore, remote control systems for cranes, bulldozers, and other heavy equipment had to be operated on class C CB channels or on an unlicensed basis, using Part 15 type transmitters, within the Citizens Band. Some industries obtained authority to use land mobile channels on a temporary, developmental, secondary basis. While frequencies have been available for several years in the 952-960 mc. band for remote control purposes, the equipment cost has been considered prohibitive.

All-in-all, the available frequencies were unsatisfactory. The possible interference in the Citizens Band could not be tolerated. And, users were reluctant to buy equipment which could only be licensed on a *developmental* basis.

The National Association of Manufacturers and other interested parties petitioned the FCC to allocate a block of channels in the 72-76 mc. band which was in use only in areas not served by television channel 4 or 5. They sought channels restricted to low-power applications so that the same channels could be used by more than one manufacturer in the same general area. Their efforts paid off.

A block of 30 channels has been allocated to the Manufacturers Radio Service within the 72-76 mc. band. This band had heretofore been reserved for point-to-point communications use and only in areas not served by TV stations operating on channel 4 or 5. (Table 1.)

These new low-power channels may be used *anywhere*, even in areas where TV channel 4 or 5 is in use. TV receivers are protected from interference if they are within 100 feet of a transmitter operating on one of the new channels. If TVI occurs, it is the responsibility of the licensee to install filters on TV sets, within 100 feet of a low-power transmitter, but only on those sets not owned by the licensee. If the owner of the TV set does not allow the installation of filters on his set, the licensee is relieved of further responsibility in regard to TVI. On the other hand, if the TVI cannot be cleared up, the licensee must cease transmission.

Transmitter power is limited to one-watt input. The transmitting antenna must be vertically polarized and have no more gain than a half-wave dipole. It must be mounted directly on the transmitter. However, when the transmitter is installed in a vehicle, the antenna may be separated from the transmitter and may be installed at any convenient location.

Transmission bandwidth is limited to 20 kc. which means that either narrow-band FM (± 5-kc. deviation) or AM will ordinarily be employed. Either voice or tone modulation may be used.

All transmitters are licensed as *mobile units* but may be operated as fixed base or mobile stations. All communications must be carried on within plants, factories, shipyards, or mills operated by the licensee.

Of the 30 available channels, 20 are shared with fixed stations, but this presents no problem to users in areas served by TV channels 4 or 5 since there are no fixed stations operating in this band in such areas.

The problem of making equipment available for use on these channels is not serious. FM walkie-talkies for the 20-50 mc. and 150-174 mc. mobile bands can be readily redesigned for use in the 72-76 mc. band. (See Table 2.)

Receivers for use at fixed stations and in mobile applications are already available. Receivers designed for use in point-to-point communications systems can be easily modified from wide-band FM (±15 kc. deviation) to narrow-band FM (±5 kc. deviation) even in the field. Even a.c.-operated receivers can be used in mobile applications by providing a d.c.-to-a.c. inverter for operation from a battery.

While transmitter antennas are restricted to unity gain (with respect to a half-wave dipole), gain-type omnidirectional and directional antennas may be used at receivers, when greater range is required, and may be at any distance from the receiver.

The allocation of these new channels makes it possible to provide interference-free communications in dangerous and vital operations where interference cannot be tolerated. Furthermore, these channels can be used with safety for remote control of cranes, hot-slag bulldozers, TV antenna tower elevators, and other machines.

These new channels are restricted to those eligible for license in the Manufacturers Radio Service. Many manufacturers, including radio equipment makers, operate mobile radio systems under licenses in the Business Radio Service, probably unaware of their eligibility for license in the Manufacturers Radio Service whose channels are not nearly so congested. However, transmitters licensed in the Manufacturers Radio Service may not be used in connection with retail sales activities. ▲

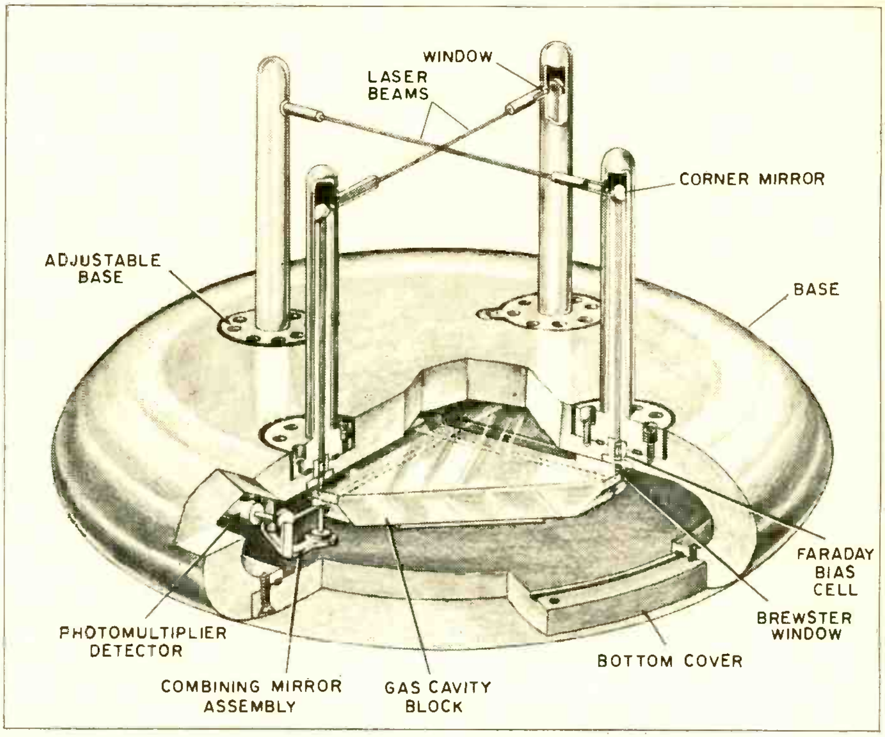
Table 1. Listing of low-power Manufacturers Radio Service channels.

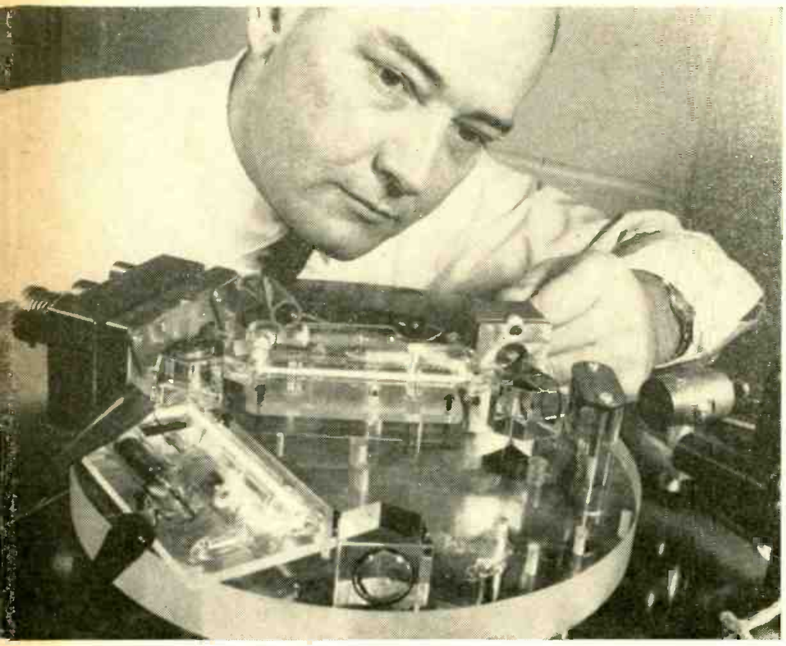
72.02	Shared with fixed stations	72.22	72.44
72.04		72.24	72.48
72.06		72.26	72.52
72.08		72.28	72.56
72.10		72.30	72.60
72.12		72.32	75.44
72.14		72.34	75.48
72.16		72.36	75.52
72.18		72.38	75.56
72.20		72.40	75.60

Table 2. Some manufacturers of 72-76 mc. low-power equipment.

Barrett Electronics Corporation 630 Dundee Road Northbrook, Illinois	Motorola, Inc. 4501 W. Augusta Blvd. Chicago, Ill. 60651
Femco, Inc. Irwin, Pennsylvania	Union Switch and Signal Division Westinghouse Air Brake Company Swissvale, Pennsylvania

Laser Anemometer. (Right) A cutaway view of an experimental laser anemometer that can measure the flow rate of gases and liquids with extremely high accuracy is shown here. In lab tests, the unit, which is less than 2 feet in diameter and 1 foot in height, has measured the flow rate of air slower than a half-mile an hour and the flow rate of water as slow as a thousandths of a mile per hour. The Sperry-Rand device uses two laser beams rotating in opposite directions around two perpendicular square-ring paths. A portion of beam paths is exposed to the gas or liquid whose flow is to be measured. With no flow, the frequencies of the two laser beams are identical and the photomultiplier detects no difference frequency. If the gas or liquid begins to move, then the light beam moving closer to this direction speeds up while the other beam slows down. A difference frequency is then produced which is sensed by the photocell and converted into a precise measure of flow rate. The change of light velocity in a moving, transparent medium was theorized by Fresnel, about 150 years ago.





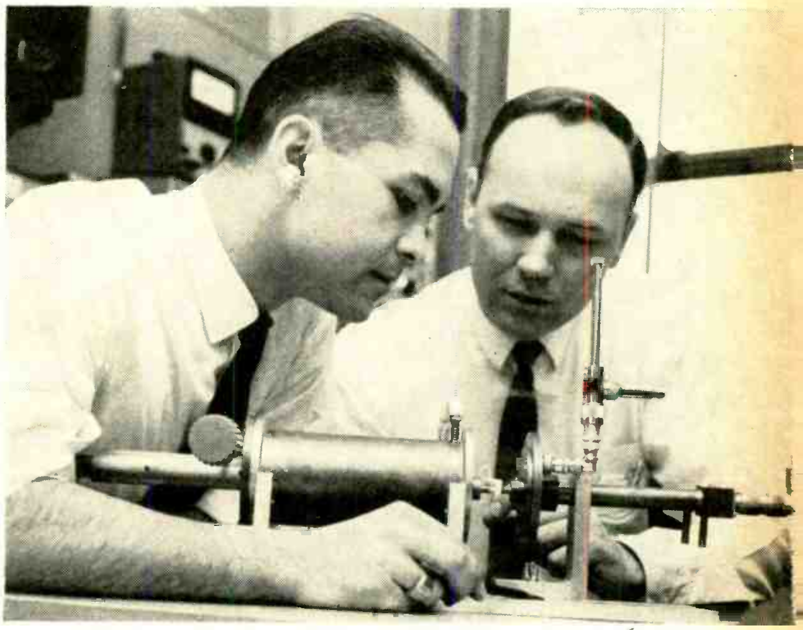
RECENT DEVELOPMENTS in ELECTRONICS

Miniature Laser Gyro. (Left) The smallest laser integrating gyro is shown here being tested at Honeywell's research lab, where a program is underway to develop a practical unit for inertial-guidance systems. Using the principle of internal reflection to form a small, low-loss triangular cavity, the gyro uses three prisms instead of the more conventional front-surface, dielectric-coated mirrors. The device operates on a 1.15-micron wavelength (infrared) from a helium-neon discharge provided by either r.f. or d.c. pumping of two gas tubes 4 inches long. The gyro is about a half foot in diameter and weighs under 8 lbs.

CCTV for Psychiatry. (Right) Closed-circuit TV and tape recording are being used by psychiatrists at the State University of New York's Psychiatric Treatment Research Center (Brooklyn) to view reactions and to analyze interviewing techniques. The 20-bed center televises and video records interviews between patients and psychiatrists on an Ampex portable video recorder. In addition, an audio recorder is used to duplicate the sound along with an instrumentation recorder for such data as patient respiration, galvanic skin response, and heart rate. Once the interview is over, the psychiatrists attempt to find meaning in the behavior of patients (and themselves) by observing the TV tape playback.

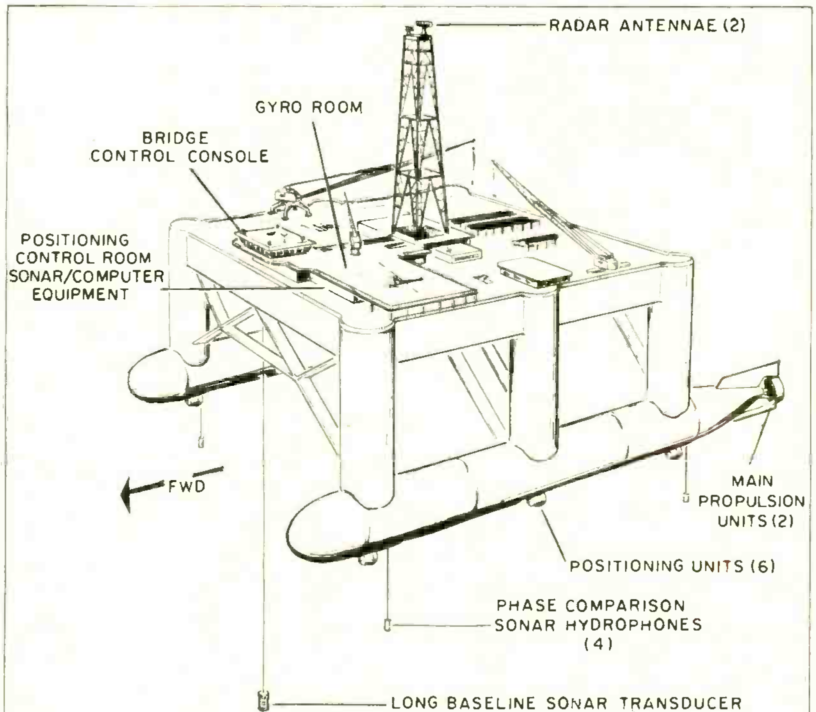
Yugoslav Microwave System. (Left) A $1 million contract to supply and install microwave transmission equipment for three television systems in Yugoslavia was announced by General Telephone & Electronics International. Four links covering 600 miles total will be constructed as part of an over-all network which eventually will extend for the length of the country. The microwave links will be built in Serbia, Macedonia, and Slovenia, and will be employed to bring television programming to some sections of the country where it presently does not exist.

Semiconductor Microwave Generator. (Right) Continuous and coherent microwave oscillations of substantial power have been generated for the first time in a semiconductor—gallium arsenide. In recent studies at Bell Telephone Laboratories, scientists produced c.w. oscillations at 4350 mc. with power output of 15.5 milliwatts. The material is placed in a microwave cavity and a high-amplitude electrostatic field is applied to it.



Projection Oscilloscope. (Left) The unusual looking instrument shown here is a new projection oscilloscope that can display waveforms, computer data readout, or any symbol that can be generated on a standard scope. The instrument projects on a screen images from 28 inches to 12 feet wide. Separate X, Y, and Z axis inputs are used for voltages from .1 to 100 v. at 100,000 ohms input impedance. Brightness on a 12-foot standard beaded screen is 4 footlamberts. The instrument is being marketed by Dalto Electronics.

Project Mohole Drill Platform. (Right) The electronically positioned platform shown here will be used in a program to penetrate the earth's crust to the Mohorovicic Discontinuity. Subsurface sonar and surface radars provide ranging signals. These signals, processed by computers aboard the platform, are used by six electric engines to drive propellers under pontoons (three per pontoon). The propellers push the platform in any direction desired, despite 30-knot winds and heavy ocean currents. Manufacture of the system by Honeywell has started under a $1½ million contract. Delivery is expected in early 1966. After 3 years and 15,000 feet of underwater drilling near the Hawaiian Islands, the crust bottom will be reached.



MARINE RADIOTELEPHONE ANTENNA

By ELBERT ROBBERSON

A simple, grounded shunt-fed antenna for runabouts that is both electrically safe and highly efficient for the 2- to 3-mc. band. Antenna is not affected by rain or salt-spray and may be touched while transmitter is on.

BOATS as small as 16-footers often carry 2-3-mc. radiotelephones today. New equipment is sufficiently compact and economical of battery power for such installations to be entirely practicable. But the antenna systems, scaled down from those used on larger craft, have shortcomings that are often serious enough to render the radiotelephone ineffective when it may be needed most.

Fig. 1A represents a conventional boat antenna. The generator is the output of the r.f. amplifier tube, $L1$ is an amount of antenna loading coil located in the radiotelephone, and $L2$ is loading inductance situated in the antenna itself. The latter coil is ordinarily at the center of the antenna although it may be near the base, the top, or distributed in the form of a long helix.

Certain unfavorable conditions are inescapable in such antennas. These are well known and, in summary, are: (1) short length requires loading coil to achieve antenna circuit resonance; (2) radiation resistance is low, being a function of antenna height; and (3) loss resistance due to loading coils, ground connection to water, insulator leakage, and shunt capacitance of base insulators and lead-in is large in proportion to radiation resistance, and can easily rise high enough to disable the transmitter.

On a large vessel these troubles can be tolerated. The antenna is usually up out of the zone normally hit by spray, antenna-mounting and lead-in insulators are fairly well protected, and the antenna is far enough away from the boat's personnel not to be affected by their presence or movements. So, although the installation does not operate at a high order of efficiency, it is at least consistent enough to provide necessary communications in almost all weather.

However, in the *small* boat, the base of the antenna is low, spray is the order of the day, and a damp coating of salt or dirt is bound to form on insulators and antenna wiring, lowering their resistance to ground. Proximity of the antenna to ground and other objects causes high shunt capacitance; and personnel and other lossy objects are often right up against the "hot" antenna and its lead-in. In addition, the antenna mounting insulators are often under high mechanical stress due to the limited base on which they must be mounted, and breakage is a constant danger.

Thus, the "normal" troubles are aggravated in the small boat. This is largely attributable to the fact that the conventional short antenna carries a high voltage at its base, and its bottom is of sufficiently high impedance to be extremely sensitive to shunt capacitance and resistance, and any changes therein.

The situation is represented by the equivalent circuit of Fig. 1B. The generator is the output of the r.f. amplifier, L is the loading inductance, R is the total circuit resistance, and C is the antenna capacitance.

With the unloaded antenna (a straight metallic "whip" or wire), the voltage impressed on it would be $E = (e \times X_L)/R$. Assuming some reasonable figures, at the mid-point frequency of 2.5 mc., a ten-watt radiotelephone might inject an r.f. voltage, e, of 10 volts. With an antenna having a capacitance of 50 pf., a loading coil with a reactance of approximately 1270 ohms is required. With a circuit resistance of 20 ohms, antenna voltage would be $(10 \times 1270)/20$ or 635 v.

With a loaded antenna, the voltage at its base depends upon the ratio of the antenna loading inductance that is in the radiotelephone to that which is built into the antenna. However, the base voltage can always be expected to be sufficiently high to cause serious losses under less-than-perfect conditions. The fact that the base of the antenna is a relatively high impedance point also means that movement of objects near the antenna can cause detuning of the circuit. This lowers radiation efficiency. Contact with the antenna may throw it completely out of operation and, in the case of higher powers, possibly give the "contactee" an r.f. burn.

Grounded, Shunt-fed Antenna

These disadvantages are eliminated by a grounded, shunt-fed antenna. The antenna to be described does not require mounting insulators, utilizes coaxial-line feed that may be of any length and routed anywhere, and is impervious to the effects of rain or salt spray. The antenna base is grounded, so that although it carries r.f. current, it is not affected if other objects touch it, or even if the operator holds onto it while transmitting.

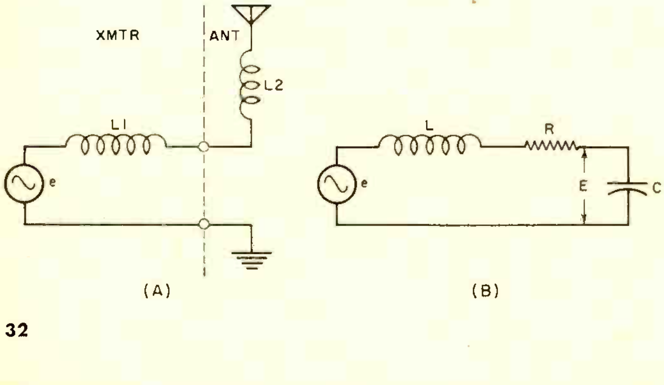
The design of the antenna is shown in Fig. 2A. The coaxial base section is rigid metal tubing that is directly grounded and which supports the rest of the antenna structure. The shunt feed line is tapped onto the resonating coil at a match-point for the generator output impedance. None of the radiotelephone loading inductance is used, so the feed to the antenna is low impedance. The function of the capacitor is to resonate the antenna for different frequency channels. A variable inductor would serve the same purpose, but would make the antenna more complicated.

The practical antenna circuit is illustrated in Fig. 2B. A length of flexible coaxial cable is used for the connection to the radiotelephone, and is fed down to the ground point through the supporting tubing. The only insulation in the circuit is that joining the base section and the top whip, and it is sufficiently elevated to be up out of the spray. The only portion of the system carrying high voltage and having a high impedance is the upper part of the coil and whip, out of reach of the influence or touch of people or things in the boat. The shield of the coaxial cable assumes the potential of the antenna base, and is effectively at ground potential for its entire external length.

Mechanical Details

Mechanically, the antenna is made up of a six-foot bottom section of one-inch diameter, and a top six-foot length of half-inch diameter aluminum tubing. For lightness, strength, and corrosion resistance, 6061 alloy tubing is used. The center insulator is one-inch diameter Bakelite rod, 10 inches long. It is bored two inches at the top to receive the whip,

Fig. 1. Conventional boat antenna and equivalent circuit.



and turned down for two inches at the bottom to press inside the base section. The loading coil is connected between the upper and lower tubing sections, secured to the screws that fasten the insulator to the tubings. The coaxial cable goes through a hole in the bottom of the Bakelite rod into the supporting aluminum tubing.

One of the photos shows the assembly of the resonating and coupling circuit. The tuning capacitor connected across the loading coil is mounted inside the bottom of the coil, secured to an L-bracket at the lower joint. A ¼-inch hole through the bottom of the Bakelite insulator passes the coaxial cable from inside the base section. The outer braid connects to the base section, and the central conductor to a coil clip secured three turns from the bottom of the loading coil. The tuning elements and the insulator are protected by a housing made from an inverted quart-size plastic juice container with a ½-inch hole in the bottom. A ⅜-inch hole is cut in the cover to pass the tuning capacitor shaft, and the pouring-hole stopper is removed. When assembled, as shown in the photo, the cover is pressed tightly in place and the top ½-inch tubing opening sealed with *G-E* silicone rubber "Marine Seal."

The antenna base is secured directly to the boat by screws or metal clamps, preferably close to the ground plate. The ground plate is connected by means of a heavy cable to the bottom of the one-inch aluminum base tubing.

Connecting and Tuning

At the radiotelephone, the shield of the coax is connected to the ground terminal, and the center conductor to the antenna terminal. The entire loading coil and any other antenna tuning coils (such as fine-tuning inductors) are short circuited, or taken out of the circuit. The antenna is resonated for transmitting by adjusting its tuning capacitor for maximum voltage on the top section, shown by a neon bulb, or by one of the simple diode comparative field-strength meters. On the Distress and Intership frequencies, it can also be tuned by listening for maximum receiver output. Once found, the capacitor settings should be marked on the plastic cover for ease in resetting to the channels used. The transmitter coupling must then be adjusted to give proper plate current. With the antenna resonant, receiver tuning should be touched up on all channels.

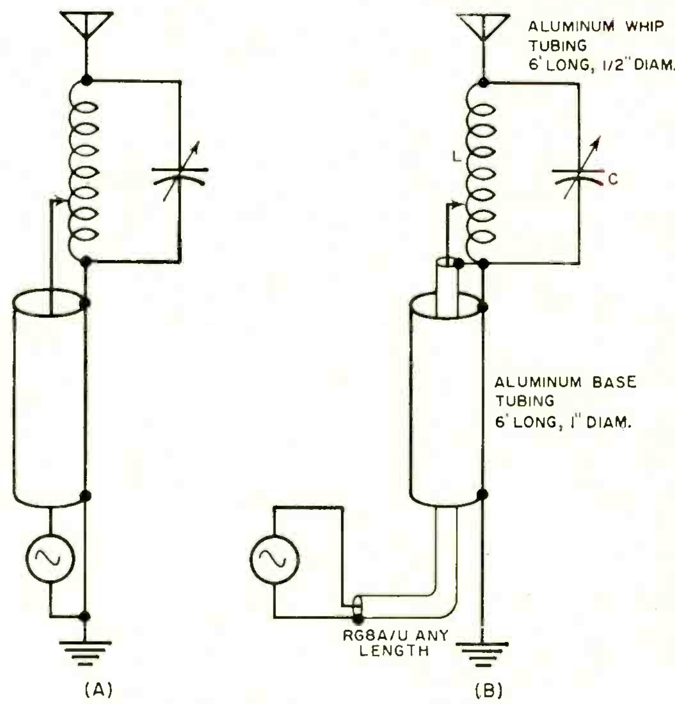
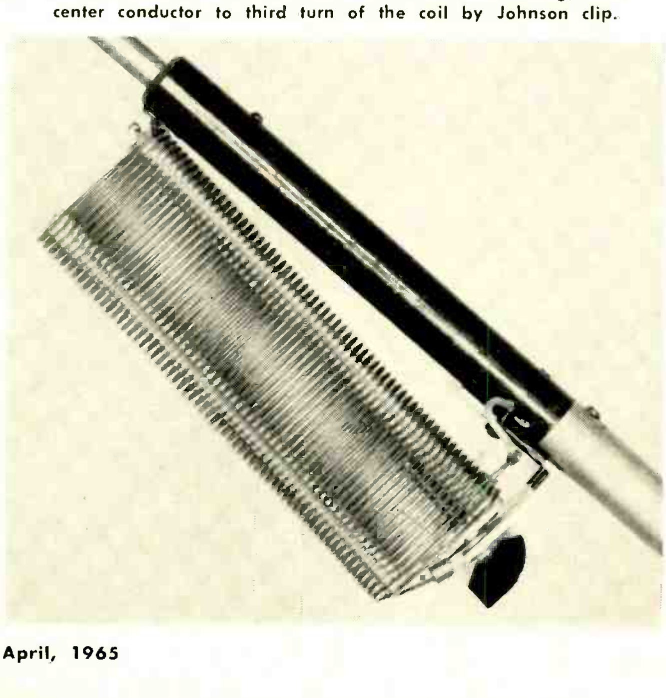


Fig. 2. (A) Grounded-base antenna. (B) Practical grounded antenna made of tubing. L is 48 turns of Airdux 2406T, 3-inch diameter, 6 turns/inch. C is Hammarlund MC-100-SX, a 100-pf. double-spaced air variable capacitor. A sufficient length of RG8A/U or RG58A/U should be employed to reach radiotelephone.

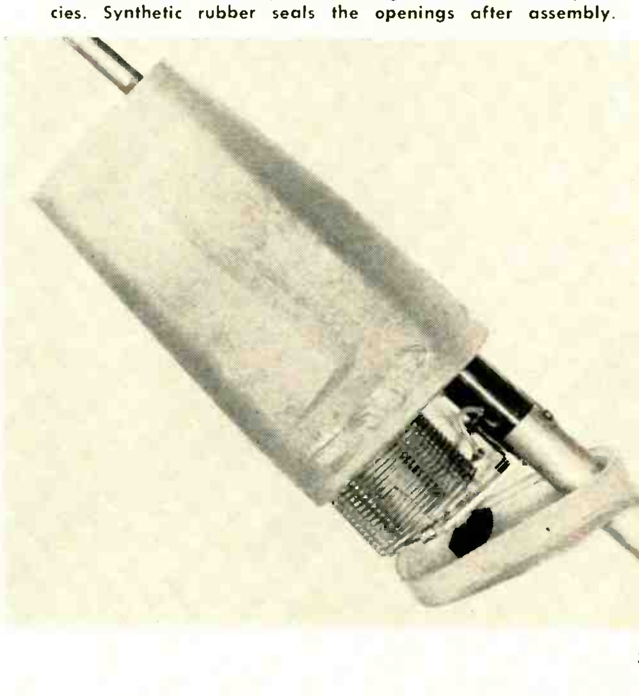
Unlike conventional boat antennas, the lead-in of this antenna can be run anywhere (even through the bilge) without loss or engine-noise pickup. It can be touched or immersed in water. Because the coax line length is noncritical, the telephone may be installed in one part of the boat and the antenna in another without electrical complications. And because the base section of the antenna is "cold" as far as r.f. voltage is concerned, chance contact with other objects has no effect. The installation affords excellent lightning protection.

In short, this is an antenna that can be "lived with" in a small boat, instead of having to be pampered. ▲

Antenna resonating assembly. Coil is mounted between terminal screw in top tubing and L-bracket secured to base tubing. The tuning capacitor is shaft-mounted on the L-bracket and projects into the center of the coil. Coaxial cable feed is led from inside base tubing through hole in the Bakelite rod insulator; outer braid connects to the base tubing, and center conductor to third turn of the coil by Johnson clip.



Tuning assembly is protected by plastic juice container. The whip projects through a half-inch hole cut in the container bottom, base tubing through pouring hole in the lid. A hole is also cut in the lid for the tuning capacitor shaft, and a knob is secured to the shaft on the bottom after assembly. Cover is marked for capacitor settings for different frequencies. Synthetic rubber seals the openings after assembly.



NEW LINE-CORD-OPERATED TRANSISTORS

High-voltage power transistors permitting line-cord instant-play all-transistor a.c.-d.c. sets may revolutionize receiver industry. Other uses include TV deflection circuits, high-voltage regulators.

THE availability of high-voltage (collector-emitter voltage ratings of 300-400 volts) transistors has recently been announced by *RCA* and *Delco*. These devices may well revolutionize receiver design, with all-transistor a.c.-d.c. sets becoming a common household item. Power transformers as well as voltage-dropping resistors for the power transistors are eliminated. These factors add up to savings in cost and weight and minimization of heat dissipation. Because the power supply operates at line voltage, the filtering section of the receiver is also simplified.

Besides their use in home receivers and amplifiers, the high-voltage transistors have other significant applications. Among these are in TV deflection circuits and high-voltage regulators and converters.

The *RCA* 40264 is designed for use as an audio power amplifier; the *Delco* DTS-413 and 423 units appear ideally suited for switching applications. Table 1 summarizes some of their important characteristics. Although prices at this time are on the high side, it is felt that these devices will become competitive with vacuum tubes in similar applications.

Table 1. Characteristics of RCA 40264 and Delco DTS-413,423.

	40264	DTS-413	DTS-423
Operating temperature (max. °C)	−65 to 150	−65 to 150	−65 to 150
Collector-to-base voltage, V_{CBO} (max. volts)	300	400	400
Collector-to-emitter voltage, V_{CEO} (max. volts)	300	400	400
Emitter-to-base voltage, V_{EBO} (max. volts)	3	5	5
Collector current, I_C (max. amps)	0.1	1	2.5
Static forward current gain, h_{FE} (min.)	30 @V_{CE}=10 v. I_C=50 ma.	20 @V_{CE}=5 v. I_C=0.5 a.	30 @V_{CE}=5 v. I_C=1 a.
Gain-bandwidth product, f_T (typical, mc.)			
Cutoff frequency, f_β (typical kc.)	25	*	*
Collector-to-emitter saturation voltage,	*	115	110
$V_{CE(SAT)}$ (typical, volts)	*	0.3	0.3
Cost, 1 to 99 units	**	$9.75	$10.75
100 to 999 units	**	$7.23	$ 7.96

*Values not specified on manufacturer's data sheets.
**Prices not available at the time the article was prepared.

Description and Characteristics

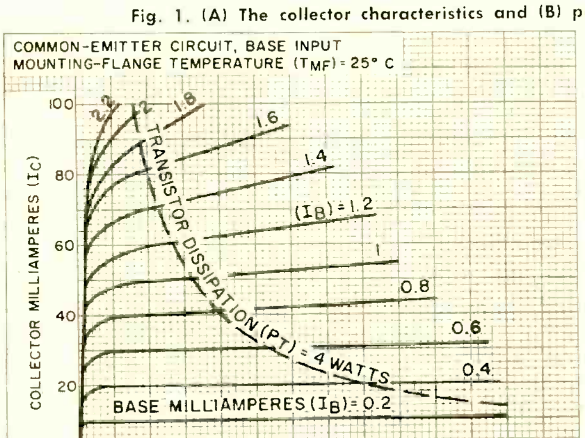
The line-operated transistors are *n-p-n* silicon units of triple-diffused mesa construction. Triple diffusion provides good frequency response for the device. High resistivity silicon is used to achieve the high-voltage rating. In addition, the processing of the transistor is done under ultra-clean conditions and the resulting device is finely coated with silicone resin to minimize leakage current.

Typical collector characteristics and power derating curves for the *RCA* 40264 are given in Fig. 1. Maximum collector current and voltage ratings are 0.1 ampere and 300 volts, respectively. A maximum collector dissipation of 4 watts is permitted for temperatures up to 70°C provided the transistor is properly mounted. The collector is connected to the case in both the *RCA* and *Delco* units. Under no conditions should the mounting flange be soldered to the heat sink or chassis. The heat of the soldering operation may permanently damage the transistor if this is done.

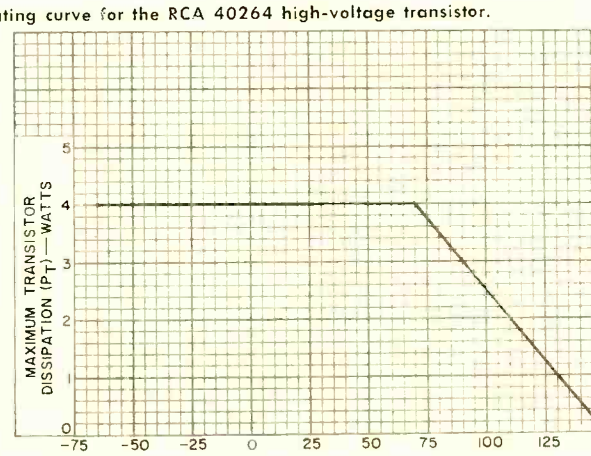
A.C.-D.C. Receiver & Amplifier

The receiver circuit shown in Fig. 2 was designed to match

Fig. 1. (A) The collector characteristics and (B) power-derating curve for the RCA 40264 high-voltage transistor.



(A)



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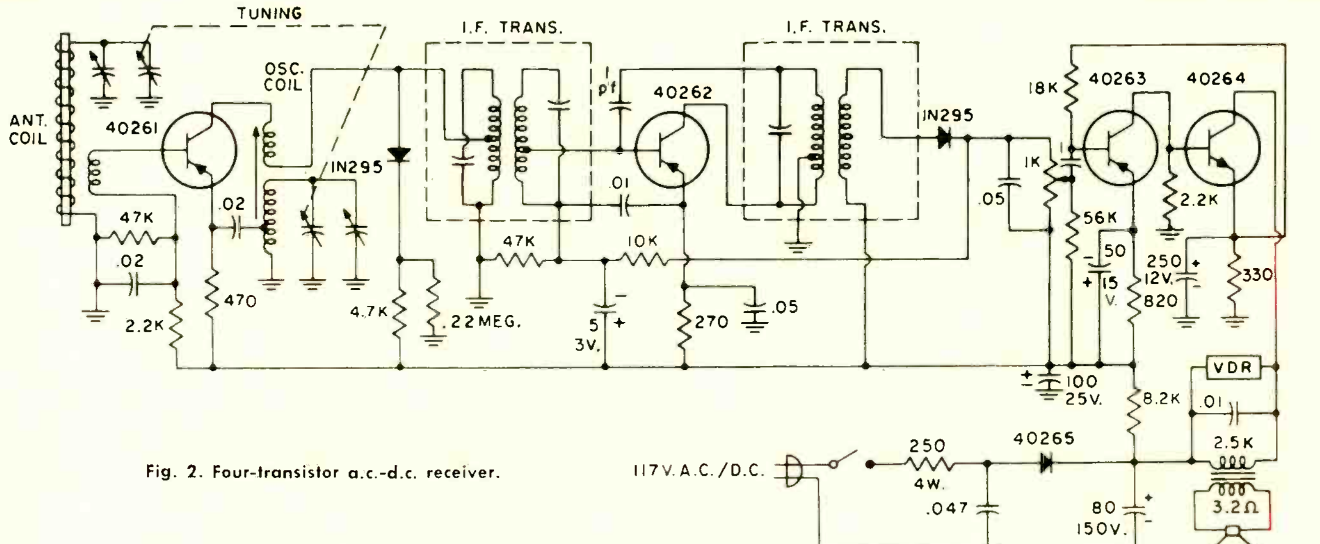


Fig. 2. Four-transistor a.c.-d.c. receiver.

the performance of the popular five-tube (including rectifier) a.c.-d.c. receiver. The 40264 is used as the audio power amplifier. Note there is no dropping resistor in the collector circuit. The transistor obtains its collector voltage directly (through the primary winding of the output transformer) from the output of the half-wave rectifier. A large bypassed 330-ohm emitter resistor allows the circuit to maintain a constant emitter current in the output stage for wide variation in *beta* without sacrificing a.c. gain.

The purpose of the component marked *VDR* across the output transformer will now be considered. The letters *VDR* stand for "voltage-dependent resistor." It is also referred to as a varistor. Being made of semiconductive material, the resistor exhibits a nonlinear relationship between its resistance and applied voltage. The unit recommended by *RCA* is the *Ferroxcube* No. E299DD-P340 or equivalent. The voltage of this device varies from approximately 38 volts to 110 volts for a current range of 10 μa. to 7 ma.; dissipation rating is 0.8 watt.

Using this resistor in line-operated equipment protects the output circuit against the harmful effects of transient voltages. These transients can occur as a result of intense radiation such as that which exists during electrical storms or the radiation emitted by fluorescent lighting. Such spurious emission causes transient pulses to appear at the detector circuits. When amplified, these pulses result in voltages across the output transformer and transistor as much as five times the magnitude of the supply voltage. The use of a *VDR* minimizes these harmful effects and does not degrade over-all performance of the equipment.

The audio driver transistor 40263 is a germanium *p-n-p* alloy device with high gain and good linearity characteristics. The a.g.c. voltage is obtained from the second detector diode as shown.

The converter stage, using a 40261 drift-field transistor, is of conventional design. A voltage divider maintains constant base bias. Injection voltage is about 120 mv. and remains relatively constant over the band. Oscillator injection and stability are adequate at both high and low line voltages. A reverse-biased clamping diode is shunted across the primary winding of the first i.f. transformer to provide r.f. overload protection.

The i.f. amplifier consists of a single 40262 drift-field transistor. The circuit is neutralized and designed for maximum variable gain consistent with good stability. For ease of production, the unloaded "Q's" and the tuning capacitors of the primary and secondary windings of the double-tuned transformers are equal.

A half-wave rectifier with a capacitor input filter makes up the power supply. The 250-ohm series resistor serves to limit surge current as well as filtering ripple, which is less than 2%.

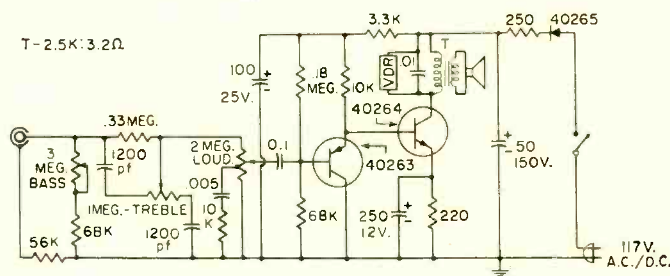


Fig. 3. Circuit diagram of the phonograph amplifier discussed.

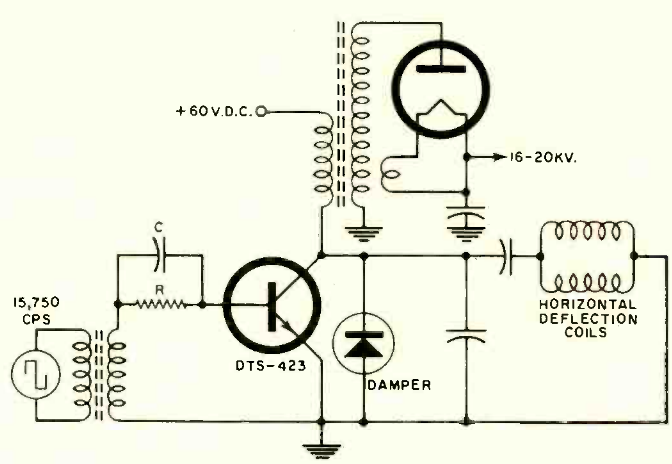
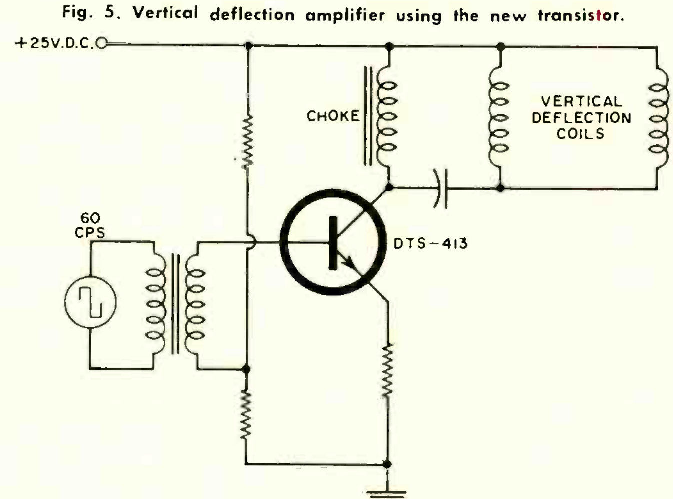


Fig. 4. Horizontal deflection amplifier using the new transistor.

Fig. 5. Vertical deflection amplifier using the new transistor.



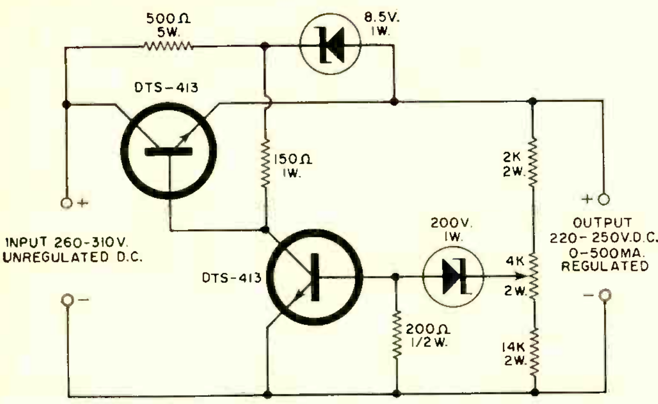


Fig. 6. High-voltage d.c. regulator circuit diagram.

An a.c.-d.c. phonograph amplifier that will deliver a maximum power output of 2.2 watts or 1 watt at the clipping level is shown in Fig. 3. Power gain for the basic amplifier is 68 db at 1-kc. input signal. For a constant input voltage of 580 mv., the output power is essentially 600 mv. over a temperature range from 25° to 70°C. Total harmonic distortion is less than 2% at 500-mw. output.

At a line voltage of 117 volts, the output transistor idles at a dissipation of 2.5 watts; idling dissipation may approach 4 watts at high line voltage. The 40264 should be connected to a suitable heat sink so that the junction temperature will not exceed 150°C under "worst-case" conditions.

TV Deflection Circuits

The *Delco* DTS-423 transistor is well suited as a horizontal amplifier in magnetically deflected television receivers. Full-size line-operated models are practical with "B+" ranging up to 60 volts. Current gain at 2.5 amperes is a minimum of 10. In some cases, deflection systems have been built requiring peak currents of up to 4.5 amperes with equivalent current gains of from 5 to 8.

The circuit of Fig. 4 is a typical layout for a 60-volt system. The speed-up *RC* combination in the base circuit results in a fall time of less than 1 microsecond.

The DTS-413 may be used in vertical-deflection circuitry, as shown in Fig. 5. The class-A, transformer-coupled circuit is biased at a collector current of 200-300 ma. Vertical amplitude and linearity are maintained with adjustment for a normal percentage over-sweep at cold turn-on conditions.

High-Voltage Regulator

Fig. 6 illustrates the application of the DTS-413 unit in a voltage regulator with an output current of 0-500 ma. from 220 to 250 volts, adjustable. To eliminate the need for a 200-volt, 10-watt zener diode in the emitter of the error-sensing amplifier, a 1-watt zener diode is inserted between the base lead and arm of the voltage-divider pot. The effect is essentially the same in that the base current to the error amplifier is proportional to the pot setting as long as 200 volts are present across the zener diode. The 1-watt zener represents a considerable saving in cost over the 10-watt type.

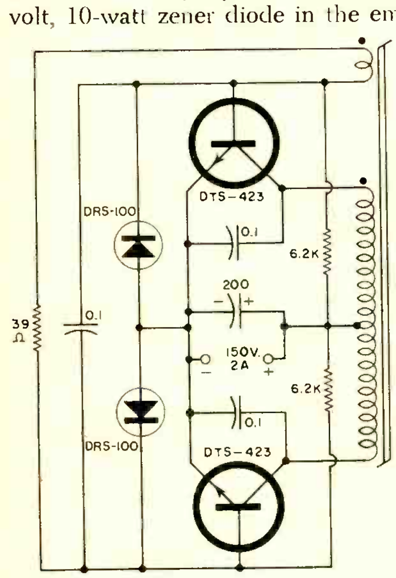


Fig. 7. High-voltage converter that is operated from 150 v.

Power Converter

The converter of Fig. 7 uses two DTS-423 transistors in a conventional circuit except that it is operated from a 150-volt d.c. source. For doubling the "B+," the 325 volt sustaining limit (discussed below under testing) provides a 25-volt safety margin. The oscillator was designed to operate at 1100 cps and an efficiency of over 80% was realized over a temperature range from −65° to +100°C. Converter output is a low voltage at high current.

The drive circuit is unique in that one transformer winding is used to serve both transistors with the aid of two diodes. These diodes alternately act as steering and clamping devices. A diode, while acting as a clamp for the emitter of an "off" transistor, is also performing a steering function for the drive current to the "on" transistor.

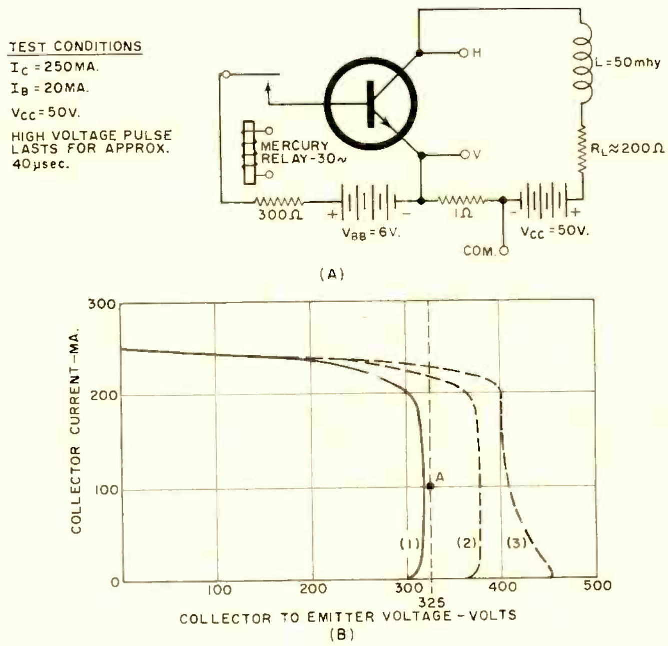


Fig. 8. Test circuit and characteristic curves for determining sustaining voltage. A unit is acceptable when the trace falls to the right of point A. For example, curves (2) and (3) are for acceptable transistors; curve (1) is of reject.

Testing Circuit

To insure safe operation with inductive loads, (*e.g.*, deflection circuits and converters) a sustaining voltage rating, $V_{CE(sus)}$, is applied to the DTS-413 and 423 transistors. The minimum such rating for these devices is 325 volts. The sustaining voltage capability can be examined by forward bias pulse operation with either a resistive or inductive load. Use of a load inductance allows a smaller power supply voltage to be used than with a resistive load.

A test circuit recommended by *Delco* and the resultant V_{CE}-I_C oscilloscope plots are shown in Fig. 8. A 10:1 attenuator is required for the voltage input to the scope. The peak voltage in the circuit is a function of $L(\Delta i/\Delta t)$ value of the load which is sufficient to reach the sustaining voltage of the transistor. The base bias circuit is arranged to apply an open base condition during the sustaining interval. Duration of the peak-power pulse is approximately 40 microseconds. The mercury relay is driven from an audio generator at a frequency of 30 cps. ▲

The Fixed Resistor Industry

Vice-President, Marketing, Speer Carbon Company, the author has been connected with the radio and electronics industry since graduating in engineering from Stanford University in 1924. He is a director of EIA, vice-chairman of its Parts Division, and chairman of the Resistor Subdivision. He is also vice-chairman of the Carbon Section of NEMA. He is a member of IEEE, American Society for Engineering Education, and American Institute of Metallurgical Engineers. He has been associated with RCA, P. R. Mallory, Sylvania, and Federal.

EDWARD W. BUTLER

Guest Editorial

IN order to appreciate the importance of any industry, it might be instructive to consider what would happen if it were wiped out. If a major disaster were to strike Milwaukee, Bradford (Pa.), Kane (Pa.), and Philadelphia, facilities of the four resistor manufacturers headquartered in these cities would be destroyed and the source of all the fixed composition resistors (about 85% of all fixed resistors) made in the U.S. would be wiped out.

Even if other types of resistors could be substituted, plant capacities would be inadequate to meet the six-fold increase in demand. In addition, the higher prices of film and wirewound types would place a serious burden on electronic equipment producers.

All this points up the importance of a strong resistor industry in our military preparedness and national economy. In a fiercely competitive field, four major composition-resistor companies have survived because of technical improvements in their products, fair prices, and realistic delivery scheduling. Similar attrition is taking place among producers of other types of resistors and, like those in the fixed-composition field, the ones that survive will be those whose research and development efforts produce an improved product at reasonable cost.

The total U. S. usage of all types of fixed resistors in all applications amounted to about 2,800.000.000 units in 1963 (the last full year on which data is available). Of these, about 2.400.000,000 were of the fixed composition type while about 275.000,000 were of various film types, and the balance wirewound.

About 2.160,000.000 of these fixed composition units were used in consumer goods and industrial equipment and about 240,000.000 in military apparatus during 1963.

Although usage of fixed composition and metal films continues to rise, the volume of carbon film and precision wirewounds shows a decline. Their volume is being preempted by metal, metal-oxide, and "thick" inorganic film components. These conclusions are confirmed by comparing the figures for 1962 and 1963 which show over-all unit sales of composition units in 1963 up 109,000.000, metal film up 44.000.000, deposited carbon down 14,000,000, and precision wirewound down 3.000.000.

The explosive growth of color-TV has given a substantial boost to the demand for resistors, especially those of the fixed composition type. A color set takes approximately 180 resistors compared to 60 to 70 for a black-and-white receiver. This means that an increase of 500.000 color sets creates an additional market for 90.000.000 composition resistors, assuming that black-and-white production is not reduced.

In looking ahead it is interesting to note that industry growth projection estimates are 1,400,000.000 circuits per year by 1975 (each transistor or tube represents an active circuit). This compares with 640,000,000 circuits for 1963.

Economic and technical factors will determine what percentage will use discrete components or integrated circuits. There are circuit applications where extremely small size and very light weight are worth a substantial price premium, and there are also others in which the circuitry is repetitive, where the volume is large, and production stable. In such equipment, various forms of integrated circuitry may be advantageous if unit cost, including cost of design and tooling, is economically sound.

But, by and large, the vast bulk of the circuits do not have to be very small or very light and here discrete components offer the advantages of quick availability, great design and production flexibility, conservation of design time, long established reliability, and low cost.

Take a non-military TV design, for example. At the factory level, discrete components for a typical circuit stage cost about 53 cents. This is broken down into 35 cents for a tube, 3 cents for ⅓ diode, 7 cents for four resistors, and about 8 cents for three capacitors. From this it appears that the dollar value of active components in the average circuit is several times that of the required passive components. Thus, any reduction in the price of discrete active components favors the use of discrete passive components.

Looking ahead five years or so, let's assume that economic and technical factors will determine the choice of integrated or discrete components. Since forecasters estimate that 175.000.000 integrated circuits will be used in 1970 and 375,000.000 in 1975, at an average individual price of \$3 by 1970 and from \$1 to \$2 by 1975, obviously a difference of 100% would be of major importance in swaying the equipment designer's choice. Now, if we assume that 1.400.000.000 circuits will be used in 1975 and that of these 375.000.000 will be integrated circuits, the remainder of about 1.000.000.000 will be made up of discrete components. If each uses the present average of 4-plus resistors, we can expect a 1975 market for these passive discrete components of about 4.000.000.000 resistors.

How this potential 4.000.000.000-resistor market will be broken down among carbon composition, various film types, and wirewounds is anybody's guess at this stage. Improvements in carbon composition types may close the performance gap between them and metal and other inorganic film types. On the other hand, metal and other inorganic film types may become more competitive costwise because of improvements in production techniques.

No matter how this market is to be shared, the industry as a whole would seem to have a bright future before it. ▲

Carbon-Composition Resistors

By OSCAR H. BIECK and CHARLES O. VAN HECKE
Allen-Bradley Company

Combining high dependability, reasonable stability, universal usefulness at low cost, composition resistors account for more than five out of every six resistors that are employed today.

Editor's Note: Carbon-composition resistors are made by several different processes. Allen-Bradley's hot-molding process combines resistor materials, insulation, and leads into an integrally molded structure, known basically as slug-type construction. Others, including Speer Carbon Company and Stackpole Carbon Company, also use the slug-type construction, but materials are different, and molding is done at a lower temperature. IRC resistors consist of carbon-composition material applied as a coating to the outside surface of a hollow glass tube. Leads are inserted into the tube and an insulating jacket is molded around the assembly. Due to different manufacturing materials and techniques, each type exhibits its own characteristics. It should be understood that the characteristics and curves shown in this article apply primarily to the hot-molded, slug-type resistors made by Allen-Bradley.

THE standard carbon-composition fixed resistor is considered by many to be the backbone of the electronics industry. This remarkable little device is frequently the designer's first choice for a discrete and dependable small package of electric resistance, and has such an outstanding reputation for usefulness that it has become the most popular of all electronic components.

The degree of popularity that the composition resistor enjoys is well known among circuit designers. In 1963, for example, of the several billion resistors that were purchased, more than 5 out of every 6 were standard composition fixed resistors. In the broadest range of applications, from undersea cables to TV sets, hearing aids and complex computers, to orbiting satellites, the composition resistor has proven itself to be the work horse of the electronics world. Its broad usage attests its true value.

Composition resistors are available in a wide range of resistance values and in power ratings from 1/10 to 5 watts. While all composition resistors are similar in that they use carbon as the conducting material, the resemblance ends there. Since each manufacturer uses his own mixture of carbon and binders and a different process of manufacture, the resulting resistors are different in many respects. For example, our hot-molded resistors are produced by fully automatic production machinery, which practically eliminates the human element. This exclusive process, using high temperature and pressure, molds the insulation, resistance material, and headed lead wires together into a single dense structure. This produces precise uniformity from one resistor to the next and results in high over-all reliability.

No matter how reliable and time-proven any component may be, none exists which can be applied blindly and without consideration for its peculiar characteristics. The carbon-composition resistor is no exception. While this device probably comes closest of all to being "foolproof" in its application, a brief discussion of its characteristics should help the circuit designer use it to best advantage.

In the selection of a resistor by the designer, four major factors must be considered. They are:

1. *Resistance value and permissible tolerance,* dictated by Ohm's law and available values, in addition to the circuit tolerance to resistance deviation from the nominal value.
2. *Wattage rating,* also dictated by Ohm's law, but determined by life-test procedures, as explained later.
3. *Voltage characteristics,* the first of the "built-in" characteristics of resistors that the designer may consider.
4. *External influences,* such as temperature and moisture, having an influence on *all* components. They must be considered on the basis of their capacity for producing unwanted or undesirable effects.

Resistance-Value Selection

Many composition resistor specifications indicate that resistors are available in nominal values from 10 ohms to 22 megohms. However, hot-molded resistor types are available from 1 ohm to 100 megohms. Nominal values have been standardized by the Electronic Industries Association (EIA) and military agencies. Values are arranged so that, in the 10% tolerance group, for example, in adjacent nominal values, such as 100 ohms and 120 ohms, the low-tolerance limit for the higher value will approximately (to the nearest two-digit number) coincide with the high tolerance limit of the lower value. In this case, the high limit (+10%) for 100 ohms would be 110 ohms, and the low limit (−10%) for 120 ohms would be 108 ohms. Referring to the table at the top of page 51, you can see that adjacent value selection is the basis for the standard values in all available tolerance categories: 5%, 10%, and 20%.

Wattage-Rating Selection

Composition resistors are available in wattage ratings from 1/10 to 5 watts, based on a 70°C (158°F) ambient temperature. The need for a certain wattage depends on the voltage and current in the circuit. However, many factors determine the wattage rating of the resistor to be selected. The "correct" resistor is not necessarily that with the lowest wattage rating capable of handling the load. As will be pointed out shortly, the life of a resistor is largely determined by the resistor operating temperature which is a result of both the amount of power dissipated and external heat encountered.

As you might expect, the chemistry of a composition resistor is quite complex and there are considerable differences among the products of various manufacturers. All composition resistors will undergo change due to prolonged

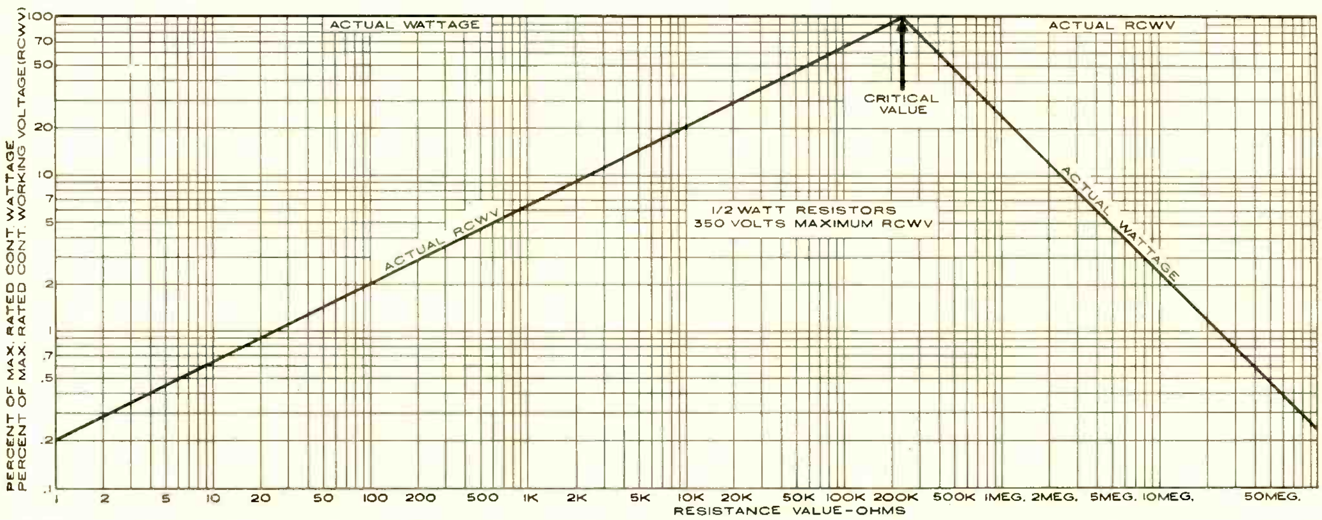


Fig. 1. Critical resistance of ½ w., 350 v. resistor is 245,000 ohms. R critical for other composition resistors is close to this value. For 1/10 w., 150 v. resistor, R critical is 225,000 ohms; for ¼ w., 250 v. resistors, it is 250,000 ohms; and for the 1-watt, 500-volt composition resistor, the critical value of resistance is 250,000 ohms.

exposure to elevated temperature. In the case of hot-molded resistors, this change will be a decrease in resistance, and it is predictable. The rate of change will depend on several things, such as the power the resistor is dissipating and the temperature at which it is operating.

The power or wattage rating of a resistor is determined by an industry standard test known as "load life." This test consists of 1000 hours operation at an ambient temperature of 70°C (158°F) during which the resistors are operated at full rated wattage for cycles of 1½ hour "on," ½ hour "off." At the end of this 1000-hour test, during which the resistor has been exposed to considerable heat, the maximum specified change for hot-molded resistors is 8% (10% for other composition types), and the average of changes over many samples must be less than 6%. But there are other interesting factors which come into play.

For example, higher nominal resistance values are more sensitive to heat than lower nominal values. This is not only true for load life, where the continued heating of higher resistance materials has a greater permanent effect, but it is also true for transient resistance changes due to temperature, as we will explain shortly. In higher nominal resistance values, the maximum voltage rating becomes a factor, and at a resistance defined as *critical value*, the resistor operates at maximum voltage and maximum power at the same time.

At values above the critical resistance value, the power is less than maximum because the voltage is at its specified limit. Below the critical value, the voltage will be less because the power has reached its limit. Fig. 1 shows this relationship. In practice, the critical resistance value is ordinarily defined as the nearest standard value below the point at which maximum wattage is dissipated with the maximum rated voltage.

It can be seen that the load-life test is obviously severe, but it is a regular test imposed by military and industrial qualification requirements. But of more interest is the fact that the vast majority of applications never demand as much of any resistor as this test. In fact, if the surface temperature of a hot-molded resistor is kept below 100°C, which corresponds roughly to operating at one-half rated power in a 70°C (158°F) ambient atmosphere, a typical resistance change of only 2½% would be observed after more than 10,000 hours of actual operation.

A very important factor in the power rating or life of composition resistors is the heat sink to which they are connected. As a rule of thumb, approximately ¾ of the dissipated heat goes out through the lead wires, and naturally it must have some place to go. In the standard load-life test, the specifications call for "lightweight" terminals about an inch from the resistor body. Obviously, then, if in an actual application, the resistor is connected to a heat sink with greater thermal capacity, the performance would be expected to be better than when lightweight terminals are used.

By the same reasoning, the life of the resistor would be shortened if it were connected to the pins on the socket of a hot tube, which would make it difficult for the resistor to get rid of its heat. In fact, in the latter case, the resistor might actually be absorbing heat from what was intended to be a heat sink. For this reason, it becomes apparent that

Helpful Hints for Using Composition Resistors

1. Resistance changes due to humidity are temporary and in hot-molded resistors are reversible.
2. Resistance increases with increasing moisture content and decreases with decreasing moisture content.
3. Resistance change due to humidity in low-value resistors is less than in high-value resistors.
4. Change of resistance which has occurred due to humidity may be essentially eliminated by conditioning the resistor at 100°C for 48 hours.
5. Operating resistors with as little as 1/10 rated wattage tends to minimize the effects of humidity.
6. Hermetically sealed resistors do not exhibit resistance change because of humidity.
7. Resistance change due to load life is permanent and ultimately negative.
8. Resistance change due to load life can be minimized to a few percent in many thousands of hours by limiting the maximum operating surface temperature of the resistor under load to 100°C, typically achieved by operating at 70°C ambient air with 50% derating.
9. Resistance change due to heat of soldering is positive and may be permanent if the resistor has moisture present in its body. It can be greatly minimized if resistors are dry at the time of soldering.
10. The heat sink to which a resistor is connected affects its rating. Resistors operated in series or parallel should be derated unless an adequate heat sink is provided.
11. The temperature characteristic of hot-molded resistors is essentially zero between 0°C and 85°C.
12. The voltage characteristic is negative and is less at elevated operating temperatures than at room ambient.
13. The voltage characteristic is less in low-value resistors than in high-value units.

Nominal Resistance Range	Recommended Test Voltages	
	For all above ⅛ watt	For ⅛ watt and below
10 to 91 ohms	0.75 ± 0.25 volt	0.4 ± 0.1 volt
100 to 910 ohms	2.75 ± 0.25 volt	1.0 ± 0.5 volt
1 to 9.1 k ohms	9.0 ± 1.0 volt	3.0 ± 1.5 volt
10 to 91 k ohms	27 ± 3 volts	10 ± 5 volts
0.1 meg. and higher	90 ± 10 volts	30± 15 volts

Table 1. The following test voltages take heating into account.

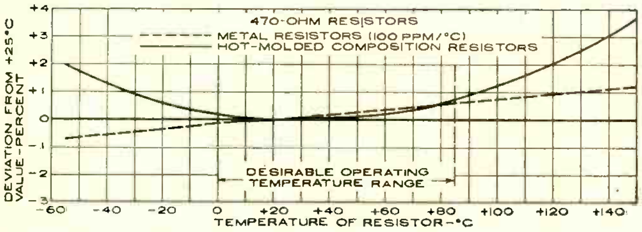


Fig. 2. Typical temperature characteristics of resistors.

a 4-watt resistor cannot be made from two 2-watt resistors by simply connecting them in series or parallel without taking adequate precautions for removing their heat.

Some applications have recently come about in which small composition resistors have been required to carry kilowatts for short periods, hence are worthy of mention. Such pulse applications have, on occasion, stressed composition resistors far beyond their ratings with no apparent damaging effects.

In our laboratories, for example, we have repeatedly discharged several kilovolts from a capacitor through a standard hot-molded ⅛-watt resistor and it has remained unchanged. A possible key to survival, we believe, is the basic ruggedness of the construction and the exceptional momentary overload capacity of such resistors.

Generally, we have found that when the integrated pulse energy dissipated in the resistor is less than the integrated energy would be for steady-state full wattage, the resistor will very likely survive. There is, however, much to be learned about pulse operation of resistors before simple and dependably valid solutions will evolve.

Effects of Voltage

Another factor the designer may want to consider in the use of composition resistors is the voltage characteristic. The voltage characteristic is the measure of the voltage dependence of a resistor and reflects the change in resistance per volt, or voltage *versus* current non-linearity due to changes in voltage. This characteristic is instantaneous

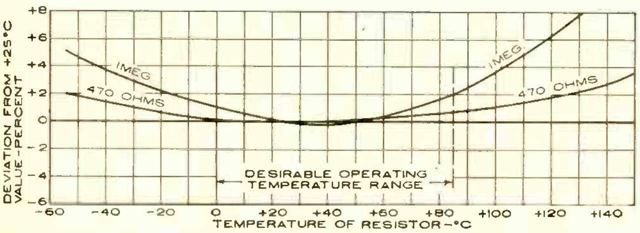


Fig. 3. The temperature effects for two values of resistance.

Table 2. Recommended drying time for composition resistors.

Composition Resistor Types	Wattage Rating	Recommended Conditioning Time @ 100°C
HB	2 watts	120 hours
GB	1 watt	120 hours
EB	½ watt	72 hours
CB	¼ watt	48 hours
BB	⅛ watt	16 hours

and should not be associated with the resistance change due to the heat produced by power dissipated when a voltage is applied. In terms of magnitude, its maximum value is only 0.05% per volt, and this is lower in the lower resistance values, where, for example, it will be 0.005% per volt maximum for 1000-ohm resistors.

Of course, when you are measuring resistance precisely, a momentary voltage application should be used so that heating will not affect the value measured. Recommended test voltages are shown in Table 1.

Temperature Characteristics

Somewhat related to the subject of the aging effects of heat, but transient in nature, is the temperature characteristic. This is the temporary change in resistance due to the actual temperature of the resistance material.

Note in Fig. 2 that metal resistors (wirewound or film) have a linear characteristic with respect to temperature. Composition resistors, as can be seen, exhibit a non-linear temperature characteristic, resembling a saucer. However, it is centered roughly between 10° and 50°C. Thus, in a range of approximately 0° to 85°C, the curve for these resistors is nearly flat, corresponding to an unusually low temperature coefficient.

Temperature coefficient is probably best defined as the slope of the temperature characteristic. If the slope is a straight line, the use of a single temperature coefficient number is appropriate. However, in composition resistors, this is not the case.

You can see that any single number would poorly describe the parabolic characteristics since it would have to indicate a curve that goes from a negative slope, through zero, and on into a positive slope. The true picture can best be shown with curves or a table indicating a resistance deviation range at certain temperatures and for specific resistance values. The nominal value of a resistor is an important factor in temperature characteristic. Temperature stability is better in low value resistors than in those of higher value, as can be seen in Fig. 3.

Effects of Moisture

Every component somehow responds to an excessively humid atmosphere. In composition resistors, an extended period of exposure to such moisture results in temporary increase in resistance. Sensitivity to moisture is somewhat proportional to the nominal value of the resistors, the lower values being less sensitive, and the higher values more so. In addition, the length of time of moisture penetration is dependent on the physical size of the resistor. Smaller resistors will respond more quickly than the larger resistors to changes in humidity.

Absorbed moisture is in no way harmful to hot-molded resistors and is easily removed by drying the resistors in dry 100°C air. As explained previously, the size of the resistor determines the speed of the response to changes in moisture, and thus a table of recommended drying times can be made (see Table 2).

It should be understood that this is only a rule-of-thumb guide, since the true necessary drying time depends somewhat on the amount of moisture in the resistors. A "drying out" such as this can restore the original properties of fresh, dry resistors.

It has been explained, now, that the changes due to an increase in moisture are positive and are reversible. However, sudden heating of resistors, as might be caused by the high external heat of soldering, could cause a permanent resistance change *if* the resistors have been stored in a humid location and no drying precautions were taken.

Resistors, originally fresh and dry, or conditioned as suggested, and operating in equipment with as little as 1/10 their rated power in an ambient temperature of approximately 70°C, remain virtually unaffected by humidity. ▲

Common Problems in Specifying Resistors

By DONALD O. WARD / Applications Engineer, Victoreen Instrument Co.

Comments on resistor rating, temperature effects, and the use of resistors in high-voltage circuits.

RESISTORS are rated according to maximum wattage, maximum voltage, and resistance range. Consider for a moment the common insulated composition fixed resistor covered by MIL-R-11. It provides for power ratings of 1/10, 1/4, 1/2, 1, and 2 watts and a maximum continuous working voltage of 500 volts for 1-watt resistors, yet it covers resistances as high as 22 megohms. According to the Power Law, $E=\sqrt{PR}$; 4700 volts would have to be applied to a 22-megohm resistor to dissipate 1 watt. But the resistor is limited by a MIL-spec to the application of 500 volts. Quite obviously, then, this same 22-megohm resistor is not a 1-watt resistor.

Since $R=E^2/P$, it is apparent that the "critical-resistance" value is 250,000 ohms. It is the only resistance value at which both maximum voltage and maximum wattage can be tolerated. Values above 250,000 (the critical resistance) are limited in wattage (wattage limited) by the maximum voltage (500), and we find that the 22-megohm resistor is only capable of slightly more than .01-watt dissipation.

Fundamentally, the maximum ratings indicate those values above which the resistor can be damaged. It is apparent then that the dissipation of heat (wattage rating) is one important factor in the rating.

Using High-Voltage Resistors

Some engineers have obtained unexpected results when using a high-voltage resistor. They may have intended it as a series filter resistor in an *RC* network to be inserted in the positive leg of a high-voltage supply having a negative ground. Full precautions were taken so that neither the power rating nor the applied voltage drop was excessive, yet the resistor failed in an alarmingly short period of time. The cause of this failure was the lateral electric field from the resistive element to the nearest grounded object wherein the voltage was in excess of 10 kv. Usually the carbon of the resistive element pulls from the rod at the positive end of the resistor, causing an open circuit.

The Bureau of Standards has, for many years, recognized the detrimental effect of lateral fields. It has found that excessive lateral electric fields will so seriously disturb the resistance of such stable components as precision wirewound resistors that it destroys their accuracy when used at high voltage. For this reason, high-voltage precision standards, made up of precision wirewound spool resistors, are assembled in electrostatic shields with the shield having the same potential as one end of the resistor. The shields are then stacked to form a string with no more than 100 volts across each individually shielded section.

Temperature Derating

The power rating for resistors, particularly those whose values lie below the "critical resistance" for the series, is based on the maximum "hot-spot" temperature which may be tolerated. It follows, then, that the resistor may dissipate more power under conditions of reduced ambient temperature than it can at elevated temperatures. This, in turn, gives rise to the well-known temperature derating charts.

Assume that a particular resistor has a 75°C temperature rise for full wattage rating and that this resistor is limited to maximum "hot-spot" temperature of 100°C. If the ambient room temperature were 25°C, then full dissipation would produce a "hot-spot" temperature of 100°. Obviously, if the ambient temperature were increased, then full power dissipation would produce a temperature exceeding the maximum allowable temperature for the resistor. If the operating ambient were 60°C, then the power must be limited to that amount which will produce only an additional 40° rise. Reference to a derating chart may show that the resistor can handle only 40 percent of rated power under these conditions. Therefore, this resistor must be derated to 40 percent of its listed power for operation in ambient temperatures of 60°.

If provision is made to carry away the heat at a faster rate than normal radiation, conduction, and convection will permit, then the derating chart may be exceeded by whatever this additional cooling will permit.

Temperature Coefficient of Resistance

It is well known that the change of resistance with temperature (temperature coefficient of resistance) is negative in the case of carbon and positive for almost all other conductive elements. Hence, when carbon is used as the resistance material, its resistance value falls as the temperature rises. Therefore, a resistor has an exact resistance value at only one temperature.

This consideration is frequently overlooked in the design of a temperature-compensated precision voltage-divider string. The designer generally considers that if such a string can be made up of resistors having identical temperature coefficients of resistance he will have a string which will give a precise voltage division under all ambient temperatures.

If all elements of the string were of identical resistance values, they would dissipate equal amounts of power and would be subject to uniform temperature rise. But this condition is possible only when the steps in the voltage divider are uniform. If one step in the divider string requires ten times the voltage drop as another step, it will have ten times the power dissipation and ten times the temperature rise. No longer do the elements have the same temperature and even though they have the same temperature coefficients of resistance, no longer will the one step be exactly ten times the resistance value of the other and the precision of this string is destroyed. ▲

Resistor Noise Graphs

By ROBERT JONES

Calculation and measurement of amount of thermal and current noises generated by resistors in a.f., r.f., or i.f. circuits.

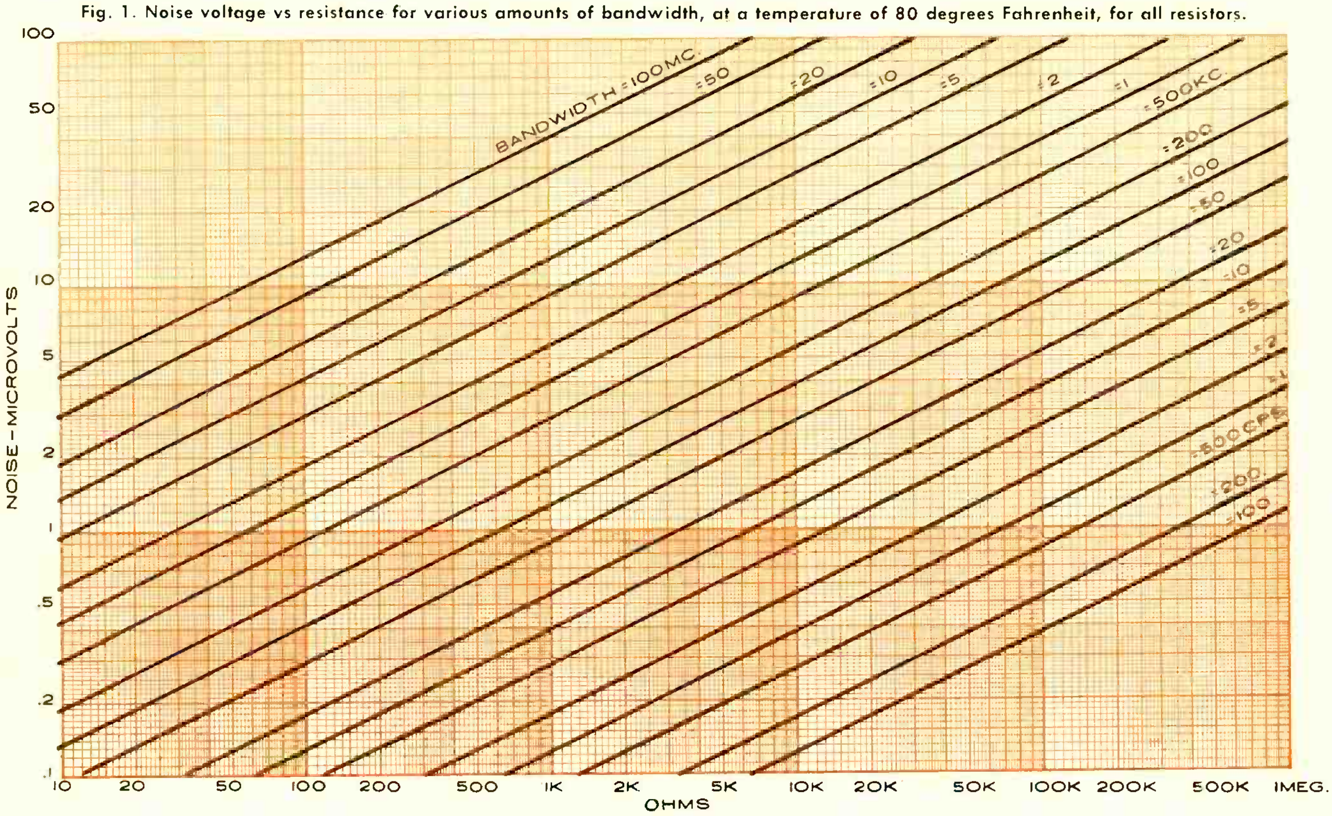
RESISTOR noise becomes important in any amplifier that has high gain and wide bandwidth. This applies equally well to audio, intermediate-frequency, and radio-frequency amplifiers. This noise is created by virtue of the molecular action of the material that makes up the resistor. This molecular action takes place in any solid and becomes more and more violent as the temperature increases. As the collisions between molecules takes place randomly, the frequencies generated by these same collisions are also of a random nature. This random frequency is generally called "white noise" since there is no single frequency predominant and all frequencies are present at the same time.

This molecular action follows the same general motion that the molecules of a gas would follow in an enclosure. The ratio of the mean total energy of a gas molecule to its absolute temperature is given by a constant called "Boltzmann's constant." Considering the free electrons in a conductor as a confined gas allows us to apply Boltzmann's constant to find the value of energy available across the ends of this gas container. In this case, of course, the container is the resistor and the ends refer to the ends of the resistive element not the ends of the leads.

Application of these conditions to a practical resistor resulted in the practical formula: $e = \sqrt{4KT\Delta FR}$, where K is the Boltzmann's constant of 1.38×10^{-23}, T is the absolute temperature in degrees Kelvin, ΔF is the bandwidth in cycles per second, and R is the resistance in ohms. The value e is the r.m.s. value of the generated noise voltage. The graph of Fig. 1 simplifies the application of this formula.

When a resistor is required to carry current, a second type of noise becomes apparent. Fig. 2 shows the extent of this noise and represents the formula $\mu v./v. = log_{10} R$. This noise voltage is commonly called current noise and varies with the type of resistor. As this voltage increases linearly with the applied voltage, the current noise voltage of the graph must be multiplied by the voltage across the resistor. Wirewound resistors and high-stability deposited-carbon resistors do not show this effect of current noise. Molded composition resistors and metalized carbon resistors are covered by Fig. 2.

Fig. 1. Noise voltage vs resistance for various amounts of bandwidth, at a temperature of 80 degrees Fahrenheit, for all resistors.



To find the total noise generated by a composition resistor requires that the noise voltage from both Figs. 1 and 2 be added in the following manner: $e_T = \sqrt{e_1^2 + (e_2 v)^2}$. The value of e_1 is from Fig. 1 and e_2 is from Fig. 2. These noise voltages are the maximum value for resistors that are not defective. Resistor defects contributing to noise are loose connections between the resistance element and its leads, touching turns in wirewound resistors, and cracks in the carbon of both deposited carbon and molded carbon resistors. Defects are often brought about or aggravated by the temperature cycling of the resistor, when the equipment using this component is turned on and off.

When equipment is found to be noisy, tubes are usually the first component to be tested. However, if this fails to remedy the noise problem, then resistors fall suspect. Resistors which come under suspicion are the input grid leak of the first stage of amplification. Second in line is the cathode resistor. In both cases replacement is the only answer. Testing for faulty resistors boils down to two methods. One is to replace the suspected part. The second is to bypass the component with a capacitor, thus allowing the stage to operate without disturbing the d.c. operating conditions. Both methods ultimately reduce the noise.

Choosing a resistor for lowest noise depends upon the resistance value required. Wirewound resistors usually have the lowest value of noise, but they often are limited to the lower values of resistance. When high resistance values are required, then the deposited carbon type becomes the choice. If cost is the problem, a selected molded carbon can be used, but if used where it must dissipate heat, the resistor wattage should be as high as possible. Metal film and oxide resistors are also good possibilities.

Total Noise Magnitude

Some idea of the magnitude of the noise can be obtained by measuring the gain from input to output and measuring the r.m.s. value of the output noise. This noise output divided by the gain, will provide some measure of the noise voltage at the input of the first stage. As a general rule, the noise voltage will be about 2 or 3 times the value indicated by this method and Figs. 1 and 2. Some of this noise will be contributed by other sources, such as shot noise in the plate of the input tube. When the equivalent resistance of this first tube is known, then the calculation can become more meaningful. The equivalent noise resistance of the tube can be put in terms of input voltage noise by using Fig. 1 and the total noise then becomes: $e_T = \sqrt{e_G^2 + e_K^2 + (e_C v)^2 + E^2}$ where e_T is total noise voltage, e_G is grid resistor noise voltage, e_K is the cathode resistor noise voltage, e_C is current noise voltage (cathode), v is the voltage across cathode resistor, and E is the noise voltage produced from the equivalent resistance of the input tube.

Using a 6SJ7 pentode for the first stage with a grid resistor of 500,000 ohms and a bypassed cathode, provides us with a working example. Let us say the completed amplifier has a bandwidth of 20 kc. The equivalent noise resistance of this tube is 6100 ohms in a typical pentode amplifier circuit. Applying Fig. 1 to both the grid resistors and the tube equivalent resistance provides us with a noise voltage of about 13.0 μv. and 1.4 μv. The total noise is then 13.1 μv.

If we desired a signal-to-noise ratio of, say 50 db, and the above 6SJ7 circuit were the input of the amplifier, then the input would require a minimum signal of 316 (50 db = 316 times) times 13.1 microvolts, or about 4140 microvolts. This is, of course, assuming that this amount of signal does not produce overloading in another stage of the amplifier.

Total resistor noise (usually measured in molded composition resistors), is measured in practice by the circuit shown in Fig. 3. Battery voltage is adjusted as high as possible without causing excessive dissipation in either the standard resistor and the test resistor. The standard resistor is selected to match the resistance value of the test resistor and is usually a wirewound unit. Capacitor C is usually 50 μf. or so in value. The total noise is read on the meter and is divided by the gain of the amplifier. Because current noise is not uniformly distributed and decreases in amplitude gradually from about 40 cps upwards, an amplifier bandwidth of 100 kc. is usually considered adequate for these measurements. Total noise measured is compared to the root of the sum of the squares of the two noise voltages obtained from Figs. 1 and 2. This is, of course, the same as $e = \sqrt{e_1^2 + e_2^2}$ where e_1 is from Fig. 1 and e_2 is from Fig. 2. ▲

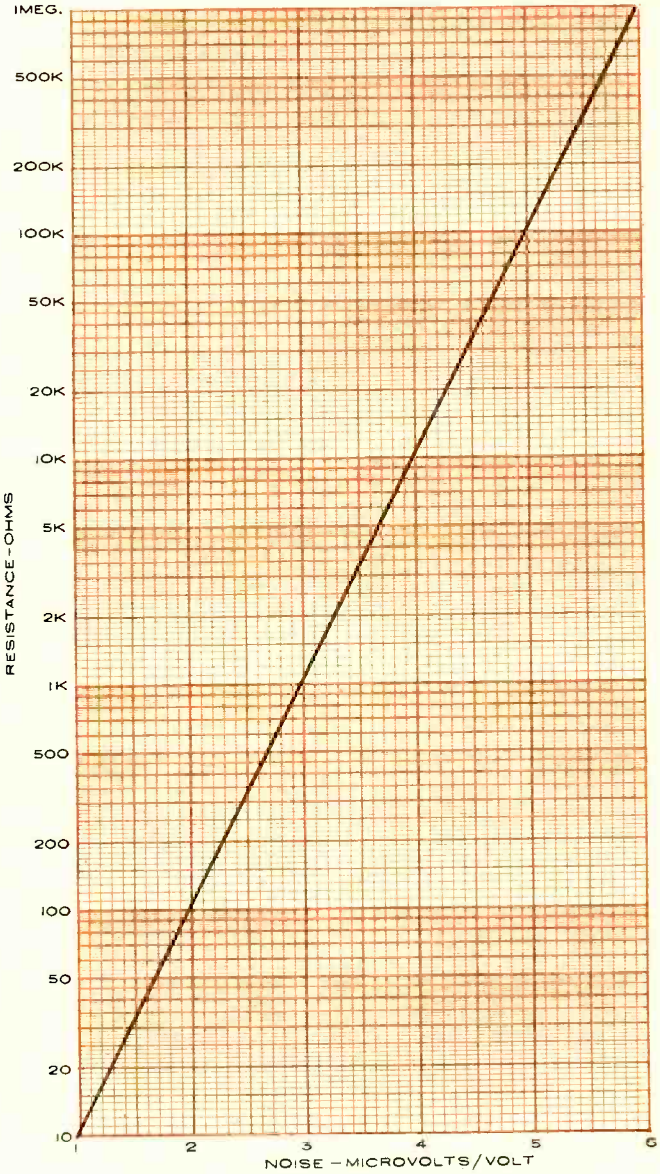


Fig. 2. Generated noise when resistor is carrying current.

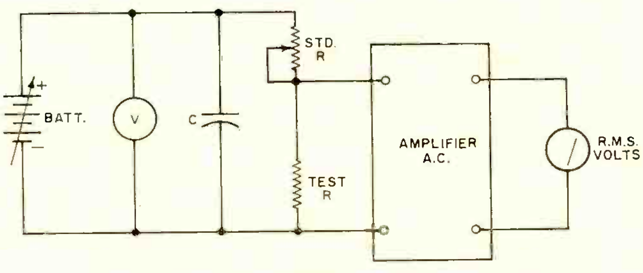


Fig. 3. Setup for measuring the total resistor noise.

Thin-Film

By WENDELL MOYERS / Director of Engineering, Burlington Div., International Resistance Company

These devices are ideally suited wherever precision, stability, reliability, low-noise, or good high-frequency characteristics are prime considerations.

THIN-FILM fixed resistors are defined by the electronics industry as those fixed resistors whose resistance element is in the form of a film having a thickness on the order of .000001 (one-millionth) of an inch. Because of the highly sophisticated manufacturing techniques used for these types of resistors, their electrical parameters can be closely controlled. This makes for high-precision, close-tolerance components.

The need for precision resistors has increased many fold in recent years . . . and film resistors have satisfied a large part of this need. Compared to other precision resistors, mainly wirewound, film devices have the advantages of small size and low cost. There are two basic types of resistive films now being used: pyrolytic carbon films and metal films.

Carbon film was the first to appear. Practically every resistor in German military equipment used in World War II was of the pyrolytic carbon-film type. These had initial tolerances from ± 1% to ± 20%. During this same period, carbon films were used in the U.S. for semi-precision (± 1%) applications only. During World War II, *Western Electric* was the only U.S. carbon-film manufacturer; later, they licensed their process and techniques to other American firms.

IRC introduced metal film in 1958. For the first time, a truly precision resistor was available in the film type. Tolerances of ±0.05% with temperature coefficients of resistance of 25 PPM/°C became available in metal films.

Manufacture of Film Resistors

There are seven basic steps in film-resistor manufacture, regardless of type: application of film, termination, rough sorting, spiraling (adjusting to final range), application of protective media, marking, and testing. Most film resistors use a cylindrical ceramic substrate.

Application of Film

Carbon film is *deposited* by cracking carbon-bearing gases at extremely high temperatures. First, ceramic substrates are heated to approximately 2000°F in an inert atmosphere or in a rough vacuum; then carbon-bearing gases are introduced near the hot substrates and the gas is cracked. The carbon is deposited on the ceramics. Sometimes, other elements are co-deposited with the carbon to give a harder, higher-resistance, carbon-alloy film.

The deposition time and the amount of carbon available in the gases determine the film thickness and the blank (substrate with film applied) resistance.

Metal film is obtained by *condensing* metal on a ceramic substrate in a very high vacuum. The substrates are mounted in a vacuum chamber where the metal, initially in wire or powdered form, is heated to evaporation temperature. The substrates are rotated for uniform exposure to the metal-vapor stream boiling off the heated metal source. The type of metal evaporated, usually nickel, chromium and/or aluminum, and the condensed film thickness determine the blank resistance of the basic device.

Spiraling

After film application, the blanks are limited in maximum range to a few thousand ohms. To make resistors having a higher resistance range, the blank resistance must be increased.

A spiral cut through the film to the non-conducting substrate, down the length of the blank, makes the resistive path long and narrow. The result is a resistance increase of up to several thousand times.

The spiraling equipment has associated bridge circuitry that monitors the resistance value as the cut is being made. When the resistance reaches the desired value, the cut is stopped and the resistor is ejected from the machine. At the completion of the spiraling operations, the resistor is electrically complete.

Before spiraling, the blanks are sorted into groups of approximately ±5% initial tolerance. This makes it possible to set the pitch at a constant value for each group and thus achieve maximum utilization of the resistive film length. Each group is worked on in turn.

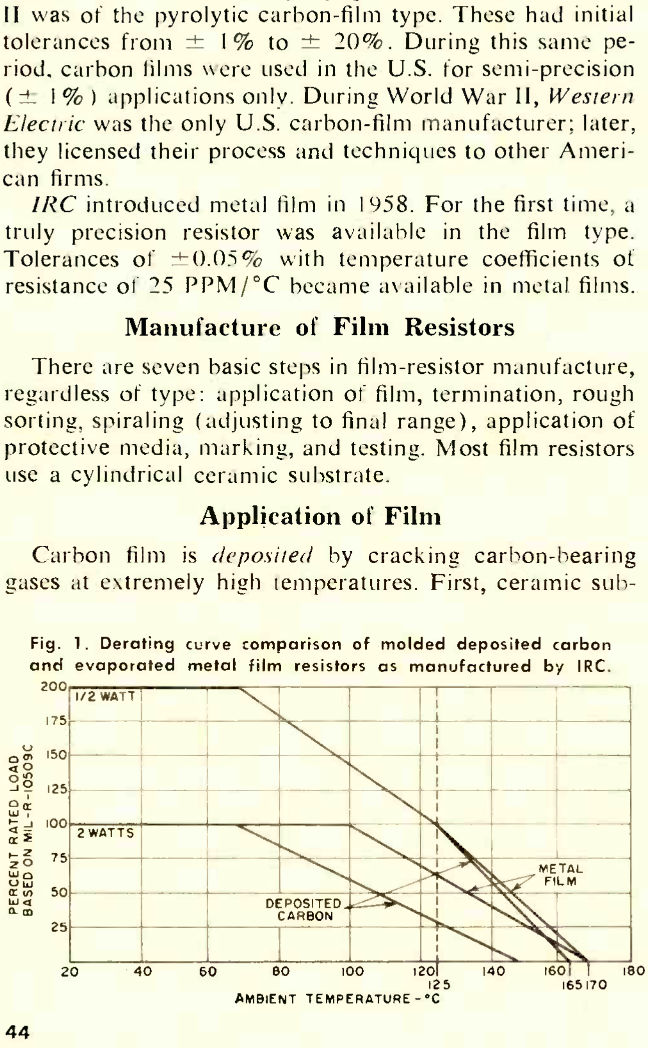
Enclosing the Resistor

There are two basic types of enclosures used for environmental protection of the film resistor: the hermetic seal enclosure and the organic enclosure. The former enclosure is made of glass or a combination of ceramic and metal. The organic enclosure is applied by painting, molding, or dipping. Typical materials used are silicones, epoxies, alkyds, phenolics, or diallyl phthalates. The organically housed variety of film resistors are the most commonly used types at the present time.

Resistor Comparison

Table 1 summarizes the essential characteristics of both deposited-carbon and metal-film resistors. Fig. 1 shows

Fig. 1. Derating curve comparison of molded deposited carbon and evaporated metal film resistors as manufactured by IRC.



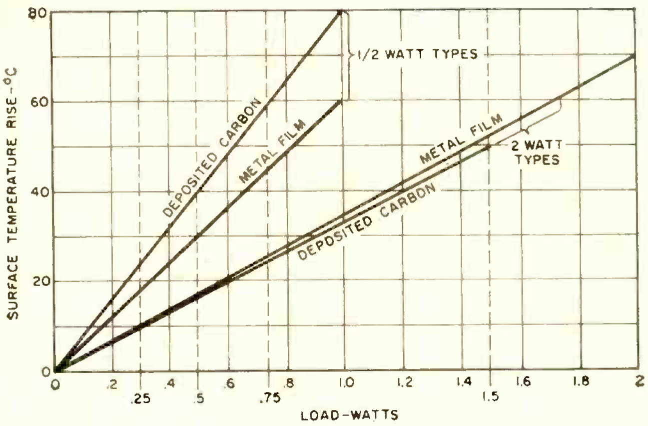


Fig. 2. Surface temperature rise vs load for IRC molded deposited carbon and molded evaporate metal film resistors.

typical derating curves as applied to ½-watt and 2-watt versions of both metal-film and deposited-carbon types. Fig. 2 illustrates the surface temperature rise as a function of the load for both ½-watt and 2-watt deposited-carbon and metal-film precision thin-film resistors.

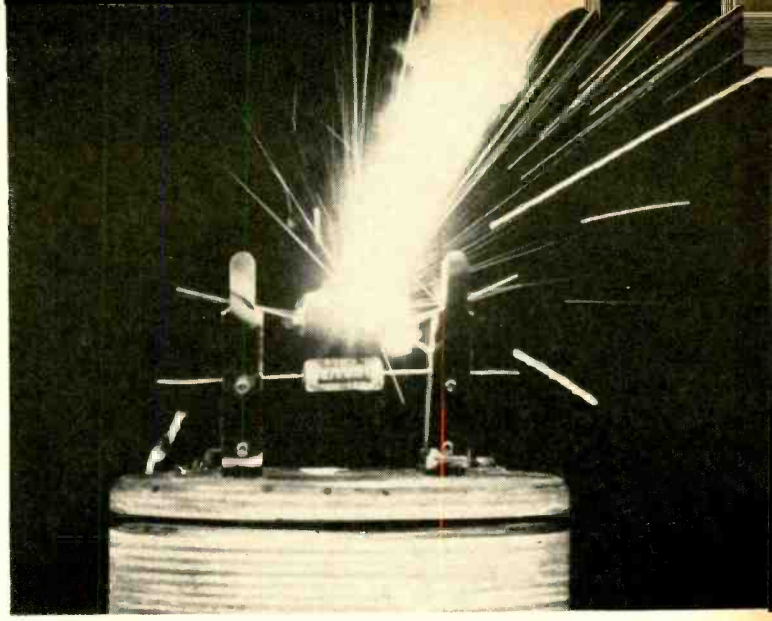
The principal advantages of deposited carbon are precision, stability, cost, and resistance ranges available. Metal film is the most stable of any of the film types. These resistors are used as resistance standards where, under light loading and moderate temperatures, they exhibit resistance changes of less than 0.02% over a period of several years.

The prices of metal-film resistors are now coming into line with previously less-expensive carbon films. New types of metal films are also making the high-resistance ranges possible. As this occurs, carbon-film resistors will gradually be replaced by metal-film resistors.

Film resistors are commonly used in computers and military equipment. Precision voltage dividers and meter multipliers are also typical applications. The metal films are used in large numbers in the major missile programs such as the Minuteman and Polaris.

Some circuit designers have found that by specifying a precision film resistor in place of a composition resistor, a lesser degree of precision is required for the semiconductors used in the circuit. The result is an over-all savings, even though the film resistor may cost a few pennies more than the composition type.

In general, wherever precision, stability, reliability, low noise, or good high-frequency characteristics are of prime consideration, film resistors fill the requirement.



The unusually high short-term overload characteristics of a hard-glass encapsulated, hermetic sealed carbon-film resistor is shown by Texas Instruments. The non-hermetically sealed unit withstood up to forty times rated voltage before failure.

	Res. Range	Temp. Coeff. (PPM/°C)	Res. Tol.	Load Change	Power Rating (watts)	Noise Level (μv./v.)
Deposited Carbon	1 Ω to 200 meg.	−150 to −500	.5 to 2%	.25%	1/10 to 5	approx. 2
Metal Film	1 Ω to 40 meg.	3 to 150	.01 to 1%	.15%	1/20 to 5	less than .1

Table 1. Possible characteristic ranges available from various manufacturers. Thin-film resistors fall under MIL-R-10509 (and others) and figures shown surpass all MIL requirements. In many cases figures are superior, depending on manufacturer.

Because of the relatively low resistivity of metal films, they have, in the past, been limited to lower resistance ranges, especially in the higher wattage sizes. New processes using simultaneous evaporation of metals and dielectric materials have now resulted in films with metal-films characteristics but with ten or more times the resistivity of pure-metal films. Resistors using these new films are now becoming available.

Besides these individual film resistors in discrete packages, networks of resistors using films applied to very small flat substrates are also being made. The degree of precision obtainable from the small integrated networks is somewhat less than would be possible in networks made up of individual resistors. ▲

SOME RESISTOR PRECAUTIONS

Maximum Operating Voltage

It is recommended that resistors be selected so that the peak voltage impressed across them will never exceed 700 v. d.c., or 495 volts r.m.s. per linear inch of core length.

The relation $\sqrt{watts \times ohms}/core\ length\ in\ inches$ so as never to exceed the above figures should be maintained.

Enclosing

For resistors in non-ventilated enclosures, use one watt per square inch of inner enclosure surface as a guide to the total wattage to be allowed. The resistor wattage should be derated 100% if the enclosure area is total; and approximately 15% if the enclosure is of mesh construction. Multiply calculated ratings by 1.15 to 2.0 to get rating.

Air Cooling

The required wattage rating may be reduced if cooling air is constantly circulated over the resistor. The expression for the volume of cooling air required to cool a given enclosed load so that the temperature rise will be limited to a determined amount is given by $V = (3170/\Delta T)\ KW$ where V is the volume of air in cubic feet per minute, ΔT is the allowable temperature rise in degrees F, and KW is the power dissipated within the enclosure in kilowatts. For example, if the issuing air one inch above an enclosure is to be restricted to 350°F, what volume of forced air would be needed for a 1 kw. load in a 100°F ambient? Answer: (3170/250)1=12.7+25% safety factor for pockets of hot air, or 16 c.f.m.

Soldering Precautions

Since composition resistors are sensitive to thermal extremes, caution must be followed during soldering or welding. Experimental results show that time-temperature product is important. On dip solder tests, a 2% permanent resistance change can be noted at either a 3-second dip in 650°F solder, or a 21-second dip in 475° solder. Intermediate temperatures show proportional factors.

Changes due to soldering are more severe on resistors that have been exposed to humidity for long periods of time than for normal dry units. Operation under d.c. voltage may cause more severe changes on such resistors than on normal dry ones. These changes are permanent and not simply due to reversal of the moisture absorption effects. ▲

Precision Wirewound Resistors

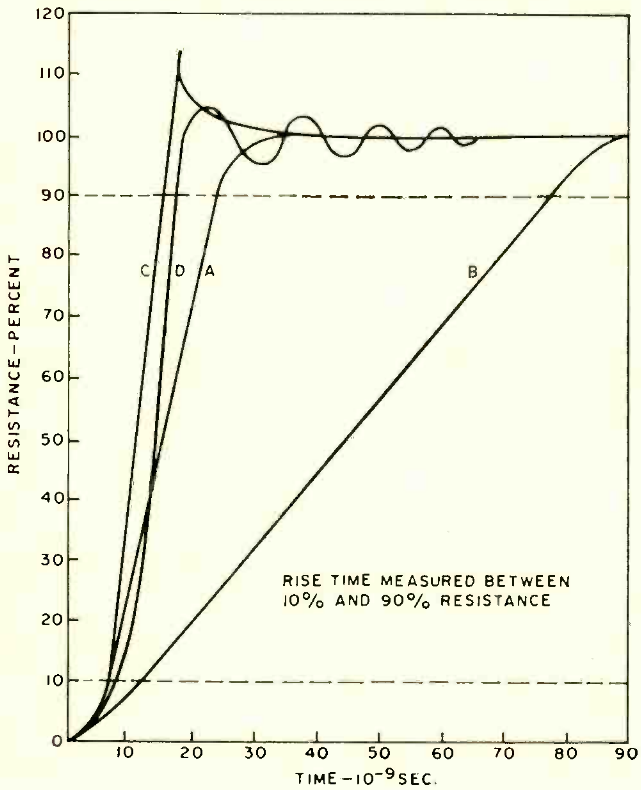
Precision wirewound resistors have been the mainstay of resistance standards. The introduction of new metal alloys and new winding techniques have removed some of the past electrical drawbacks, such as inherent reactance that has limited their pulse risetime.

A PRECISION wirewound resistor is an accurately determined length of metal-alloy wire, wrapped around a core, and sealed to protect it from mechanical or environmental hazards. These resistors are being made to ever-improving standards with some present-day limits being resistance range from .001 ohm to 60 megohms, wattage from .04 to as high as 250 watts in some cases, tolerance reaching .001%, and temperature coefficient approaching .5 PPM/°C. Because of manufacturing precautions taken for this type of resistor, MTBF's can reach 10 million hours.

These resistors come in a variety of packages ranging from very small for printed-circuit use to relatively large encased units that are used as accurate resistance standards.

In order to meet the exacting demands of modern electronic design, many manufacturers have spent considerable time and energy investigating and creating different types of metal alloys and winding techniques. Manganin, used as a resistance element for many years, is being replaced with the so-called 800-ohm alloys (800 ohms resistance per circular-mil-foot). These newer alloys exhibit superior electrical characteristics to the previously used metal-alloy wires.

Fig. 1. Resistor response curves: (A) 20 nsec. risetime resistor; (B) units having high inductive reactance; (C) unit having high capacitive reactance; and (D) a resistor having both high inductive and capacitive reactance showing how these can produce ringing in the characteristic.



Even the method of winding the metal-alloy wire on the supporting form has undergone a number of modifications. The new winding techniques produce virtually strain-free windings to eliminate superimposed temperature coefficients caused by winding, while at the same time high-frequency response is improved.

Precision wirewound resistors are usually made by loose winding a length of wire greater than required (the resistance is determined by alloy material, cross section, and length of wire), then "peeling" back until direct measurement of the resistance shows that the desired value has been reached. To avoid inaccuracies due to electrical heating, low voltages are used in these measurements. In fact, one resistance bridge (*General Radio* Model 6003) measures in the microvolt region.

Wirewound resistors have always suffered from the fact that they are electrically similar to a coil and have some of the coil's characteristics, such as inductive and capacitive reactance and inherent phase shift. These factors limit the high-frequency use of wirewound resistors, which is why metal-film and carbon-film resistors have dominated this field. Now, however, new winding techniques, coupled with other manufacturing approaches, have produced wirewound resistors with a risetime on the order of 10 to 20 nanoseconds.

The reactances of these new wirewounds is usually less than 10 pf. distributed capacitance for values above 2000 ohms, and less than 10 μhy. inductance for values below 2000 ohms, with one manufacturer claiming less than 1 μhy. inductance for a 500-ohm resistor and less than .8 pf. for a one-megohm resistor, and another claiming shunt capacitance of .2 pf. at ambient temperature of −55 to +145°C.

Fig. 1 shows the response curve (A) for one of these new wirewound resistors in which it attains 90% of its value within 20 nanoseconds. Curve B shows the risetime needed for a resistor having a high inductive reactance. The effect of high capacitive reactance is shown in curve C, with the effect of both high inductive and high capacitive reactance producing the curve shown in D.

The ability of these devices to perform over the megacycle pulse frequency range while maintaining excellent tolerance over an extended temperature range makes them useful for high-speed computers or other high-speed devices. ▲

Wirewound Power Resistors

By HERBERT LEVY / Chief Product Design Engineer, Ohmite Manufacturing Company

Available in a wide range of resistance and power ratings, and made in many shapes and sizes, these resistors are often considered to be the workhorses of the resistor world.

THE unique facility with which the wirewound resistor can be made to provide resistances ranging from the very low to the very high, to carry small currents or large currents, to dissipate many watts of power, to be made in many shapes and sizes, and to meet a great variety of special requirements, has long ago established it as the "workhorse" of the resistor world. Almost all resistor applications requiring the dissipation of more than one or two watts of power, either d.c. or commercial-frequency a.c., and going up through the audio frequency range, are well handled by wirewounds.

Wirewound power resistors used in electronic circuitry vary from tiny one-watt units approximately 9/16" long by 1/8" diameter to 1500-watt sizes 20" long by 2½" diameter. Resistances vary from less than an ohm to hundreds of thousands of ohms or even megohms. Wirewound resistors may be classified in many ways, as by shape, type of coating, operating temperature, type of termination, fixed or adjustable, method of mounting, environmental capabilities, inductive or non-inductive winding, and many more classes or sub-classes which cut across each other.

An examination of industry practices reveals that wirewound resistors are generally catalogued as shown in Table 1, with most types available in three different kinds of coating, namely, the generally accepted industry standard vitreous enamel, the more recently developed silicone coverings, and an old but limited-application group of cements. Fig. 1 shows many examples of these various types.

Fig. 2 is a cutaway cross section of a typical tab (or lug) type resistor. A ceramic tube, generally steatite but also supplied in other vitreous and refractory bodies, is equipped with two metal bands. These bands are typically made of a nickel-iron, low-expansion alloy chosen so that once the ends are drawn tight and welded, the band will remain solidly located during heating and cooling cycles.

The resistance alloy wire is space wound at a predetermined pitch and has its ends welded or brazed to the terminals. An immense range of resistance values is obtained by selection of the resistance alloy, the wire size, and the number of turns. The most important wire alloys are listed in Table 2. The pitch, or distance from center-to-center of adjacent turns, can be a distance slightly more than the wire diameter up to not more than five times the wire diameter in order to achieve the desired total ohms.

A protective coating embeds and completely covers the turns of wire to: (1) mechanically protect the wire; (2) keep the turns fixed in position to avoid shorting; (3) insulate the turns against voltage breakdown across the coil;

Table 1. A wide variety of wirewound power resistors is available, with ratings and windings to suit virtually every circuit requirement.

Type	Wattage Range	Resistance Range (ohms)	Winding Possibilities	Other Features
Axial Lead	1 to 14	1-200k	Inductive or Non-inductive	Fixed
Other Small Wire-Lead Resistors	3 to 20	0.5-100k	Inductive or Non-inductive	Fixed
Tab Terminal Tubular*	5 to 1000	0.1-1.7 meg.	Inductive or Non-inductive	Fixed, Tapped or Adjustable
Tab Terminal Tubular with Exposed Corrugated Ribbon Winding	10 to 1500	0.1-110	Inductive	Fixed, Tapped or Adjustable
Ferrule Equipped	5 to 220	0.1-100k	Inductive or Non-inductive	Fixed, Tapped or Adjustable
Edison Screw Base	10 to 215	1-185k	Inductive or Non-inductive	Fixed
Live Bracket	5 to 220	0.1-1 meg.	Inductive or Non-inductive	Fixed, Tapped or Adjustable
Strip Type Miniature & Regular	10 to 95	0.1-150k	Inductive or Non-inductive	Fixed, Tapped or Adjustable
Metal Clad	5 to 250	0.5-60k	Inductive or Non-inductive	Ratings based on heat-sink mountings
Bare (Heavy Current) Units: Edgewound or Round Wire	220 to 1200	0.4-42.1	Inductive	Fixed or Movable Taps

*Tab styles provide for soldering, bolted connections, and quick-connect shapes for push-on connectors, and also wire-wrap types.

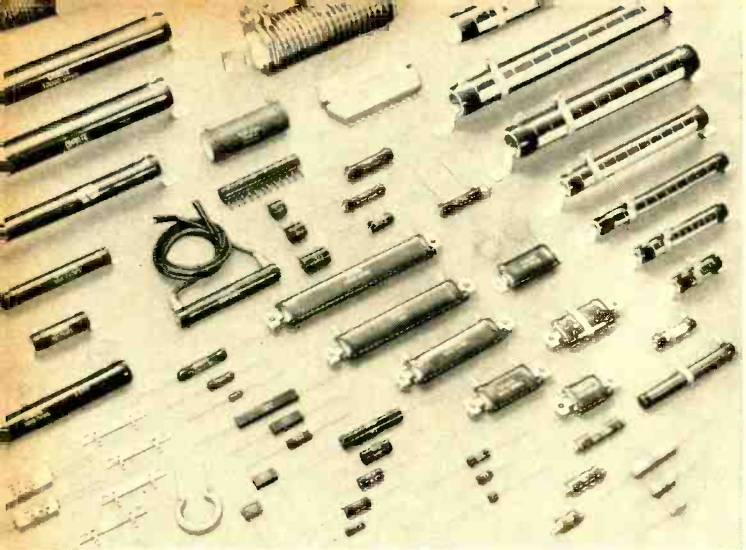


Fig. 1. Wirewound power resistors are available in many sizes.

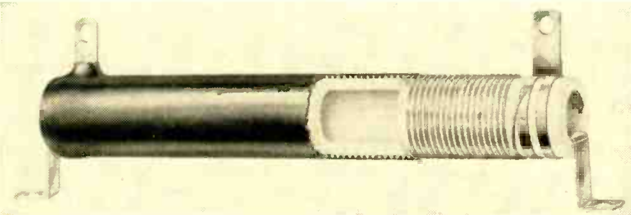


Fig. 2. Cutaway of vitreous enameled lug-type fixed resistor.

(4) prevent oxidation of the wire; (5) protect against corrosion from humidity or salt water; and (6) help carry away and distribute the heat from the wire.

Axial-lead resistors, which now constitute the major portion of the volume of wirewound resistors produced annually, differ from the lug- or tab-type primarily in substituting caps over the ends of the core, replacing the bands. Wire leads, which have been welded to the caps, serve to connect and to support the resistor.

Importance of the Wire

The series of metals listed in Table 2, and a few others, are the special alloys which are made and drawn in wire form to produce carefully controlled resistance per unit length, temperature coefficient of resistance, tensile strength, specified ductility, and ability to operate for long periods at elevated temperatures. The resistor designer must select from these alloys to obtain the combination of properties required for a given application. The perfection, in recent years, of alloys combining high specific resistance with very low TC (temperature coefficient of resistance), has made possible the small precision-power resistors required by electronic computers. Some of the 800-ohm/c.m.f. (circular mil foot), low TC alloys are limited to a maximum temperature of 275°C if they are to have minimum change of resistance after full-load use. TC is now generally specified as the change in resistance in "parts per million per degree centigrade," abbreviated as PPM/°C.

The actual TC of the finished resistor depends on more than the wire and is influenced by such things as the core diameter, winding tension, thermal treatment after winding, and nature of the core and coating.

For maximum reliability, many government and other specifications place limitations on the use of very fine wire (sizes as small as .0005" diameter are in use). Military Specification "Resistors, Fixed, Wirewound," MIL-R-26C, limits the wire size to nominal .00175" diameter. Some specifications for small (axial-lead) resistors permit wire of .001" or even .0008". Another limitation (for reliability) by specification requires lower operating temperatures.

Importance of the Coatings

Proved and improved over more than a half-century of use, vitreous enamel is the standard high-temperature coating. This completely inorganic material is a complex mixture of minerals which is generally applied as an aqueous suspension of fine powder, dried, and then fired at temperatures around 1400°F to fuse into a smooth glassy covering, well bonded to the core. There are variations in composition among the vitreous enamels used by different manufacturers which affect the firing temperature, match of coefficient of expansion with the core, capability of standing thermal cycling without cracking, maximum op-

Table 2. A representative group of resistance alloys that are generally used in the manufacture of resistors and rheostats.

Alloy	Trade Names	Ohms per C.M.F.	Mean Temp. Coeff. PPM/°C for Temp. Range ASTM B267-60T	Resistance Range for which used	Av. Range of Change in Res. at Full Load 300°C Rise
*Nickel-Chromium-Aluminum, etc.	Evanohm Karma 800 Alloy	800	−65° to +250° 0, ± 20	Very High, Medium and up for Low Temp. Coeff.	±1 to ±2%
Nickel-Chromium-Iron (60%-16%-24%)	Nichrome Chromel C Alray C Alloy C Nikrothal 6 Tophet C	675	−65° to +200° +140, ± 30	High and Medium	+5 to +8%
Nickel-Chromium (80%-20%)	Nichrome V Chromel A Alray A Alloy A Nikrothal 8 Tophet A	650	−65° to + 250° +80, ± 20	High and Medium	+4 to +6%
Copper-Nickel (55%-45%)	Advance Cupron Excelsior	294	−65° to + 150° 0, ± 20 or 0, ± 40	Low and Low to Medium for Low Temp. Coeff.	±1 to ±2%
Copper-Nickel	#180 Alloy Midohm	180	−65° to +150° +180, ± 30	Very Low	+5 to +8%
Copper-Nickel	#90 Alloy #95 Alloy	90	−65° to +150° +450, ± 50	Very Low	+5 to +10%

*Kanthal DR (Fe,Cr,Al,Co) available at 812 ohms/c.m.f. and Nikrothal L (Ni,Cr,Si,Mn) available at 800 ohms/c.m.f.

erating temperature, insulation resistance, and other characteristics.

The art and techniques of vitreous enameling of wire-wound resistors are difficult ones. Specialized methods, developed over many years, are needed to produce satisfactory resistors, especially when very high resistance, very low temperature coefficient, and very low resistance tolerances are involved. Vitreous enamel coatings are customarily fairly thin and conformal but a recent manufacturing innovation produces molded axial lead resistors with a thick, uniform, cylindrical coating, resulting in high insulation value and other improved characteristics.

The availability of silicone resins in commercial quantities after World War II resulted in the creation of new types of power-resistor coatings. Capability of withstanding temperatures required in some power resistors, excellent humidity resistance, and processing at moderate temperatures, are properties which have led to widespread use for small axial-lead resistors, particularly where very high resistance, close tolerance, and low TC are needed.

Low processing temperatures (baking at temperatures around 300°C) greatly simplify manufacturing problems. Silicone coatings most generally consist of mixtures of silicone resins with fine inorganic powders (such as silica) which produce opacity, body, increased hardness, controlled thermal expansion, and improved heat resistance.

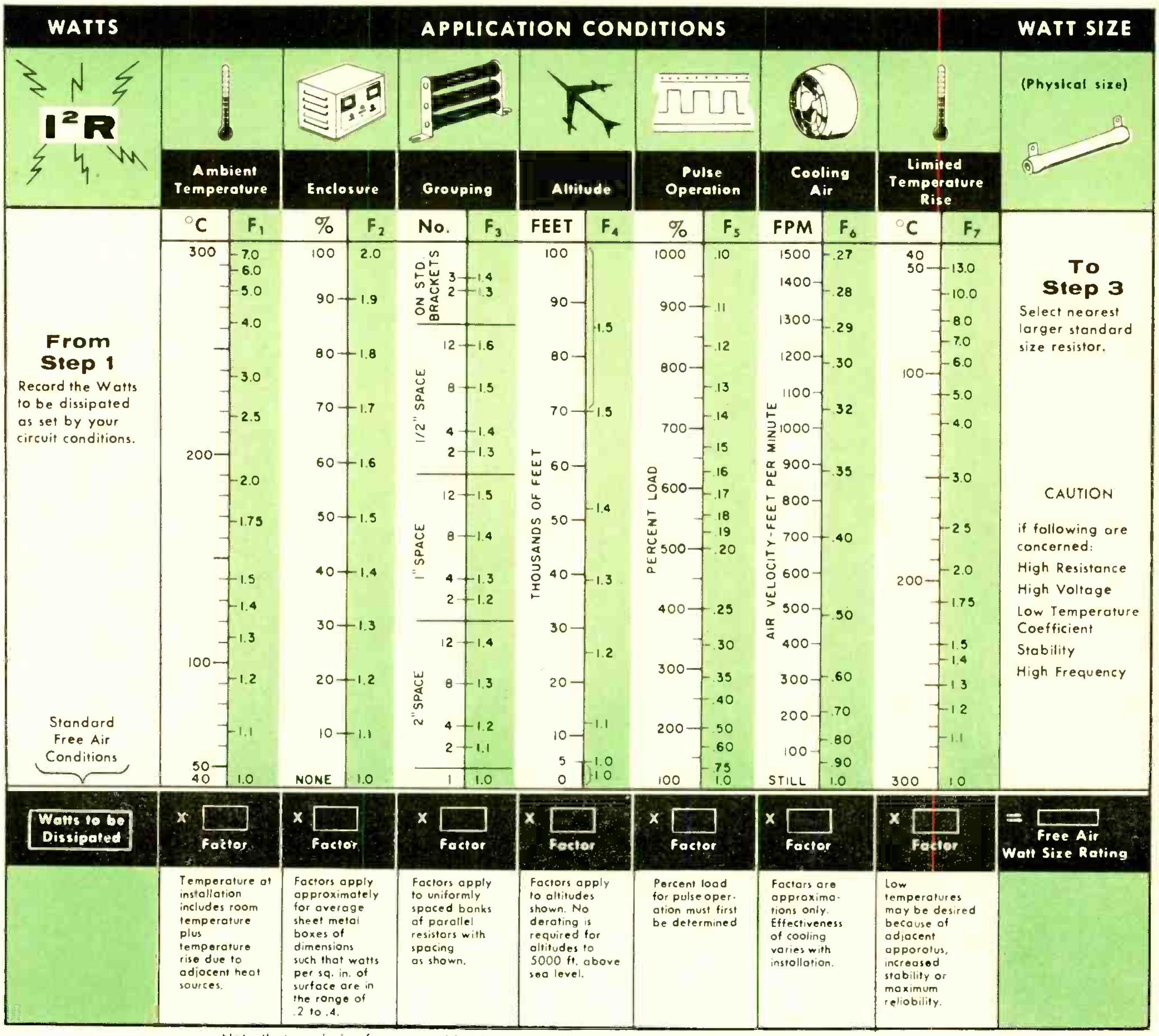
These coatings are generally conformal but molded silicone-ceramic coatings on axial lead resistors are also produced.

Various kinds of cements have been used on power resistors from the earliest days of the electrical industry. Silicates, phosphates, and Portland cements have been used as the binder but as all such cement-coated resistors suffer from poor resistance to humidity and wire corrosion produced by polarizing voltages and other causes. Cement coatings are now rarely used for general-purpose resistors.

Metal-Clad & Other Heat-Sink Types

Resistors insulated in various ways and sealed in cast metal housings designed to transfer heat efficiently to a metal structure, are available in several sizes, 5 to 250 watts. The heat-sink qualities of the mounting are depended upon to keep the resistance winding and insulation temperatures within established limits. Strip or thin resistors,

Fig. 3. Selecting your resistor: To find the size required as influenced by application conditions: (1) For each condition locate the relevant value on the scales below and record the corresponding factor (F_1 to F_7). Note: The Standard Free Air Condition Factor is always 1. (2) Multiply the Factors together. (3) Multiply Watts by the product of (2).



Note that analysis of some combinations may indicate total derating may be reduced safely.

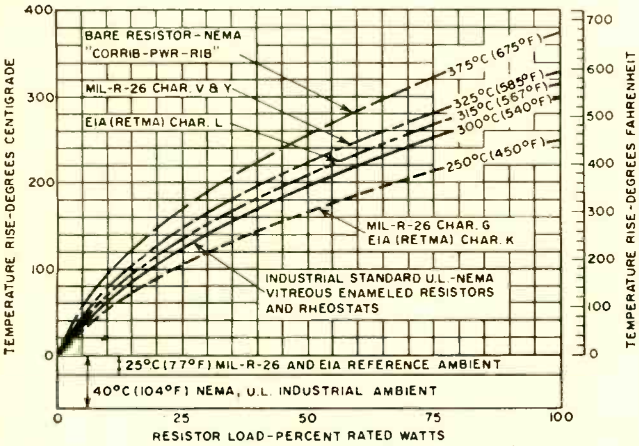


Fig. 4. Hot-spot temperature rise of various power resistors.

which have a metal strap, generally of aluminum, fastened in the core, also depend on the transfer of heat by conduction to the mounting surface for their full rating.

Small tubular resistors, when mounted on aluminum studs, can more than double their ratings. Some axial-lead resistors (with molded vitreous enamel, molded silicone-ceramic, or with metal sleeves) when mounted with special clips, can also greatly increase their ratings.

Three more types of small resistors frequently used in TV sets and similar consumer-type equipment are generally wound on fiberglass cores. One type (½, 1, and 2 watts) is molded in plastic similar to composition resistors. Another type (5 and 10 watts) is embedded in a rectangular cross-section ceramic case. Still another type (3, 5, and 10 watts) is enclosed in a cylindrical ceramic shell.

Principles of Resistor Rating

While it is well understood that the passage of electricity through a resistor generates heat proportional to I^2R, the step from this to the temperature attained by the resistor and how this is related to the resistor wattage rating is generally known only to a resistor specialist.

Empirical factors related to the materials of construction, the size and shape, and also the environmental conditions, make the temperature rise of a resistor something best determined by measurement. Once a curve of temperature *versus* watts for standard conditions has been determined, allowances for other conditions can be established. See Fig. 4. Resistors are rated on the basis of standard conditions, something referred to as "free-air watt rating," as the resistor is suspended horizontally, for test purposes, in free still air remote from any confining surfaces. A thermocouple and potentiometer are used to measure the hot spot of the resistor. The temperature of very small resistors is more accurately measured by special infrared pyrometers. *The wattage rating is the power in watts which the resistor can dissipate continuously in a stated ambient and with the hot spot not exceeding a stated maximum temperature.*

The hot spot of a horizontal resistor occurs at the middle, on the top side. For tubular resistors, 10 watts and larger, the temperature rise at the ends is approximately 60% of the hot-spot rise. Axial-lead types and other very small resistors will show less differences along the length.

The temperature of a resistor operated at a constant wattage stabilizes when the sum of the heat loss rates (by radiation, convection, and conduction), equals the heat input rate (proportional to watts). The greater the resistor area per watt to be dissipated, the greater the heat loss rate, and, therefore, the lower the temperature rise. Watts-per-square inch of radiating surface for a 300°C rise varies from 6.3 on a 160-watt core to 9 on a 10-watt core and even more on smaller axial-lead units.

Commercial vitreous enameled power resistors for many years have been rated per existing specifications of NEMA, EIA, and *Underwriters' Laboratories* for a 300°C (540°F) rise above a 40°C (104°F) ambient, resulting in a maximum hot-spot temperature of 340°C (644°F). Currently, there exists among resistor manufacturers a tendency to base the commercial rating on the same conditions as required by the standard military specification MIL-R-26, Characteristic V, which allows a maximum hot spot of 350°C (662°F) resulting from a 325°C (585°F) rise above a 25°C (77°F) ambient.

A different and relatively new concept of wattage rating, first applied in several military specifications for "precision-power" resistors is embodied in pending revision "D" of MIL-R-26 which covers "power resistors" and new classes of "precision-power" resistors. The concept, in brief, makes the wattage rating that amount of power which the resistor can dissipate on a specified load-life test (and in other tests) without the ohmic value changing by more than a specified percent from the original value. For $\pm$ 5% tolerance power resistors in the new MIL specification, the ΔR (resistance change) is 3%. A maximum ambient temperature oven test is also provided for.

A certain amount of re-rating of some long established physical sizes is now going on in the industry so that some resistors are catalogued with dual ratings as 10/12 watts, 160/175 watts, etc.

Axial-lead resistor sizes have also been affected by the effort to make them fit in with miniaturization by abandoning traditional 1-, 5-, and 10-watt sizes, and making available 1- to 12-watt sizes at almost every watt (and some closer) intervals.

Watt rating of power-type resistors coated with silicone-based materials is sometimes given the same as for vitreous enameled units. At other times, especially where exceptional load-life stability (maximum $\Delta R = 1\%$) is a prime

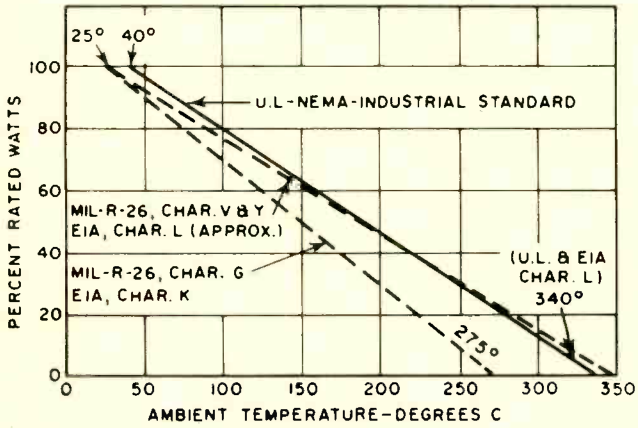
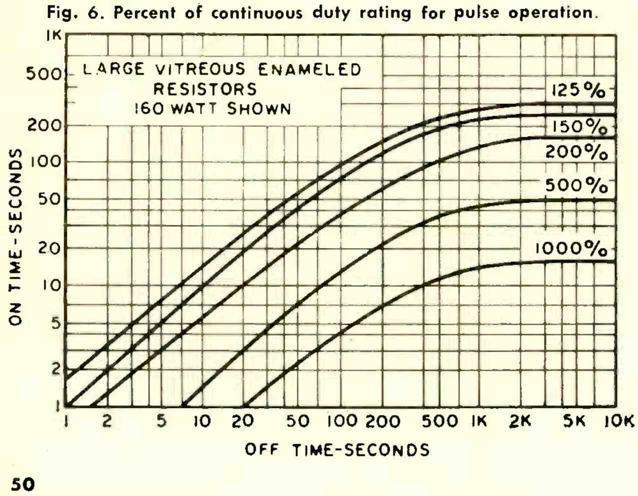


Fig. 5. Typical derating curves for high ambient temperatures.

Fig. 6. Percent of continuous duty rating for pulse operation.



requirement, a maximum hot-spot temperature of 275°C (527°F) is frequently used as the basis of rating.

Watt Rating Affected by Use

Enclosure, higher ambient temperatures, presence of nearby materials or components of lower temperature rating, and other factors affect the wattage which a resistor should be required to dissipate in a particular application. To allow for such considerations, it is general engineering practice to operate resistors at ½, ⅓, or ¼ or other fraction of nominal rating. On the other hand, resistors can safely handle pulses of power much higher than their rating, depending on the time-duration of the pulse and amount of off-time.

The chart of Fig. 3 shows various important application conditions and the factors to be used to keep the resistor maximum temperature rise within desired limits. The actual watts multiplied by the product of the factors, gives the free-air watt size required. A brief discussion of each of the conditions follows.

Ambient Temperature: Ambients higher than standard restrict the permissible temperature rise for a given hot-spot temperature and therefore reduce the permissible wattage. Fig. 5 shows the usual straight-line derating from the 100% rating.

Enclosure: Enclosure limits the flow of heat from the resistor. Accurate estimation is almost impossible except by comparison with similar known measured conditions. Calculation results in only approximate accuracy unless many factors are precisely known.

Grouping: The general derating effect due to the close proximity of other sources of heat is obvious.

Altitude: The reduced cooling ability of rarefied air is readily realized.

Pulse Operation: The temperature rise is dependent on the average power, the thermal capacity of the resistor, and other physical properties. Fig. 6 shows pulse ratings for typical large tubular vitreous enameled resistors. Pulse cycles of less than a second are calculated differently and are based largely on the heat capacity of the resistance wire alone.

Cooling Air: Forced circulation of air (or fluids) increases rating by removing heat more rapidly.

Limited Temperature Rise: Temperature rise less than maximum may be desired to protect adjacent components, reduce change in resistance with load, or increase reliability.

Other Application Considerations: Very high resistances, high voltages, radio-frequency or high-frequency pulse applications, generally require special consideration.

Resistor Specifications & Reliability

Many industrial specifications have been written by large users of resistors which, in general, have been modeled after various military specifications. Modifications include such things as different physical sizes, closer tolerances and temperature coefficients, load-life tests, different humidity test cycles, and reliability definitions.

Reliability, not in a general sense, but as "established reliability," expressed as "mean time between failures" or as "maximum failure rate in % per 1000 hours," is a concept still largely confined to certain military and aerospace applications. The enormous expenses and extended times required, as well as the lack of knowledge of the correlation between different circumstances and the test set-up, constitute formidable obstacles to wider use of such requirements.

The selection of resistors for given applications, when done with full knowledge and with proper allowances for anticipated conditions can result in long, dependable service life, satisfying industry requirements. ▲

STANDARD EIA RESISTOR VALUES

20%	10%	5%	20%	10%	5%	20%	10%	5%
10	10	10	100	100	100	1.0k	1.0k	1.0k
		11			110			1.1k
	12	12		120	120		1.2k	1.2k
		13			130			1.3k
15	15	15	150	150	150	1.5k	1.5k	1.5k
		16			160			1.6k
	18	18		180	180		1.8k	1.8k
		20			200			2.0k
22	22	22	220	220	220	2.2k	2.2k	2.2k
		24			240			2.4k
	27	27		270	270		2.7k	2.7k
		30			300			3.0k
33	33	33	330	330	330	3.3k	3.3k	3.3k
		36			360			3.6k
	39	39		390	390		3.9k	3.9k
		43			430			4.3k
47	47	47	470	470	470	4.7k	4.7k	4.7k
		51			510			5.1k
	56	56		560	560		5.6k	5.6k
		62			620			6.2k
68	68	68	680	680	680	6.8k	6.8k	6.8k
		75			750			7.5k
	82	82		820	820		8.2k	8.2k
		91			910			9.1k

For higher values, add zeros to the basic numbers up to 22 megohms, the maximum value.

APPLICABLE MIL SPECS FOR FIXED RESISTORS

MIL-R-11 —Resistors, Fixed, Composition (Insulated)
MIL-R-26 —Resistors, Fixed, Wirewound
MIL-R-29 —Resistors, Fixed, Meter Multiplier, External (High-Voltage, Ferrule Terminal Type)
MIL-R-93 —Resistors, Fixed Wirewound (Accurate)
MIL-R-10509—Resistors, Fixed, Film (High-Stability)
MIL-R-10683—Resistors, Fixed (Composition Film, Very High Frequency)
MIL-R-11804—Resistors, Fixed, Film (Power Type), General Specifications For
MIL-R-14293—Resistors, Fixed, High Megohm, (Hermetically Sealed)
MIL-R-18546—Resistors, Fixed, Wirewound (Power Type, Chassis-Mounted)
MIL-R-22684—Resistors, Fixed, Film, Insulated
MIL-R-23379—Resistors, Fixed, Wirewound, Precision, Power Type, Wire Lead Terminal
MIL-R-27232—Resistors, Fixed Wirewound (Power Type)
MIL-R-38101—Resistors, Fixed, Established Reliability
/1 —⅛ Watt, ±1.0%
/2 —Power, Wirewound, Miniature, 2 Watt, ±1%
/3 to /12—Precision, Wirewound, Various Powers and Tolerances
/13 to /18—Power, Wirewound, Various Power, ±1%
/19 and /20—Metal Film, .1 Watt and .05 Watt Respectively, ±1%
/21 to /23—Film, ⅛ Watt, ⅓ Watt, and 1 Watt Respectively, ±2%
MIL-R-39005—Resistors, Fixed, Wirewound (Accurate), Established Reliability
MIL-R-39007—Resistors, Fixed, Wirewound (Power Type), Established Reliability
MIL-R-39008—Resistors, Fixed, Composition (Insulated), Established Reliability
MIL-R-39009—Resistors, Fixed, Wirewound (Power Type, Chassis-Mounted), Established Reliability
MIL-R-39017—Resistors, Fixed, Film (Insulated), Established Reliability (established reliability version of MIL-R-22684)
MIL-R-55182—Resistors, Fixed, Film, Established Reliability
MIL-R-55188—Resistors, Fixed, Film, High-Stability (Microelement)

Directory of

General Purpose[1]: Carbon composition	General Purpose[1]: Wirewound	Semi-Precision[2] Thick Film: Metal glaze	Semi-Precision[2] Thick Film: Metal oxide	Semi-Precision[2] Thin Film: Evap. metal film	Semi-Precision[2] Thin Film: Deposited carbon	Precision[3]: Wirewound	Precision[3] Thin Film: Evap. metal film	Precision[3] Thin Film: Deposited carbon	Power[4] Wire-wound: Precision	Power[4] Wire-wound: Non-precision	Power[4] Thick Film: Metal glaze	Power[4] Thick Film: Metal oxide	Other: Strips and discs	Other: Fusible	Other: High frequency	Other: High voltage	Availability[5]	Company
						●			●								c	Ace Coil and Electronics Co., 912 Lincoln Highway, Metuchen, N.J.
	●					●	●	●									a b c	Aerovox Corp., Hi-Q Div., Olean, N.Y.
●							●										c	Allen-Bradley Co., 136 W. Greenfield, Ave., Milwaukee, Wisc.[9]
				●													d	Alpha Microelectronics Inc., 2416 Reedie Dr., Wheaton, Md.
				●			●								●	●	c	American Components Inc., 8th at Harry, Conshohocken, Pa.
					●												c	American Elite Inc., 48-50 34th St., Long Island City 1, N.Y.
					●												b c	Amperex Electronics Corp., 230 Duffy Ave., Hicksville, N.Y.
							●		●							●	c	Angstrohm Precision Inc., 7341 Greenbush Ave., North Hollywood, Calif.
						●			●								c	Atlas Coil Inc., 63 Main St., Ansonia, Conn.
						●											a b c	Bond Electronics Corp., 60 Springfield Ave., Springfield, N.J.
	●					●			●	●				●			c d	Bradford Components Inc., 65 South Ave., Salamanca, N.Y.
						●		●						●		●	c	Brys Instrument Co., 7026 Sixth Ave., Brooklyn 9, N.Y.
						●											d	Calbest Electronics Co., 4801 Exposition Blvd., Los Angeles 46, Calif.
						●											c	Calibration Standards Corp., 1031 Westminster Ave., Alhambra, Calif.
	●					●				●							c	California Resistor Corp., 1631 Colorado Ave., Santa Monica, Calif.
				●	●		●	●		●							b c	Campbell Industries, Dover, N.H.
													●		●	●	c	Carborundum Co., Buffalo Ave., Niagara Falls, N.Y.
	●					●			●								a b c	C-F Electronics, 14709 Keswick St.. Van Nuys, Calif.
				●	●		●	●		●							b c	Clarostat Mfg. Co., Inc., Dover, N.H.
						●											c	Cohu Electronics Inc., Kin-Tel Div., Box 623, San Diego 12, Calif.
	●									●							c	Connolly and Co. Inc., 914 Rengstorff Ave., Mountain View, Calif.
						●											c	Consolidated Ohmic Devices Inc., 900 Third Ave., New Hyde Park, N.Y.
						●											c	Consolidated Resistance Co. of America, Inc., 44 Prospect St., Yonkers, N.Y.
				●	●		●	●									b c	Continental-Wirt Electronics Corp., 26 W. Queen Line, Philadelphia 44, Pa.
			●									●					a b c	Corning Glass Works, Corning, New York[6]
		●											●				c	CTS Corp., 1142 W. Beardsley Ave., Elkhart, Ind.[8]
●	●			●	●	●	●	●	●	●							a c	Dale Electronics Inc., Box 609, Columbus, Neb.[7]
						●											c	Daven Div., General Mills Inc., Rt. 10, Livingston, N.J.
				●			●	●									a b c	Electra Mfg., Co., 800 N. 21st. St., Independence, Kansas
						●											c	Electro-Scientific Ind. Inc., 13900 N.W. Science Park Dr., Portland 29, Ore.
											●		●		●		c	EMC Technology Inc., 1133 Arch St., Philadelphia, Pa.
						●											b c	EMP Electronics Research Labs, 3131 N. 29th Ave., Phoenix, Ariz.
				●	●		●	●					●		●		c	Film Components Co., 80 Kings Road, Madison, N.J.[7]
				●			●						●				c	Filmohm Corp., 48 W. 25th St., New York 10, N.Y.
						●			●							●	c	Gam Electronics Inc., 138 Lincoln St., Manchester, N.H.
	●					●			●	●							a b c	Gamble Industries, Reeder and Monroe, Riverside, N.J.
										●							a b c	General Electric Company, 1 River Rd., Schenectady 5, N.Y.
						●											a b c	General Instrument Corp., 96 Mill St., Woonsocket, R.I.
						●											c	General Radio Co., 22 Baker Ave., West Concord, Mass.
						●											c	General Resistance Inc., 430 Southern Blvd., New York 55, N.Y.
						●											c	Genistron Inc., 6320 W. Arizona Cir., Los Angeles 45, Calif.
				●													c	Halex Inc., 139 Maryland St., El Segundo, Calif.
										●				●			a c	Hamilton-Hall Resistor Corp., 227 N. Water St., Milwaukee 2, Wis.
					●					●						●	c	Hardwick-Hindle Corp., Div. of Memcor, 41 E. Park Dr., Huntington, Ind.
						●											c	Instrument Resistors Co., 503 Adamston Rd., Bricktown, N.J.
													●				c	Intellux Inc., 30 S. Salsipuedes St., Santa Barbara, Calif.
●	●	●		●	●	●	●	●	●	●	●		●	●	●	●	a b c	International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.
●					●		●	●									c	Ionetics Corp., 27 William St., New York, N.Y.
	●					●			●								a b c	Jordan Electric Co., 14709 Keswick St., Van Nuys, Calif.
						●									●		c	Julie Research Labs Inc., 211 W. 61st St., New York 23, N.Y.
						●									●		c	Kelvin Electric Co., 5907 Noble Ave., Van Nuys, Calif.
				●	●												b c	Key Resistor Corp., 321 W. Redondo Beach Blvd., Gardena, Calif.
						●	●		●	●						●	c	K-F Development Co., 2606 Spring St., Redwood City, Calif.
				●	●		●	●									c	Kidco Inc., Rt. 541, Lumberton, N.J.
						●				●				●			c	Lectrohm Inc., 5560 N. Northwest Hwy., Chicago 30, Ill.

1. Up to 2 watts, 5%, 10%, 20% tolerance.
2. Up to 2 watts, 2% to 5% tolerance.
3. Up to 2 watts, 1% or better tolerance.
4. Over 2 watts.
5. a.—parts distributor b.—industrial distributor c.—direct d.—custom made only

Fixed Resistor Sources

Company	Availability[5]	Other				Power[4]				Precision[3]			Semi-Precision[2]				General Purpose[1]	
						Thick Film		Wire-wound		Thin Film			Thin Film		Thick Film			
		High voltage	High frequency	Fusible	Strips and discs	Metal oxide	Metal glaze	Non precision	Precision	Deposited carbon	Evap. metal film	Wirewound	Deposited carbon	Evap. metal film	Metal oxide	Metal glaze	Wirewound	Carbon composition
Leeds & Northrup Co., 4970 Stenton Ave., Philadelphia 44, Pa.	c											●						
Logan Electronics Corp., 44 Breed St., East Boston 28, Mass.	c											●						
Mallory, P.R. & Co. Inc., 80 S. Gray St., Indianapolis, Ind.	abc					●		●										
Marstan Electronics Corp., 204 Babylon Turnpike, Roosevelt, N.Y.	abc											●						
Memcor, 41 E. Park Dr., Huntington, Ind.	abc	●						●					●					
Mepco, Inc., 35-37 Abbett Ave., Morristown, N.J.	bc								●	●	●							
Metavac, Inc., 45-68 162nd St., Flushing 58, N.Y.	c				●						●			●				
Micro-Ohm Corp., 1031 S. San Gabriel Blvd., San Gabriel, Calif.	c											●						
Miller Electro-Research Labs, 5529 S. Fifth St., Milwaukee 7, Wisc.	c												●					
Milwaukee Resistor Co., 700 W. Virginia St., Milwaukee 4, Wisc.	abc		●	●	●			●	●								●	
Molded National Resistor Co., 3133 E. 12th St., Los Angeles 23, Calif.	c												●					●
Muter Co., 1255 S. Michigan Ave., Chicago 5, Ill.	c			●				●									●	
Nucleonic Products Co. Inc., 3133 E. 12th St., Los Angeles 23, Calif.	bc									●			●					●
Nytronics Inc., 550 Springfield Ave., Berkeley Hgts., N.J.	abc									●	●		●	●				
Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, Ohio	c				●			●										●
Ohmite Mfg. Co., 3601 Howard St., Skokie, Ill.	abc							●				●					●	
Omtronics Mfg. Inc., 2406 Leavenworth St., Omaha 5, Nebraska	abc								●			●					●	
Oneida Electronic Mfg. Co., 843 N. Cottage St., Meadville, Pa.	ab			●					●								●	
Pacific Resistor Co., 2320 Pontius Ave., West Los Angeles 64, Calif.	c											●					●	
Penn Resistor Corp., 526 N. Broad St., Lansdale, Pa.	bc							●	●	●		●	●				●	
Precision Inc., 4748 France Ave., Minneapolis, Minn.	c							●	●			●					●	
Precision Resistor Co., 109 U.S. Hwy. 22, Hillside 5, N.J.	d								●			●						
Pyrofilm Resistor Co. Inc., 3 Saddle Rd., Cedar Knolls, N.J.	abc	●	●		●					●	●							
RCL Electronics, 1 Hixon Pl., Maplewood, N.J.	bc							●	●			●					●	
Regan Engineering Corp., 1000 S. 24th St., Phoenix, Ariz.	cd							●										
Reon Resistor Corp., 155 Saw Mill River Rd., Yonkers, N.Y.	c											●						
Resistance Products Co., 914 S. 13th St., Harrisburg, Pa.	abc	●	●									●	●					
Rex Rheostat Co., 149 Babylon Turnpike, Roosevelt, N.Y.	abc							●										
Rho Engineering Co., 2234 Colby Ave., Los Angeles 64, Calif.	c											●						
Riedon Div., 11728 Vose St.. North Hollywood, Calif.	c											●						
Robinson Electronic Components, Inc., 409 McGroarty St., San Gabriel, Calif.	c								●									
R-Tronics Inc., 134-20 Jamaica Ave., Richmond Hill, N.Y.	c								●			●						
Ruckelhaus Labs Inc., Madison, N.J.	bc										●							
Sage Electronics Corp., Box 3926, Rochester 10, N.Y.	bc								●			●						
Shallcross Mfg. Co., Preston St., Selma, N.C.	c	●										●						
Speer Resistor, Div. Speer Carbon Co., Bradford, Pa.	c																	●
Spicer Electronics Inc., 409 McGroarty St., San Gabriel, Calif.	c											●						
Sprague Electric Co., 125 Marshall St., North Adams, Mass.	abc							●	●	●	●		●	●			●	
Stackpole Carbon Co., 201 Stackpole St., St. Marys, Pa.	bc																	●
States Co., 19 New Park Ave., Hartford 6, Conn.	c		●															
Superex Electronics Corp., 4-6 Radford Place, Yonkers, N.Y.	c									●			●					
TIC of California, 850 Lawrence Dr., Newbury Park, Calif.	c											●						
Tech-Ohm Electronics Inc., 36-11 33rd St., Long Island City 6, N.Y.	c							●	●			●	●				●	
Tel-Labs Inc., 1050 Second St., Manchester, N.H.	c							●	●			●						
Tepro Electric Corp., 5 St. Paul St., Rochester, N.Y.	c								●			●					●	
Tepro of Florida Inc., 375 Patricia Ave., Dunedin, Fla.	c								●			●						
Texas Instruments, Inc., Box 5012, Dallas 22, Texas	abc									●	●		●	●				
Ultronix Inc., 461 N. 22 St., Grand Junction, Colorado	ac								●			●						
United Mineral & Chemical Corp., 16 Hudson St., New York 13, N.Y.	b	●	●	●				●	●	●		●	●				●	
Vac-Ohm Electronics Co., Box 444, Haddonfield, N.J.	c	●	●		●		●				●			●		●		
Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio[7]	abc	●	●							●			●					
Ward Leonard Electric Co., 115 MacQuesten Pkway. S, Mt. Vernon, N.Y.	bc				●			●	●		●	●					●	
Wells Inc., 90 Nepperhan Ave., Yonkers, N.Y.	bc									●			●					
Welwyn International Inc., 811 Sharon Dr., Westlake, Ohio	bc	●				●				●	●		●		●			
White Dental Mfg. Co., 10 E. 40th St., New York 16, N.Y.	c																	●

6. Also makes precision thick metal film.
7. Also makes power thin film.
8. Also makes Cermet types.
9. Also 2% to 5 watt types.

Unusual Resistors

In this sampling of some new ideas in resistors, unconventional types are featured. These range from 4-foot long, 150-kw. types to multi thin-film resistor networks on tiny substrates. Microwave applications are covered as well as resistor strips whose final design is limited only by the imagination of the design engineer.

THERE are many special applications in electronics that require the use of a resistor whose electrical or mechanical characteristics may not fall under any of the more common categories. Some of these unusual types may be needed because of the high voltages encountered in the circuit, some because certain electrical responses must be met at higher (microwave) frequencies, while others may arise because of the need for a resistor whose electrical parameters or mechanical arrangement cannot be fulfilled by the "conventional" types. It is in this latter category that many manufacturers have been making steady headway and have come up with some unusual examples of new developments in the resistor art.

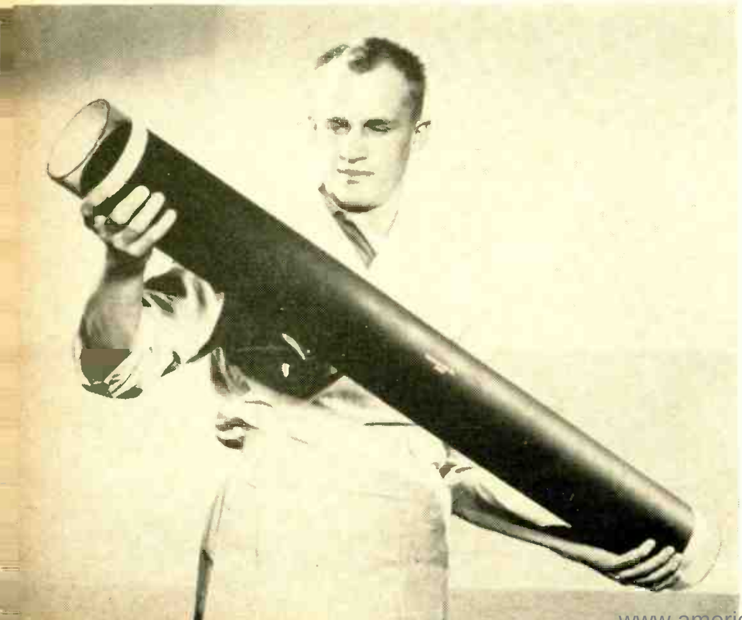
High-Power Resistors

A new type of high-power, glass-substrate resistor, manufactured by *Corning Glass* for special applications, is about four feet long and five inches in diameter (Fig. 1). These resistors were specifically designed for use as dummy antenna loads since they have a low and almost uniform reactance between 2 and 28 mc.

The resistors were designed to dissipate 3 to 6 kw. each. However, with forced-air cooling they will dissipate about 9 kw., and with water cooling they will dissipate up to 150 kw. The resistors are combined for both balanced and unbalanced loads, using 140- and 300-ohm values to obtain the needed 70- and 300-ohm termination.

The resistor consists of a tin-oxide film fused onto a Pyrex glass cylinder with a silicone coating for protection. The resistive element is spiraled to obtain the specific ohmic value and to produce uniform heat dissipation as well as minimum series inductance and shunt capacitance.

Fig. 1. This high-power, tin-oxide resistor is used as a dummy load for high-power, high-frequency radio transmitters.



Gas-Filled Resistors

To extend the wattage and voltage limitations of small-sized resistors and to improve their long-term stability, while reducing the detrimental effects of temperature cycling and moisture absorption, a line of glass-sealed, glass-filled, deposited-carbon resistors is available from *Victoreen Instrument Co.* (see Fig. 2).

The carbon resistive element is not coated with a paint or an epoxy, as the coefficient of expansion of the paint and the carbon element do not exactly match. When filled with a gas of high *dielectric* constant, a two-watt, deposited-carbon element normally limited to 750 volts may well tolerate the application of as much as 10,000 volts or three watts. The critical resistance for this series is 33 megohms (which compares to 250,000 ohms for carbon-composition resistors).

The high value of critical resistance of gas-filled resistors enables them to be used in high-voltage power supplies, since a single resistor can then be used in lieu of a series of lower voltage resistors. Resistance values as high as 200 megohms are available at tolerances as close as 1%.

They are also suited for use as high-voltage multipliers for precision voltmeters and vacuum-tube voltmeters as well as precision high-voltage dividers. In such applications, they usually dissipate but a small fraction of their rated wattage and their drift will be but a small fraction of one percent in ten years. When filled with a gas having excellent *thermal* conductivity, the two-watt element now becomes a 10-watt resistor capable of withstanding 2000 volts. The critical resistance for this series is 400,000 ohms, and it is available in values of two megohms.

Housed Power Film Resistors

In many cases, circuit designers desiring to use the high-stability, low-reactance properties of metal-film resistors have been hampered by the low power ranges that were available. In other cases, designers using housed power wirewounds have been handicapped by their relatively narrow resistance range and low working voltage as contrasted with the metal-film types. To bridge this gap, *Dale Electronics Inc.* has developed the housed metal-film resistor, Fig. 3. The resistance element is molded into an aluminum housing that screws on the chassis for maximum heat transfer. The resistor is rated at four watts in the resistance range 50 ohms to one megohm, with an upper limit of 2 megohms available.

Fig. 2. Glass-sealed, gas-filled deposited carbon type resistor.

Fig. 3. This housed power-film resistor is finned so it can be mounted on a metal chassis for the purpose of dissipating heat.

Strips and Discs

On some occasions, applications might include terminating resistors that can fit within a coaxial connector, special-shaped resistive cards to be used within a waveguide, or a specially shaped resistor for a unique mechanical packaging.

IRC fabricates a line of disc resistors whose external dimensions range from ¼" to 1½", internal dimensions from ⅞₂" to 1¼", having a resistance range between 5 and 100,000 ohms at 10% tolerance, and capable of dissipating up to 1.3 watts. Maximum rated voltage is 500 volts per inch of current path.

These resistors are die-stamped from resistance strips and have inner and outer rings of colloidal silver to provide contact with coaxial line fixtures. Mechanical pressure is used to contact these rings.

This same company also manufactures a line of resistance strips 0.027 inch thick whose resistive path is 12 inches long and whose width ranges from ⅜" to 2¾". The colloidal-silver contact strip can run along either pair of opposite edges. Resistance range is between 19 ohms-per-square to one megohm-per-square at tolerances between 10% and 20%.

Resistance strips are specified in ohms-per-square rather than in ohms-per-square-cm. or ohms-per-square inch. Fig. 4 will help explain this seemingly confusing lack of definition.

Assume any size square of resistive material, *R*, and construct on this square another square using three squares of the same resistive material *R*. This produces a series-parallel arrangement of resistors from any edge of the new square, of two series elements of 2*R* each in parallel with each other to the opposite edge. This produces an equivalent resistance of $(2R \times 2R)/4R$ or *R*, the same value as the original small square, which shows that any square of the same resistance material has the same resistance between opposite edges, regardless of its dimensions. The terminology ohms-per-square is then used as the basis for specifying requirements.

The basic formula for calculating ohms-per-square is $(R_{ab} \times W)/L$, where R_{ab} is the total resistance required, *W* is the width of the active area, and *L* is the length between terminations. For example, R_{ab} required is 100,000 ohms, *L* is one inch, and *W* is 0.25 inch. From the formula, calculate $(100{,}000 \times 0.25)/1$; the result is 25,000 ohms-per-square.

The desired shapes can be cut from the basic resistance strip by a high-speed diamond wheel, punches, or dies; sawed with a jeweler's saw; or cut to the desired dimensions with any very sharp instrument.

Resistors for Microwave Equipment

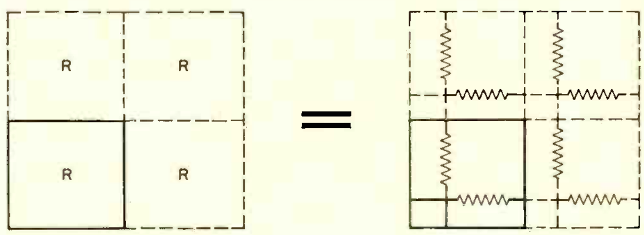
One way of producing resistors that can operate at microwave frequencies is to use thin-film techniques. Usually, this is done by deposition of a thin metal film on a high-resistivity substrate, with this metal film having a final thickness as fine as 50 to 500 angstroms (0.2 to 2 μin.). This makes the film thin compared to the skin depth (current penetration at microwave frequencies). The thin film eliminates the skin effect, or drop off in resistance, except at the higher frequencies (approaching 10,000 mc.). Often, carbon-film, pyrolytically deposited on alumina substrates, is used for pulse applications. Techniques have been developed for depositing a thin protective quartz coating to seal out moisture and provide some mechanical protection for the resistor.

Filmohm Corp. makes a line of microwave resistance cards (up to 300,000 mc. use) that are used as microwave attenuators, terminations for directional couplers, isolation and impedance matching, protection of crystals, and mode suppressors. The resistance material is a film of pure metal approximately 50 millionths of an inch thick deposited on the surface. A protective coating is used. Resistivities from 25 to 800 ohms-per-square are produced at 2% to 10% resistance tolerances. Resistance cards are made of various materials and range from 5 by 12 to 8 by 22 inches with thicknesses ranging from 0.00025 to 0.25 inch. Dissipation is up to 8 watts and some devices can operate at 350°C maximum surface temperature.

Another form of special microwave resistor made by the same company is the evaporated metal-film rod and disc resistor used for r.f. pads, broadband attenuators, dummy loads, and precision coaxial terminations, among other microwave uses. These devices are made by simultaneous deposition and fusion of a low-temperature-coefficient, pure-metal alloy to a special ceramic base. The metal film is permanently fused to the substrate and then protected with a sealed-on micro-thin layer of quartz. Noise level is very low, and the resistor can be operated at 200°C. Resistance range is 0.010 to 400 ohms at tolerances of 2% and 5%. The discs can dissipate up to 8 watts and the rods up to 15 watts.

When it becomes necessary to check crystal-diode mounts, the crystal mixer, or other components of a microwave system for electrical mismatch, the possibility always exists that a crystal diode can be damaged by excessive voltage or current applied to it. As some of these diodes can cost in excess of $100, a reasonably priced substitute should be used. By depositing a pure-metal re-

Fig. 4. Development of the ohms-per-square calculation.



sistance film on a standard crystal-diode body, a stable and reliable resistor that can be plugged in in place of the crystal diode can be made. Measurements that are independent of crystal impedance (which can vary from crystal to crystal) can then be made without damaging an expensive diode. Such crystal resistors (made by *Filmohm*) range from 25 to 400 ohms at 2% and 5% tolerance. Rated power dissipation, based on 100°C ambient, is up to one watt. Other applications include matched terminations and calibrated mismatches.

Dual Resistors

Precision film resistors offer marked advantages in weight, inductance, load life, and other environmental stress characteristics over wirewound, but their advance came to a halt on the low value of temperature coefficient and stability of their temperature-coefficient characteristics over wide temperature spans.

By creating a dual-metal film resistor, *Angstrohm Precision Inc.* claims to have a precision resistor with a temperature coefficient of 5 PPM/°C over the range of −55° to +175°C. Resistance range is between 10 ohms and 25 megohms, wattages are from 1/10 to 2 watts, and resistance tolerance ranges from a low of .01% to a high of about .5%.

The dual-metal film resistors are connected in parallel and their metal-film materials are matched to provide maximum mutual compensation of resistance variation due to temperature coefficient, load life, moisture, and total excursion due to combination effects.

Flexible Flat Resistors

Recently introduced by *EMC Technology Inc.* is a line of flexible flat resistors with substrate dimensions of 1.25 by 0.1 by .005 inch and actual resistance element size of .250 by 0.1 by .003 inch.

These vacuum-coated metal-film resistors were designed for circuits where packaging densities of up to 10^7 resistors per cubic foot are desired. Resistance range is between 5000 and 25,000 ohms, tolerance is to 1%, and free-air dissipation is 0.1 watt at 25°C.

Four-Terminal Resistors

Designed to nullify the effect of lead and contact resistance, *R-Tronics, Inc.* has developed a line of four-terminal resistors between .01 and 10 ohms with .01% accuracy. Thermal e.m.f. is 3 μv./°C maximum. ▲

MILITARY SPECIFICATIONS FOR FIXED RESISTORS

MILITARY specifications (MIL Specs as they are commonly called) came into existence to insure that devices being purchased for use by various government agencies would be of the highest quality, and that each similar item would have the same characteristics and be capable of fulfilling its applicable acceptance standards regardless of who the manufacturer was or where he was located.

There are 21 MIL Specs covering fixed resistors and these are shown on page 51. These spell out, in detail, the acceptance standards required before government purchase of one of these components. Most MIL Specs have a letter suffix indicating that they have either been updated to reflect the need for an improved resistor, that improved manufacturing techniques have been developed which enable a better type of resistor to be produced, or that a need exists for a closer tolerance or higher reliability component. Special MIL Specs have been issued that reflect these ever-tightening resistor reliability standards.

In many cases, resistor manufacturers come up with a new approach to resistive material or resistor construction that is not covered by an applicable MIL Spec. In this case, the manufacturer cannot use or advertise it as a MIL item. However, he usually states which MIL Spec he claims his item is superior to. For example, in the area of thick-film resistors, only the metal-oxide types are directly covered by MIL Specs (one spec for the power types and another spec for the semi-precision types). Some manufacturers have developed other forms of thick films that they feel are better than metal oxide and advertise them as exceeding the requirements laid down by either MIL-R-11804D (Resistors, Fixed, Film, Power Types) for the metal-oxide power resistors, or MIL-R-22684B (Resistors, Fixed, Film, Insulated) for the metal-oxide semi-precision types.

A circuit designer can only use a non-spec resistor if no approved type can be found to fill a particular need. In that case, depending on the provisions of the contract, a waiver must be requested from the contracting agency. Usually such waivers are granted for engineering and prototype models. When the equipment is produced in quantity and approved for field service, the non-spec resistor can be submitted for approval and inclusion in the appropriate MIL Spec. After extensive tests, a new MIL Spec may be assigned or an existing spec may be amended to cover the new resistor type. This, by the way, is the usual method by which non-spec components get MIL Spec classification.

As an example of the type of information spelled out in a typical MIL Spec, let us examine MIL-R-11—the specification that covers fixed composition resistors, a popular type whose use ranges from consumer products to space hardware.

This particular spec is divided into four major areas: electrical and mechanical characteristics, quality assurance, and delivery.

Electrical Characteristics

Among the electrical qualifications detailed in this section are:

1. Maximum ambient temperature allowed for full-load operation.
2. Maximum allowable change in resistance with temperature.
3. Allowable tolerance for various resistance values.
4. Power rating of a resistor based on full-load operation and including any derating operation at various ambient temperatures.
5. Maximum continuous working voltage (d.c. or r.m.s.) allowed.
6. Maximum allowable resistance change with temperature.
7. Effect of vibration on the device.
8. How much voltage the dielectric should withstand.
9. Ohmic value of the insulation resistance.
10. How the resistors should operate at low temperatures.
11. How the resistance value changes after temperature cycling.
12. Change of resistance value with moisture.
13. Change in characteristic with a short-term overload.
14. How resistance changes during resistor life.

Mechanical Characteristics

Among the mechanical qualifications detailed in this section are:

1. Type of material to be used in manufacture of the resistor.
2. Physical dimensions and tolerances for the various classes.
3. How the terminals should react to bending and twisting.
4. The device's mechanical resistance to soldering heat.
5. A quality check of the insulation seal.
6. The device's response to mechanical shock in the three major planes.
7. Effect of vibration on the device.
8. Determination of terminal solderability.
9. Method of marking the resistor and how this method is applied.
10. General mechanical workmanship.

Quality

The qualification areas covered in this section include descriptions of the various inspection procedures to be followed: details of a sampling procedure to be used to insure that all units are mechanically and electrically sound; and details of the method of examination to be used for these inspections.

Delivery

Here, four basic areas cover the methods to be used for cleaning the components, drying them, preserving them during shipment, and packaging and shipping them.

Once a resistor has passed through the above-mentioned series of electrical, mechanical, and quality tests, it will then have a high degree of reliability, and resistors made by different manufacturers will be extremely similar. ▲

Thick-Film Resistors

By STEPHAN H. ROLLIN / President, EMC Technology, Inc.

JAY UTKEN & / Chief Engineer & Development Engineer, Film Resistors
J. BUCKLIN / Mallory Controls Co., Div. of P.R. Mallory & Co., Inc.

Certain combinations of metals and insulating materials in a matrix, or certain metal oxides, display controllable resistance characteristics. Because these components are used in film form on a substrate, and the thickness is over .000001 inch, they are called thick-film resistors.

THICK-FILM fixed resistors are defined by the electronics industry as those resistors whose resistance element is in the form of a film having a thickness greater than .000001", or thick enough to be seen.

Thick-film resistors are manufactured as precision and semi-precision relatively low-power types (up to two watts dissipation with tolerances of 1%, 2%, and 5%), and as relatively high-power types having as power dissipation greater than two watts and a tolerance in excess of 5%.

The three major types of thick-film resistors presently being manufactured are metal-oxide, metal-glaze (including "Cermet"), and bulk-property types.

Metal-Oxide Type

Metal-oxide film resistors are a relatively new development, having come into common use only within the last eight years. Many basic materials have been tried and tested but tin oxide, used as the film material, seems to be the most suitable for these devices. The *Mallory* metal-oxide resistor employs a film that is .000040" thick; hence, it is considered to be a thick-film resistor according to the above definition.

It is a tough film that will withstand considerable handling without damage; is inert to common acids, alkalies, and solvents; can withstand high temperatures; and has a good temperature coefficient of resistance; a low noise value; and a low voltage coefficient. It is also low in cost, resulting in resistors whose price is in the area of carbon-composition types.

The oxide film is usually applied to the tubular ceramic substrate at a high temperature by reacting a spray or vapor of tin-chloride solution on the surface of the heated substrate. This process results in a film so tightly bonded to the substrate that it cannot be removed without destroying the film. Additives are introduced to modify the electrical properties of the resistive film.

Final adjustment is made by cutting or grinding a spiral groove around the surface of the substrate, which will permit resistance-value increases up to three thousand times the basic value. The process is electronically controlled to produce any desired value.

The tin-oxide film can be used with low design tolerances because expected load-life changes, as well as environmental changes, are invariably smaller than the ones common with carbon-composition resistors. *Corning*, for instance, supports its claim for low design tolerances with the following facts:

1. *Corning* metal-oxide load-life curve is essentially flat.
2. No wear-out was evidenced at 30,000 hours, even at 140% of rated power.
3. Temperature coefficient will cause increases of less than 1% at full loading and 70°C. Mean change is less than 0.2%.
4. The design tolerances of 3% for precision and 10% for general-purpose resistors apply with no derating necessary.
5. *Corning* tin-oxide resistors have demonstrated failure rates of less than 0.000083 per 1000 hours.

The most drastic demonstration of ruggedness of this type of product is shown in *Corning's* 30,000-hour load-life chart of Fig. 1.

Metal-oxide film resistors meet MIL-R-22684 Specs, which is not as stringent as MIL-R-10509 (metal films) but considerably tighter than MIL-R-11D. They are thereby filling a technological gap. Although this type of resistor is relatively new, one manufacturer has already achieved MIL-R-10509 performance.

Metal-Glaze Type

No sooner had the first oxide film appeared on the market than an entirely new technology came to life. In August, 1960, *duPont* introduced its resistive compositions for application of resistor films on ceramic substrates by firing.

This class of resistor is composed of powdered glass and extremely fine metal particles (typically 56% palladium and 44% silver) in an organic handling vehicle deposited on a ceramic substrate. The 56:44 ratio of palladium to silver derives from the fact that this proportion of metals in the alloy produces the lowest temperature coefficient of resistance (TC) of about 20 PPM/°C. However, the TC of a finished metal-glaze resistor can vary from about 50 PPM at the lower resistance values to almost 200 PPM at the higher values.

Resistor development groups all over the country began

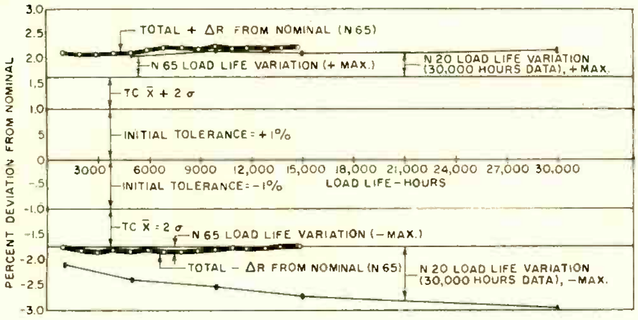
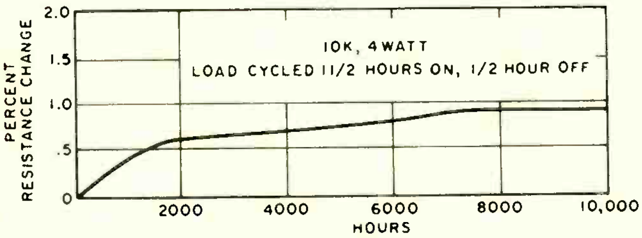


Fig. 1. Long-term behavior of Corning's tin-oxide resistors.

Fig. 2 The load life of Mallory's metal-oxide film resistors.



to apply and modify these compositions ("Cermet," for example) by dip, brush, spray, or screen in order to develop a "better" resistor. The basic process is simple.

The powdered glass/metal particle combination is deposited on a substrate and subjected to a programmed temperature gradient, peaking at about 800°C. During this process, the organic handling vehicle burns off and the glass melts, leaving the metal particles in a fixed relationship and permanently fused to the substrate.

By cutting the metal-glaze film in a spiral pattern, similar to the process used in metal-oxide resistors, various values of resistance can be created.

The result is a resistor of great stability that is extremely hard and almost impervious to environmental extremes such as moisture, temperature variations, shock, vibration, and chemical attack. Nor is it easily damaged by high overloads. Power density is almost twice as high as comparable carbon-composition units.

Resistors made by this process have proven to be good MIL-R-22684 performance-equivalents to metal-oxide films. This is likely to become a reality shortly, but the military specifications do not tell the full story. These products have inherent advantages over metal films in terms of their power-load ability, packaging density, and application which are likely to lead to an exceptional growth rate.

"Cermet"

A variation of the metal-glaze type, the "Cermet" resistor, is composed of precious metals and insulating materials applied to a ceramic substrate and fired at high temperatures. Like metal glaze, "Cermet" is not seriously affected by abrasion, heat-shock, humidity, oxidizing atmospheres, and other environmental extremes. Unlike metal glaze, "Cermet" is usually applied by a screening process. This means that several of these resistors can be fabricated on a very small sized substrate.

Bulk-Property Metal-Film Type

Of even more recent vintage are bulk-property film resistors which use only metal to conduct the current. They are the first to challenge precision wirewound resistors. Tolerances of .01% combined with a 50 PPM-per-year stability and a TC of ±5 PPM enable the user to operate in the 0.1% design-tolerance area.

Generally, performance of precision wirewound resistors are matched in terms of precision and stability, while the inherent capabilities of film resistors, such as high-frequency behavior and fast response, are maintained.

In these new devices, special alloys produce a low temperature coefficient of resistance. Control of crystal structure, strain, substrate characteristics, deposition techniques, and stabilizing treatments minimize resistance changes.

A flat film construction keeps inductance and capacitance low and processing resistors in large groups and applying uniform treatments insures good tracking characteristics. The basic unit is essentially non-inductive. It does have an equivalent parallel capacitance of 0.22 pf. for a 5000-ohm resistor at 100 mc. Distributed capacitance effects are so small as to permit resistor rise time of 1 nanosecond.

Table 1. Operating characteristics of metal-oxide, metal-glaze, Cermet, and bulk-property thick-film resistors.

	Metal Oxide		Metal Glaze		Cermet	Bulk Property
	Power	Semi-Prec.	Power	Semi-Prec.		
Rating (watts)	2-115	¼-2	2-10	¼-2	to 10	.3-.75
Res. Range	10 ohms-4.2 meg.	10 ohms-1.5 meg.	10 ohms-1.5 meg.	10 ohms-1.5 meg.	10 ohms-10 meg.	30 ohms-100,000 ohms
Standard Tolerance	5%, 10%	2%, 5%	2, 5, 10%	2%, 5%	1%	.01%-1%
Temp. Coeff. (PPM/°C)	±250	±200	±200	±250	±50	±5
Noise Level (μv./v.)	.1	.1	Not measured		Function of resistance	Very low
Volt. Coeff.	.001%/v.	.001%/v.	Not measured		.005%/v.	—
Load Life (Stability)	5%	2%, 3% for 2 w.	1%	3%	1%	.02%
Meets MIL Spec (MIL-R-)	11804D	22684B	—	—	22684B	—

Special photo-etch patterns have been used to improve these properties and to make flat (0.002-inch thick) unencapsulated strip-line resistors for use in the microwave region up to 2000 mc. Fine control of temperature coefficient is by means of mechanical compensation of inherent resistivity change in the alloy. As specific resistivity of the alloy changes with temperature, the dimensions of the relatively massive substrate used vary by thermal expansion. The superimposed resistance element is constrained to follow the deformation of the substrate. These two temperature-sensitive effects occur simultaneously. By proper matching, a TC of 0 ±1 PPM/°C between 0° and 60°C is obtainable.

Another advantage of these units is their small size which allows the production of small resistor networks.

Due to the fact that this resistor is based on a thick film, it is difficult to produce high ranges. The present 100,000 ohms is the maximum. Another present limitation of this particular product is the lack of long-term performance data due to its fairly recent development.

Resistor Comparisons

Table 1 summarizes some important electrical characteristics of thick-film fixed resistors. It will be noted in Table 1 that only the metal-oxide type is *directly* covered by MIL Specs.

Power-type metal-oxide film resistors are available in ratings between 2 and 115 watts. Below 10 watts, this type is being very widely employed in the entertainment market because of its low cost and high reliability. Oxide-film resistors are also used in high-frequency applications where the reactive effects of wire-wound types would be objectionable. Standard tolerance is 10% although other, closer tolerances are available. Resistance change after about 1000 hours of load-life testing is 5% maximum, although in most cases it averages 3% and lower. Fig. 2 shows a load-life curve for a typical metal-oxide film resistor made by *Mallory,* while Fig. 3 is the derating curve for several power ratings of this type of resistor.

Metal-oxide semi-precision resistors are used in applications where a high-quality, close-tolerance resistor is required and the power-dissipation requirement is two watts or less. Standard tolerance here is 2% with resistance change after 1000 hours of load-life testing about 2% maximum for resistors below two watts and 3% for the two-watt size. Fig. 4 is the derating curve for the *Mallory* semi-precision type.

In addition to the two types of metal-oxide film resistors just discussed, special very-high-power types, rated in many kilowatts, are available for use as transmitter dummy loads. Also, precision oxide-film resistors are available in tolerances of 1% with temperature coefficients of 100 PPM/°C.

Metal Glaze

Metal-glaze resistors may be considered semi-precision types, somewhat superior to carbon-composition units. Their most attractive applications fall between conventional carbon-composition and precision deposited-carbon and metal thin-film types. When deposited thin-film quality is desired but 2% tolerance is enough, metal-glaze resistors may be used at a slight savings in price. According to *IRC,* in certain quantities a ¼-watt deposited-carbon resistor costing 10 cents may be replaced with a 2%, ½-watt metal glaze costing about 8 cents. Also, it is possible to replace a one-watt carbon-composition (± 5% or higher) resistor costing 5.7 cents with a 2% metal-glaze resistor costing 6 cents.

At present, metal-glaze resistors are made in semi-precision types between ¼- and 2-watt units while power types are available in 2- to 10-watt units. The derating curve

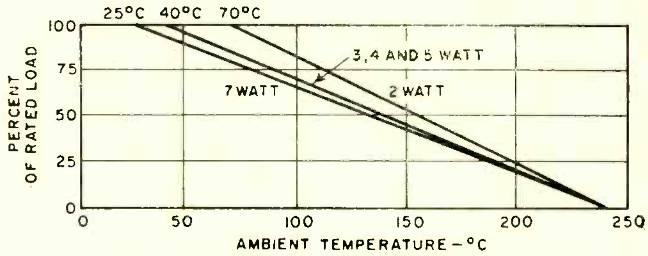
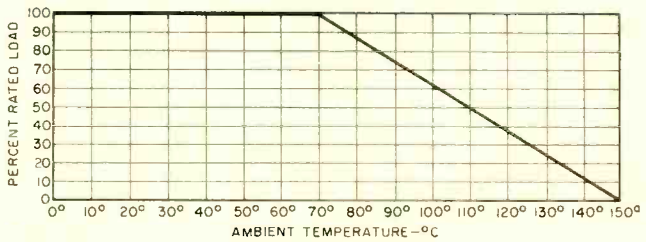


Fig. 3. Derating curves for Mallory power metal-oxide units.

Fig. 4. Derating curve for semi-precision metal-oxide film (Mallory) is similar to that of semi-precision metal glaze.



for semi-precision metal-glaze resistors is very similar to that for metal-oxide film resistors shown in Fig. 4, while Fig. 5 shows how the temperature coefficient varies with resistance value for the ¼- and ½-watt semi-precision metal-glaze units.

According to *Vishay Instruments,* a manufacturer of bulk-property film resistors, noise generated within these resistors is unmeasurable on present-day instruments, as is the inherent inductance. Overload is up to six times the rated wattage for five seconds, the capacitance of the resistor is less than 0.3 pf. at 100 mc., and the risetime is approximately one nanosecond, making this resistor ideal for high-speed computer use.

Bulk-property film resistor specifications (they have no MIL Spec) better the stringent requirements of MIL-R-10509E (Resistors, Fixed, High-Stability), the tightest specification for high-stability film resistors. Fig. 6 is the temperature-resistance curve for this particular type of resistor.

Because of the low wattages of these devices (0.3 to .75 watt), they can be packaged in small-dimension cases or simply with a sealing epoxy coating. ▲

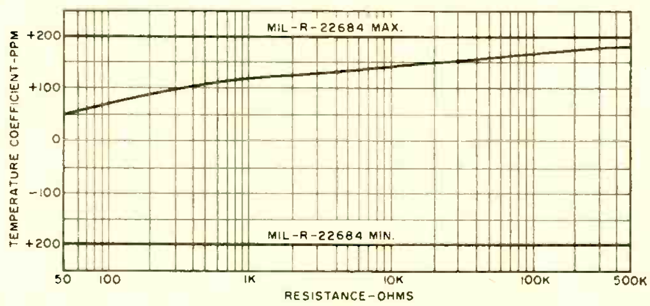
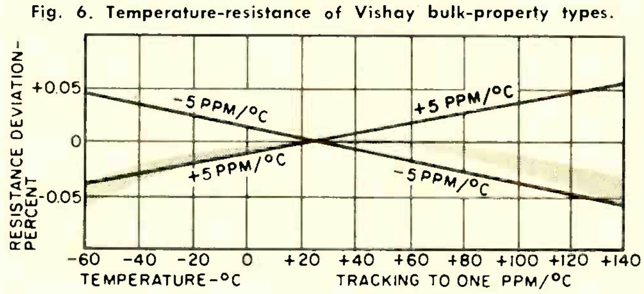


Fig. 5. Temperature coefficient of semi-precision metal glaze resistors (IRC) increases as the resistance value goes up.

Fig. 6. Temperature-resistance of Vishay bulk-property types.



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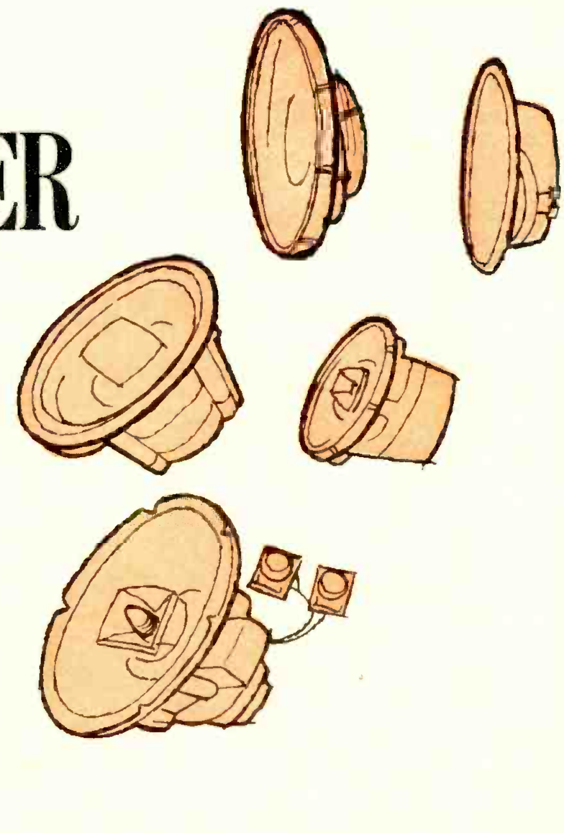
DESIGNING THE HI-FI LOUDSPEAKER



By ABRAHAM B. COHEN
Manager of Engineering
LTV University

Engineering quality into a loudspeaker design requires time, effort, and know-how. Here are ten important characteristics and features and how they are handled by the speaker engineer.

Editor's Note: Designing a good loudspeaker system is not a simple task. It requires the talents of a knowledgeable and experienced designer who must take a good many factors, many of them conflicting, into account. Most speakers or speaker systems that are sold under a known and respected brand name are backed with this kind of engineering knowledge. In the case of unbranded or unknown-branded products, however, the user must be prepared to take the risk that the low-priced speaker system he is considering may not have had the benefit of such know-how and good design.

THE loudspeaker segment of the high-fidelity industry is today faced with a serious dilemma concerning "brand-name" *vs* "brand-X" products and systems. Whether or not one should rely solely on brand-name designs or take a chance with the unknown or the newcomer to the field, is a problem most audiophiles must face.

It is possible to get good loudspeaker systems from relatively unknown manufacturers providing their engineers adhere to the design principles and techniques which brand-name manufacturers have adopted. In some cases, brand-name manufacturers may even supply components and engineering precepts to the smaller company for use in systems to be marketed under "private labels."

The purpose of this article is not to enter into a marketing controversy but rather to outline those principles of design involved in good loudspeaker practice, whether they are incorporated in well-known "brand-name" units or "private-label" systems. The ten salient points which the author has selected might be called "Ten Commandments of Speaker Design." We will consider each item in turn.

1. Frequency Response

Perhaps the most familiar speaker specification is its frequency response. The speaker designer often faces a serious problem in obtaining wide frequency range if he is limited to the use of a single speaker, but it can be done. It is possible to obtain reasonably good reproduction from a single speaker if the choice of design parameters is carefully made. In general, like in musical instruments, low frequencies are more easily produced by a large unit than by a small one.

In Fig. 1 there are two curves, A and B, the lower frequency performance of curve A being more easily obtained from the large speaker of (A) than from the smaller speaker (B). The graphical interpretation (Fig. 1C) of the acoustic output of a piston of diameter, d, in relation to wavelength, λ, of a sound being reproduced indicates that the larger the ratio of diameter to wavelength, the larger the radiation resistance seen by the piston and the greater the acoustic output. A large-diameter piston will have a higher radiation resistance, R, for a given low-frequency wavelength than will a small diameter piston. Since radiation resistance determines the acoustic power output, the larger diameter piston will provide better sound output for a given low-frequency wavelength. Because this is true, the design engineer usually picks a larger structure to provide lower frequencies.

2. Resonance

Very often it isn't just a matter of picking a bigger speaker. The design engineer has to deal with the matter of actual resonance of the speaker, which again determines its low-frequency response. Fig. 2 shows the two impedance curves of two different types of structures: (1) a low-resonance system (curves A and D) with good lows, and (2) a higher resonance system (curves B and C) with poorer low-frequency response. This difference can be equalized if the smaller piston is loosely suspended and allowed to vibrate more freely than the larger piston. Figs. 2C and 2D illustrate a larger piston suspended by a relatively stiff—or low-compliance—edge, difficult to flex, while the smaller piston is shown supported by a high-compliance edge, this latter being easily flexed.

By careful selection of the compliance by which the piston is supported, it is possible to achieve as low a resonance from a small structure as is obtainable from a large structure, with resultant equalization of low-frequency power between the two. This generality is summarized in Figs. 2E and 2F, where

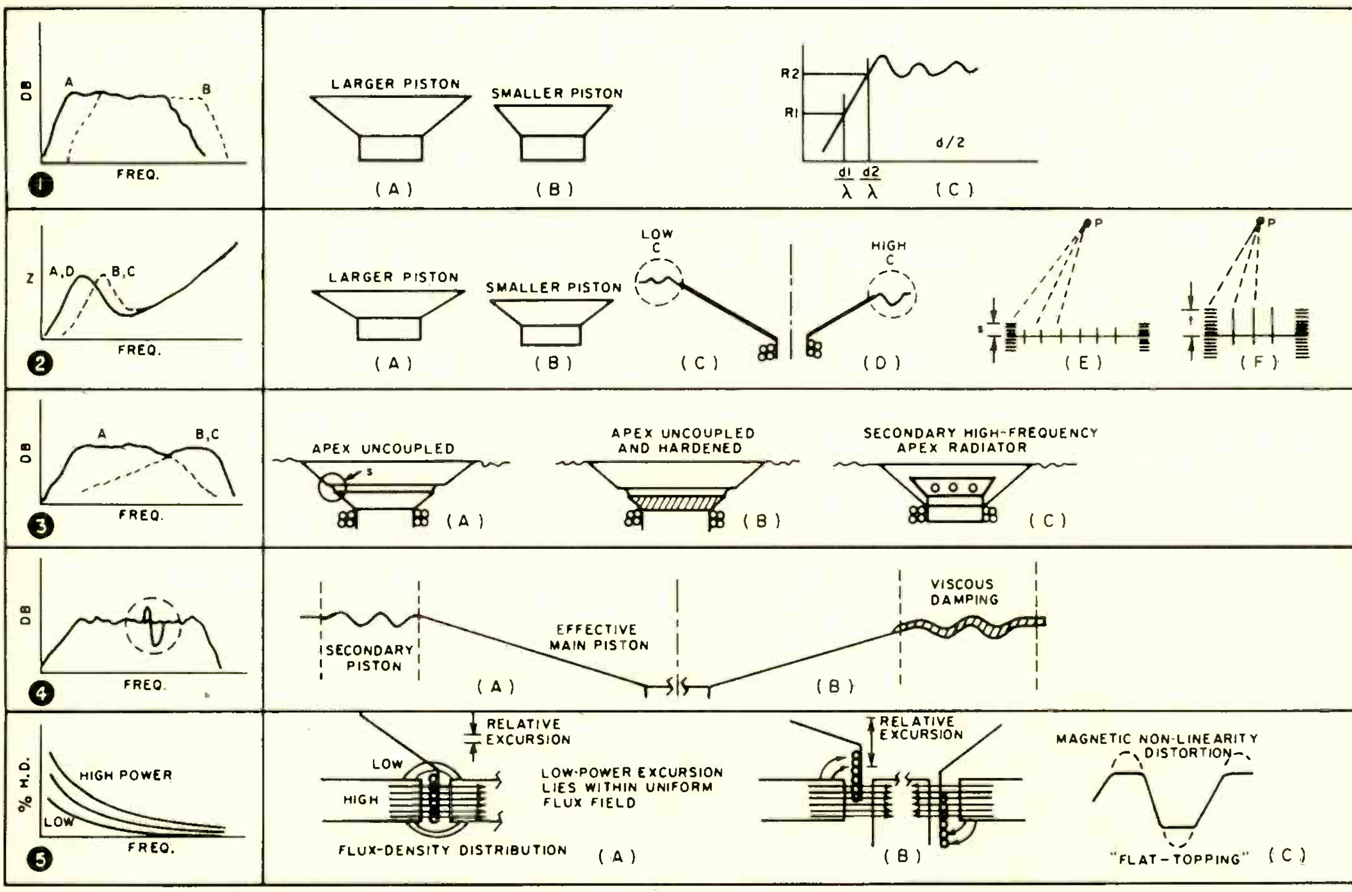


Fig. 1. Effect of cone size. Fig. 2. Effect of compliance. Fig. 3. Cone treatment. Fig. 4. Viscous damping. Fig. 5. Distortion.

2E is a large piston vibrating over a small distance (indicated by the bracketed excursion limit, "*s*").

The total sound pressure measured at point *P* is the sum of the pressures produced by each small area of the piston. This same pressure may be obtained at point *P* from a smaller diaphragm, as indicated in Fig. 2F, where there are fewer units of area to be summed.

Each area is now producing a sound pressure "*t*" which is far greater than in the previous case because of its freer motion. Thus, sound pressure at point *P* in each case may be the same even though one diaphragm is smaller than the other but is moved axially to greater distances.

Thus, the designer can choose to reproduce low frequencies from a large piston or a small one, providing he chooses the right resonance for each and the proper compliance.

3. Dual-Diaphragm Structures

Let us now consider the treble range. It is at this point that the design engineer must begin to compromise since it is not possible to create a system which will be uniformly efficient over the entire range. If the design engineer is limited to a single speaker to cover the entire range, he is faced with the problem of modifying that single-speaker structure in order to obtain the required wider frequency response.

Toward this end there have been several devices developed for mechanically converting the single over-all piston into two sections. This, in effect, produces two diaphragms in one, with low- and high-frequency response as illustrated in Figs. 3A and 3B, respectively. In order to obtain this mechanically separated low- and high-frequency action, a little spring, "*s*" in the diagram, is built into the paper construction of the cone.

At low frequencies, the voice coil driven by the electrical signal drives the apex of the cone and the vibrations of the apex, being driven at a low frequency are, in turn, transmitted, through the "spring" of the uncoupling section "*s*," directly to the major part of the cone. Thus, for all practical purposes, the whole cone vibrates as a single piston, giving the low-frequency response shown in curve A of Fig. 3. However, as the audio frequency of the input signal increases, the vibratory rate of the apex section of the cone increases.

At this increased rate of vibration, the spring between the apex and the cone and the major part of the cone now begin to act as a shock absorber and tend to isolate the major part of the cone from the driving section. The high-frequency vibration does not get lost in the major part of the cone, but is restricted to the smaller apex section. This small apex vibrates as an independent small diaphragm. In this manner, the engineer may thus design a dual-diaphragm structure although it may appear to be one single piece. This over-all diaphragm structure will reproduce the low frequencies while the uncoupled apex section will reproduce the high frequencies.

By careful selection of such uncoupling sections, it is possible to extend the upper-end frequency response of a large piston which is primarily designed for low frequencies. This is done by means of the mechanical crossover device (the built-in spring, mentioned previously) which creates a small high-frequency radiator within the large low-frequency radiator.

In some cases, after this decoupling agent is installed, the apex area is hardened with lacquers, as in Fig. 3B, to make it stiff so it may act as an even more widely separated high-frequency auxiliary radiator.

Another and more efficient method of using a single-speaker driving system for wide range is to attach to the main radiating diaphragm a separate, smaller high-frequency piston, as shown in Fig. 3C. Usually these auxiliary radiators, known as "whizzers" or "Diffusicones," are independent of the main radiator although they are driven by the same voice coil. The main radiating diaphragm is so designed that it will reproduce the low frequencies, but is of a soft nature down near the apex so that when the high frequencies are applied

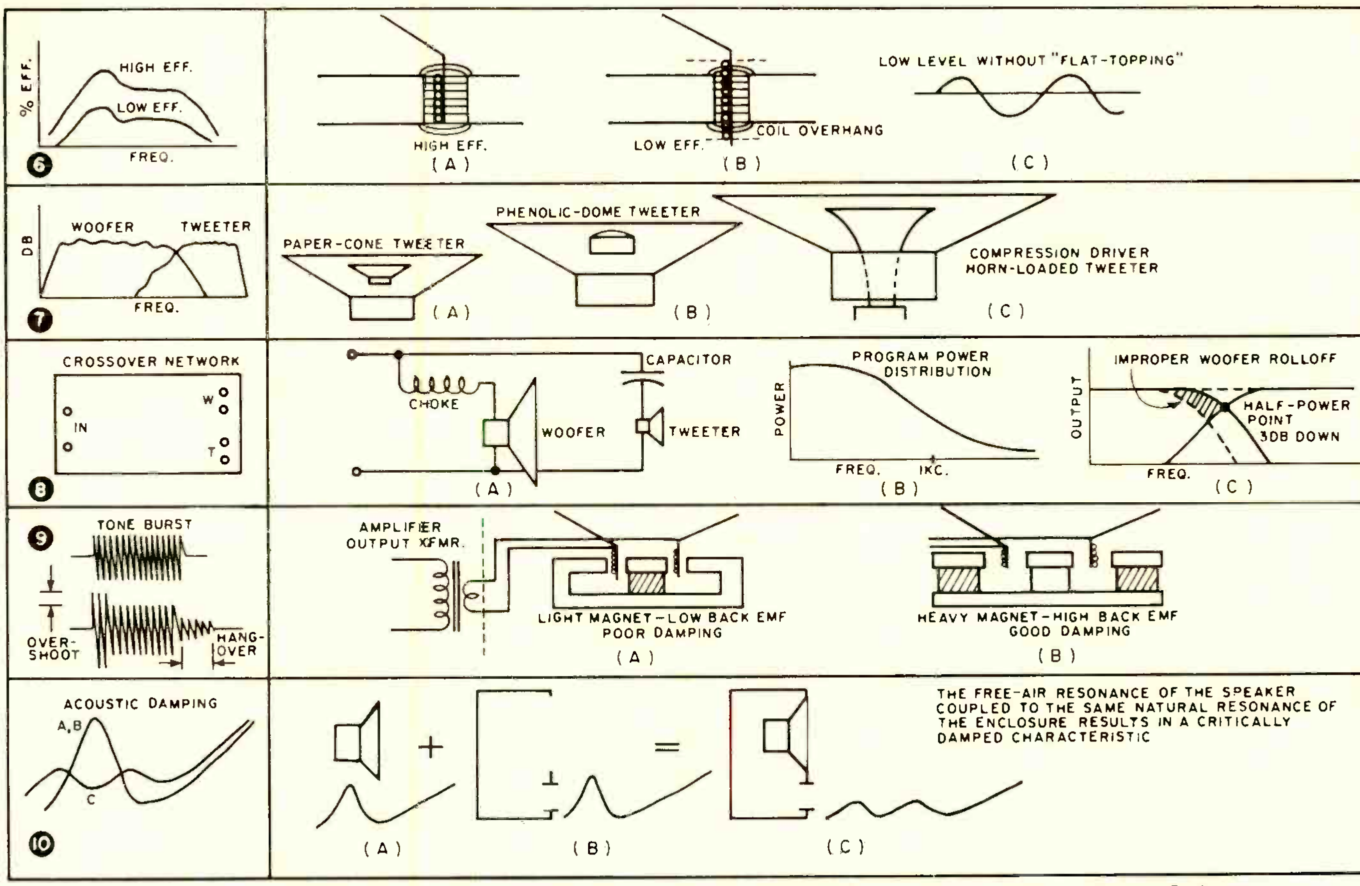


Fig. 6. Speaker efficiency. Fig. 7. Use of tweeters. Fig. 8. Crossover network. Fig. 9. Transient response. Fig. 10. Enclosure.

to the voice coil, the larger coil remains virtually at a standstill while only the smaller cone attached at its apex takes over and reproduces the higher frequencies.

4. Smoothness of Diaphragm Response

Smoothness of response is an important consideration in loudspeaker design. Even though irregularities in response may not necessarily be heard, they may exist and lead to other types of distortion, such as transient distortion. An extreme irregularity, shown in Fig. 4, is a common fault in speakers but is seldom given sufficient attention.

If, however, upon examination a speaker appears to have its edge treated with a sticky or tacky compound, it is evidence of the fact that the design engineer has taken steps to remove irregularities in the mid-frequency response caused by edge resonance. From Fig. 4 it will be noted that the actual diaphragm of the speaker is made up of two sections: the body of the cone itself and the edge suspension (a rather large area compared to the diaphragm itself) which holds the body of the cone to the basket. In the mid-frequency range these two sections of the cone may vibrate out-of-phase and the over-all sound pressure produced by the outer rim of the cone will cancel out part of the radiation of the major piston, introducing the severe anti-resonant point, as shown in Fig. 4.

In order to overcome this condition, the viscous damping is applied to the edge section as shown. This viscous damping acts as a means of limiting the free excursion of the edge of the speaker cone and smooths out this undesirable mid-range anti-resonance effect.

5. Harmonic Distortion

One of the most common types of distortion encountered in loudspeakers is harmonic distortion. The extent of the distortion will be determined by the excursion of the voice coil in and out of the linear portions of the magnetic field in which it vibrates and by the excursions of the diaphragm edge suspension being driven into areas of non-linearity.

Fig. 5 gives some indication of how the harmonic distortion varies with the power fed to the loudspeaker. The diaphragm moves most at high power and low frequencies; so a combination of these two conditions will produce the highest harmonic distortion.

Fig. 5A indicates that where the motion of the cone is very small, the coil rides in a uniform gap flux and, therefore, there is no excursion into areas of magnetic non-linearity. Where the voice coil rides in and out of the gap into fields of non-uniform flux (Fig. 5B), there will be "flat-topping" or distortion. Physical examination of speakers in which this type of distortion has been reduced to a practical minimum will show that when the loudspeaker is not moving there is actually some portion of the voice coil visible outside of the magnetic gap so that when the coil moves over its expected excursions there will be a constant number of turns of the voice coil within the effective linear portion of the magnetic field. Another alternative is the use of a longer gap and a shorter voice coil so that the coil remains in the uniform flux field produced by the speaker magnet at all times.

6. Efficiency

The foregoing discussion leads to consideration of matters of efficiency, for if a good part of the voice coil is outside of the gap, then it is relatively inefficient.

Fig. 6 indicates the general efficiency curve of direct-radiator loudspeakers. The high-efficiency speaker is one wherein there is near-perfect coupling between the voice coil and the gap energy, with the voice coil almost exactly the dimensions of the gap itself, so that as it moves in and out of the gap only a small bit of coil leaves the gap. But in view of the fact that the near fringing effects of the flux are almost as dense as the direct flux immediately at the gap, no appreciable amount of non-linearity is introduced.

If this voice coil were to be overdriven, however, part of the coil would be out of the gap and "flat-topping" would ensue. Coils have been designed to considerably overlap constant flux area, under which conditions the same proportion of the coil will always remain within the gap so that there will be a uniform push or pull on the coil for its normal excursion. However, one of the side effects is that since the power is put into the ends of the coil as well as the middle, but the ends never really see any flux field to which they may react, motion is not produced. This is wasted energy and gives rise to the designation "low efficiency."

It should not be inferred, however, that a low-efficiency speaker is a poor one. On the contrary, low-efficiency speakers can provide excellent low-frequency reproduction, but at a lower level than high-efficiency units for given power input. While low-efficiency drivers may be used as woofer components, high-efficiency structures are universally used where high frequencies are to be reproduced and where the motion of the diaphragm is imperceptible. In such a case, any attempt to provide other than optimum coupling between the coil and the gap would result in a serious loss of high frequencies. Therefore, in the case of the single "wide-range" speaker, the design engineer must strike a balance between the low-frequency area in which the speaker is to be used (and which determines the degree of coil overlap) and the high-frequency area which requires optimum coupling between coil and gap.

An overhanging coil, such as that found in low-frequency speakers, does not make a good wide-range single speaker for wide-range systems, and the design engineer is faced with the problem of compromising in terms of efficiency and smoothness of response over the entire range.

7. Multi-Component Systems

By dividing reproducing equipment into at least two component parts, the bass woofer and the treble tweeter section, the design engineer finds it possible to put into practice the desirable features of specialized low- and high-frequency designs without compromising the performance of either.

Fig. 7 shows the response curve that might be expected from such a two-way system. It is not possible to indiscriminately choose a tweeter and then a woofer, put them together, and hope for the best. For smoothness of the over-all curve they must be balanced in terms of efficiency and response at the crossover point. If the efficiency of the tweeter and woofer were not matched, then there would be an imbalance in the character of the sound produced by the speaker; on the one hand sounding dull and muddy and lacking brilliance, on the other hand sounding strident and harsh without good solid bottom bass.

There are several different types of tweeters from which the design engineer may choose. One is the very popular cone-type tweeter which is, in all aspects, a small cone speaker, very much like any other paper type of reproducer except that it has been designed specifically for high frequencies.

There are other types of tweeters, such as the phenolic-dome tweeters. These can be recognized by the fact that the acoustic reproducing area is not the usual black paper diaphragm but is, characteristically, of amber colored phenolic material. In some instances the phenolic dome is entirely a free radiating surface; in others, it has a frequency extending device near its face. Tweeters of this nature have relatively high efficiency and extremely wide-angle response. The comparatively small high-frequency dome or diaphragm acts as a pinpoint source and produces broader spatial radiation.

In woofer-tweeter designs, the loudspeaker engineer can now equalize high-frequency and low-frequency reproduction without sacrificing any response at either end. He can also improve the wide-angle response of the system by proper choice of the tweeter size.

Another type of tweeter which can be used is the compression-driver horn-loaded tweeter, as shown in Fig. 7C. In this case, a compression driver (with a phenolic diaphragm) which is put into a compression chamber and front-horn-loaded, provides extremely high efficiency compared to direct radiators. This technique is used primarily with speakers or systems of exceptionally high efficiency. Furthermore, with these horn-loaded speakers, the design engineer finds it possible to contour the sound dispersion by shaping the mouth of the horn. By using either wide-angle horns or diffractive-type horns, it is possible to spread high-frequency sounds out over a broad area, thus eliminating spatial faults in the distribution of sound.

Such a dual-speaker system may be able to eliminate a great deal of the distortion that would otherwise be produced in a single-speaker system. By divorcing the high-frequency diaphragm from the motions of the low-frequency diaphragm, it is possible to completely eliminate intermodulation distortion between the woofer and the tweeter.

By means of a dual-, or even three-way, system, the design engineer may gain several important benefits: 1. a more extended frequency range; 2. cleaner response within the frequency range; and 3. better frequency distribution into the listening space in which the speaker is to be used.

8. Crossover Networks

Multi-speaker systems require "frequency-policing" devices, usually known as crossover networks, whose internal circuitry is indicated in Fig. 8. The two reactive elements, the choke and the capacitor, serve very important purposes. The choke prevents high-frequency power from being wasted in the woofer, and the capacitor keeps low-frequency power from being transmitted to the tweeter—with perhaps disastrous results.

Fig. 8B shows how program power is distributed over the audible frequency spectrum; with most of the power in the low frequencies. This is one of the important reasons for making the tweeter as efficient as possible and also for keeping the highs from being lost in the woofer through the use of a series choke. However, we cannot use any choke or capacitor indiscriminately in a crossover network. The roll-off characteristics, *i.e.*, the rate at which the high frequencies are rolled off by the choke and the low frequencies by the capacitor, must be such that they cross over in approximately that area where the curves are 3-db down from their flat, or half-power points. The design engineer must be very accurate in coordinating the rate of roll-off of the speaker and its roll-off characteristics at the desired crossover point in order to give a smooth curve resulting from the combining of the woofer and tweeter characteristics.

9. Transient Response & Electrical Damping

Fig. 9 shows another important characteristic of loudspeaker design, namely transient response—the ability of a speaker to faithfully respond to suddenly applied signals and to cleanly and quickly come to a stop when the signal stops. The curves of Fig. 9 show a typical sharp signal tone burst, with the accompanying response of the loudspeaker in which the transient characteristic is not of the best. There is an overswing on the start of the tone and a trailing decay towards the end. This lack of good transient response causes muddiness of tone, especially for percussive tones, and a blurring of notes in rapid passages.

Good transient response of a loudspeaker can be a function of its magnet weight or, more precisely, the flux in the gap. When a speaker cone and voice coil have been put into motion by means of a signal, it is, for all practical purposes, an electric motor. In fact, the moving system of a speaker is often referred to as a "loudspeaker motor." As in all electrically energized components where there is moving copper in a magnetic field, there is a back e.m.f. which tends to oppose the force causing the initial action.

In the case of the loudspeaker, if a signal impulse starts the system moving, it will continue to move forward of its

own free will unless it is subjected to some braking force. This braking force is the degree of back e.m.f. generated. If the magnet structure is weak, the reaction will be weak and the diaphragm will continue forward in an unrestrained overshoot condition (except for the restraint of its limiting compliance). If the magnetic strength is great, there will be a strong reaction to the driving signal and it will surge forward only to the extent that the signal tells it to, without any override due to its own free, undamped motion. A well-damped speaker will thus give good transient response (for both attack and decay times) and good damping may be obtained by heavy magnet structures and dense flux fields in the voice-coil gap.

It is usually possible to see the magnet size in most loudspeakers. However, many excellent speakers have protective covers hiding their magnet structures. On the other hand, some very inexpensive speakers have rather large covers in order to make them appear as though heavy magnets have been included in their designs.

10. The Enclosure

With the exception of one or two specialized types of speakers, all such units need to be enclosed in some sort of baffle or cabinet. This is especially true of the woofer and, in this context, a baffle is not just a decorative box for the mounting of the loudspeakers. It is a device that performs two distinct technical functions: it is a frequency-controlling device and it is an acoustic-damping device.

Fig. 10 illustrates this dual-control action of bass-reflex types of enclosures. The damping characteristic may be readily seen. The large resonant peak of the speaker disappears (or is damped out) when the speaker is put into an enclosure *designed for it*. In place of this one resonant peak two much smaller peaks are produced. With each peak displaced approximately an octave on either side of the initial resonance peak, the low-frequency response of the *system* is extended.

We must emphasize the *system* because the enclosure is truly an acoustic network which must be designed to match the driver energizing it. The indiscriminate mounting of a speaker in a box is not necessarily a matched system; more often it is merely a "boom in a box."

The loudspeaker design engineer, having gone to great pains to build into his speaker the properties outlined here, seriously takes to heart the necessity of topping off his project properly. His enclosure will not be a "box," but will be as truly an acoustic component as the speaker itself—and will be the last step in the design of a *quality hi-fi system*. ▲

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CIRCLE NO. 170 ON READER SERVICE PAGE

JOHN FRYE

More rapid and accurate diagnosis of heart sounds is now possible with the use of a number of electronic devices.

COMPUTER ANALYSIS OF HEART SOUNDS

REDHEADED Barney was pestering Matilda, the office girl, in the reception portion of Mac's Service Shop when the shop owner called from the service department at the rear: "Hey, Barn, you wanta hear the most interesting sound in the world?"

"I'll bet you've rigged up a satellite receiver!" Barney guessed.

"Charles Lamb said the most interesting sound in all the world was a knock at the door," Matilda offered, tagging along behind Barney into the service area.

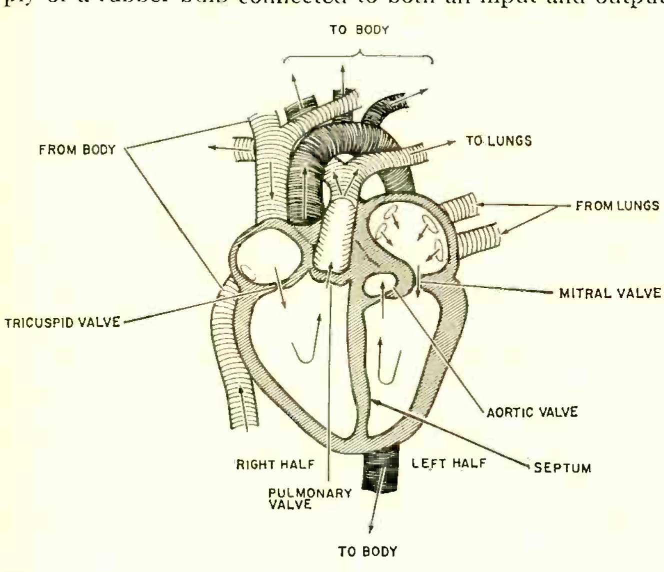
"You're both wrong," Mac said. "Here, Red, unbutton your shirt and place the front of this special contact microphone against your chest a little left of center."

As Barney obeyed, handling the sensitive microphone produced a great rustling and thumping from the bass-reflex speaker cabinet resting on the bench beside the hi-fi amplifier to which the half-dollar-sized microphone was connected; but this ceased when the mike was in place, and a muffled, rhythmic "lubb-dup, lubb-dub, lubb-dup" sound filled the room.

"That's the original *This Is Your Life* program we're hearing," Mac said, "for when the sound of your beating heart finally stops, the remainder of your life is measured in seconds. Recognition of the importance of this sound was given last November when *Western Union* chose the heartbeats of a mother and her unborn child to be among the first sounds transmitted over its new $80,000,000 transcontinental microwave system from Los Angeles to New York. You agree that sound we're hearing is important—to you at least?"

"Man, you know it!" Barney exclaimed, listening in fascination. "How does the heart make that noise?"

"Actually the heart is a double hydraulic pump operating on the principle of that gasoline-siphoning device known jokingly as a 'hillbilly credit card.' The gadget consists simply of a rubber bulb connected to both an input and output hose with a pressure-operated valve in each hose. When the squeezed bulb is released, the resulting vacuum opens the valve in the input hose and sucks gasoline from the tank. Squeezing the bulb produces pressure that closes the input hose valve and opens the valve in the output hose through which gasoline is expelled.



"Think of veins as input hoses and arteries as output hoses, and remember the heart has built-in muscles to do its own squeezing as we follow the flow of blood through this drawing of a human heart," Mac suggested, pointing to a drawing on the bench. "The heart is a little larger than your fist, and the septum partitions it into two separate parts. The right portion of the pump circulates blood through the lungs; the left portion, through the remainder of the body. Notice each pump-half is double-chambered. Blood from the great vein returning from the body enters the right 'receiving chamber,' or auricle, and passes through the tricuspid valve into the expanding right 'pumping chamber,' or ventricle. When the walls of this ventricle contract, pressure exerted on the enclosed blood closes the flapper-type tricuspid valve and forces open the pulmonary valve so blood can flow into the pulmonary artery and thence to the lungs.

"Oxygenated blood returning from the lungs flows into the left auricle and thence through the mitral valve into the left ventricle. The same muscular contraction that forces blood into the pulmonary arteries pushes the mitral valve shut and opens the aortic valve so the left ventricle can pump blood into the aorta and thence to the body. As pressure inside the ventricles starts to fall at the end of the pulse, back-pressure from the distended arteries snaps shut the pulmonary and aortic valves. When ventricular pressure falls still lower, the tricuspid and mitral valves open, and the cycle is ready to start again.

"The first 'lubb' sound results from the contraction of the ventricles, tension of the auriculo-ventricular valves, and the impact of the heart against the chest wall. This prolonged, dull sound coincides with the carotid or neck-artery pulse. After this first sound there is a short pause, and then the second sound, the short, high-pitched 'dup,' is heard. It results from the closure of the aortic and pulmonary valves. In a twenty-four hour period the heart of a normal man will repeat this operation 100,000 times, and the left ventricle will expel more than 80 barrels of blood against a pressure of 120 mm. of mercury. In an athlete, violent exercise can triple this rate of pumping.

"Doctors call eavesdropping on internal organs 'auscultation,' and in the beginning this was done by placing the ear directly against the body. In 1819, however, auscultation became a scientific method with the invention of the stethoscope by a French physician named Rene Laennec. I've heard or read three different versions, all interesting, of his discovery:

"The first story goes that he was making a house call when he saw some children playing beside a wooden beam. All but one placed their ears alongside one end of the beam while the remaining child scratched a pin across the other

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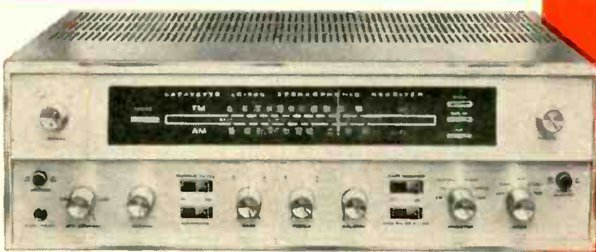

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end. Each time he scratched the surface of the timber his companions shouted to prove they heard the faint sound. Arriving at his patient's bedside, Laennec rolled a piece of paper into a tube and placed one end against the patient's chest while he listened at the other end. He was delighted to discover he could hear the beating of the heart clearly.

"The second version is that the doctor was a bashful man who was distressed at having to place his head against the bosom of a female patient to listen to her heart, and he invented the stethoscope to relieve his embarrassment. The third story says the doctor was working in a Paris hospital receiving many indigent patients who were dirty and infested with vermin. He disliked having to listen to the chests of these patients for fear of acquiring some of their fellow travellers by the contact; so he invented his ear-extension and solved his problem. Believe whichever story you like according to whether your credulity inclines more to the practical, the romantic, or the pediculous!"

"Well, I still have to see my first bashful doctor," Matilda observed; "and please shut off that sound. It makes me nervous. It's a little *too* vital, if you know what I mean. What does a doctor listen for, anyway?"

"He listens for any sound indicating mechanical defects in the pump. Heart 'murmurs' are one of the most significant and may indicate defective valves or lesions in various septa between the right and left chambers. Hissing or gurgling sounds indicate valves aren't opening sufficiently, called *stenosis*, or closing properly, called *insufficiency*. Also, a hole in the septum will produce an audible shunting path for blood flow. Most murmurs occur between the first and second heart sounds when ventricular pressure is highest and are called 'systolic'; but they can occur after the second heart sound and then are termed 'diastolic.' These heart murmur sounds are relatively high-pitched compared to the low-frequency 'lubb-dup' sound and are not heard in the operation of a normal heart."

"Tell me, Doc: where did you dig up all this?" Barney asked curiously; "and why?"

"I became interested about five years ago when I ran across a paper written by J. J. Hofler and Dr. D. S. Gerbarg of the *IBM* Engineering Laboratory at Kingston, N. Y. describing a new technique they termed 'quantitative analysis of heart sound.' First they recorded heart sounds on a *Cambridge* phono-cardiographic disc record. This recording was transferred to tape, and a selected portion was normalized and fed into an analog-to-digital converter where the sound amplitude at each of 8000 sample points per second was translated to a 6-bit binary number in the range

000 000 to 111 111. This digital information could then be fed into a high-speed *IBM* 704 computer whose memory had been stored with information from normal heart sounds and from a tape library of sounds from proven heart-disease patients collected by a Dr. Butterworth. In the computer, data from the heart sound being investigated would be compared with data in the memory bank, and pattern-recognition would indicate any abnormality and—hopefully—diagnose the heart defect.

"I became busy with other things and forgot about this until quite recently when I learned that a new two-pronged attack on the same basic problem had been launched at the Bio-Medical Engineering Center on the campus of Northwestern University under the direction of Dr. John E. Jacobs. There, two projects underway are aimed at a common goal: computerizing the diagnosing of heart ailments.

"In the first project, a graduate student working for his Master's degree has already designed a small computer for distinguishing between normal and abnormal heart sounds, and this instrument is being prepared for field testing. In designing the computer, the fact was recognized that in a normal heart, for the most part, very little if any sound exists in the interval between the first and second heart sound, and then from the second back to the first. The computer is designed to sample the time interval between the first and second heart sounds and to discover if there is any sound in this region. If so, it attempts to classify the type of heart defect based on the number of zero crosses per unit time within the interval."

"What are 'zero crosses'?" Barney asked.

"A zero-cross detector is a form of Schmitt trigger that registers the number of times a signal passes through a reference voltage level. Since a normal heart has no high-frequency components in its sound, the number of zero crossings will be small. Abnormal hearts, though, are rich in high frequency and produce a significantly large number of zero crossings. While this technique sounds simple, it works because the cardiovascular sound-analysis problem is a rather specialized one that lends itself well to such an approach."

"What's the other project? You said there were two," Barney remarked.

"Dr. Jacobs believes heart defects have characteristic sound spectra, and that if these spectra can be positively identified, computers can be programmed to automate diagnosis. Along this line, a Northwestern student at the Ph.D. level in hydraulics is investigating sounds generated at the orifices of the heart, a field not previously investigated extensively. If he is successful in separating and tagging various heart defect sounds, results from the two projects may be combined in a truly automatic heart-diagnosing instrument. At the present time, all methods of heart diagnosis still depend, in part, on the physician's visual or audio diagnosis."

"That certainly would be wonderful," Matilda mused. "It would probably be much faster and more accurate than present methods."

"Possibly the most important use would be in what is called the 'mass-survey technique' used now in making chest x-rays for tuberculosis and lung-cancer detection. In a recent survey approximately 30,000 heart sounds of children were recorded on tape and played back for doctors to analyze. A doctor required 75 minutes to analyze 140 hearts. If 26,000 of the hearts were murmur-free, time spent listening to them would be wasted. A portable detector that could rapidly sort out the questionable or borderline cases would save a great deal of time. Even if it couldn't analyze heart sounds rigorously for exactness and degree of murmur, these cases could then be referred to a physician."

"Well," Barney remarked as he pressed the microphone against his chest again and started the rhythmic "lubb-dup, lubb-dup" sound in the speaker, "it makes me feel sort of good to know I'm in a field, although pretty far down the ladder, that may soon be spotting heart defects in little kids in time to correct the defects and let the children lead normal lives." ▲

MICROELECTRONICS LECTURES

IEEE is sponsoring four outstanding lectures on "Microelectronics" which the Chicago Section will host at Chicago's Lane Technical High School.

The four lectures on four successive Monday nights in April will start at 7:30 p.m. Price for the entire series is $6.00. Tickets are available from IEEE Microelectronics, Box 25, Orland Park, Illinois.

The April 5th lecture will be "An Introduction to Modern Microelectronic Circuits" presented by Dr. Richard E. Lee, President of Siliconix, Inc.

On April 12, Mr. C. Harry Knowles, General Manager, Molecular Electronic Division, Westinghouse, will talk on "The Manufacture of Integrated Circuits."

"Choosing Between Conventional and Microelectronic Circuits" will be the topic on April 19th, presented by Dr. Arthur Lessor, Manager of Thin Film Electronics, International Business Machines.

The final lecture, on April 26th, will be presented by Mr. Stephen Levy, Product Manager for Integrated Circuits, Motorola Inc. His topic will be "Procedures for Converting Circuits to Microelectronics."

The committee in charge of this lecture series anticipates a turn out of more than 1000 engineers. For this reason, the earliest possible reservations should be made to insure a seat at what promises to be an impressive survey of the entire field of microelectronics. ▲

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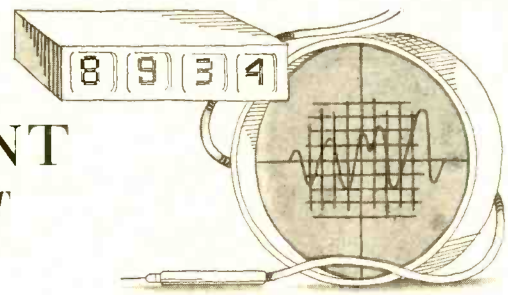


Jerrold Model 890 Sweep Generator

For copy of manufacturer's brochure, circle No. 58 on coupon (page 88).

THE new *Jerrold* Model 890 is a wide-band sweep generator designed for production-line and laboratory use. Operating in the h.f., v.h.f., and u.h.f. ranges, it supplies a sweep signal with its center at any frequency from 500 kc. to 1000 mc. Sweep widths may be as narrow as 100 kc. or as wide as 200 mc.

Using the 890, the entire response of any electronic unit, circuit, or component can be observed on an oscilloscope. Portions of response as narrow as 500 kc. can be isolated for detailed examination. With the 890 and an r.f. switcher in a measurement-by-comparison set-up, measurements of gain, loss, and v.s.w.r. can be made quickly and accurately (see scope-trace photo).

A sweep oscillator using a type 5675 pencil triode is the heart of the instrument. The center frequency on u.h.f. is varied by moving a short-circuiting plunger, which varies the length and therefore the inductance of an air-dielectric coaxial line.

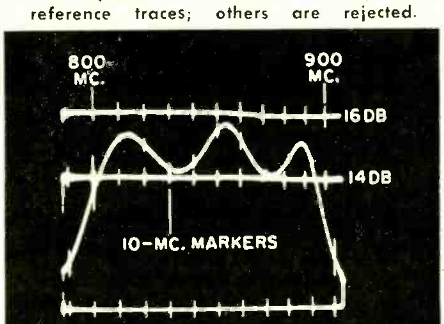
Matched crystal diodes feeding a two-stage push-pull automatic-level-control amplifier maintain output flat ±0.5 db up to 800 mc. and ±1.5 db from 800 mc. to 1200 mc., at maximum sweep width.

To provide the v.h.f. range, the unit uses a fixed 600-mc. oscillator employing another 5675 pencil triode. A crystal diode mixer combines the 600-mc. signal with the u.h.f. oscillator output. The difference frequency can vary between 500 kc. and 450 mc. This signal is carefully filtered and sent to the v.h.f. output connector.

Wobbulator drive is achieved by capacitor plates connected to the coax inductor and mounted on a voice-coil-driven loudspeaker mechanism. When the 60-cps voice-coil drive voltage is varied, the amplitude of plate motion varies, providing oscillator frequencies over a very wide range—more than 1000 to 1.

Either the forward or the return trace can be eliminated by a blanking pulse. The horizontal deflection voltage (60-cps sine wave) is applied through an

Scope trace showing response of a u.h.f. amplifier using the sweep generator and an r.f. switcher. The production-line tester passes units if their 806- to 890-mc. response falls within the two preset reference traces; others are rejected.



isolating *RC* network to a cathode-coupled driven multivibrator to provide this pulse. The constants of the multivibrator are chosen to produce a 60-cps square wave. For those applications requiring a continuous sweep r.f. output, the blanking pulse can be disabled.

Inputs for marker signals from one or two marker generators are provided on the front panel of the instrument. This facilitates frequency calibration of the response curves obtained.

The instrument is quite ruggedly constructed. All parts of the sweep oscillator are machined from silver-plated brass stock, and the slider moves in a rhodium-plated tube. Shock mounts prevent transmission of external shock to the sweep mechanism, as well as mechanical hum from the generator onto the test bench. Removed from the cabinet, the unit can easily be mounted on a 19-inch standard rack. The generator sells for $845. ▲

RCA WV-38A Volt-Ohm-Milliammeter

For copy of manufacturer's brochure, circle No. 59 *on coupon* (*page* 17).

VOLT-ohm-milliammeters are available today in bewildering varieties of types and prices, and the factors important in selecting a v.o.m. are too numerous for discussion here. But the intended applications for the v.o.m. should narrow the purchaser's field of choice considerably and enable him to select the best instrument for his needs.

Design of the *RCA* WV-38A v.o.m. is oriented toward general electronics servicing, including troubleshooting in transistorized and electron-tube radios, TV receivers, and industrial equipment. Furnished with a large 5-inch meter, the WV-38A can be used to measure resistance, a.c. and d.c. voltage, direct current, and audio signals in decibel units.

Two features should be of special interest to those who service transistorized equipment: low, full-scale, d.c.-voltage ranges of 0.25 and 1 volt, and a front-panel switch for reversing polarity of the test leads on both d.c.-voltage and resistance measurements. This latter feature is convenient when resistance measurements are made in semiconductor circuits, which can have different resistances in different directions. The two low-voltage ranges are likewise helpful in these circuits, which often operate well below 1 volt.

Such low-voltage readings are made possible by use of a high-sensitivity meter requiring only 50 microamperes for full-scale deflection. With the WV-38A, direct current as low as 1 microampere (lowest scale division) can be measured.

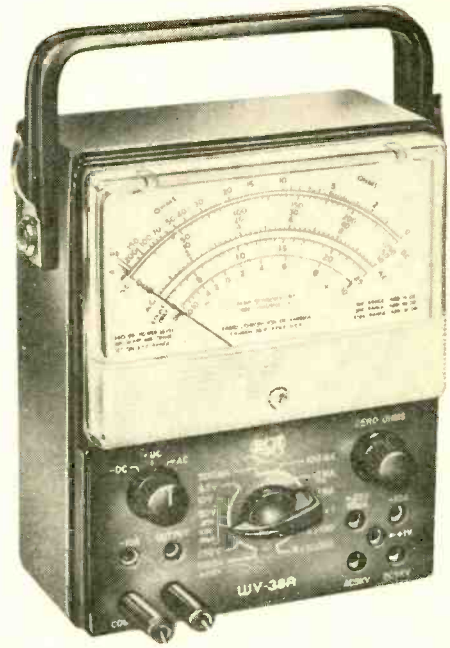
The WV-38A has three resistance ranges and can measure as high as 20 megohms (highest scale division). Eight d.c.-voltage ranges are provided, with full-scale values from 0.25 volt to 5 kilovolts. With a basic resistance of 20,000 ohms per volt, the WV-38A has a d.c. input resistance of 20 megohms on its 1000-volt range and 5 megohms on its 250-volt range.

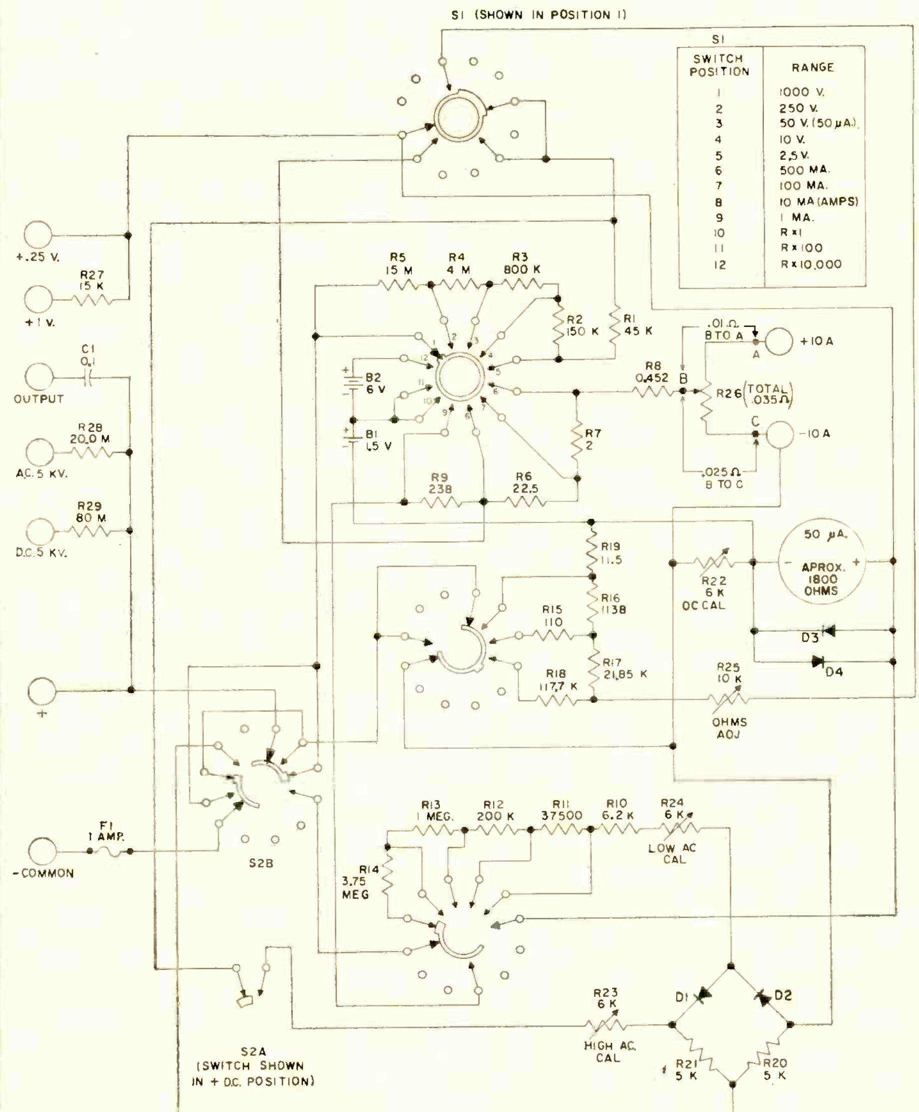
A.c. voltages from 2.5 to 5000 volts (full-scale values) can be measured in six ranges. Six direct-current ranges provide for measurements from 50 microamperes to 10 amperes (full scale). Audio signals from 2.5 to 250 volts and decibel levels from −20 to +50 db can also be measured.

Accuracy is more than adequate for general service and industrial maintenance. The WV-38A has a full-scale accuracy of ±3% on d.c. volts and direct current and ±5% on a.c. volts. Resistors of ±1% tolerance are used in all critical measurement circuits.

The meter circuit for a.c. volts, d.c. volts, and direct current consists of calibrating potentiometer *R*22 connected in series with the meter. The eight ranges of the d.c.-volts circuit are obtained by adding successively higher values of resistors in series with the meter circuit.

Diodes *D*1 and *D*2, along with *R*20 and *R*21, form a full-wave rectifier (half-bridge) circuit and convert the a.c. input signal into pulsating d.c. voltage. Resistors *R*10 through *R*14, plus resistor *R*28, comprise the a.c. voltage-divider





network. *R24* is a calibrating potentiometer for the low a.c. ranges. *R23* is used for calibration on the higher ranges. Direct-current ranges are obtained by switching the appropriate shunt across the meter circuit.

On resistance measurements, the ohms control, *R25*, is connected in series with the meter and is used for calibrating or "zeroing" each range. On the R×1 and R×10 ranges, one 1.5-volt D cell is connected in the circuit. On the R×10,000 range, the four 1.5-volt penlight cells are added, resulting in a test voltage of 7.5 volts.

V.o.m.'s have been with us since the earliest days of radio, and innovations have been few. One of the most recent, however, has been the use of a silicon diode across the meter terminals to eliminate overload burnout. When excessive voltage appears across the meter, the diode conducts and acts as a short circuit. The WV-38A is equipped with two silicon diodes to provide protection from overloads of either polarity. The ohms circuit is separately fused to protect the precision resistors from excessive overload.

Several minor features of this v.o.m. should prove helpful to the user. Color coding of the front panel and the meter scales simplifies operation; all jacks are recessed to reduce shock hazard, two handle clips provide for test-lead storage, and a keyhole slot is provided in the rear of the case for hanging the instrument on the bench or wall.

Internal layout is neat and efficient. Nearly all parts are mounted on a single printed-wiring board. Symbol numbers are printed adjacent to their corresponding parts, a convenient feature for kit-builder or troubleshooter.

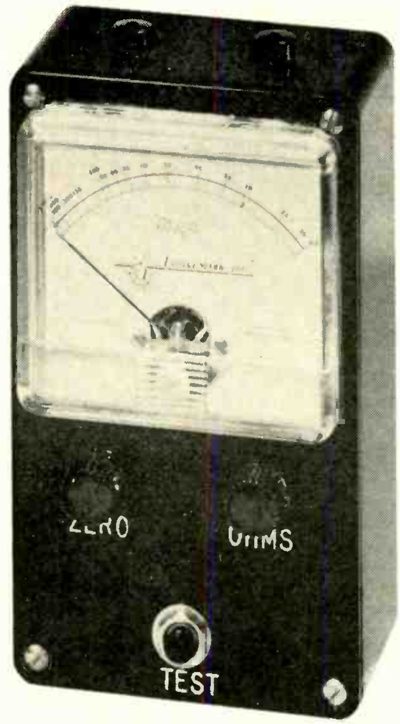
The instrument is available in kit form at $29.45 or factory-wired at $43.95. ▲

Instrumark "Megit" Megohmmeter

For copy of manufacturer's brochure, circle No. 60 on coupon (page 88).

THE need for a portable, accurate means of testing electronic and electrical equipment for insulation resistance has been with us for some time. For many years, manual and motor-driven, generator-type, high-voltage insulation testers have been available. These rather bulky instruments, as well as their less bulky but heavier battery-operated counterparts, are convenient for use on easily accessible equipment. They are inconvenient to use in the field, especially for remotely located equipment.

The compact, lightweight megohmmeter shown here was designed to fill the gap between the frequently used standard v.o.m. ohmmeter and the high-voltage megohmmeter previously available. This instrument, known as the "Megit" and marketed by *Instrumark, Inc.*, has a



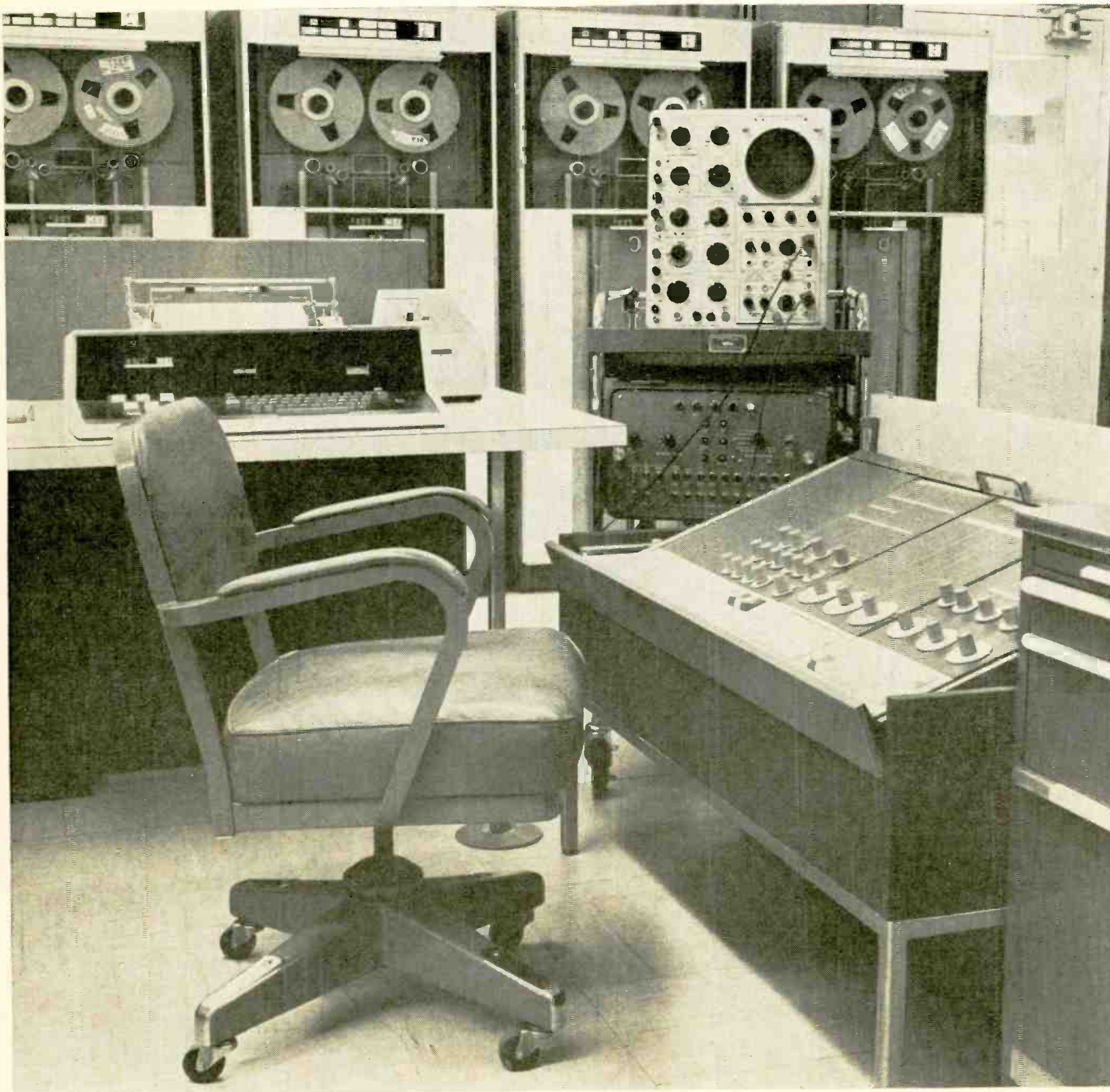
3-inch direct-reading meter graduated to 1500 megohms with an applied potential of 500 volts.

The high-impact, non-conducting phenolic case houses an all-transistorized circuit. This includes an oscillator, powered by a 30-volt and a 1½-volt penlight battery, feeding a d.c.-voltage tripler circuit through a miniature transformer, the primary of which is a part of the tuned oscillator circuit. The 500-volt output from the tripler is applied to the unit under test through a one-megohm resistor. The resistor prevents shocks to personnel. The meter circuit that is employed in the instrument is a typical v.t.v.m. circuit.

It is generally desirable to keep graphs on various pieces of equipment, charting their insulation resistance over a period of time. Normally, as insulation ages there is a gradual decrease in insulation resistance over a period of years. A sudden, large decrease in resistance is a warning that insulation is about to fail.

In using the unit to check insulation resistance of a motor, for example, the test leads are connected between a motor lead and ground, the operate button is pressed, and the insulation resistance is read directly from the meter scale. For equipment designed to operate at 440 volts or lower, a reading of 200 megohms or higher would be expected, although on 110-volt motors a 100-megohm reading is not a cause for alarm. Transformers should be tested by connecting the megohmmeter leads between each winding and every other winding, as well as from each winding to ground. Of course, these measurements should always be made with the power off.

The "Megit" weighs less than 2 lbs., measures about 6"x2"x4", and is priced just under $90. ▲



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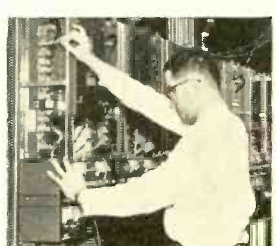

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1965 NATIONAL ELECTRONICS WEEK SET FOR N. Y.

March 31-April 4 conclave replaces Parts Show formerly held in Chicago during May.

IN order to provide the largest possible audience for its forums and exhibits, the Electronic Industry Show Corporation is, this year, running the 1965 National Electronics Week (March 29-April 4), replacing the Parts Show which has traditionally been held in Chicago during the month of May.

By broadening the scope of the show and increasing eligibility, the Show Corporation hopes to make this "the major marketing event in electronics" of the year.

To assure proper atmosphere for conducting business, attendance is limited to qualified electronics industry personnel and buyers of electronic products. Badge categories include: Exhibitor, Distributor, Commercial Sound, Audio/Hi-Fi Specialist, Sales Representative, Advertising Agency, Export Agency, Industrial Account, and Government Personnel.

Admission will be free to eligible personnel who register in advance for badges. This year, all persons obtaining their badges in advance will have access to all exhibit areas at all times the exhibits are open.

There will be two locations for the meeting: The "Sound Theatre" at the Americana Hotel in New York City will feature exhibits of products in the audio, high-fidelity, commercial sound, and analogous categories; and the "Electronic Showcase" in the New York Hilton Hotel, for electronic parts, components and equipment not requiring audible demonstration.

This year the Institute of High Fidelity is cooperating with the sponsors of the Show Corporation in planning educational programs of interest to the audio/hi-fi trade during the "New Business Forum."

The first two days of the show, March 31 and April 1, are allocated for these forums, as well as conventions and meetings.

The last three days, from Friday, April 2nd through Sunday, April 4, will be devoted to the exhibits.

Those interested in attending the National Electronics Week programs and exhibits can secure information on obtaining the proper credentials and details on registration by writing direct to the Electronic Industry Show Corporation, 100 S. Wacker Drive, Chicago, Illinois 60606. ▲

The Electronics Industry

(*Continued from page 28*)

and recommend to the Governor new and promising areas of technological research and to maintain continuous liaison with industrial and university research activities." The Committee has made many recommendations to augment the state's research and technological resources.

Despite generally leveling or lower sales of many defense-aerospace electronics companies in 1964, the U.S. Gross National Product in 1964 rose to a record $624 billion. One of the electronics companies that generally profited despite declining government business and benefited from rising national economy is *International Business Machines*. However, *IBM* is modest about revealing technical manpower statistics.

Although *IBM*'s technical manpower employment was "high" in 1963, in 1964 the company says it employed greater numbers of electronics engineers, scientists, and technicians "than in any previous year." Still no statistics available, yet a "high level of recruiting is expected to be continued in 1965."

While *IBM*'s interests reach from East to West Coasts and around the world, a good part of its American activities centers in New York City, suburban Westchester County, and upstate New York communities, such as Poughkeepsie and Endicott. Other *IBM* East Coast facilities are in Vermont and Maryland. *IBM* holds about 70% of the profitable electronic computer business, which is steadily being nibbled at by East Coast competitors ranging from *Honeywell*'s computer operations in Massachusetts to *RCA*'s computer operations in Florida.

Computer success has brought competitors and profits to *IBM* which gradually has been diversifying into other electronic operations ranging from dictation machines to electronics equipment and components. Currently, the company's major commercial product, introduced in 1964 and to be available in 1965, is the System/360 computer using integrated circuits. *IBM* now mainly seeks specialists in semiconductor, process, integrated circuit, memory, and electrical test equipment engineering. The company's other broad technical manpower needs include design automation engineers and computer programmers as well as aerospace systems specialists in radar, lasers, satellites, avionics, and missile guidance.

New York Area

However, government business was depressed among many contractors in New York—particularly those who were not sufficiently diversified in consumer or industrial markets. Defense cuts slashed deepest out on Long Island, where *Republic Aviation* had recovered from its 1957 defense contract setback, only to be hit again in 1962 through to the present. Professor R. P. Loomba of the Electrical Engineering Department of San Jose State College, California, publicly chastised *Republic* for not giving advance notice to its employees, although it knew a year previously that its F-105D jet fighter-bomber orders would be curtailed. He estimated that "nationally some 20,000 engineers and scientists" were laid off by defense-aerospace contract cuts and cancellations—especially in California. Professor Loomba did not specify types of technical personnel nor source of his statistics, but electronics specialists were hard hit.

Government business also declined for other Long Island firms, ranging from *American Bosch Arma's* Arma Division to *Sperry Gyroscope*. However, Long Island technical manpower found an oasis in *Grumman Aircraft Engineering*. That company has, for a long time, thrived on Navy aircraft contracts, plus NASA's Orbiting Astronomical Observatory: OAO II, and the Lunar Excursion Module (LEM) to land Apollo astronauts on the moon. *Grumman* hired numbers of *Arma* and *Sperry* engineers and technicians, among others, but now seeks specialists in areas including electromagnetic compatibility (formerly called "radio-frequency interference"), reliability, and systems analysis.

A study by Columbia University showed defense-related manufacturing to be 50.1% of all manufacturing employment on Long Island, but only 3.5% in New York City, 4.1% in Westchester County, and about 2% in Rockland County. All of these areas are suburbs of Metropolitan New York whose main attraction is its great numbers of scientists, engineers, and technicians. However, the main drawback is the reluctance of such personnel to leave the area to work elsewhere on the East Coast or in the U.S.

Upstate New York is also an electronics stronghold, particularly with *General Electric's* electrical-electronics interests in Schenectady, Utica, and Syracuse. In Greater Syracuse, for example, *General Electric* is the leading employer with some 15,000 persons, 2000 of whom are graduate engineers in the electrical-electronics fields. Of electronics interest is the Rome Air Development Center at Griffiss Air Force Base, Rome, New York, near Utica.

Operations in New York and New Jersey, as well as California, involved some 4500 scientists, engineers, and technical support personnel working for *General Precision Equipment Corp.* By 1964 this figure had dropped to about 3500, reflecting reduced defense busines. In 1965 *GPE* may keep about the same number of technical people on its payrolls. Employment of scientists and engineers is being stabilized by transferring them from production work into *GPE's* increasing aerospace R&D activities.

The Greater New York-Northern New Jersey area has about 100,000 scientists and engineers, including about 25,000 electrical engineers. To encourage a technological atmosphere that attracts science-based business, New York State recently created the Science and Technology Foundation. It promotes scientific research activities and encourages leading scientific and technological educators to join facilities of state-supported schools, colleges, and universities.

Simmonds Precision Products of New York and Vermont, one of the smaller electronics firms, considered itself "fortunate to be so deeply involved in the space and defense business." From 1962 to 1964 its total engineering department grew from 100 to 175 persons. While *Simmonds* prospered in government defense-aerospace business, other firms did well in government oceanography and anti-submarine-warfare business. *Edo Corp.* of College Point, N.Y., for example, anticipates the highest sales in its 40-year history and increased earnings for the fourth straight year, mainly from anti-submarine-warfare work. *Alpine Geophysical As-*

sociates of Norwood, N.J. also did well, chiefly in the important and growing field of oceanography.

Pennsylvania & New Jersey

Decreased government spending and contract cuts caused *RCA* to lay off about 800 scientists and engineers in the Camden-Moorestown, N.J. area (near Philadelphia) around 1962-1964 and rehire some of these men at its plants elsewhere. However for 1964 *RCA* earned about $80 million on about $1.8 billion in sales, highest in its 45-year history. "Profit rise stemmed from increased commercial sales, which more than offset the continued industry-wide decline in government sales," said *RCA*'s Chairman David Sarnoff.

In 1965 *RCA* expects its sales to rise along with an anticipated 15% industry rise in computer sales and rentals, and industry sales of more than 2 million color-TV sets. *RCA* continues big in defense-aerospace, although its government business declined to 25% of total sales and contributed less than 10% of profits after taxes. Government backlog declined, then leveled off. In nearby Philadelphia, *Leeds and Northup* which specializes in instruments and automatic industrial controls, reported record highs for new orders, shipments, and earnings from capital expansion by mid-1964.

The Philadelphia-Northern New Jersey area is another technical manpower center, with schools and universities including Moore School of the University of Pennsylvania in Philadelphia, Princeton University, and the nearby scientific-industry research complex. There are more than 30,000 scientists and engineers in the Philadelphia area, many of them electrical engineers, putting the area on a par with Boston and San Francisco in technological importance. Philadelphia's military operations include the Navy's Air Development Center, Army Signal Corps procurement operations, and the Federal Aviation Agency's National Aviation

HIRING OF ENGINEERS & TECHNICIANS

Hiring of all types of experienced engineers dropped 11% in 1963, and recruiting totals for 1964 decreased another 11%. In effect, older technical professionals, such as those trained mainly in vacuum-tube and related electronics technology, were among those in lesser demand. Some of these engineers, whose skills became narrowly overspecialized, were being phased-out with certain electronics products and systems.

New graduate hiring dropped only 6%, while 1964 recruiting goals for graduate engineers remained virtually unchanged. Electrical-electronics graduates were apparently more desirable because they had been more broadly educated in the solid-state technologies, among other disciplines.

Largest reductions in demand for engineers were reported by government and industry groups involved in defense-aerospace activities. These included electrical-electronics, instruments, and aerospace companies.

Job opportunities for 1964 engineering graduates were quite bright, despite employment difficulties for experienced engineers including electrical-electronics specialists.

By mid-June, 88% of new graduates had definite commitments to employment, graduate studies, military service, or other plans. Another 10% was considering employment and 2% had neither offers nor plans.

Combined, 21.7% will pursue graduate studies: 5% of these planned to take post-graduate training while employed.

In January 1965, EMC (Engineering Manpower Commission) reported that the "typical engineer's salary rose from $10,375 to $11,325" during 1963 and 1964. The survey covered more than 231,000 degree-holding engineers in all types of business and government.

In 1962 a Federal Government engineer's median salary was $10,700 for 15 years of experience, compared with $12,300 in industry. By 1964, the Government and industry both paid $13,000. Supervisory and managerial engineers generally received higher pay rates than on-line engineers.

Facilities Experimental Center contract branch at nearby Atlantic City, N.J. Some miles to the north is the Army's vital Electronics Command with the Signal R&D Laboratory and procurement and production interests at Fort Monmouth, N.J. New Jersey is also the home of the *Bell Telephone Laboratories*.

South Atlantic States

Electronics companies, divisions, subsidiaries, or representatives are located in Maryland, Virginia, and Delaware close to Washington's legislative and technical research-administrative agencies.

In Baltimore there are big plants of *Westinghouse* and the *Martin Co.*, among others. *Martin*, for example, pioneered in airplanes, then missiles, then broadened its corporate base by joining with the *Marietta Corp.* which has interests in the construction materials business. *Martin Marietta's Aerospace* East Coast activities are in Baltimore and Orlando, Florida. At the end of 1963, its heavily electronics-oriented technical personnel numbered about 8700. In 1964, government billings declined and technical employment fell to about 7300 by year's end. Government business has stabilized and employment of technical manpower may remain fairly constant at *Martin Aerospace* during 1965. Also, Baltimore's science-based industry has been enhanced by activities of the Johns Hopkins Applied Physics Laboratory.

A growing "research triangle" is attracting technical manpower and contracts to the University of North Carolina, Duke University, and North Carolina State College. Both North and South Carolina are priming the pump of Southern industrial development with their technical-training programs. Richland Technical Education Center, at Columbia, S.C., like similar southern schools, trains students without charge in electronics technology, data processing, and other technical disciplines, to serve local electronics and other factories and laboratories.

In 1964 and 1965 there has been an increase in research and development, test and evaluation facilities in the fast-developing "Golden Crescent" around the Gulf of Mexico, from Texas east to Florida. Along the East Coast, Florida alone is represented as part of this complex. Here, NASA's John F. Kennedy Space Center at Cocoa Beach, Florida can be added to other installations such as the Air Force Missile Test Center at Patrick Air Force Base, Cocoa Beach, Florida, and the Air Proving Ground Center at Eglin Air Force Base, Fla.

Some businessmen were attracted to the South by favorable power costs, lower taxes, mild weather requiring lower construction and heating costs, the political appeal of "labor surplus areas" that helps attract defense-aerospace contracts, and the clustering and mushrooming effect that caused countless orange groves in Florida, for example, to be transformed into electronics and laboratory centers.

The latest lure of the South is its build-up as the nation's "Spaceport," in the Cape Kennedy-Cocoa Beach complex.

The Future

In the future, defense-aerospace electronics will experience a shifting, declining, and stabilizing government market. By 1970, profitable defense production may drop about 30%. Funds for R&D, test and evaluation may drop about 15%. NASA's potential 10% aerospace budget increase will fall short of offsetting the difference. These estimates, based on Government statistics, are made by *Arthur D. Little, Inc.*

One government move to ease this situation is the U.S. Arms Control and Disarmament Agency's contract with New York State's Labor Department Employment Division, among others, to study the "impact on the Long Island labor force of defense contract phase-outs." More optimistically, NASA's Electronics Research Center will be built in the Boston, Mass. area for about $50 million and may ultimately employ about 2000 scientists, engineers, and technicians.

Electronics companies are exploring new markets in: automated electronically controlled highways, commercial nuclear energy instruments and controls, water desalinization instruments, education and re-training, urban renewal including high-speed electronic railway controls, improved health and medical care using bio-medical apparatus, air and water pollution control, crime control, computers for process control and general business and scientific applications, including documentation and information retrieval.

Consumer electronics products would benefit from anticipated cuts in Federal excise taxes. And East Coast firms are already dipping deeper into oceanography instrumentation. Atlantic seacoast activities involve Woods Hole Oceanographic Institution in Massachusetts, Columbia and New York Universities in New York, Duke in North Carolina, and the University of Miami in Florida.

Electronics technical personnel, directed by corporate management, must meet the needs of expanding populations and declining Federal budgets. Some companies have achieved "instant growth" by merger or acquisition of other companies. Other firms strive to convert defense-aerospace technology into commercial products. A few firms already have succeeded. The challenges equal the opportunities. ▲

EW Lab Tested

(*Continued from page 22*)

db on low-level inputs, at 1000 cps. Crosstalk from high-level (tuner) inputs to low-level inputs was unmeasurable.

The amplifier performed well, delivering clean, effortless power with sufficient reserve for the least efficient speaker systems. Switching inputs with the volume set fairly high produced thumps from switching transients, so the gain should be kept low when such switching is done. The amplifier tested was an early production model and we have learned that later production models do not have this problem. In all other respects, the operation of the amplifier was faultless.

The price of the *Sherwood* S-9000 is $299.50. ▲

Weathers "Townsend" Turntable/Arm

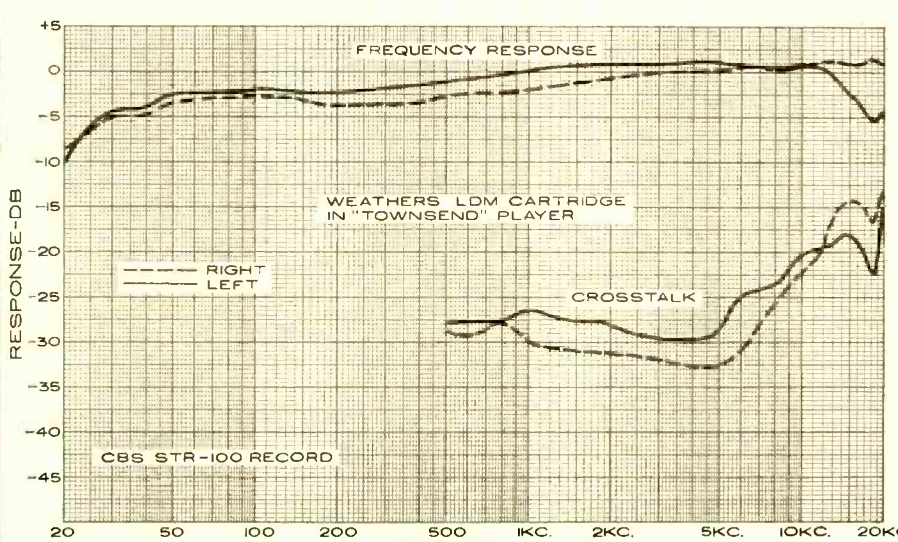
For copy of manufacturer's brochure, circle No. 57 on coupon (page 17).

MANY new record players are being offered in integrated packages, containing an arm and turntable mounted on a base. At most, they require the addition of a cartridge and are then ready to use. The *Weathers* "Townsend" is a low-cost integrated record player with excellent performance, at a price competitive with many low-priced record changers.

The player follows the design of earlier *Weathers* turntables, using a very light aluminum platter driven by a small 600-rpm synchronous motor. The motor resembles an electric clock motor in size and power, but is adequate to drive the low-mass turntable with the fairly low tracking forces required by modern stereo cartridges.

The drive is through a soft rubber wheel on the motor shaft which contacts the inside of the turntable rim. It operates only at 33⅓ rpm. The "on-off" switch mechanically disengages the rubber wheel from the turntable to prevent the formation of "flats."

The turntable and arm are on a rigid plate, suspended from the motorboard on three compliant springs. The resonant frequency of the system is about 5 cps,



making it relatively immune to the effects of jarring and vibration. This makes this player especially suited to use in installations where acoustic feedback is a problem. The arm is the familiar wooden design used by the manufacturer for some time and is made of walnut. It will mount any standard cartridge and has an adjustable counterweight for setting tracking force. The arm handles well and has a well-placed finger lift. The entire player comes on an attractive walnut base. It is available with or without a factory installed *Weathers* LDM ceramic cartridge.

The lateral rumble (unweighted) of the player was −25.5 db, and its vertical rumble was −18.5 db. These were measured in accordance with the NAB standard which does not allow for the fact that the basic rumble frequency is too low to be audible. The 600-rpm motor has a basic frequency of 10 cps so that, in practice, the rumble is quite inaudible.

Wow and flutter were each 0.05%, which is very low. The synchronous motor drives the turntable at exact speed, which is unaffected by stylus drag or by line voltage variations from 70 to 135 volts. Even with the turntable placed directly in front of the speaker, no acoustic feedback could be induced.

The arm design results in low tracking error, less than 0.4 degree per inch of record radius. Any cartridge can be adjusted in the arm for correct overhang, with consequent minimum tracking error.

The unit tested was equipped with an LDM ceramic cartridge. This has a very flat, smooth response, within ±3 db from 30 to 20,000 cps. On the test sample, one channel fell off slightly above 12,000 cps, but not to an audible extent. The stereo separation was about 30 db below 5000 cps, and never less than 17 db up to 18,000 cps. This cartridge, in spite of its low cost, is a very clean, smooth unit which can stand comparison with many cartridges costing several times as much.

The output of the cartridge is about 7 millivolts. Being ceramic, it is not subject to magnetic hum induction, but system grounding is very important if hum from ground loops is to be avoided. A separate ground wire with a clip is part of the system and, when properly used, hum is inaudible. The cartridge tracked well at 3 grams, which is the factory setting.

The turntable has a foam plastic record pad, which tends to lift off the turntable when a record is removed. It should be a simple matter to cement it down and eliminate this minor annoyance.

The *Weathers* "Townsend" sells for $59.95 without a cartridge, and $69.95 with the factory-installed LDM. It is an excellent value and is compatible with any good high-fidelity system. ▲

READER SERVICE PAGE

As a convenience to our readers, we have included two separate reply coupons in this issue which should simplify the process of requesting information on products and services appearing in this issue.

Unfortunately, many companies will not furnish additional information to a home address. Therefore, to assure a reply, make certain that the proper coupon is used.

To get more information, promptly, about products and services mentioned in this issue, simply circle the number corresponding to the ad or editorial mention and send the proper coupon to us. Your request will be sent to the manufacturer immediately.

FOR PROFESSIONAL USE: In requesting information on products and services listed in the coupon below it is necessary to fill out the coupon COMPLETELY, stating your company, address, and your function or title. If the coupon is incomplete it cannot be processed.

FOR GENERAL USE: In requesting information on products and services listed in the coupon on page 17, you may use your home address.

You can use both coupons, since each contains specific items, if each coupon is filled out completely.

See Page 17 for "GENERAL USE" Coupon

Mail to: ELECTRONICS WORLD P. O. BOX 7842, PHILADELPHIA 1, PA.

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(VOID AFTER MAY 31, 1965) 4

NEW PRODUCTS & LITERATURE

Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupons appearing on pages 17 and 88.

COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • HAM • COMMUNICATIONS

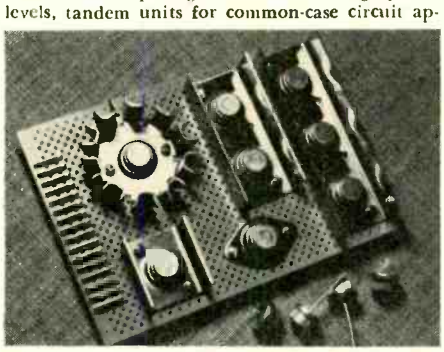
COLOR-TV RESISTOR KIT

1 **Workman Electronic Products, Inc.** is now offering a kit of two resistors, a thermistor and a varistor, designed for use in the degaussing circuits of color-TV sets.

These resistors are used in **RCA, Zenith, Warwick, Magnavox, General Electric, Wells Gardner,** and many other color-TV sets.

RECTIFIER & TRANSISTOR HEAT SINKS

2 **Daedalus Company** is now offering the "700" series of heat sinks for press-fit rectifiers which feature: dimensions suitable for typical circuit-board spacing, medium- to high-power levels, tandem units for common-case circuit applications such as rectifier bridge assemblies, plus easy removal and replacement of the rectifier without damaging the heat sink.



The company is also marketing the "600" series of heat sinks for power transistors. These are being offered in a variety of hole patterns and finishes.

Both types of heat sinks are covered in application notes available from the manufacturer.

LABORATORY POWER SOURCE

3 **Mid-Eastern Electronics, Inc.** is now offering the Model 632 universal laboratory power source which combines adjustable high-power outputs, precision d.c. and a.c. metering, with military quality and low price.

Input is 110-130 volts a.c., 50-400 cps, single-phase. Outputs are 0-14 volts at 0-10 amps a.c. or d.c.; 0-34 volts at 0-5 amps a.c. or d.c., selectable by front-panel switch; and 0-120 volts a.c. at 0-3.5 amps at a rear polarized receptacle. All outputs are isolated from ground and the case for safety. Ripple is less than 1% r.m.s.

There is metering, a.c. and d.c., for both voltage and current. The entire unit is completely protected against overloads and shorts.

UNIVERSAL TRANSDUCER SET

4 **Don Bosco Electronics, Inc.** has introduced the Model PHD-100-A, a compact, multiple-use signal-detection system with specially designed transducer-accessories and high-gain (1000×) self-contained pen-size signal tracer.

The unit can be used in the fields of electronics, mechanics, electro-mechanics, acoustics, vibration, magnetic recording, and r.f. communications. The unit can also be used as an oscilloscope or voltmeter preamp, thereby increasing the range of these instruments.

The transducer set is supplied with the company's "Stethotracer" and its three interchangeable attenuator tips, one r.f. detector crystal diode, ground clip lead, and battery. Included among the transducer-accessories are: inductive detector, miniature magnetic microphone, vibration pickup, tape head, photovoltaic detector, output adapter, input adapter, and BNC connector adapter.

The set is housed in a fitted case measuring 10¾"x 7¼"x 1½".

COLOR-CODED TERMINALS

5 **Zierick Manufacturing Corporation** is now offering a new line of insulated solderless terminals which features color-coding for easy wire-size identification. Insulation sleeve i.d.'s match the wire sizes established for the basic non-insulated parts, and the insulation is color-coded for quick identification of the desired size during assembly.

Made of pure electrolytic copper with heavy cadmium plating, the solderless terminals have a chromate finish to resist corrosion and prevent shelf deterioration. They have full quarter-inch barrels, beveled ends for easy wire threading, and improved gripping "V" ridges for wire protection.

SOLDERING-IRON CADDY

6 **Dania Electronics** is now offering the "Simpson" soldering-iron caddy which eliminates dangling service cords, broken soldering irons, and burned articles on the bench. The unit provides a safe a.c. outlet and soldering-iron holder for the work bench or production line.

With the caddy, service cords can be shortened so that they do not drape across the bench. A holder is provided for both gun and pencil-type irons. One of the upright outlets is equipped with a switch and pilot light at the base. The flexible arms provide ample range and the spring-held iron holders are pressure adjustable to any height or position. The base outlets are polarized and a 3-wire grounded outlet is also provided.

SOLID-STATE DIGITAL V.O.M.

7 **The Roback Corporation** has announced a new all-solid-state 3-digit digital volt-ohmmeter which is being marketed as the Model 33 "Reporter." The unit provides voltage accuracies of ±0.1% and resistance accuracies to ±0.5% of full-scale, ±1 count. In addition it uses plug-in cards exclusively and is portable (20 pounds). A non-segmented, in-line, high-intensity digital readout is provided, including display of decimal point to indicate range.

Three voltage ranges and four resistance ranges are accommodated: 10, 100, and 1000 volts and 1000, 10,000, 100,000 ohms, and 1 megohm. Over-range readings up to 10% beyond full scale are provided.

A more sensitive version with a 1-volt range (Model 34 shown) is also available.

HIGH-VELOCITY FAN

8 **McLean Engineering Laboratories** is now offering a two-way, push or pull type "Venturi" fan which can be quickly and easily mounted anywhere on an electronic rack. There are no parts to be assembled, the unit is merely bolted to the rack opening.

The fan is of black anodized aluminum. The motor mount and propeller guards are of heavy gauge wire, lustre-zinc plated. Over-all depth is 3⅞". The motor is a 4-pole shock-mounted, 117-volt, 50-60 cps, single-phase, shaded-pole type. The motor is corrosion resistant and fungus protected.

IN-CIRCUIT CAPACITOR TESTER

9 **B & K Manufacturing Co.** has developed a new capacitor tester that checks capacitors in-circuit.

The Model 801 Capacitor Analyst makes measurements of capacitors, including electrolytics, on a practical basis, picking up all defects that will affect the performance of TV, radio, hi-fi, and other electronic equipment.

Electrolytics up to 2000 μf. can be tested by means of a new circuit using a balanced bridge. It determines how well the electrolytic stores and returns electrical energy. It detects marginal electrolytics that should be replaced, and predicts the life expectancy of any electrolytic rated 3 volts or more.

A unique in-circuit leakage test eliminates the need for disconnecting the capacitor from the circuit to measure actual leakage resistance. Capacitor values can be tested accurately within the range of 25 pf. to 100 μf.

PC ASSEMBLY STAND

10 **Vero Electronics** has developed a new assembly stand which is designed to hold the firm's "Veroboard" or any other printed-circuit boards when assembling or soldering components.

Featuring maximum flexibility in that it can be readily adjusted for any height or working angle convenient to the operator, the stand can be completely turned over for working on the underside without removing the board from the holding arms.

The spring-loaded, insulated Bakelite arms allow circuit testing on the stand and will accommodate any boards up to 12½" long and from 1/32" to ⅛" thick.

ELECTRONIC TRAINING FILMS

11 **Bray Studios Inc.** has announced the availability of three new training films which are being offered on either a purchase or rental basis.

The first film is "The Printed Circuit Story," a color motion picture for engineers, technicians, electronic assembly and service personnel. This 25-minute, 16-mm. sound film was produced in cooperation with the Institute of Printed Circuits. Rental is $20.00 a day.

"Semiconductors" Part 1, presents the basic physics and theory of hole and electron flow as related to the "p-n" junction, as well as basic transistor characteristics and how and why the transistor is an amplifying device. Part 2 reviews electron and hole flow leading to a comparison of transistor and vacuum-tube amplification circuits and presents an analysis of the operation of the common-emitter and common-base circuits. Each of these films rents for $10.00 a day.

Full details on availability of these films, including purchase prices, are available from the producer.

SWEEPING OSCILLATOR

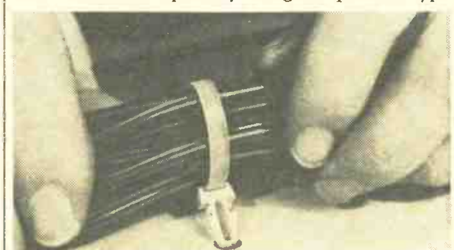
12 **Kay Electric Company** has developed a new series of sweeping oscillators which provide full two-to-one fundamental frequency sweep to display broadband circuits in a single sweep.

Designated the 1400 Series, the new units sweep a full octave anywhere in the 100 to 1000 mc. range; electronically a.g.c.'d flat, and frequency linear. The instruments may also be used as continuously variable (both width and center frequency) narrow-band sweeping oscillators.

A 200-400 mc. model could be utilized to sweep 225-440 mc. receivers. Sweep can be narrowed down for i.f. response. Available on special order are i.f. bands at 20 mc., 60 mc., etc. All units contain crystal-controlled frequency markers, precision attenuators, and remote tuning.

HARNESS TIE/CLAMP

13 **The Thomas & Betts Co.** has introduced a new easy-to-install combination harness tie and clamp, Model TY-38 and TY-38M. The new unit features a specially designed push-in type



mounting device. This permits the "Ty-Rap" strap to be installed around the harness or wire bundle in the conventional manner and installed as a clamp simply by inserting the projecting prongs in a hole and pushing the prongs in. Once installed, the unit holds the harness firmly and securely.

PRECISION VOLTAGE REFERENCE

14 **General Resistance, Inc.** is now offering a new and improved "Dial-A-Volt" which features in-line digital readout and dialable voltage selection.

The new unit permits positive selection of voltages from 10 nanovolts to 10 volts. Stability of ±10 PPM/8 hours or ±25 PPM/year provide an ideal reference source for long- and short-term stability tests of power supplies, temperature-measuring systems, and other d.c. instrumentation.

The possibility of error in reading selected voltages is eliminated by using numeric dial switches. The instrument is being offered in several models with 4, 5, or 6 decades and accuracies of .005% or .01%.

INTEGRATED CONVERTER/ANTENNA

15 **Channel Master Corp.** has recently introduced a new unit that integrates a u.h.f. converter and an 82-channel antenna into a single package.

The "Convertenna" Model 4003 combines the company's VU-82 all-channel indoor antenna with a built-in transistorized u.h.f. converter. It provides reception of v.h.f., u.h.f., black-and-white, color, FM mono, and FM stereo. The antenna section is actually two separate antennas combined into one, each operating independently. A dipole with 96" long non-tarnish elements provides good v.h.f. and FM-stereo performance. A stacked u.h.f. antenna using a Super Turnstile butterfly provides the u.h.f. performance.

SMALL PRECISION PLIERS

16 **S-K Wayne Tools** has added five small precision pliers, measuring just 4½ inches, to its line. The new pliers are designed expressly for accurate and exacting working in all phases of

electronics. All five pliers have polished heads and cushion-grip handles.

The line includes diagonal cutting pliers, end-cutting nippers, chain-nose pliers without cutters, flat-nose pliers without cutters, and round-nose, round-jaw pliers without cutters.

12-VOLT BATTERY CHARGER

17 **Dynamic Instrument Corp.** is now marketing the "Charge 'n Start" which is designed to keep 12-volt automobile batteries fully charged. The unit operates from ordinary household current and requires no installation, clamps, or clips. The charger is simply plugged into an ordinary power line and the charging cord is plugged into the cigarette lighter receptacle of the car.

The safe constant-voltage charging method starts charging the battery at over ½ ampere and automatically tapers down as the battery charges to a safe continuous level that keeps the battery at full charge. The unit cannot overcharge the battery.

DISPOSABLE LEAD HOLDER

18 **Eugene Dietzgen Company** is now offering a new low-cost disposable lead holder containing more than 5 inches of high-quality diamond extruded drafting lead.

The "Keen-Point" disposable lead holders are available in drafting grades HB, F, H, 2H, 3H, 4H, 5H, and 6H as well as in red, blue, green, and yellow colored leads. Lead breakage is held to a minimum due to the built-in shock absorber effect of the unique patented tip.

AUTOMATIC TRANSISTOR TEST SYSTEM

19 **General Applied Science Laboratories, Inc.** is now offering a new automatic switching time-test system for testing and sorting over 3000 transistors per hour to nanosecond switching parameters.

Known as the Model AST-2A, the test system is completely automatic and provides three simultaneous tests such as "turn-on" (rise time, turn-on delay, and turn-on time) or "turn-off" (fall time, storage time, and turn-off time) parameters for each test. The transistors are automatically sorted into bins according to their switching speeds and counters record the number of units in each bin.

The system has two major units—a mechanical handling unit and an instrument rack/cabinet.

VISUAL CONTROL BOARD

20 **Timewise Products, Inc.** is now marketing a new "Change-A-Board," a visual control board which helps reduce paper work and shows facts at a glance. It is suitable for scheduling, shipping, purchasing, sales, inventory, etc. The user writes on the board with special red and black pencils and makes clean erasures with a dry cloth or tissue.

The board is magnetic and urgent items can be spotlighted by bright colored magnets. The board has 16 horizontal lines permanently etched 1" apart. Vertical columns are made with thin black self-adhesive ruling tape supplied. The board measures 25"x 19" with extruded aluminum frame. It weighs 4 pounds and is easily portable.

COMPACT TUBE TESTER

21 **Mercury Electronic Corp.** has added the Model 1101 tube tester to its line of service instruments. The unit will check the quality of the very latest tube types including decals, magnavols, and 7-pin nuvistors. In addition, it tests all the older and presently used tubes including battery-types, auto radio hybrids, and most industrial types. It will check for emission, shorts, leakage, and gas content.

The tester is housed in a scuff-proof airplane-luggage design case which measures only 8⅝"x 11⅜"x3¼" and weighs only 4 pounds.

"OVERLAY" POWER TRANSISTOR

22 **RCA Industrial Tube and Semiconductor Division** has announced a new "overlay" transistor featuring a two-fold power improvement over previous units. The 2N3632 provides a power output of 13.5 watts (minimum) at 175 mc. and 10 watts (typical) at 260 mc.

The new unit will find extensive use in industrial, military, and aerospace 28-volt amplifier applications, such as portable, mobile, aircraft, and marine radio transmitters.

The 2N3632 is a silicon "n-p-n" epitaxial planar transistor using a new emitter electrode pattern called an overlay. The overlay structure permits the transistor to operate at much higher efficiency and higher gain than power transistors using the circle, ring, comb, or other types of geometric designs.

The JEDEC TO-60 double-ended $\frac{7}{16}$" stud package is employed for the 2N3632.

TV MONITORING CAMERA

23 **Springdale Electronics** has developed a compact TV camera for all types of video monitoring with output fed direct to a standard home-type TV receiver.

Called "Video-eye," the camera weighs less than 6 pounds and uses less current than a 20-watt bulb. Featuring telescopic or close-up viewing, indoors or out, the camera is supersensitive to light and shadow (2 ASA), has 400-line resolution, and 16-mm. lenses (Std. "C").

The camera is just plugged in and the home TV set is tuned to channels 3 or 6 for continuous monitoring of the selected area.

RECTANGULAR COLOR TUBE

24 **Sylvania Electric Products Inc.** is now sampling TV set manufacturers with its 19-inch, 90-degree rectangular color tube which uses europium "rare earth" phosphor for increased brightness.

The special phosphors, coupled with a unique screening process, provide substantially brighter pictures than are obtainable with standard phosphors, according to the company. The new tubes will be available in bonded shield and unbonded versions.

The tube has minimum useful screen dimensions of 15.585 x 12.185 inches, minimum useful screen area of 180 square inches, over-all length of 17.865 ±.375 inch, neck length 6.693 inches ±.188 inch, and a weight of 20 pounds unbonded and 24 pounds bonded.

VINYL FOAM TAPES

25 **Behr-Manning Division** has added four versatile pressure-sensitive tapes made with closed-cell vinyl foam to its line. Uses include sealing, calking, bonding, assembly, and absorption of vibration and shock.

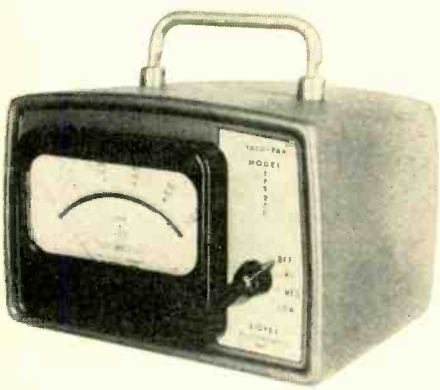
The line includes two multi-purpose tapes with adhesive on one side and foam thickness of 1/8 inch; a tape with 1/8-inch foam of putty-like consistency designed specifically for calking; and a double-faced tape (both sides adhesive) with foam 1/16-inch thick.

All four tapes are bulk-packed in rolls from 1/4 inch through 27 inches in width. The double-faced tape is rolled in 100-foot lengths while the others come in rolls of 50 feet.

MULTI-RANGE TACHOMETER

26 **Airpax Electronics Incorporated** is now offering a compact, portable, direct-reading tachometer of high sensitivity designed for use with turbine-type flowmeters as the "Tach-Pak" Model TPS-275. A 0-50 mv. recorder output, with better than 1/4% accuracy, is a built-in feature.

Three rpm ranges appear on the mirrored scale. Modification of the instrument for expanded-scale monitoring is available to permit its use for calibrating the orifices of oil-burners used in power generating plants. Expansions up to 20:1 are possible.



The instrument operates from 117 volts a.c., 50 to 400 cps with provisions included for 12-volt d.c. operation.

HIGH-SPEED HOLE SAWS

27 **Proto Tool Company** has announced two new series of high-speed hole saws, the "Proto-Mol" and "Proto-Quik." The former is made of high-speed molybdenum steel and features a quick-change mandrel. It also has a follow-through feature for cutting successive pieces of stacked material and easy core removal. The cutting edge is welded to a shatterproof back for extended service life. Diameter sizes range from 3/4" to 2 1/2" holes and the depth measurement is 1 1/8".

The "Proto-Quik" is made of special alloy steel. Although it has a standard mandrel, it has a follow-through design feature for deeper hole cutting and removal of cores as cutting progresses. It has a diameter size range from 3/4" to 2 1/4" and a depth measurement of 7/8".

CCTV CAMERA WITH SOUND

28 **GBC America Corporation** is now offering a low-cost CCTV camera with both sight and sound which is designed to operate through the ordinary home TV set as well as a professional video monitor.

The Model AE-50 is a one-piece, 9-pound transistorized unit incorporating its own power supply as well as a sensitive and efficient sound circuit. A conventional 1/4-inch coaxial cable running from the camera to the antenna leads of the TV set or video monitor completes the hookup. The unit has a built-in automatic light compensator to take full advantage of changing light conditions. It comes equipped with a 25-mm. f/1.4 lens. Additional lenses are available for wide-angle viewing, telephoto, or extreme close-ups.

CATV DISTRIBUTION LINE AMPS

29 **Kaiser Aerospace and Electronics** is now in production on the first of a line of CATV low-band and all-band trunk line and distribution line amplifiers.

The new amplifiers, Models KAA-25 and KMA-25, feature high gain, high output, all silicon-transistorized circuitry and are designed especially for service in CATV systems with up to 12-channel TV and full-band capability. They are designed as direct replacements for vacuum-tube all-band amplifiers without extensive system changes.

A convenient a.c. power cable and the weatherproof messenger-mounted housing provided permits flexible application in a variety of trunk and distribution-line situations.

SHIELDED CABLE TUBING

30 **The Zippertubing Company** is now offering its new **Type SHN3** tubing which is designed for RFI shielding, protection, and grounding of multi-conductor wiring or cables—all in a single operation.

Made for heavy-duty use where wiring or cables are subjected to abuse or where extreme or continuous flexing is required and greater shielding properties are necessary, the SHN3 has a zipper closure that permits repairs, modifications, or cable additions. The cable jacket zipper can also be permanently sealed if desired.

COLOR-TV TUBE KIT

31 **RCA Electronic Components and Devices** has announced a new package designed to assist distributors in merchandising popular types of color-TV receiving tubes to service dealers.

The package offers an assortment of the 17 most popular color types, one each of 17 tubes used primarily in color sets. Tube types included are: 1V2, 3A3/3B2, 3AT2, 6AW8A, 6BK4A, 6DQ5, 6GF7, 6DW4, 6EA8, 6EW6, 6GH8A, 6GM6, 6GU7, 6GY6, 6HF5, 6JE6, and 12BY7A. The kit of tubes comes packed in a fiberglass thermo-insulated utility bag which is reusable.

SPECIAL-PURPOSE CABLE ASSEMBLY

32 **Fairhill Products Corporation** is now in production on special-purpose electrical cable assembly for use where low-frequency operation is desired for testing and OEM manufacture.

The new cable consists of COS-2(18) MIL-C-3884 wire terminated at one end with a PJ-047 plug and a 5" strip with spade lug at the other end. The cable assembly can be made to any desired length and with any type of termination. It can also be manufactured to Military or commercial specs.

HI-FI AUDIO PRODUCTS

CONTINUOUS-DUTY FM TUNER

33 **Truetone Electronics, Inc.** is now marketing the Model 481, a low-cost, no-drift FM tuner designed especially for use in background music and commercial sound installations in which continuous duty is a prime requirement.

Frequency range on this "Raymer" tuner is 88 to 108 mc. with sensitivity less than 20 μv. for 30 db quieting. Bandwidth is 300 kc., assuring maximum fidelity reproduction, especially where multiplex stereo and/or SCA reception are involved. Frequency response is 20-20,000 cps ±1 db.

The tuner is housed in a tan metal cabinet which measures 9 1/2" long x 7" deep x 2 15/16" high. Power consumption is 21 watts.

POWER AMPLIFIER

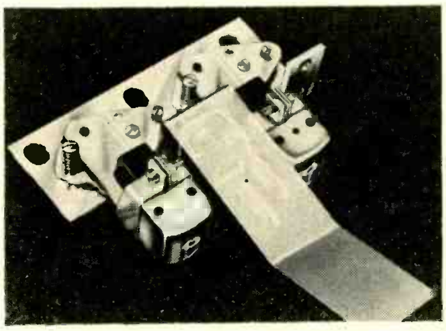
34 **Acoustech, Inc.** is now offering a factory-wired version of its popular power amplifier kits as the "Acoustech V." The new unit utilizes the output stage of the "III" power amplifier kit. The resulting amplifier has less than 1% IM distortion at 50 watts per channel. Like the "III" and "IV," the new unit is transistorized.

SELF-STICK PRESSURE PADS

35 **Robins Industries Corp.** is now offering a new line of self-stick, pre-cut pressure pads as replacement components for tape recorders. The new pads are supplied in packages of 44 pads in two thicknesses, pre-cut to fit most recorders. Each package also contains felt pads which may be cut to take care of odd makes and models.

HEAD-BRACKET ASSEMBLIES

36 **The Nortronics Company, Inc.** is now offering three new head bracket assembly quick kits which are designed to update existing broadcast tape cartridge recorders of the "Fidelipac" and "Viking" type, reduce head installation and alignment problems, and eliminate the need for rear-mount heads.



"Micrometer" adjustments permit setting of head height, face alignment, and azimuth. A special lock screw on each head bracket "freezes" the adjustments. Each kit contains a completely assembled head bracket (less heads), a cartridge guide bar which may be installed on the deck plate to insure proper alignment of the 4-inch cartridge as it is inserted into the machine, and a template to position the unit accurately during installation.

MAGNETIC CARTRIDGE TAPE

37 **Reeves Soundcraft** is now offering a new magnetic cartridge tape for home and professional use, utilizing a 1-mil Mylar base. The Type 441 tape consists of long-wear instrumentation type coating on one side of the base and a .00004-inch Permograph lubricated coating on the reverse, producing efficient anti-static and low friction characteristics.

The new non-shedding magnetic tape features low-frequency sensitivity of −1, ±1 db and high-frequency sensitivity of 0, ±2 db.

It is available in individually boxed 7-inch reels of 1700 feet per reel or in professional packs of 7-inch reels in plastic bags and in professional bulk hubs of 3400 to 3500 feet each.

CAMERA-SIZE TAPE RECORDER

38 **Concord Electronics Corporation** is now marketing a compact new tape recorder which is the size of a small camera.

The Model F-85 "Sound Camera" has complete push-button operation despite its two-pound weight. The unit is designed to both record and play back. The all-transistor circuit has a constant-speed motor for both recording and playback and uses standard reels and 1/4" tape which can also be played on any other recorder having 1 7/8 ips speed. Tapes made on other recorders at this speed can be played on the F-85.

The unit comes complete with microphone and carrying pouch, take-up reel, and full reel of recording tape.

CB-HAM-COMMUNICATIONS

NOISE-CANCELING MOBILE MIKE

39 **Roanwell Corporation** is now offering its new Model RM-515 noise-canceling carbon microphone which is specifically designed for mobile applications. Canceling an average of 18 db of ambient noise, the new unit is human-engineered for secure and comfortable hand operation. It is housed in a high-impact, thermoplastic case. A soft-action press-to-talk d.p.s.t. switch (125 volts a.c., 5 amps) activates the microphone.

Frequency response is 300 to 3500 cps, sensitivity is −17 db ref. 1 mw./nm.$^{-2}$ (10 dynes/cm.^{2}) or + 33 db ref. 1 mv. into 100 ohms load for 10 dynes/cm.^{2} The unit has a four-conductor retractile cord, vinyl insulation and jacket, and tinned leads. It measures $2\frac{7}{16}$" w. x $3\frac{7}{8}$" h. x $1\frac{11}{32}$" d. A mounting bracket is included.

LOW-COST CB TRANSCEIVER

40 **Hammarlund Mfg. Co.** is now offering a low-cost CB transceiver designed to meet the requirements of business communications. The CB-212 features ruggedized construction throughout. It utilizes crystal-controlled transmit and receive functions on any six of the available CB channels. A front-panel switch determines the channel in use.

A built-in dual power supply is provided with 117-volt a.c. input for fixed station applications and 12 volts d.c. for mobile applications. Reliability is enhanced by all-electronic transmit and receive switching.

Sensitivity is better than 0.5 μv., bandwidth is 6 db of 3.3 kc. from eight tuned i.f. circuits, the a.v.c. range is from 5 to 100,000 μv., and the audio power capability is 3 watts minimum.

MONITOR SCOPE

41 **Control Radio Labs** is now offering the Model MS-5 "Moniscope," a miniature monitor scope for CB and amateur radio applications. The instrument measures 7"x 5"x 3"x and has a 2" screen.

There are two front-panel controls; focus and a three-position function switch. In the monitor position all incoming signals may be observed. The unit permits accurate visual tuning of incoming signals, the spotting of frequencies more accurately, and the exact adjustment of speech clippers, preamps, compressors, and continuous observation of audio modulation.

The instrument comes completely assembled and is connected by means of one wire and a shield.

COMMUNICATIONS LOGGING UNIT

42 **C.H. Stoelting Company** is offering a line of communications logging systems which are assembled by use of completely transistorized modules, having their own individual power supplies when required. This building-block concept permits systems to be tailored to each user's individual requirements. Systems can be expanded at some future date by the addition of modules.

The tape transports are continuous-duty, professional quality. The standard tape unit has a four-track recording head on ¼-inch tape; seven-track heads are available on special order.

Available modules include: audio amplifiers, voice switches, lead selectors, erase, monitor, break or tape-end alarm, tape transfer, audio filters, and audio compressors.

Inputs can be from telephones, radios, or microphones. The system functions automatically without attendants.

SOLID-STATE CB CONVERTER

43 **Instrument Devices Corporation** is now marketing a new solid-state, self-contained CB converter for use with standard automobile and marine radios.

The new unit, Model 10-4, features solderless, instant installation and provides reception of all 23 CB channels. A single "on-off" switch in the unit allows the user to switch his radio back to normal broadcast bands instantly.

The converter features a printed circuit, three transistors, and r.f. stage, mixer, and a crystal-controlled oscillator. Power requirements are 9 volts at 3 ma. from a self-contained battery. The broadcast-band image rejection is 80 db.

The unit measures 5" x 2¼" x 2¼" and weighs only 6 ounces.

HEAVY-DUTY VIBRATOR ELIMINATOR

44 **I.E.H. Manufacturing Co.** is now marketing a new type solid-state vibrator eliminator for heavy-duty communications applications. The

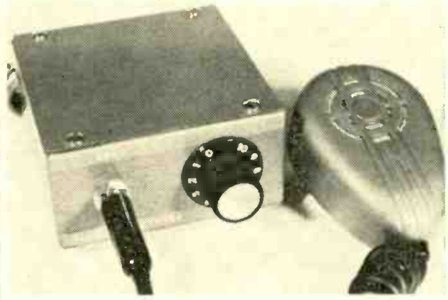
"Vi-Tran II" will replace the standard 4-pin vibrator in communications equipment operating from 5 watts up to 25 watts of power, either 6 or 12 volts. It can be used for commercial and emergency applications such as police radio, ambulances, fire engines, cabs, heavy-duty CB equipment, and business band.

Two models are currently available: VE 196 has pin #1 positive while VE 197 has pin #1 negative.

SPEECH BOOSTER/COMPRESSOR

45 **Rann Industries** has developed a four-stage microphone preamp and compressor which is designed to be used with SSB or AM ham equipment as well as CB units.

The Model CA-1 has input for high-impedance dynamic, ceramic, or crystal mikes, and output for high-impedance mike input on the transmitter. The unit is powered by two penlight cells and is fully transistorized. The unit is completely self-contained and can be used in mobile or fixed-station applications.



The accessory is designed to increase the average depth of modulation, thus providing more "talk-power" without overmodulation.

MANUFACTURERS' LITERATURE

MERCURY REFERENCE CELLS

46 **Mallory Battery Company** is now offering an 8-page booklet which describes the various performance features and applications of its mercury reference cells.

Calibration of oscilloscopes, volt-ohmmeters, and v.t.v.m.'s, as well as direct measurement of unknown d.c. voltage, are among the applications discussed, and each application is accompanied by a schematic diagram. A section on operating procedures is also included.

ANTENNA BOOKLET

47 **New-Tronics Corporation** has issued a 4-page illustrated booklet listing the company's line of new base-station and mobile antennas and accessories. Bulletin NT-106 includes antennas for both amateur and Citizens Band use.

DUAL VOICE COIL SPEAKERS

48 **Oxford Transducer Corporation** has announced publication of a product information bulletin (C-105) giving complete specifications and information on Models DVC-8H4 and DVC-8J4 dual-voice-coil speakers.

According to the company, the bulletin will be of interest to those who desire a speaker unit for situations where immediate broadcasting access is necessary, such as for emergency warning calls, alarm signals, or voice communications to be made over the main program channel.

ISOSONIC CONTOUR CHARTS

49 **Jensen Manufacturing Company** is offering a 4-page technical bulletin (No. 45) which discusses the use of isosonic (equal-sound) contour charts as a design tool by the sound-system layout engineer.

Two charts have been developed showing the sound coverage of the company's "Calstar®" column speakers, Models 55 and 1010. These charts (14" x 20" transparent plastic templates) are designed to be placed directly over the architect's elevation drawing regardless of scale to indicate the correct location and tilt angle for the column speakers to attain any desired audience coverage.

Information is included on how to obtain the templates discussed, small-sized reproductions of which are provided in the bulletin.

RCL BRIDGE

50 **Wayne Kerr Corporation** has made available a 4-page illustrated brochure describing the company's model B-601 r.f. RCL bridge and its low-impedance adapter, Model Z-601.

Features of both the bridge and adapter are discussed, along with theory of operation of the bridge. Complete specifications for both instruments are given.

SOUND REINFORCEMENT

51 **Electro-Voice, Inc.** has issued a timely booklet covering sound reinforcement and changes in the Catholic Church liturgy.

The book will be of interest not only to sound installers but their customers and lay people on the periphery of the sound business who might be asked by members of the Catholic clergy to give them advice on the problems of sound reinforcement resulting from changes in the liturgy; involving the Mass in English and participation by the congregation.

The presentation is in the form of a "Q&A" colloquy between "Mr. Jackson," a sound specialist, and "Father Smith."

The booklet is illustrated and the inside back cover has some technical information on the firm's mikes and speakers for p.a. applications.

PRODUCT PAMPHLET

52 **Melcor Electronics Corporation** has published a new 4-page pamphlet entitled "Amplifiers for Industry" describing the company and the various products it manufactures. Photos and information are given regarding the transistorized amplifiers, circuit modules, power supplies, and servo subsystems offered by the firm.

TOOL DATA

53 **Xcelite Incorporated** is currently offering information on regular- and junior-sized "Seizers" in a revised edition of Bulletin N564. Smaller and slimmer than regular 6" "Seizers," the new 5" "Jr. Seizers" reach more easily into tight spots and facilitate close work involving fine wires and small components.

SPACERS AND POSTS

54 **Technical Accessories Company** has released a 4-page catalogue (SPPM-1) listing the firm's complete line of spacers and posts. These hardware components are supplied in 13 materials and 12 compatible finishes. Tolerances, range of sizes, and specification data are indicated for all available materials and finishes.

TOOL CATALOGUE

55 **Techni-Tool, Inc.** has recently published a 48-page illustrated catalogue covering the firm's complete line of tools. Pliers, tweezers, files, knives, screwdrivers, soldering equipment, and various accessories are among the products offered. Complete specifications are supplied. ▲

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3	.08	.12	.16	.22
12	.25	.50	.65	.75
35	.65	.90	1.25	1.40
50	1.50	1.75	2.20	2.60
100	1.60	2.00	2.40	3.00

D.C. AMPS	300 PIV 210 RMS	400 PIV 280 RMS	500 PIV 350 RMS	600 PIV 450 RMS
3	.27	.29	.37	.45
12	.90	1.30	1.40	1.65
35	2.00	2.35	2.60	3.00
50	3.25	4.00	4.75	6.00
100	3.60	4.50	5.25	7.00

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PRV	7 AMP	16 AMP	25 AMP	PRV	7 AMP	16 AMP	25 AMP
25	.30	.50	.85	250	1.75	2.15	2.50
50	.45	.75	1.00	300	2.00	2.40	2.75
100	.80	1.25	1.50	400	2.40	2.75	3.25
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NEW supersensitive transistor locators detect buried gold, silver, coins. Kits, assembled models. $19.95 up. Underwater models available. Free catalog. Relco-A22, Box 10563, Houston 18, Texas.

JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266, Spokane, Washington 99207.

TV CAMERAS, transmitters, converters, etc. Lowest factory prices. Catalog 10¢. Vanguard, 190-48 99th Ave., Hollis, N.Y. 11423.

WEBBER Labs. Transistorized converter kit $5.00. Two models using car radio 30-50Mc or 100-200Mc, one Mc spread. Easily constructed. Webber, 40 Morris, Lynn, Mass.

ACHTUNG! Das machine is nicht fur Gerfingerpoken und mittengraben. Is easy schnappen der Springenwerk, blowenfusen und poppencorken mit spitzensparken. Ist nicht fur gewerken by das Dummkopfen. Das rubbernecken sightseeren keepen hands in das pockets. Relaxen und watch das Blinkenlights. This attractive, engraved metal plaque only $2.00 ea. ppd. Southwest Agents, Dept. E, Box 12283, Fort Worth, Texas 76116.

CANADIANS, transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics, P.O. Box 1437, Winnipeg, Manitoba, Canada.

INTEGRATED CIRCUIT TIE TACK. Authentic circuit embedded in black onyx-like tie tack. Circuit and interconnections visible. Custom made. $3.00. Tax included. aDASH Creations, Industry, Calif. 91745.

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ORIGINAL HEATH Legatto system with Altec-Lansing dual 16" woofer speakers and exponential horn mid-range and hi-frequency driver. Blond finish. $140. FOB Stamford, Conn., Box 582, Electronics World, 1 Park Avenue, New York, N.Y. 10016.

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750 ma. Silicon Diodes "Epoxy" or "Top Hat" PIV		PIV		Silicon Power Diode Stud 3 amps. PIV		PIV	
50	5¢	600	21¢	25	6¢	300	25¢
100	7¢	*700	25¢	50	8¢	400	28¢
200	10¢	*800	32¢	100	14¢	500	35¢
400	14¢	*900	40¢	150	16¢	600	40¢
500	18¢	*Top hat only		200	22¢	All tests	

Full Leads, Tested, Guaranteed, American made.

10 watt Sil. Zener stud, 5-130v .... $1.25 ea.
1 Watt Zener Diode Axial leads 6v-200v .... 50¢ ea.
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Thermistor, glass bead, 1200 ohms, 600°F. 2/$1.00
Silicon Power Transistors—
2N1724 $1.50—2N1936 .... $2.00 ea.

20 Watt Germanium (internal heat sink)

2n1038	8 for $1.00	2n1042	6 for $1.00
2n1039	6 for $1.00	2n1043	4 for $1.00
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150 Watt Germanium Hi-Freq Power
100 volts, 10 amp 2n1046 .... $1.50 ea.

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2n250	2/$1.00	2n457	80¢
2n456	70¢	2n458	90¢

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40 different Precision Resistors $1.00
Magnetic seed switch with mounting .... 75¢ ea.
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Varicap—voltage variable capacitor—47 pf at 4 v., 4:1, new .... $1.25 ea.

SILICON CONTROLLED RECTIFIERS

PRV	7 amp	16 amp	PRV	7 amp	16 amp
25	.28	.48	200	1.05	1.70
50	.48	.70	300	1.60	2.20
100	.80	1.20	400	2.10	2.70
150	.80	1.50	500	2.80	3.30
ALL TESTS STUD TYPE			600	3.00	3.90

Money back guarantee. $2.00 min. order, include postage, Catalogue 25¢.

Electronic Components Co.
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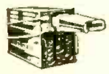
CIRCLE NO. 140 ON READER SERVICE PAGE

LORAN R-65/APN-9 RECEIVER & INDICATOR



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Used, with all parts, less tubes, crystal and visor .... Special $29.50

INVERTER POWER SUPPLY for above APN-9. INPUT: 24 V DC. OUTPUT: 115 V AC. 800 cy. Like New $22.50

12-V. Power Supply for APN-9, like New P.U.R.
Shock Mount for above $2.95
Circuit diagram and connecting plugs available.
We carry a complete line of replacement parts and accessories for above.

SCR-522 2-METER TRANSMITTER-RECEIVER

Terrific buy! VHF Transmitter-Receiver, 100-156 Mc. 4 channels. Xtal-controlled. Amplitude modulated voice. Complete with all 18 tubes, top rack and metal case. LIKE NEW!
SPECIALLY PRICED .... P.U.R.
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AN/ART-13 100-WATT XMTR

11 CHANNELS
200-1500 Kc
2 to 18.1 Mc

$79.50 EXC. USED

Complete with Tubes

Famous Collins Autotune Aircraft Transmitter. AM CW, MCW. Quick change to any of ten preset channels or manual tuning. Speech amplifier/clipper uses carbon or magnetic mike. Highly stable, highly accurate VFO. Built in Xtal controlled calibrator. PP811s modulate 813 in final up to 90% class "B." A Real "HOT" Ham buy at our low price!

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0-16 Low Freq. Osc. Coil for ART-13 .... 7.95
24V Dynamotor for ART-13 .... 11.95
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AN/ARN-6 RADIO COMPASS DF RECEIVER 100 to 1750 Kc in 4 bands. Builtin vibrator power supply for 24V DC. Complete with tubes, exc. Used $29.50

BC-312 RADIO RECEIVER for vehicles. 6-bands 1500 Kc to 18 Mc continuous tuning. Phone and CW. Internal dynamotor. Swell ham mobile receiver. Complete with tubes. Exc. Used $79.50

BC-659 TRANSMITTER & RECEIVER 27 to 38.9 Mc FM. Two preselected channels crystal-controlled, 5 to 10 watts. Complete with speaker, tubes. NEW $27.50

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AN/APT-5 AIRBORNE RADAR SET (Jammer) Complete with tubes, exc. used $69.50

FL-8 FILTER with PL55 Plug $1.95

EE-8 FIELD PHONES

Checked out, perfect working order. Complete with all parts. Excellent Condition.
LIKE NEW! Each $14.50

DYNAMOTOR VALUES:

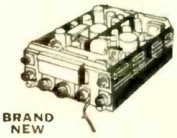
Type	Input	Output	Excellent Used	BRAND NEW
OM-32A	28V 1.1A	250V .05A	2.45	4.45
DM-33A	28V 5A	575V .16A		
	28V 7A	540V .25A	4.45	7.50
DM-34D	12V 2A	220V .080A	4.15	5.50
OM-35	12V	625V .225A	—	19.50
DM-36	28V 1.4A	220V .080A	1.95	2.95
DM-42	28V 23A	515/1030/2/8 MA 215/260	—	12.50
OM-53A	28V 1.4A	220V .080A	3.75	5.45
PE-73C	28V 20A	1000V .350A	8.95	(Like New) $10.95
PE-86	28V 1.25A	250V .050A	2.75	3.85

PE101C Dynamotor 12/24V input. Brand New ... 7.95

DM-37 DYNAMOTOR. Input 25.5 V DC @ 9.2 A. Output 625 V DC @ 225 Ma. BRAND NEW. Each $3.25

FAMOUS BC-645 TRANSCEIVER

15 Tubes 435 to 500 MC



BRAND NEW

Can be modified for 2-way communication. voice or code. on ham band 420-450 mc. citizens radio 460-470 mc. fixed and mobile 450-460 mc. television experimental 470-500 mc. 15 tubes (tubes alone worth more than sale price!); 4—7F7, 4—7H7, 2—7E6, 2—6F6, 2—955 and 1—WE-316A. Now covers 460 to 490 mc. Brand new BC-645 with tubes, less power supply in factory carton. Shipping weight 25 lbs. SPECIAL! $19.50

PE-101C Dynamotor. 12/24V input $7.95
UHF Antenna Assembly 2.45
Complete Set of 10 Plugs 5.50
Control Box 2.25

SPECIAL "PACKAGE" OFFER:
BC-645 Transceiver. Dynamotor and all accessories above. COMPLETE, BRAND NEW, While Stocks Last $29.50

AIRCRAFT AIR COMPRESSOR

Pressurization package equipment, includes Motor, Switch Assemblies, Dessicant Chamber, Absolute Press Indicator and associated valves and controls. Overall 13½"x8½"x8" high. NEW, special buy! $22.50

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- All at LOWEST PREVAILING PRICES.
- In addition to items shown on this page, we have in stock or can obtain for export and domestic customers, military electronic equipment made for World War II, Korean War, and later. We maintain one of the largest stocks of Government Electronic Surplus Equipment in America!
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ARB/CRV 46151 NAVY AIRCRAFT RADIO RECEIVER 190 to 9050 KC in 4 bands: 190-550, 550-1600, 3-6 Mc, 6-9.050 Mc. 6-tube super with local and remote tuning, band change. Complete with tubes and dynamotor, like new $49.50
As Above, brand new $79.50
Power Supply, 110 V AC wired .... $ 8.95

ARC-3 RECEIVER!

Complete with All tubes Exc. Used $21.50
Like NEW $33.50
Crystal-controlled 17-tube superhet. tunes from 100 to 156 MC., AM., on any 8 preselected channels. 28-volt DC power input. Tubes: 1-9002, 6-6AK5, 1-12SH7, 3-12SG7, 1-9001, 1-12H6, 2-12SN7, 1-12SL7, 1-12A6.
110 V A.C. Power Supply Kit for above 15.00
Factory Wired and Tested 19.95

ARC-3 TRANSMITTER

Companion unit for above tunes 100 to 156 MC on any 8 pre-selected channels. 9 tubes, crystal controlled, provides tone and voice modulation. 28V DC Power input. Complete with all Tubes: 3-6V6, 2-832A, 1-12SH7, 1-6J5, 2-6L6. Exc. Used .... Only $18.95
Like new condition $28.50
ARC-3 PUSHBUTTON CONTROL BOX $5.95

MICROPHONES Checked Out, Perfect
T-17 Carbon Hand Mike,
Exc. Used $4.45 .... Brand New $7.95
RS-38 Navy Type Carbon Hand Mike,
Exc. Used $3.95 .... Like New $5.75

HEADPHONES Checked Out, Perfect

Model	Description	EXC. USED	BRAND NEW
HS-23	High Impedance	$2.79	$4.95
HS-33	Low Impedance	3.15	5.45
HS-30	Low Imp. (featherwt.)	.90	1.65
H-16/U	High Imp. (2 units)	3.75	7.95

TELEPHONICS—600 ohm Low Impedance HEADSETS. BRAND NEW. PER PAIR $3.95
CD-307A Cords, with PL55 plug and JK26 Jack .99
Earphone Cushions for above—pair .... .50

Please include 25% Deposit with order—Balance C.O.D., or Remittance in Full. 50¢ Handling Charges on all orders under $5.00. All shipments F.O.B. Our Warehouse, N.Y.C. All Merchandise subject to Prior Sale and Price Change.

G & G RADIO SUPPLY CO.

Telephone: CO 7-4605
77 Leonard St. New York 13, N. Y.

LORAN APN-4

FINE QUALITY NAVIGATIONAL EQUIPMENT

Determine exact geographic position of your boat or plane. Indicator and receiver complete with all tubes and crystal.

INDICATOR ID-6B/APN-4, and RECEIVER R-9B/APN-4, complete with tubes, Exc. Used. $69.50

NEW! APN-4A Receiver-Indicator as above, changed to operate same as APN4-B for improved performance .... NEW $88.50
Shock Mount for above $2.95

INVERTER POWER SUPPLY for above APN-4. INPUT: 24 V DC. OUTPUT: 115 V AC, 800 cycles. Like New $22.50

12-Volt Inverter Power Supply for above APN-4. Like New. P.U.R.
We carry a complete line of replacement parts and accessories for above.

BC-929 3-Inch Scope, with all tubes, LIKE NEW $16.50
Conversion instructions, with diagram, for 110 V AC operation .... $ .65

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Crystal calibrated modulated. Heterodyne, 125 KC to 20,000 Kc. with Calibration book. Complete, like new $79.50
LM Frequency Meter as above, completely checked out, with tubes and crystal, less calibration book. Exc. Used, clean $34.50

BC-906 FREQ. METER—SPECIAL

Cavity type 145 to 235Mc. Complete with antenna. Manual and original calibration charts included. BRAND NEW. OUR LOW PRICE $14.50

BC1206-C BEACON RECEIVER

195 to 420 Kc. made by Setchel-Carlson. Works on 24-28 volts DC. 135 Kc. IF. Complete with 5 tubes. Size 4" x 4" x 6". Wt. 4 lbs.
Brand New with tubes $11.95
New less tubes 7.95
Like New with tubes 8.95
Used, less tubes 4.95

SCR-625 MINE DETECTOR

Complete portable outfit in original packing, with all accessories. Brand New $34.50
Exc. Used $24.50

AN/APR-4Y FM & AM RADIO RECEIVER High precision lab instrument, suitable for monitoring and measuring frequency and relative signal strength of signals from 38 to 4000 Mc., in 5 tuning unit ranges. For 110 V 60 cycle AC operation, built-in power supply.
LIKE NEW, SPECIAL $79.50
TN-16, TN-17, TN-18, TN-19 and TN-54 Tuning Units for above in stock. P.U.R.

SCR-274 COMMAND EQUIPMENT

ALL COMPLETE WITH TUBES

Type	Description	Used	Like New	BRAND NEW
BC-453	Receiver 190-550 Kc.	$14.95	$18.95	P.U.R.
BC-454	Receiver 3-6 Mc.	$15.95		P.U.R.
BC-455	Receiver 6-9 Mc.	$13.95	$19.50	P.U.R.

BC946 Receiver 550-1500 Kc Complete with all tubes Brand New, in original packing .... P.U.R.
1.5 to 3 MC. Receiver Brand New $21.50

110 Volt AC Power Supply for all 274 N and ARC-5 Receivers. Complete with metal case, instructions. Factory wired, tested, ready to operate $12.50

SPLINED TUNING KNOB for 274-N and ARC-5 RECEIVERS. Fits BC-453, BC-454 and others. Only .... 49¢

2.1 to 3 Mc Transmitter, Brand New $12.95
BC-457 TRANSMITTER—4-5.3 Mc. complete with all tubes and crystal, BRAND NEW $11.95
Like New $7.95
BC-458 TRANSMITTER—5.3 to 7 Mc. Complete with all tubes and crystal.
BRAND NEW $13.95
Like New $8.95
BC-696 TRANSMITTER 3-4 Mc Complete with All Tubes & Crystal. Brand New $13.50
Exc. Used $8.95
BC-456 Modulator .... USED 3.45 NEW 5.95
ALL ACCESSORIES AVAILABLE FOR ABOVE

ARC-5/T-23 TRANSMITTER 100-156 Mc., includes tubes 2-832A, 2-1625.
BRAND NEW, with Tubes $28.50
Used, with Tubes ..$12.50—Used, less tubes ..$5.95
ARC-5/R-28 RECEIVER 2-meter superhet. 100 to 156 Mc., in 4 crystal channels, Complete with 10 tubes. Excellent Used $24.50
Like NEW $29.50

234-258 MC RECEIVER AN/ARR-2

BRAND NEW 11-tube UHF Tunable Receiver with schematic. Only a few at this low price!
Complete with tubes. Exc. used $6.95 .... $9.99

2 VOLT BATTERY "PACKAGE"

1—2V. 20 Amp. Hr. Willard Storage Battery. Model #20-2. 3" x 4" x 5½" high $2.79
1—2V. 7 prong Synchronous Plug-in Vibrator .. 1.49
1—Quart Bottle Electrolyte (for 2 cells) 1.45
ALL BRAND NEW! Combination Price $5.45

WILLARD 6-VOLT MIDGET STORAGE BATTERY

3 Amp. Hour. BRAND NEW, 3⅝" x 1-13/16" x 2⅜" Uses Standard Electrolyte. Only $2.95

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FREE Catalog
OF THE WORLD'S FINEST GOV'T. SURPLUS ELECTRONIC BARGAINS

TEST EQUIPMENT:

OS-26/USM-24 Oscilloscope (Special)....Used: $59.50
TS-147B Signal Generator—8500-9600 MC..U: 59.50
TS-117 Wavemeter—2400-3400 MC......Used: 18.95
UPM-19 Pulse Generator—2650-2950 MC.Used: 39.50
URM-23 Attenuators—1000 to 4000 MC...New: 14.95
TS-102B Range Calibrator ....New: 18.95
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155-580 MC ....Used: 99.50
BC-1277 Signal Generator—2400-3400 MC..U: 22.95
I-193 Polar Relay Tester ....Used: 16.95
LAF-2 Signal Generator—90 to 700 MC..Used: 75.00
TS-118/AP RF Wattmeter ....Used: 39.50
TS-28/UPN Synchroscope ....Used: 50.00
TS-34/AP Oscilloscope ....Used: 39.50
TS-375 Vacuum Tube Voltmeter.........Used: 65.00

RECEIVERS:

R-316 Receiver—162.25 to 173.5 MC FM Used: $22.95
RAX-1 Receiver—200 to 1500 KC........Used: 29.95
BC-348 200 to 500 KC—1.5 to 18 MC....Used: 89.50
R-23/ARC-5 190 to 550 KC ....Used: 14.95
R-25/ARC-5 1.5 to 3 MC ....New: 19.95
R-77/ARC-3 100 to 156 MC............Used: 22.50
BC-1206 Receiver—200 to 400 KC......Used: 9.95
BC-229 200 to 400 KC—2500-7700 KC...Used: 8.95
R-5/ARN-7 100 to 1750 KC.............Used: 18.95
MN-26C 150 to 1500 KC................Used: 9.95
MN-26 LB 200-410; 500-1200 KC—2.9-6 MC.U: 9.95

TRANSMITTERS:

ART-13 2 to 18 MC ....Used: $59.50
BC-604 21 to 27 MC FM ....New: 7.95
BC-684 27 to 38 MC FM ....Used: 6.95
BC-191 1.5 to 12.5 MC ....New: 34.95
BC-230 3000 to 7000 KC ....Used: 8.95
T-18/ARC 2.1 to 3.0 MC ....Unused: 8.95
T-20/ARC 4.0 to 5.3 MC...New: $9.95 or Used: 6.95
T-21/ARC 5.3 to 7 MC.....New:$8.95 or Used: 5.95
T-23/ARC 100 to 156 MC ....New: 24.95
T-67/ARC-3 100 to 156 MC ....Used: 22.95
GP-7 350 to 9050 KC ....New: 29.95

RECEIVER—TRANSMITTERS:

LINK 1905-1906 152 to 172 MC FM.....Used: $59.50
RT-19/ARC-4 140 to 144 MC AM ....Used: 22.95
BC-1335 27 to 38.9 MC FM......As is—Used: 6.95
BC-645 (Converts to: 435 to 500 MC)....New: 14.95

Address Dept. EW • Prices F.O.B. Lima, O. • 25% Deposit on C.O.D.'s • Minimum Order $5.00

FAIR RADIO SALES
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"TAB", SILICON 750MA* DIODES
Tested! Factory Gtd.!

NEWEST TYPE! LOW LEAKAGE

Piv/Rms 50/35 .05	Piv/Rms 100/70 .09	Piv/Rms 200/140 .12	Piv/Rms 300/210 .14
Piv/Rms 400/280 .15	Piv/Rms 500/350 .19	Piv/Rms 600/420 .23	Piv/Rms 700/490 .27
Piv/Rms 800/560 .35	Piv/Rms 900/630 .45	Piv/Rms 1000/700 .65	Piv/Rms 1100/770 Query

ALL TESTS AC & DC & FWD & LOAD!

1700Piv/1200Rms @ 750Ma$1.20 @ ,10for$10
same 1100Piv/770Rms 75¢ @ . 16 for $11

SILICON POWER DIODES STUDS & P.F.**

D.C. Amps	50 Piv 35 Rms	100 Piv 70 Rms	150 Piv 105 Rms	200 Piv 140 Rms
3	.08	.14	.17	.24
12	.30	.55	.70	.85
18**	.20	.30	.50	.75
35	.70	2.05	1.35	1.50
100	1.65	1.00	2.50	3.15
240	3.75	4.75	5.75	8.75

D.C. Amps	300 Piv 210 Rms	400 Piv 280 Rms	500 Piv 350 Rms	600 Piv 420 Rms
3	.29	.30	.40	.48
12	1.00	1.35	1.45	1.70
18**	1.00	1.50	Query	Query
35	2.15	2.45	2.75	3.33
100	3.75	4.60	5.50	8.00
240	11.70	19.80	27.90	Query

Battery Charger 6 & 12 V Charges up to 5 Amp with Circuit Breaker $8 @ , 2 for $15.
D.C. Power Supply 115v/60 to 800 Cys. Output 330 & Tap 165V up to 150Ma $5 @ , 2 for $9
3000Piv/2100Rms @ 200Ma $1.80 @ , 6 for $10
6000Piv/4200Rms @ 200Ma $4 @ , 4 for $15
12000Piv/8400Rms @ 200Ma $10 @ , 3 for $25
5U4 Silicon Tube Repl. $1.90 @ , 6 for $11

"TAB" ★ SCR's ★ TRANSISTORS ★ DIODES!!!
Full Leads Factory Tested & Gtd! U.S.A. Mfg.

PNP/HiPower/15Amp Round TO36 Pckg!
2N441. 442. 277. 278. DS501 up to 50volts VCBO $1.25 @ , 5 for $5
TN278, 443. 174 up to 80v @ 2 for $5
PNP Diamond/3A-2N155, 156, 235, 242 254, 255, 256. 257, 301, 351 ¢35 @ , 4/$1
PNP/Signal up to 350Mw TO5 ¢25 @ , 6 for $1
NPN/Signal IF. RF. OSC, TO5, OV5, ¢25 @ , 6 for $1
PNP 2N670/300 Mw ¢35 @ . 4 for $1
PNP 2N671/1watt ¢50 @ , 3 for $1
Power Heat Sink Finned 100Sq $1 @ , 6 for $5
STABISTOR Diodes Fwd Regulators...1watt 5 for $1
Zener Diodes up to One Watt 6to200v ¢70 @ . 3 for $2
Zener Diodes Ten Watt 6to150v $1.45 @ ....4 for $5

Sil Pressfit 18A up to 100 Piv .... .4 for $1
Micro or MuSwitch CSD 3S Amp/AC-DC .3 for $1

"SCR" SILICON CONTROLLED RECTIFIERS!

PRV	7A	16A	25A	PRV	7A	16A	25A
25	.30	.50	.85	250	1.85	2.25	2.60
50	.50	.75	1.00	300	2.00	2.45	2.80
100	.90	1.35	1.60	400	2.50	2.90	3.35
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4BS8	.96
4BU8	1.20
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4BZ7	1.00
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4CY5	1.10
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4DT6	.87
4EH7	1.47
4EJ7	1.47
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4GK5	1.59
4GM6	1.25
4GS8	1.19
4GZ5	.91
4GZ6	1.19
4HA5	1.85
4HC7	1.39
4HM6	.91
4HS8	1.18
4HT6	1.24
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5AM8	.77
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5AQ5	.52
5AR4	1.75
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5AT8	.81
5AU4	1.25
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5BC3	.89
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5BK7	.89
5BQ7	.99
5BR8	.81
5BT8	.79
5BW8	1.31
5CG8	1.20
5CL8	1.19
5CM8	1.47
5CQ8	1.45
5CZ5	1.70
5DE8	1.15
5DJ4	1.00
5EA8	1.21
5ES8	2.21
5EU8	1.29
5EW6	1.01
5FG7	1.07
5FV8	1.21
5GH8	1.53
5GJ7	1.62
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5X8	.84
5Y3	.47
5Y4	1.45
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6A7	2.65
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6AQ6	1.05
6AQ7	1.55
6AQ8	1.20
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6AR6	1.50
6AR8	2.00
6AR11	1.65
6AS5	.79
6AS6	1.00
6AS7	2.85
6AS8	1.30
6AS11	1.95
6AT6	.49
6AT8	.84
6AU4	.95
6AU5	1.60
6AU6	.52
6AU7	.54
6AU8	.87
6AV5	1.45
6AV6	.44
6AV11	1.52
6AW8	.88
6AX3	1.05
6AX4	.64
6AX5	.74
6AX7	1.25
6AX8	1.34
6AY3	1.05
6AZ8	2.15
6B4	3.95
6B5	4.00
6B7	2.75
6B8	2.50
6B10	1.35
6BA3	1.05
6BA6	.49
6BA7	1.50
6BA8	1.48
6BA11	1.22
6BC4	2.10
6BC5	.62
6BC7	1.47
6BC8	1.49
6BD4	7.00
6BD5	1.20
6BD6	.94
6BE3	1.15
6BE6	.53
6BF5	.88
6BF6	.48
6BF8	1.65
6BG6	1.67
6BH6	1.00
6BH8	.94
6BJ6	.69
6BJ7	1.19
6BJ8	1.35
6BK4	3.15
6BK5	1.30
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6BL7	1.19
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6CU8	1.59
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6CW5	1.39
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6CY5	.99
6CY7	1.22
6CZ5	1.59
6CZ7	1.95
6D4	1.75
6D6	2.50
6D10	1.59
6DA4	.99
6DA5	1.05
6DB5	1.99
6DB6	1.01
6DC6	1.29
6DC8	1.22
6DE4	1.03
6DE6	.93
6DE7	1.29
6DG6	.95
6DJ8	1.65
6DK6	.89
6DN6	2.74
6DN7	1.35
6DQ5	2.75
6DQ6	1.10
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6DS4	1.55
6DS5	1.21
6DT5	.95
6DT6	.75
6DT8	1.35
6DV4	2.39
6DW4	1.39
6DW5	1.55
6DX8	1.19
6DZ4	1.53
6E5	1.89
6EA5	1.55
6EA7	1.47
6EA8	1.19
6EB5	1.75
6EB8	1.45
6EH5	1.10
6EH7	.79
6EH8	1.21
6EJ7	.79
6EM5	1.29
6EM7	1.79
6EQ7	1.10
6ER5	1.35
6ES5	1.15
6ES8	2.19
6ET7	1.49
6EU7	1.08
6EU8	1.25
6EV5	1.10
6EW6	.92
6EW7	1.50
6EY6	1.23
6EX6	2.79
6EZ5	1.39
6EZ8	1.41
6FA7	1.10
6FD7	1.73
6F4	3.95
6F5GT	1.50
6F5M	1.69
6F6G	1.95
6F6M	2.19
6F7	3.95
6F8	3.25
6FG5	1.99
6FG6	1.25
6FG7	1.12
6FG8	1.75
6FH5	.92
6FJ5	2.25
6FJ7	1.39
6FM7	1.31
6FQ7	.89
6FS5	1.19
6FV6	1.33
6FV8	1.15
6FW5	1.59
6FW8	3.49
6FY5	1.11
6G5	1.95
6G6G	1.55
6G11	1.69
6GB5	1.81
6GC5	1.19
6GE5	1.59
6GE7	1.19
6GF5	1.42
6GF7	1.69
6GH8	1.19
6GJ5	1.69
6GJ7	1.37
6GK5	1.55
6GK6	.99
6GL7	1.99
6GM5	1.21
6GM6	.91
6GN8	1.35
6GQ7	1.89
6GR7	1.42
6GT5	1.49
6GV5	1.65
6GV6	1.85
6GW6	1.55
6GW8	1.21
6GX6	.88
6GX8	1.31
6GY5	1.89
6GY6	.87
6GZ5	1.16
6HA5	1.45
6HB5	1.69
6HF5	2.79
6HF8	1.45
6HG8	1.69
6HJ8	1.25
6HK5	1.19
6HL8	1.19
6HS8	1.21
6HT6	1.19
6HZ6	.99
6H6M	.79
6J4	2.95
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6JB6	1.76
6JC8	1.15
6JE6	2.99
6JE8	1.49
6J5M	1.30
6J5GT	1.20
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6K6GT	.64
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6K8GT	1.25
6K8M	2.50
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6KD8	1.39
6KT8	1.23
6KU8	1.15
6LB8	1.49
6L5G	1.50
6L6G	.98
6L6GA	1.50
6L6GB	1.50
6L6GC	1.61
6L6M	3.25
6L7M	2.50
6L7G	1.75
6M11	1.81
6N7G	1.49
6N7M	1.85
6N7GT	1.75
6P5	1.50
6Q7GT	1.95
6Q7M	2.00
6Q11	1.29
6R7	1.75
6S4	.56
6S7	1.95
6S8GT	1.50
6SA7GT	1.39
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6SB7Y	2.20
6SC7	1.49
6SD7	1.49
6SF5	1.19
6SF5GT	1.05
6SF7	1.95
6SG7	1.65
6SG7GT	1.45
6SH7	1.21
6SJ7GT	1.19
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6SK7GT	1.25
6SK7M	1.45
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6SR7	1.25
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6W6GT	.89
6X4	.60
6X5GT	.75
6X8	.82
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7A5	1.29
7A6	1.29
7A7	1.35
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7AF7	1.65
7AG7	1.75
7AH7	1.49
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7B5	1.25
7B6	1.25
7B7	2.25
7B8	1.25
7C4	1.15
7C5	1.25
7C6	2.25
7C7	1.20
7E5	1.25
7E6	1.25
7E7	1.33
7EY6	.75
7F7	2.10
7F8	1.95
7G7	1.65
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7HG8	1.29
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12A6	.89
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12AD6	.79
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12AE7	1.25
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12AG6	1.49
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12AL5	.69
12AL8	1.95
12AL11	1.69
12AQ5	.79
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12AT7	.92
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12AV5	1.50
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12AW6	1.10
12AX3	1.03
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12AX6	.91
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12EL8	.95
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12SA7GT	1.25
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12SK7M	1.35
12SL7GT	1.15
12SN7	.89
12SQ7GT	1.15
12SR7	1.50
12U7	.93
12V6	.95
12W6	.89
12X4	.59
13DE7	1.12
13DR7	1.29
13EM7	1.83
13FD7	1.89
13FM7	1.15
13GF7	1.79
14A4	1.45
14A5	1.35
14A7	1.39
14AF7	1.65
14B6	1.69
14B8	1.95
14C5	1.75
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14E6	1.39
14E7	1.39
14F7	2.59
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16GK6	1.15
16GY5	1.90
17AX3	1.03
17AX4	.89
17AY3	.98
17BE3	1.15
17BQ6	1.49
17BS3	1.15
17C5	2.35
17C9	1.95
17D4	1.03
17DE4	1.25
17DM4	1.19
17DQ6	1.15
17DQ7	1.75
17EW8	.99
17GE5	1.50
17GJ5	1.75
17GV5	1.69
17GW6	1.49
17H3	.93
17HC8	1.24
17JB6	1.95
17JM6	1.65
17JN6	1.70
17JZ8	1.19
17L6	1.45
17LD8	1.35
17W6	1.15
18A5	1.55
18FW6	.75
18FX6	.79
18FY6	.69
18GD6	.81
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19BG6	1.95
19C8	1.25
19CL8	1.25
19EA8	1.19
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1909	1.15
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21EX6	1.95
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22BH3	1.15
22BW3	1.21
22DE4	1.15
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25AC5	2.50
25AK4	1.19
25AV5	1.35
25AX4	.95
25BK5	1.15
25BQ6	1.45
25B8	1.93
25C5	.66
25CA5	1.15
25CD6	1.69
25DK4	.63
25DN6	1.95
25EH5	.82
25F5	1.29
25L6	.75
25W4	.83
25Z5	1.49
25Z6	.98
27GB5	1.49
32ET5	.89
32L7	.85
33GY7	1.95
34DG5	.95
34GD5	.83
35A5	2.19
35B5	1.10
35C5	.73
35EH5	.83
35L6	.87
35W4	.40
35Y4	1.63
35Z3	1.49
35Z5	.65
50A5	2.25
50B5	.89
50C5	.72
50DC4	.64
50EH5	.87
50FY8	1.50
50HC6	.86
50L6	.95
50X6	1.95
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50Y6	1.49
50Y7	1.39
60FX5	.95
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24A	1.35
26	1.40
27	1.60
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32	1.15
33	1.15
34	1.15
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37	1.10
38	1.10
39/44	.95
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42	1.49
43	2.50
45	2.00
45Z3	.55
46	.95
47	3.00
48	4.00
49	3.50
50	1.75
53	3.50
55	2.75
56	1.25
57	1.50
58	1.50
59	3.00
71A	1.25
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76	1.50
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81	1.35
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1J3	6AU5	6CG8	6J5	6SK7	6X4	12C5
1L4	6AU6	6CM7	6J6	6SL7	6X5	12CA5
1T4	6AV6				7A7	12SN7
1U4	6AW8				7A8	12SQ7
1X2	6AX4				7B6	25L6
3CB6	6BA6				7B7	25Z6
5U4	6BC5				7B8	35W4
5V4	6BD6				7C5	35Z3
5Y3	6BG6				7N7	35Z5
6A6	6BH6				7Y4	50L6
6A8	6BJ6				12AD6	24
6AB4	6BL7				12AE6	27
6AC7	6BN4				12AF6	41
6AG5	6BN6				12AT7	45
6AK5	6BQ6	6CZ5	6K6	6SN7	12AU7	47
6AL5	6BZ6	6D6	6K7	6SQ7	12AX7	75
6AN8	6C4	6DA4	6Q7	6SR7	12BA6	77
6AQ5	6C6	6DE6	6S4	6U7	12BD6	78
6AS5	6CB6	6DQ6	6SA7	6U8	12BE6	84
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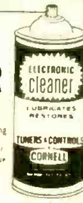

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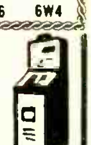

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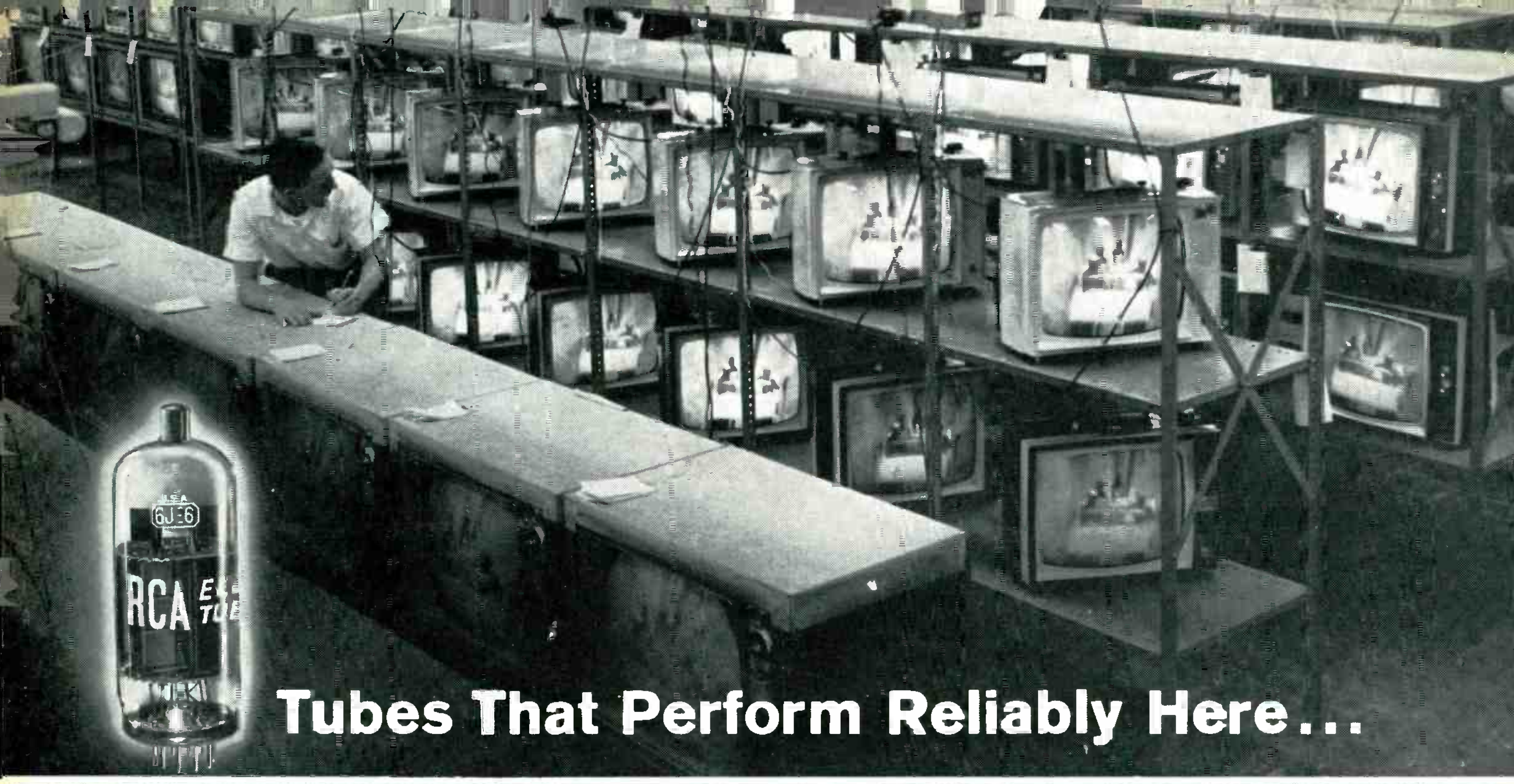

At top, you're looking into the RCA Receiving Tube Reliability Laboratory—a most important factor behind the exceptional reliability of RCA receiving tubes, and one more plus-value that you have in RCA tubes.

Here in two-hundred TV sets of all sizes—black-and-white and color—samples of each week's production of RCA receiving tubes are subjected to extensive tests under actual field conditions. The operating conditions for the TV sets vary from low-line to high-line voltages. And the sets are regularly cycled on and off to check the effects of heating and cooling on the tubes.

The Tube Reliability Laboratory reveals—*and allows us to eliminate*—problems that do not show up under normal production life testing. It also permits us to conduct pre-production tests of new tube designs to make certain that the RCA standards of quality will be fulfilled before the new tubes are marketed.

Testing in the Tube Reliability Laboratory enables us to verify the consistent high quality of RCA receiving tubes—to maintain uniformity of characteristics from tube to tube and throughout life. It is another example of the care we take to assure that RCA receiving tubes give RELIABLE PERFORMANCE where it really counts—in your customers' sets.

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